Development and Usability Testing of a Smartphone Technology for the Self-Management of Pediatric Concussion

by

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Abstract

Noticeable gaps continue to exist in the management of pediatric concussion that can lead to poor health outcomes. This research describes the development, and usability evaluation of a smartphone application to aid youth in self-managing concussion. An agile user-centered design approach was used to develop the technology, followed by a formative usability study for assessment and improvement proposals. Seven youth ages 10 to 18 years with a history of concussion, and seven healthcare professionals were recruited for this study that included, participants performing 11 tasks using the “think aloud” protocol, administration of the System Usability Scale (SUS) questionnaire, and a semi-structured interview. The mean SUS score was 83, mean task success rates were >90% for 92% of tasks, and mean task completion times were <2 minutes for 100% of tasks. The study results suggest this technology is usable, acceptable to users, and may be useful in helping youth self-manage concussion.
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Chapter 1

1 Introduction

Concussion is a common injury amongst Canadian children and adolescents that leads to a range of neurobehavioral deficits including combinations of somatic, physical, cognitive and emotional/behavioral symptoms; for example, headache, dizziness, fatigue, irritability, insomnia, concentration, or memory difficulty [1]. These post-concussion symptoms can have significant impact on the functional participation of youth in daily activities, such as sports, school, family and social [2-4]. Despite the implications and prevalence of concussion in children, little information exists specifically for the management of this injury within this population. Currently, there is a dearth of interventions for pediatric concussion management. However, consistent application of evidence-based management using comprehensive guidelines may help reduce the impact of concussion and persistent post-concussive problems in children. Best-practice guidelines for pediatric concussion management rely solely on paper-based reporting of post-concussion symptoms by youth to guide return to activity. According to these guidelines, the main resources for concussion management provided to the youth are in the form of verbal information and written handouts. However, noticeable gaps continue to exist in concussion management with inadequate application of best-practice guidelines. Consequently, individuals may receive inconsistent and incomplete messages regarding the best strategies to manage concussion which could lead to poor health outcomes. Thus, there is a critical need to enable youth to have easy access to complete and accurate concussion management information and strategies, and to provide youth with a more holistic and guidance-based approach to managing concussion.

This research was conducted in collaboration with the concussion experts at the Concussion Centre at Holland Bloorview Kids Rehabilitation Hospital. The goal of this research was to design and evaluate the usability of a smartphone technology to enable youth to better self-manage concussion by providing easy access to accurate and complete concussion management information and strategies in the form of a usable technology. An agile user-centered design approach was used in the design and development of the technology that was followed by a formative usability study to evaluate the usability of the technology.
This author was motivated by the following research objectives:

1. Design and develop a usable smartphone technology that can help youth self-manage concussion.
   1.1. Identify the context of use of this technology
   1.2. Establish the design requirements
   1.3. Design and develop the technology prototype

2. Evaluate the usability of this technology, and identify usability issues with this technology.
Chapter 2

2 Background

Concussion is “a brain injury and is defined as a complex pathological process affecting the brain, induced by biomechanical forces” [4, p.89]. Concussion may be the result of a direct blow to either the head, face, neck or other part of the body which causes an ‘impulsive’ force to be transmitted to the head [4]. Concussion is a common injury amongst Canadian children and adolescents, with conservative estimates of prevalence reported as 200 per 100,000 [2]. Despite the implications and prevalence of concussion in children and adolescents, little information exists specifically for the management of this injury within this population [1, 3, 4]. Youth can experience a range of neurobehavioral deficits following concussion that can include combinations of somatic, cognitive, physical, and emotional/behavioral symptoms; these post-concussion symptoms include, headache, dizziness, fatigue, irritability, insomnia, concentration, or memory difficulty [1]. These post-concussion symptoms can have great impact on the functionality of youth in terms of participation in daily activities, such as sports, school, family and social [2, 3]. Most individuals (80-90%) with concussion typically recover quickly (i.e. symptom resolution within 7-10 days) [1, 4]. However, post-concussion symptoms and related performance deficits have been reported to persist for several weeks to months’ post-injury in a significant number of youth [1, 4-6]; a subset (31%) of youth continue to report symptoms that persist beyond one month post-injury [6]. As childhood and adolescence are a time during which plasticity and growth occurs in the brain, the youth may be more vulnerable to concussion effects, resulting in delayed recovery and the potential for persisting functional deficits [7, 4].

Post-Concussion Syndrome (PCS) is defined by the World Health Organization as persistence of three or more of the following post-concussion symptoms after head injury: headache, dizziness, fatigue, irritability, insomnia, concentration, or memory difficulty [8]. While concussion effects are assumed to be temporary, signs and symptoms persisting beyond three weeks suggests that individuals with PCS have progressed from a temporary injury to the semi-permanent brain injury reflective of concussion [9]. The diagnosis of PCS is complicated by the number and diversity of symptoms encompassed within the syndrome, and a differential diagnosis that includes, among others, depression, somatization, and chronic pain [10, 11]. Nonetheless, PCS should be considered when individuals remain symptomatic beyond 28 days or more after head
injury [6, 9]. The assumption is that metabolic and physiologic changes in the brain of the concussed individual have not returned to homeostasis [12]. Recent research suggests that a significant risk factor for the development of PCS is three or more prior concussions [13, 14]. Consistent with this clinical observation, there is evidence of a persistently altered brain physiologic milieu (i.e., blood-brain barrier disruption and reduced global and regional cerebral blood flow) in some individuals after concussion [15]. Thus, it can be argued that there is no such thing as a “minor” brain injury [12].

Concussion is a complex health issue [16]. Sports associations, media, parents, coaches, scientists, and health practitioners, among many others, share a common goal of increased awareness and understanding [16]. Despite this collective aim, to-date there remains a prevalent sense of disconnect among all parties with regard to concussion awareness and treatment methods [16]. There is a growing evidence base demonstrating both knowledge and practice gaps in concussion management [16, 17, 18, 19]. This disconnect could be in part owing to the ambiguous nature of the injury and potentially high variation in recovery experiences between and within individuals [16]; concussion recovery rate is variable and unpredictable [20]. This disconnect can cause individuals with concussions to receive inconsistent messages regarding the best strategies for managing concussion from their health care providers, which could further lead to poor health outcomes [16, 17]. For example, according to a survey of 270 family care physicians (FPs), emergency department physicians (EDPs), and pediatricians from community teaching hospitals in Ontario, even though cognitive rest is considered part of the criterion standard of concussion recovery [4], only 49% of FPs, 57% EDPs, and 36% of pediatricians consistently recommended it [16, 17]. In addition, the field of pediatric concussion is still in its infancy compared to that of general traumatic brain injury (i.e. moderate and severe) [20]. Very few randomized control trials have studied pediatric concussion, and examined the results of possible therapies, both pharmacological and nonpharmacological [20]. In particular, the ideal duration of the physical and cognitive rest is unknown [4, 20]. As well, very few studies have examined pediatric concussion beyond the context of sports injury or examined the long-term outcomes of children/adolescents who have sustained multiple concussions and the possible link to severe cognitive outcomes [20]. So, there is a lack of a single set of strict guidelines that can be applied to manage a child’s concussion due to the complex nature of this health issue and its infancy in research [16]. Thus, there is a need to develop accessible tools that can enable youth
to have easy access to complete and evidence-informed concussion management information and strategies throughout recovery.
Chapter 3

3 Literature Review

The purpose of this literature review was to investigate how pediatric concussion is currently managed, what efforts have been made to improve concussion management and promote self-management of pediatric concussion, how the emergence of mobile technologies can aid in pediatric concussion management, and the methods of testing usability of such mobile technologies.

3.1 Management of Pediatric Concussion

Concussion has the potential to significantly impact children and families; children may experience prolonged school absenteeism and loss of social activities, resulting in depressed mood and lower quality of life [18]. Given the potential for post-concussion sequelae, accurate anticipatory guidance and application of best evidence in the initial management phase are critical [18]. Consistent application of best evidence-based management using comprehensive guidelines may help to reduce the impact of concussion and persistent post-concussive symptoms on children and adolescents [18]. Despite the lack of a concrete set of guidelines to manage a child’s concussion, best practice guidelines have been developed utilizing the best evidence that is currently available to manage concussion [20]. As stated earlier, since so few randomized clinical trials have been studied pediatric concussion, the Ontario Neurotrauma Foundation (ONF) used a broader system to rank evidence that also emphasizes the strength of systematic reviews or large studies that may not involve interventions [20]. The ONF developed the Guidelines for Diagnosing and Managing Pediatric Concussion (GDMPC) in June 2014 [20]. According to these guidelines, physicians are advised to provide verbal information and written handouts to the child/adolescent and the parents and/or caregivers regarding the course of recovery, basic concussion facts, referral to specialized care, follow ups with physician, and advice on managing various aspects of concussion (i.e. coping with fatigue, managing headaches, and managing sleep) [20]. Physicians are advised to give this verbal and written information to the patients and caregivers ‘on discharge’, ‘on interim assessment’, and ‘on re-assessment after one month’ [20]. The guidelines stated that providing education and written instructions to patients, parents and/or caregivers promotes, and leads to better recovery [20]. There is evidence that supports the idea that intensive educational programs that educate
patients and their caregivers lead to better recovery [20-23]. However, the evidence supporting providing written instructions on concussion management to patients and their caregivers is not as well supported as educational programs [20]. Also, it is possible that the amount of information provided to the youth and their caregivers can be overwhelming, especially for the youth who has had a concussion and is now experiencing post-concussion symptoms. The GDMPC guidelines also recommend that physicians consider referring the child to a specialist with experience in pediatric mental health, and/or recommend rehabilitation therapy to improve symptoms and mobility as needed [20]. However, according to a survey of 577 Ontario health care providers, only 9% (95% CI 6% to 11%) reported that they frequently or always refer patients to concussion specialists [18]. The most common barrier reported by those health care providers who answered they ‘never’ refer to concussion specialists (17% [95% CI 14% to 21%]) is the lack of concussion specialists in their region (66% [95% CI 55% to 75%]) [18]. In a few cases (13% [95% CI 7% to 22%]), physicians who reported “never” referring patients to concussion specialists stated that they were not aware of any concussion specialists or that they existed [18].

The GDMPC guidelines and international recommendations suggest a period of physical and cognitive rest until acute symptoms resolve, and then gradual reintegration of activities of progressively increasing physical and cognitive loads [1, 2, 4, 20]. However, if the reintegration of activities occurs too fast or too soon after concussion injuries, then this inappropriately timed physical and cognitive exertion can result in delayed recovery, prolonged functional deficits or more serious injuries [24]. Management of post-concussion symptoms can prevent the aforementioned delays in recovery [24]. Currently, the progression through these stages, of gradual reintegration of activities, is done through paper-based self-reporting of post-concussion symptoms, such as headache, nausea, dizziness, feeling slowed down, and sleep disturbances both during and following an activity [1, 2, 20]; self-report data is regularly obtained using paper-based forms (e.g. Post-Concussion Symptom Scale) with symptom scales which are often paper and pencil Likert-type questions that ask concussed individuals to rate the post-concussion symptoms they are experiencing on a scale of severity (e.g. no symptoms to severe symptoms) [20, 25]. The significant concern with this approach for the management of concussion is that it relies solely on the reporting of subjective parameters [1, 3, 26]. Relying solely on paper-based reporting of post-concussion symptoms to guide return to activity is of particular concern for
children and adolescents who might want to return to activities such as sports and who may not have an accurate concept of the potential long-term damage if the recommended treatment is not followed [20]. In addition, the use of paper-based diaries to record symptoms has often led to poor compliance and recording issues, which lead to inadequate collection of symptom data and analysis [27-29]. Electronic diaries are preferable to paper-based diaries as they provide several advantages that include, determination of actual compliance, reduced errors, and improved compliance [27, 28, 30].

3.2 Interventions for Patients

There is a lack of evidence-based interventions for the management of concussion for youth [4]. However, according to current best-practice guidelines, the acute management of concussion in children and youth should include early identification, education, reassurance, and physical and cognitive rest [20]. Along with advising rest, the best-practice guidelines recommend a range of concussion management strategies that include strategies focused on sleep, nutrition, and relaxation; these concussion management strategies may help improve outcomes [20]. Timely access to care may improve outcomes [31, 32]. However, knowledge and practice gaps in concussion management [16-19] may lead youth to receive inadequate and inconsistent messages from their physicians regarding concussion management. Thus, many youths may be without early access to appropriate concussion care and recovery guidance [31, 32]. Early access to medical care may improve outcomes, and reduce the development of secondary problems, so the lack of, or a delay in access to appropriate concussion care and guidance is problematic [31, 32]. Therefore, there is a need to provide concussed youth with a way to have early and easy access to best-practice concussion management strategies, and recovery guidance to optimize recovery and prevent the development of secondary problems.

Patient education [21] and self-management programs [22] can provide access to best-practice concussion management information and guidance regarding concussion recovery. Therapeutic patient education (TPE) is defined as “helping patients acquire or maintain the competencies they need to manage as well as possible their lives with a chronic disease” [23, p.26]. TPE enables patients and their families to acquire medical knowledge and expertise from their healthcare professionals through activities, so that patients become partners in their own care [23]. The goal is to aid the patient in learning, developing, and adapting behaviours in order to
improve health parameters, such as biomarkers and quality of life [33]. In a meta-analysis assessing the effect of TPE on chronic health conditions, 64% of 360 studies included showed an improvement in health parameters [23]. To study the effects of patient education of concussion, Ponsford et al. conducted a randomized control trial that investigated the impact of providing concussed children an information booklet outlining concussion symptoms, and recommended coping strategies a week post-injury. The results of this randomized controlled trial suggested that concussion management education provided recovery guidance which reduced patient anxiety and lowered the incidence of ongoing problems [21]. However, patient knowledge was not tested pre- and post-intervention, so it is not evident if improved patient knowledge regarding concussion management is what reduced anxiety. Although individual education interventions can help provide recovery guidance, they fail to empower and enable individuals to learn how to manage their own chronic health conditions [22]. In a complementary fashion, self-management programs involve having the patient participate in education and treatment, while practicing specific strategies to manage an illness on a day-to-day basis, and having the ability to reduce the physical and emotional impact of a health condition regardless of healthcare provider collaboration [34-36]. Individuals are encouraged to identify problems and generate solutions by figuring out their barriers and supports, and develop short-term, actionable goals [34]; goal setting is best practice in rehabilitation and it has been shown to increase motivation, participation, and performance in therapy [37]. However, setting and tracking goals can be onerous tasks. Individuals need tangible tools to track recovery, set and track progress towards reaching goals, and share progress with healthcare providers (e.g. in-person, or via e-mail) [34]. If the person is not successful in reaching their goals, the problem-solving process can be repeated and short-term goals can be modified or created anew [34]. Self-management programs are reported to be effective in improving health outcomes for a range of chronic health conditions [35, 36]. Self-management programs for brain injury rehabilitation have shown promising results with adults [22, 38]. Kendrick et al. conducted a pilot study for an acquired brain injury (ABI) self-management program (SMP), in order to evaluate the potential effectiveness of the SMP. The SMP involved eight coaching sessions with an occupational therapist and psychologist, carried out in the community and based on SMP principles. The results of this study suggest that SMPs may improve daily functioning in individuals with chronic mild ABI symptoms, with increased occupational performance and satisfaction, but more methodologically robust clinical trials were recommended [22].
Furthermore, this SMP was not tailored towards pediatric concussion; there are limited descriptions of self-management programs to aid youth concussion recovery [32].

To address the problems of inconsistent messages from healthcare professionals, and inadequate concussion management information/guidance due to the lack of standardization in pediatric concussion management, the following interventions targeting patients (i.e. concussed youth), and parents have been proposed.

### 3.2.1 Heads Up to Parents

The Center of Disease Control and Prevention (CDC) developed the “Heads Up to Parents” educational program that was created to help parents recognize, respond to, and minimize the risk of concussion or other serious brain injury in their children [39]. It provides educational information on concussion for parents of young athletes and schoolchildren [39]. The material is geared towards preventing concussion and how to respond to a concussion should it occur. This program is mainly Web and mobile-based, with information available in PDF form for print [39]. The CDC also developed the “Heads Up for Parents” mobile application for Android and iOS, in partnership with the CDC Foundation and support from a grant from the National Operating Committee [39]. Promotion of this mobile application was done through a helmet company via Quick Response (QR) codes embedded on the inside of manufactured helmets; the QR codes directed the user to the mobile application’s download page [39]. This program is a great resource on helping prevent concussion in youth, with details on helmet safety and playground safety. It is also a good resource for educating the parents on the warning signs of a concussion, and the dangers of not getting diagnosed early, which is aimed to reduce the potential risks of unreported injury. However, this program is primarily athlete-specific, targeted for parents of young athletes, focuses on concussion diagnosis, and it does not provide detailed strategies on how to aid the child in recovering from a concussion after a diagnosis is made, other than limiting the child’s return to activity. Without specific recommendations on how to manage the child's symptoms and gradually allow the child to return to activities, parents may be unsure of how to implement these recommendations [32, 40]. Furthermore, prolonged rest can have a negative impact on concussion recovery [41, 42]. This resource provides limited access to strategies that can help the child cope with and manage their injury. There is a need to
provide youth with easy access to the best-practice strategies to aid youth in self-managing concussion.

3.2.2 Sports Legacy Institute Community Educators (SLICE)

SLICE is a concussion education program that aims to teach student-athletes about concussions early in their athletic careers through a 40 to 60 minute presentation lead by trained health-related student volunteers [43]. These presentations incorporate audience demonstrations, case studies of professional and high school athletes, personal testimonies from collegiate athletes, and interactive audience discussions [43]. SLICE emphasizes how student athletes can recognize and respond to concussion symptoms in themselves or their teammates [43]. The effectiveness of this program was evaluated with a study of 599 students, through the scores of concussion knowledge quizzes given pre- and post-SLICE presentations [43]. The results were favourable, with mean concussion quiz scores increasing from 43% ± 16% to 65% ± 20% [43]. Like [42], this program was also primarily athlete-specific, and only general guidelines for recovery post-concussion were provided. The presentations mainly focused on enabling student athletes to recognize concussion symptoms to encourage self-removal from sports practice or games, and seek a diagnosis; self-management strategies for concussion recovery were not emphasized. Furthermore, this program is presented by trained health-related student volunteers, who may lack the years of expertise traditional healthcare professionals with experience in concussion care have.

3.2.3 Self-Monitoring Activity-Restriction and Relaxation Treatment (SMART)

SMART is an educational Web-based application for concussion self-management [44]. It is a tool that is to be used daily after discharge, consisting of a 22-item Post Concussion Symptom Scale (PCSS), a summary screen comparing symptom levels to the previous day (i.e. the symptom level is better, worse, or about the same), followed by a self-reflection page asking the user to state how much of certain behaviours did the user partake in (i.e. cognitive activities, physical activities) [44]. After rating these behaviours, the user is asked to figure out which behaviours may have contributed to symptom changes and what he/she will change tomorrow to reduce symptoms [44]. SMART uses this approach to encourage real-time self-monitoring, and increased awareness of behaviour and symptom associations [44]. After completing these daily
evaluations, the user is directed to complete psychoeducational modules. The content of these eight modules are developed from evidence-based problem-solving treatments for severe pediatric brain injuries, as well as CDC guidelines [44]. Module content is based on staying positive and focused, dealing with stress, problem-solving, guidelines for returning to school and activities, and tips on caring for oneself [44]. A usability evaluation for SMART was conducted with 4 child/parent pairs, and the perceived usability of the application was determined by a System Usability Scale (SUS) [44]; the mean child score was 81 (standard deviation=22.8), while the parents’ mean score was 89 (standard deviation = 10.7) [44]. This may indicate that the application had certain features that resonated better with older users than younger users. Qualitative analysis revealed that users suggested there be more visuals and less text throughout the application [44]. In analyzing usability data regarding time-on-module, a mean of 49 minutes was spent on completing 6 of the 8 modules (2 modules were missing timing data), and there was a total number of 103 web pages across the 8 modules [44]. While users agreed that the information in these modules greatly supplemented the information provided by the pediatric emergency department, the time and reading required to complete these modules was considered intrusive [44]. Users felt that there was too much reading involved in the entire process [44]. One parent felt that it would be challenging for her child to complete the number of modules required [44]. Another parent stated that the information in the modules would have been too difficult to comprehend for a patient [44]. The results of the SMART application’s usability study suggest that youth may require a considerable amount of physical and cognitive effort to use this technology daily; the application contains 103 web pages, 8 modules, and required on average 49 minutes to navigate. However, following a concussion inappropriately timed physical and cognitive exertion can result in delayed recovery, prolonged functional deficits, and more serious injuries [24]. Thus, the safety with which this application can be used by concussed youth is unclear, and should be validated. While the application involves the self-management of symptoms, it does not empower or enable the user to implement specific concussion management strategies. A technical limitation of SMART, a web-based application, is that it requires an Internet connection which may not always be available or reliable. This limits the access of this application to individuals that have access to the Internet. In contrast to web-based or HTML applications, native applications offer robust offline functionality which is preferred for mHealth tools targeting individuals who may live in rural areas with poor Internet connectivity, or who do not have access to the Internet [37, 45]. In
addition, native applications provide a richer user experience, and better and more innovative capabilities than web-based applications [37, 45]. Furthermore, the design of the SMART application’s user interface (UI) was centered around the use of a computer and mouse which misses the opportunity to include a touchscreen-ready interface for use on a mobile tablet browser, which limits access to this program. In addition, this application was developed for use on a computer, not a smartphone, and its’ usability was evaluated on a 13” HP laptop computer [44]. There is a need to develop tools that are easily accessible to youth, assist them in implementing best-practice concussion management strategies, and that require minimal engagement by the user to ensure safety.

3.2.4 Concussion & You

“Concussion & You” is an evidence informed self-management education program for concussed youth and their families [32]. It features a concussion curriculum based on best evidence and expert opinion, and was integrated within a self-management framework. Concussion & You aims to provide evidence-informed, best practice guidance regarding concussion recovery, enable participants to build an idiosyncratic concussion recovery “tool kit”, and encourages networking between participants [32]. It is a bi-weekly, 90-minute interactive education session presented by occupational therapists, and knowledge translation specialists with expertise in clinical concussion care and research [32]. The first hour of each session is a slide presentation, which is accompanied by a resource work booklet that contains best practice curriculum on energy conservation, sleep hygiene, nutrition, relaxation, return to activities, and development of a concussion recovery toolkit [32]. An overview of concussion and the symptoms experienced by concussed youth is given, and the participants are guided through strategies on how to explain their concussion to others [32]. The participants are then asked to create a visual care plan, facilitated by the “wheel of health” (Figure 1) in the supplied work booklet [32].
The effects of prolonged recovery and symptom exacerbation are discussed, and management strategies are identified. Participants are encouraged to fill in blank spaces on the wheel with strategies to “keep their gas tank full”, effectively building a customized concussion recovery toolkit [32]. The sessions end off with Q&A, encouraging discussion and information sharing regarding participant experiences [32]. The feasibility of this program was validated in a pilot study that led to an increase in patient knowledge post-intervention [32]. Concussion & You mitigates the gaps in concussion healthcare service delivery by providing youth and families with timely access to evidence-based concussion education, a support network, and the ability to enable and empower youth to learn self-management strategies [32]. Participants noted that Concussion & You provided self-management information that would have been valuable to
implement sooner post-diagnosis [32]. Furthermore, the program is not simply for patient education, self-management to promote a successful recovery within participants is a major focus [32]. Participants are empowered to create a tailored self-management concussion recovery toolkit that can be used throughout the concussion recovery process [32]. Youth and families are able to implement strategies into their daily routines with the use of supplied daily planners, activity logs, and post-concussion symptom scales, and results from the post-session survey indicated that these tangible tools positively impact participant recovery [32]. However, this program has a few limitations that are outlined below.

- **Accessibility:** This program is a one-time program that is only offered bi-weekly, and requires that youth come with their parent/guardian to the sessions located at Holland Bloorview Kids Rehabilitation Hospital in Toronto, Ontario to take part in this program [32]. There was also a Web-based option to attend the program, but the feasibility of this option has not yet been validated, and relies on youth having access to, and knowing how to navigate the web.

- **Time:** The program takes 90 minutes to complete, which may not be feasible for some youth and their families to attend.

- **Cost:** The program is offered by occupational therapists and brain injury researchers at Holland Bloorview’s Concussion Centre, which requires the allocation of personnel and resources (e.g. program handbook, pens, concussion management handouts).

- **Paper-based:** The use of paper-based diaries to has often led to poor compliance and recording issues especially among youth, which lead to inadequate collection of symptom data and analysis [28, 29, 44].

Nonetheless, Concussion & You addresses many gaps that exist in concussion management by providing youth with the education and strategies to self-manage their concussion which can significantly improve the quality of life, and outcomes of concussed youth.
### 3.2.5 Summary of Interventions

#### Table 1. Summary of Pediatric Concussion Interventions

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Description</th>
<th>Limitations/Drawbacks</th>
</tr>
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| Heads Up To Parents [42] | - Educational program for parents  
- Consists of online resources and mobile application  
- Geared toward concussion prevention and encourages seeking a diagnosis  
- Brief guidelines for recovery | - Limited self-management techniques or strategies discussed  
- Mainly focuses on concussion in youth athletes, and not the general pediatric population                                                                                                           |
| SLICE [43]            | - Educational program for student athletes  
- 40 to 60 minute presentation given by student volunteers  
- Consists of audience demonstrations, case studies, personal testimonies  
- Geared towards recognition of a concussion in oneself or teammates, and encourages removal from a game/practice to seek a diagnosis  
- Study showed increase in concussion knowledge in participants | - Presentation given by trained student volunteers, who may lack years of expertise in concussion care  
- Limited self-management techniques or strategies discussed  
- Mainly focuses on concussion in youth athletes, and not the general pediatric population                                                                                   |
| SMART [44]            | - Web-based educational and self-management program for pediatric concussion  
- Daily tool to be used to record symptom levels, review symptom changes, and self-analyze behaviour and symptom relationships  
- Contains 8 educational modules on concussion  
- Usability study was favourable, with a mean SUS of 85, and users agreed the content was useful | - Too much text and reading involved for concussed youth  
- UI does not support touch-screens  
- Requires an internet connection  
- Does not enable user to implement self-management strategies, or provide feedback on which strategies may be working  
- Application designed to be used on a laptop computer (13 inch)                                                                                                           |
| Concussion & You [32] | - Evidence-informed, educational, self-management program for concussed youth and families  
- Bi-weekly, 90-minute sessions facilitated by occupational therapists and knowledge translation specialists  
- Consists of concussion education, enabling participants to create personal concussion recovery toolkits based on | - Paper-based reporting has been shown to have low compliance  
- Duration of 90 minutes may be too long for some families, and only accessible in one location within Toronto, Ontario  
- Cost of personnel (e.g. occupational therapists, etc.) and |
best-practice strategies, facilitating networking among participants, Q&A, personal testimonies and experiences
- Work booklets contain a concussion recovery toolkit, a daily planner, activity logs, and PCSS to aid in self-management
- Fills a health system service gap
- Results of pilot study show the program is feasible, increases knowledge regarding concussion management, and is acceptable to youth and their families

resources (e.g. work booklets, handouts, pens, etc.)

3.3 Mobile Health

Many clinical researchers have begun harnessing technology to develop innovative approaches that hold great promise for enhancing the accessibility and quality of care available to people [46, 47]. Mobile Health (mHealth) technologies such as smartphones are well suited to serve as platforms for self-management as they are ubiquitous, have great computational capabilities, and are commonly carried on the person [48, 49]. Also, mHealth technologies can facilitate access to self-monitoring resources, time-sensitive health information, prompts, reminders, and personalized self-management tools in real-time [48, 49]. Though the use of mHealth behavioral interventions is a new era of research, the use of mHealth applications has shown to improve patient outcomes in some chronic disease populations [47]. Recent Pew Internet & American Life Project reports states that mobile phones are a primary communication tool for most youth, they are adopting this technology in a more immersive way than any previous generation, and that mobile phones are practically ubiquitous in the lives of youth in the United States [50, 51]; 75% of 12 to 17-year-olds own mobile phones [51]. Thus, given the ubiquity of mobile phones, youths’ propensity for new technology, and the fact that the majority of adolescents own mobile phones, interventions using mobile technology may provide important and innovative opportunities for engaging youth in self-managing health conditions, and to improve self-management skills and behaviours [50, 52].

The fast adoption of smartphones by the general pediatric population highlights the opportunity for developing mHealth services related to concussion management. A review of concussion-related applications on app stores found that while some applications exist, they primarily
educate the user on how to spot a possible concussion, what steps to take to receive a diagnosis, general information on concussion symptoms and recovery recommendations, and are not specific to pediatric concussion nor do they emphasize strategies or the provision of tools to promote recovery. Furthermore, these applications have not been validated in the peer-reviewed literature, and thus their efficacy in helping youth manage concussion is unclear. Thus, there is a dearth of validated smartphone applications that have been made for the self-management of pediatric concussion. Furthermore, the development and release of healthcare mobile applications is not monitored; Abroms et al. [53] reviewed 47 iOS and 51 Android applications for smoking cessation, and determined a lack of adherence to clinical best-practice guidelines. There is a need for the release of healthcare-related applications to be controlled and validated through appropriate means (e.g. clinical review and U.S. Food and Drug Administration approval).

3.4 Usability

Usability assesses how easy the UI of a product (e.g. screwdriver, doorknob, mobile application, etc.) is to use [54]. Technologies with inadequate consideration of the needs of the intended users are difficult to learn, will be misused or underutilized, and will ultimately fail to accomplish objectives originally set out [55]. The term “usability” in the context of the software development process represents an approach that focuses on the end-user [56-58]: a user-centered design that incorporates end-user needs, concerns and advocacy throughout the design process [54, 56-58]. An aspect of this approach is usability testing, where users work and interact with the software’s UI [56-58]. Following the interaction, the user then shares any usability issues and recommendations with the design and development teams [56, 57, 59]. Having a user perform a set of tasks that relate to product features, and are representative of the tasks that the user may use the technology for is an excellent way to determine the usability of a feature or feature workflow [54, 56]. Usability studies are commonly used to evaluate mobile health technologies [60-62].

Usability testing focuses on measurable user performance and preference metrics. There are numerous aspects of usability [54]. ISO 9241-11 (1998) defines usability as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use [59, 63]. Effectiveness refers to the accuracy and
completeness with which user can accomplish specified goals [59]. Efficiency refers to the resources (i.e. amount of effort) a user expends to complete a task. User satisfaction can be measured by the extent to which users have achieved their pragmatic and hedonic goals, and ISO/IEC CD 25010.2 suggests the following types of measures: likability, pleasure, comfort, and security [63]. There are many different measures of usability that can be used to assess a product [59, 64]. As discussed, there are also other aspects of usability, for example, learnability that measures how performance improved or fails to improve over time [59]. There are many research methods used to assess the usability of a technology [58, 59, 65]; common usability evaluation methods include lab-based usability studies, concurrent “think aloud” protocol, usability benchmarking, questionnaires, and interviews [58, 59, 65]. Lab-based usability studies are one of the most commonly used research methods used to assess a product’s usability [58, 59, 65]. Formative lab-based usability testing is a widely used usability testing approach that is iterative in nature [59]; the goal of this testing is to make improvements in design before releasing the product [59]. This includes, identify and diagnosing problems, making and implementing recommendations, and then re-evaluating the product [59]. An essential requirement for conducting usability studies is that the participants must attempt tasks that are indicative of what eventual end-users will need or want to do with the technology [59]. However, due to time and resource constraints it is not possible to test every possible task that the end-users can do with the technology. Dumas and Redish state that a good task for a usability study is a task that “has the potential to uncover a usability problem” [64]. Think aloud is considered one of the most valuable usability research methods [26]. The think aloud protocol asks the user to continuously verbalize their thoughts about their underlying thinking, i.e. their opinions, attitudes, feelings, perceptions, and assumptions, behind their interactions with the smartphone technology. This method allows the user to effectively verbalize what they are doing and why, state when they encounter a problem, and how they feel while using the technology. This method is robust, flexible, economical, and it occurs simultaneously while the participant interacts with the technology [26]; it is useful to instantly get feedback for each task, and avoids the need for rationalizations later on [56, 66]. Also, this method does not rely on self-report measures which can lead to incorrect or inaccurate accounts of a participants’ actions [26]. However, a concurrent think aloud protocol may impact task completion time, and may influence how participants complete a task. However, a good solution is to ask participants to “hold” any longer comments until after a task is completed [59]. In addition, Neilson states that
participants quickly become very engaged in the test tasks, and forget that they are in a study [26]. Questionnaires and interviews are user experience research methods that are commonly used in usability studies to collect qualitative and quantitative data regarding user preferences, perceived usability and utility [56, 59, 65]. The perceived usability and satisfaction of a product can be evaluated using the System Usability Scale (SUS) [59, 67]. The SUS consists of 10 questions, and uses a five-point Likert-scale answering scheme, to get a reliable and robust evaluation of a product [59, 67, 68]. The SUS is a validated, and reliable questionnaire [59, 67]. Research has shown that the SUS questionnaire provides a reliable measure of the perceived usability of a system with small sample sizes (i.e. 8 to 12 users) [67, 69]. This survey has been widely used for a variety of research projects and evaluations in industry due to its easy of use and reliability [59, 67, 68]. According to previous research, an SUS score of 68 is considered to be average (i.e. satisfactory), and SUS scores higher than 68 indicate above average usability across comparable applications [67-69].

It is important to perform a usability study for a mobile health technology with prospective end-users, in order to effectively determine how well the target audience interacts and relates to a technology. Furthermore, it is important to use measurement methods that are least obtrusive to a usability study participant. For example, is common to record the screen of a mobile phone during a usability study of a mobile technology, as is recording audio during the think aloud approach [70]. The use of an external camera and external audio recording device can be used, but these methods are typically seen as obtrusive and further removes the study participant from a “real-world” setting [70]. Instead, the mobile screen and think aloud audio can be recorded with the phone itself. It has been noted that some users still might find this method obtrusive, causing them to modify their task performance, positively improve behaviour towards the study facilitator, and limit the number of negative comments on the design (i.e. the Hawthorne effect) [71]. However, this is the least obtrusive method of collecting data pertaining to mobile device interaction, and does not require any extra recording equipment other than the mobile device itself [70].

As discussed, there is a need to develop accessible tools that can enable youth to have easy access to complete and evidence-informed concussion management information and strategies, and to aid youth in implementing the management strategies throughout recovery. The goal of this research was to design and evaluate the usability of a smartphone technology that will help
enable youth to better self-manage concussion by providing easy access to accurate and complete concussion management information and strategies in the form of a usable technology. This technology is expected to prevent delayed recovery, prolonged functional deficits, and more serious injuries, thus reducing the duration and severity of post-concussion symptoms. Overall, this technology is expected to improve the quality of life of concussed youth by allowing the quick and safe return to daily activities such as, sports, school, family, and social activities.

3.5 NeuroCare

This research is inline with the research objectives of the five year CIHR team grant project titled “NeuroCare as innovation in intervention: a neurophysiological approach to determine readiness for return to activity”. This is a three-phase grant: develop and validate the NeuroCare approach, develop the smartphone technology needed to implement NeuroCare, and evaluate the usability and feasibility of NeuroCare. This research was inline with phases two and three (i.e. usability) of this grant. This team grant project consisted of many members which included, brain injury researchers, engineers, and health care professionals. This grant is referred to as the NeuroCare grant, and its’ team members are referred to as the NeuroCare team members in this research.
Chapter 4

4 Research Questions and Objectives

The goal of this research was to design and evaluate the usability of a smartphone technology that can help enable youth to better self-manage concussion by providing easy access to accurate and complete concussion management information and strategies in the form of a usable technology.

4.1 Research Objectives

The research objectives for this research proposal are stated below:

1. Design and develop a usable smartphone technology that can help youth self-manage concussion
   1.1. Identify the context of use of this technology
   1.2. Establish the design requirements
   1.3. Design and develop the technology prototype
2. Evaluate the usability of this technology, and identify usability issues with this technology.

4.2 Research Questions

The proposed research will answer the following question:

1. How usable is the smartphone technology?
2. Does this technology have any usability issues?

4.3 Research Hypotheses

The hypotheses for the research question are stated below:

1. Overall, the technology will have high perceived usability with a System Usability Scale score higher than 68 (average/satisfactory usability).
2. The effectiveness of the technology will be high; task success rate will be equal to or higher than 90%, and the frequency of errors per task will be low (~ < 11 errors).
3. The efficiency of this technology will be high; the task completion times will be less than 2 minutes.
4. This technology will have many low and moderate severity usability issues, and a few (~< 5) severe usability issues. The severe usability issues will be identified, and design changes to resolve each issue will be provided.
Chapter 5

5 Requirements Analysis

Research Objective 1: Design and develop a usable smartphone technology that can help youth self-manage concussion

As mentioned early, there is a dearth of interventions for management of pediatric concussion. Thus, the main objective of this research is to develop a usable and useful smartphone technology that can help youth self-manage their concussion. The methods used to design and develop this technology are discussed in the following chapters. This chapter focuses on identifying the user requirements that are necessary to ensure the technology is useful, usable, and meets the needs of the end-users.

5.1 Methods

A user-centered design and Agile development methods were used to design and develop this technology in order to ensure that it was useful and usable for helping youth self-manage their concussions.

5.1.1 Agile user-centered design

A core principle of Agile development is to provide valuable software to the user on a continuous basis from the earliest of development stages [72]. This practice allows developers to seamlessly accommodate changes in user requirements at any stage of the development process [73]. Furthermore, end-users or proxies are involved throughout the development process, providing input that can lead to a successful software application [73]. Software applications are deemed valuable if the UI is considered usable by the target audience, but Agile methods alone do not ensure high UI usability [72]. Therefore, there has been interest in combining Agile methods with user-centered design (UCD) practices [72]. UCD is a simple concept that demands that the user is accounted for during each step of the design and development process [74]. Each user experience implementation or change should be the result of a conscious user-centered decision by the development team [58, 74]. Additionally, end-users are consulted about their needs, and are typically involved during the requirements gathering and usability testing phases [75]. In support of existing empirical evidence that the Agile and UCD methodologies coexist
effectively, it was found that products created using Agile UCD methods are superior in design to "waterfall" versions using UCD techniques [76]. Agile methods are shown to decrease the gap between uncovering and acting on usability issues [76].

5.1.2 Design team and proxies

Normally, Agile UCD requires end-users to be involved throughout the design process [72]. However, it may be difficult to involve the end-users in the design of the technology due to time and resource constraints, and the difficulty of recruiting the specific end-user populations [77, 103]. When it is not possible to involve all the end-users required to represent the different perspectives of a technology, user proxies are commonly used [77-79]. User proxies represent the end-users during design and development phases, but they need not be eventual end-users; however, for this research most of the proxies used were the secondary (i.e. health care professionals) and tertiary (i.e. brain injury researchers) end-users of this technology. It is important to select appropriate user proxies to ensure that a usable and useful product is developed [77-79]. To ensure that the background and motives of a specific user proxy did not solely drive the design of the technology [77], many user proxies were used; the proxies included, health care professionals (e.g. occupational therapists), concussion experts, business personnel, and brain injury researchers. The key proxies were the secondary end-users of the technology, the health care professionals, since these professionals are in continuous contact with the primary end-users, concussed youth, and have substantial domain knowledge in pediatric concussion management. These user proxies, and key stakeholders, made up a design team that was iteratively involved in the development of this technology.

The general phases of the agile UCD process includes the following four steps: (1) identifying the context of use, (2) identifying design requirements, (3) prototype design and development, and (4) prototype evaluation [72, 80]. The methodology and results for the first two phases are described next.
5.2 Identifying the Context of Use

Research Objective 1.1: Identify the context of use of this technology

The first phase of UCD involves identifying the end-users, the purpose for which end-users will use the technology, and under what conditions they will use the technology. To identify the context of use of this technology, a series of group discussions and informal interviews were conducted with the design team; the results are summarized next.

The design team identified that the primary end-users of this technology are concussed youth between 10 and 18 years of age, and the secondary end-users are the health care professionals that are involved in concussion assessment and management. A concussed youth will use this smartphone technology to better self-manage their concussion, and health care professionals will use this technology to provide their patients with better direction and support to help them manage their concussion. Both end-users will use this technology to improve communication between each other, which has shown to improve patient health outcomes, specifically emotional health and symptom resolution [81]. Health care professionals will provide youth with access to this smartphone technology as soon as a youth is diagnosed with a concussion, or youth may gain access to the technology through the online smartphone application stores. The youth will be instructed to use the application throughout their concussion recovery to help in managing their concussion, which can take from two weeks to several months [1, 4-6].

In UCD, it is common to create a target user group profile to better understand the end-user throughout the design and development process. User group profiles describe the main characteristics of the end-users of the technology [82]. Using the above description of the target user, context of use of the technology, group discussions with the design team, and the literature (e.g. pediatric concussion management guidelines), the primary user group profile was identified as a concussed youth 10 to 18 years of age who:

- Has been attending school regularly before their concussion diagnosis
- May have been involved in sports activities prior to their concussion
- Will use this technology daily throughout their recovery
- Will own or have access to a smartphone daily
- Will have some previous experience using smartphone applications
- Will have some knowledge of basic smartphone application UI elements
- May be experiencing one or many post-concussion symptoms; specifically, they may be sensitive to light and noise [1]
- May have no or limited knowledge of how to self-manage their concussion
- May have had one or more concussions in the past
- May not have a health care professional accurately guiding them through their concussion recovery [32]
- May not be able to comprehend complex terms, specifically youth under 14 years of age

It is common to create personas from a target user group profile in order to empathize with the target users. Personas help to provide design teams with a unified vision of the target end-users, and help bring the focus back to the end-users throughout technology design and development [83]. During design and development of a technology, a persona acts as a fictional end-user; the persona should be kept in mind (considered) when any decisions regarding technology design are made [83]. To guide this research, a persona named “Andrew” was developed. Andrew was 14 years of age, attending a high school in Toronto, Ontario, an avid swimmer, outgoing, and enjoyed spending time with friends and family. He had suffered from a head injury at school that resulted in a concussion; this was Andrew’s first concussion. Andrew was experiencing some post-concussion symptoms that included light and noise sensitivity, headaches, sadness, and nervousness/anxiousness. Andrew owned a smartphone, and would regularly use the phone; for example, to play games and send text messages to friends. Andrew had a doctor that was helping him in his concussion recovery. The doctor told Andrew to monitor his post-concussion symptoms (fill out the Post-Concussion Symptom Scale [84]) weekly, and the doctor said that when his symptoms reduced or went away completely, Andrew could get back to doing all the activities he used to do before his concussion. Andrew was not aware of concussion management strategies he could use to improve his concussion recovery, and he was not provided information on how to self-manage his concussion.
5.3 Identifying Requirements

Research Objective 1.2: Establish the design requirements

The next phase of UCD involves the identification of design requirements. The requirements of this smartphone technology were identified through a series of brainstorming sessions and group discussions with the design team, using the literature (e.g. pediatric concussion management guidelines), using the Concussion & You work booklet, and through observations and group discussions during Concussion & You program sessions. Despite brainstorming not regularly being used to collect and define requirements, under appropriate constraints it is an effective tool to identify, develop, and collect design ideas in a group setting [85].

5.3.1 Design Team Discussions

The design team meetings all took place at Holland Bloorview Kids Rehabilitation Hospital. The design team meetings occurred iteratively during each phase of technology development. The meetings took the form of brainstorming sessions, and group discussions were the members expressed ideas regarding what this technology should contain, do, and look like in order to be useful helping youth manage their concussion; providing a valuable, safe, usable self-management tool were the key requirement for this technology. Also, the team meetings were used to evaluate technology prototypes, discussed later. In addition, the team members shared their experiences in concussion care, including their experiences in helping youth manage their concussions, things youth found difficult in managing their concussions, and the lack of timely access to pediatric concussion expert care.

5.3.2 Concussion & You Handbook

Dr. Nick Reed and colleagues, experts in youth concussion from Holland Bloorview Kids Rehabilitation Hospital Concussion Centre, designed the Concussion & You handbook to help youth with concussion management and recovery [32, 86]. The team of experts included healthcare professionals, from neuropsychologists and pediatricians to occupational therapists. This handbook provides youth with concussion management strategies, techniques, resources, and knowledge that can help speed the youth’s path to recovery [32, 86]. The concussion management strategies in this handbook are separated into six clusters: energy conservation, sleep, nutrition, relaxation, return to school, and return to physical activity and sport [32, 86].
The management strategies are based on expert knowledge, cutting edge research, and best-practice guidelines [32, 86]. It was decided that the technology developed would incorporate the concussion management strategies outlined in this handbook.

5.3.3 Concussion & You Program Sessions

*Observations and informal group discussions:* Despite not having access to the primary end-users due to time and resource constraints, and the difficulty and safety concerns associated with recruiting concussed youth, there were some opportunities presented to observe and informally speak with concussed youth during the development of this technology. The Concussion & You program is run multiple times per week by occupational therapists specializing in pediatric concussion rehabilitation (management) at Holland Bloorview Kids Rehabilitation Hospital [32].

The session begins by the healthcare professional introducing himself/herself, and everyone in the room gets acquainted. The Concussion & You program work booklet, and other concussion resources are distributed to all attendees. Then, the healthcare professional walks the youth and parents through a PowerPoint presentation that provides a brief overview of the material available in the work booklet. The presentation includes information on what a concussion is, how it occurs, how it affects people, and what strategies youth can use to avoid further injury, feel better, and recover faster. The sessions are interactive, and group discussions were regularly observed. Patients and their families would discuss the problems they were facing with managing their concussion, and other families would contribute to the talk. The healthcare professional answered any questions that were asked throughout the session. Near the end of the session, the youth were asked to open their work booklet, and to find the wheel of health (Figure 1). Then, the youth were educated on how to use this wheel of health to self-manage their concussion. Youth were told to choose a few strategies for each category, and to use them daily, for a week. At the end of the week, the youth were instructed to assess their plan and see if it is helping them feel better. If not, then it was recommended that youth try a different set of strategies. The goal was to figure out which strategies could help them feel better, and then to continuously apply those strategies throughout their concussion recovery. Following this, there was opportunity for questions and answers, which usually took the form of a group discussion with the health care professional providing their expert opinion when required.
The author attended multiple Concussion & You sessions, and observed the interactions between the concussed youth, their parents, and the health care professionals; the attendance of the sessions ranged from three to fifteen individuals. The observations helped understand the needs of the youth, their parents, and the youth’s willingness to learn and engage in their concussion recovery. At the end of the sessions, the author took part in informal group discussions with the concussed youth, and their patients to understand if providing this program in the form of a technology would be useful or not. The group discussions also included understanding user requirements, and content that should be included in a smartphone technology to help youth manage their concussions. The results from the discussions informed and confirmed design choices, and user requirements. The discussions also supported the fact that a smartphone technology based on the Concussion & You is needed, desirable, and overall may be useful in helping youth in self-managing their concussions.

5.4 Results

The design requirements identified for this technology are summarized in Table 2 below. These design requirements were used to identify key design principles (Table 3) and features (Table 4) for this smartphone technology.

Table 2. Identified design requirements

<table>
<thead>
<tr>
<th>Finding</th>
<th>Design Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>The brain of a concussed youth is in the process of recovering. Reintegrating into activities of physical or cognitive load too early may lead to exacerbation of symptoms, delayed recovery, or more serious injuries [1].</td>
<td>Should be safe (zero-risk); it should not advise youth to do anything that may lead to delayed recovery, or other injuries.</td>
</tr>
<tr>
<td>A technology should be tailored to the users needs [87].</td>
<td>Aim to be simple and demand minimal engagement from the concussed youth, in order to reduce the amount of cognitive effort required from the youth; the technology should have high usability.</td>
</tr>
<tr>
<td>Should be child friendly, provide a fun user experience, and use age-appropriate language. Favour the use of visuals over words [88], and make the UI colourful.</td>
<td></td>
</tr>
<tr>
<td>There is a lack of pediatric concussion management interventions [4].</td>
<td>Should be a general concussion self-management technology (i.e. not specific to any sport or lifestyle), in order to serve the entire concussed youth population.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>The focus of current concussion management is on symptoms, and associated activity restrictions.</td>
<td>The design team recommends that this technology take a holistic approach to concussion management, a common approach used in occupational therapy; to focus on the person as a whole rather than solely their injury or illness [89].</td>
</tr>
<tr>
<td>Understanding and implementing the management strategies outlined in the pediatric concussion guidelines may be difficult for concussed youth and their families. Concussion &amp; You is one of the only evidence-informed programs that enables youth to self-manage their concussion, by providing access to the best-practice concussion management strategies, helps youth understand the strategies, and providing a paper-based approach to implementing those strategies [32]. However, the program is a one-time program, only available once bi-weekly, youth do not receive guidance or feedback after the program and between health care provider visits. There is also a health service gap that exists for concussed youth, where they may not receive periodic feedback from their health care provider. Thus, many youth are left without guidance and feedback throughout their concussion recovery.</td>
<td>The application should provide youth with a way to easily understand and implement strategies in the Concussion &amp; You program on a daily basis; it is recommended that these strategies be used daily.</td>
</tr>
<tr>
<td>Goal-setting and creating weekly action plans can help in aiding self-management of disease [34, 90].</td>
<td>Provide youth with feedback and guidance throughout their concussion recovery.</td>
</tr>
<tr>
<td>Providing youth and/or their families with education on concussion management may</td>
<td>Should be a coaching application, not an informational application. Must guide youth throughout their concussion recovery, and help youth understand what strategies are working for them, and how they can further improve their recovery.</td>
</tr>
<tr>
<td></td>
<td>Enable youth to create their own short-term concussion recovery action plans, ideally weekly plans. Team needs to transform best-practice concussion management strategies from the Concussion &amp; You program into actionable goals that the youth can easily understand and implement [34].</td>
</tr>
<tr>
<td></td>
<td>The technology should provide youth with access to evidence-based concussion education.</td>
</tr>
<tr>
<td>help increase health outcomes post-concussion [1].</td>
<td>management education, and educational resources [34].</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Youth may not see their health care provider for weeks to months after a concussion diagnosis [1]. Sharing progress with a health care professional has shown to encourage patients take a more active role in their healthcare (patient activation) [91].</td>
<td>Should allow youth to share their concussion recovery progress with their health care professional.</td>
</tr>
<tr>
<td>Provide summaries of useful data to enable a healthcare professional to make more informed decisions about a youth’s recovery. The data should be displayed in easy to digest digital formats.</td>
<td></td>
</tr>
<tr>
<td>Youth are typically socially and/or physically active pre-concussion. Following a concussive diagnosis, youth often feel socially isolated, lonely or depressed because treatment demands rest and avoidance of activities [4, 20, 92]. Strategies focused on mental health, and reducing social isolation (and the loneliness that accompanies it) may be beneficial for concussed youth [4, 20, 92].</td>
<td>The application should include information regarding mental health, and social activities that the youth can/should take part in despite their concussion diagnosis. As the term “mental health” has a negative connotation, the technology should include a “social” goals section focused on mental health and reducing social isolation.</td>
</tr>
<tr>
<td>The application should provide feedback through positive and motivational wording; negative wording should be avoided [34].</td>
<td></td>
</tr>
<tr>
<td>Photophobia and noise sensitivity are common post-concussion symptoms. [93]</td>
<td>UI should be made up of soft colours, and colour relationships within the application should not strain the eyes.</td>
</tr>
<tr>
<td>Should minimally utilize smartphone sounds or tones.</td>
<td></td>
</tr>
<tr>
<td>Mobile reminders that remind users of medical appointments are seen to improve health outcomes [94].</td>
<td>The technology should include reminders/prompts to remind the youth to implement their concussion management strategies daily.</td>
</tr>
</tbody>
</table>

### 5.4.1 Design Principles

The design principles were used to guide the development of all features and functions for the technology; the design principles were kept in mind at each stage of design and development. For example, an essential requirement for this technology was that it should be highly usable. Thus, the design of this technology was based on accepted application design principles and
guidelines, such as Nielsen's 10 usability heuristics for UI design [87], and Android’s application development guidelines were used to guide the design and development of this technology [95]. The design principles of the smartphone technology are listed in Table 3.

Table 3. Summary of Design Principles

<table>
<thead>
<tr>
<th>Design Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>All visuals, educational resources, actionable goals, and advice in the application should not exacerbate post-concussion symptoms, delay recovery, or cause injury. Minimize constant engagement by the youth (i.e. to avoid overuse).</td>
</tr>
<tr>
<td>Navigation</td>
<td>Navigation around the application should be intuitive, simple, and demand minimal engagement from the concussed youth [87]. The technology should have high usability. Ensure simple page designs to prevent navigation errors [87]. Minimize the concussed youth’s memory load by making navigation actions/options recognizable; user should not need to recall how to navigate the application [87].</td>
</tr>
<tr>
<td>Visuals</td>
<td>Prefer visuals over text and numbers, where possible [96]. Avoid bright colors and mismatched color relationships [97]. Use mobile OS color and icon standards for actionable buttons [98].</td>
</tr>
<tr>
<td>Audio</td>
<td>Sounds and tones should be avoided throughout the smartphone application workflow [97].</td>
</tr>
<tr>
<td>Text</td>
<td>Text should be youth-friendly (i.e. not complex). Text should be positive, motivational, and encouraging [34]. Negative text should be avoided.</td>
</tr>
</tbody>
</table>
5.4.2 Mobile Application Features

The smartphone application’s features that were decided upon are listed in Table 4. These features are listed in a priority sequence, with the Data Recording, Feedback, Support and Educational features determined as must-have, and Data Sharing features determined as desirable but not necessary, for the usability study with end-users.

Table 4. Summary of Mobile Application Features

<table>
<thead>
<tr>
<th>Category</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Recording</td>
<td>The concussed youth can record how they are feeling on a daily basis, to get a holistic view on their concussion recovery.</td>
</tr>
<tr>
<td></td>
<td>The concussed youth can create a goal-oriented action plan to self-manage their concussion, based on the Concussion &amp; You program strategies, and record completion status (per goal) on a daily basis.</td>
</tr>
<tr>
<td>Support</td>
<td>The concussed youth should be provided prompts/reminders to remind them to use the application.</td>
</tr>
<tr>
<td></td>
<td>Guide the user in navigating the application</td>
</tr>
<tr>
<td>Feedback</td>
<td>The concussed youth will receive feedback on which goals (strategies) are working for them, and what more they can do to improve their concussion recovery.</td>
</tr>
<tr>
<td>Education</td>
<td>The concussed youth will have access to concussion-related education within the application.</td>
</tr>
<tr>
<td></td>
<td>The concussed youth will have access to concussion recovery webpage links for more information.</td>
</tr>
<tr>
<td>Data Sharing</td>
<td>The concussed youth can share, with a healthcare professional, how they are doing in their concussion recovery.</td>
</tr>
<tr>
<td></td>
<td>The healthcare professional can review shared data in an easy-to-consume manner. Data can be collected anonymously, and analyzed from a large sample size of patients to understand what strategies are helpful in the self-management of pediatric concussion.</td>
</tr>
</tbody>
</table>
5.4.3 Concussion Self-Management Goals

The action plan goals in the technology were to be based on the concussion management strategies outlined in the Concussion & You program work booklet. The design team identified that the strategies are not specific enough to be used as goals, and therefore the concussion management strategies were transformed into simple, easy to understand, and easily implementable goals. Four categories of goals were created: “Energy conservation”, “Sleep”, “Nutrition”, and “Relaxation”. For each goal, a lean and descriptive title was chosen, and detailed, understandable descriptions of each goal were created using the existing material. These descriptions were provided to answer what the goal entailed, how it can help the youth in concussion recovery, and how the goal can be implemented.

In addition, another requirement of this technology was to include goals regarding mental health, and social activities, that would help reduce the impact of social isolation and depression that may accompany a concussion diagnosis [4, 7, 92]. This researcher conducted literature searches to identify social and mental health topics that should be covered, and corresponding strategies that could be transformed into goals. After a preliminary list of key topics and goals was developed, this researcher conducted a series of informal interviews and group discussions with member of the design team, an adult with a history of pediatric concussion, and with the concussion experts currently responsible for the Concussion & You program; these were conducted to identify additional key social and mental health topics, and to transform the topics into actionable goals. The information collected through literature searches [1, 20, 86, 92, 99], informal interviews, and group discussions were informally analyzed (i.e. grouped into categories) to identify the key social and mental health topics that should be included in this technology. The Concussion & You program presentation was recently edited, and this author also reviewed the revised program presentation for further information. Six new “mental health” strategies were identified, and the category name for these strategies was initially suggested to be “Mental health goals”. However, the word “mental” may have a negative connotation. In addition, most of the strategies identified involved taking part in social activities. Thus, the category name selected for these goals was “Social goals”. For this technology, the final goals list is outlined in Table 5.
### Table 5. Concussion self-management goals

<table>
<thead>
<tr>
<th>Goal Type</th>
<th>Goal Names</th>
</tr>
</thead>
</table>
| Energy Conservation | • Work in a Quiet Area  
                      | • Prioritize Daily Tasks  
                      | • Plan My Day  
                      | • Pace Myself  
                      | • Set Limits for Activities |
| Sleep            | • Regular Sleep Schedule  
                      | • Relaxing Bedtime Routine  
                      | • Sleep Position, Sleep Only Zone  
                      | • Avoid Long Naps  
                      | • Avoid Eating Before Bed  
                      | • Avoid Caffeine  
                      | • Jot Down Sleep Problems |
| Nutrition        | • Eat a Balanced Diet  
                      | • Regular Meals and Snacks  
                      | • Eat Healthy Carbohydrates  
                      | • Drink Water |
| Relaxation       | • Find Relaxation Methods  
                      | • Practice Relaxing Everyday  
                      | • Learn Stressors  
                      | • Practice Deep Breathing  
                      | • Practice Visualization |
| Social           | • Talk to a Friend  
                      | • Go for a Short Walk  
                      | • Jot Down 1 Proud Moment  
                      | • Give Someone a Hug  
                      | • Connect with Others  
                      | • Talk to a Counselor |

The design requirements outlined in this chapter were used to design the smartphone technology prototype as discussed next in Chapter 6; prototype design and development is the third phase of the user-centered design approach being used to develop this technology.
Chapter 6

Prototype Design and Development

Research Objective 1.3: Design and develop the technology prototype

Creating a viable design from user requirements is not a straightforward path in software development. However, agile development processes aid in creating software that is centered around the user perspective rather than the technical perspective [72]. In the following sections, the methods used to develop and test the fully functional prototype for usability testing are described in detail.

6.1 Methods

6.1.1 Design Requirements and Agile User Stories

A common approach in Agile development is to convert key design features into user-stories [100]. A user story is a software development tool that aims to capture a description of a software feature from the perspective of an end-user. A user-story is a piece of functionality or a feature that is of value to the end-user [100]; they are high-level, lean descriptions of a requirement. An epic is a large user story, which can eventually be broken down into many smaller user stories [100]. Here, this author determined the three epics and related user stories from the perspective of a concussed youth, and one epic and related user stories from the perspective of a healthcare professional.

Table 6. Concussed Youth Epic 1

<table>
<thead>
<tr>
<th>User Story</th>
<th>Technical Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>I want to record how I feel on a daily basis, so that I can track how I’m feeling throughout my concussion recovery.</td>
<td>Create a ‘How am I feeling today?’ page that allows the user to record this information. Make the history of recorded feeling-related information available as well.</td>
</tr>
<tr>
<td>I want to create a list of goals (action plan) that I can try to accomplish every day, so that I can feel better post-concussion.</td>
<td>Allow the user to add to their action plan from a pre-determined list of goals, specifying the duration of the goal, and how they will accomplish it.</td>
</tr>
</tbody>
</table>
I want to be able to say if I completed a goal or not, so that I increase my accountability.

Once a goal has been added to an action plan, allow the user to record if they completed a goal or not. Make each goal’s history of completion available to the user.

I want each goal to be descriptive in how it can help me deal with my concussion, so I can implement each goal better.

Provide a detailed description of each goal, during goal selection and afterwards, as well, for reference.

I want to be able to modify my list of goals (action plan) at any time, so I can increase customizability of my action plan.

Give the user the ability to add or delete a goal, or modify the duration of a goal.

As a concussed youth, I want to be able to create customizable, short-term action plans so that I can better self-manage my concussion.

### Table 7. Concussed Youth Epic 2

<table>
<thead>
<tr>
<th>User Story</th>
<th>Technical Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>I want a summary of which goals make me feel better post-concussion, so that I can make appropriate adjustments to my action plan.</td>
<td>Create a summary page. Give the user a summary of which goals may be helping them feel better post-concussion, by correlating goal completion and feeling-related data.</td>
</tr>
<tr>
<td>I want recommendations on goals that may help me feel better post-concussion, so that I can add them to my action plan.</td>
<td>Recommend new goals to the user. These goals can be goals users have not tried, or goals that their doctor recommends.</td>
</tr>
<tr>
<td>I want to be reminded to ‘check-in’ to the application so that I use it on a consistent basis, so I can make the self-management of my concussion habitual.</td>
<td>Allow the user to set a notification reminder that will remind them to come into the application and go through the user workflow.</td>
</tr>
</tbody>
</table>

As a concussed youth, I want to receive feedback on which parts of my action plan are helping me feel better, and what more I can do, so that I can make informed decisions in my self-management of concussion.

### Table 8. Concussed Youth Epic 3

<table>
<thead>
<tr>
<th>User Story</th>
<th>Technical Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>I want accessibility to concussion-related education and online resources, so I can make more informed decisions about concussion.</td>
<td>Provide user with data relating to concussion in a singular location. Provide user with links to online resources.</td>
</tr>
</tbody>
</table>
how to I can best self-manage my concussion. | resources regarding concussion management. Ensure the language is youth-friendly.
---|---
I want to have contact information for concussion experts and professionals that I can trust, so that I will have access to support when in need. | Create a ‘Contact Us’ page. Provide user with contact information for pediatric concussion experts and professionals that are trustworthy; provide the contact information for Holland Bloorview’s Concussion Center.
I want a description on what the goal of this application is, and how it can help me, so I can understand the value of using the application on a daily basis. | Create an ‘About this App’ page that explains the goal of this application, and how it can help the user.

As a concussed youth, I want to have access to education and resources regarding concussions, so that I can make informed decisions in my self-management of concussion.

Table 9. Healthcare professional Epic 1

<table>
<thead>
<tr>
<th>User Story</th>
<th>Technical Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>I want to receive a summary of how my patient felt over the past week, and what strategies they tried each day, so I can better understand my patient, what they are trying, and make more informed decisions about their concussion recovery.</td>
<td>Provide an overall view of how the youth is feeling, and what goals they are trying each day, that the doctor can easily look at and understand. In addition, allow the user to send all this data to the doctor via e-mail.</td>
</tr>
<tr>
<td>I want to receive an overall view of all the recorded data in order to determine which goals/strategies are working for my patient, so I can perhaps recommended those goals/strategies to my future patients.</td>
<td>Allow the user to view on the application, or send a summary of all the recorded data to their doctor while ensuring the user’s anonymity is intact.</td>
</tr>
</tbody>
</table>

As the healthcare profession of a concussed youth, I want to receive data and summary information on my patient’s progress in their action plan, so I can better understand which strategies are working for them.

6.1.2 Storyboarding

Storyboarding is a common practice in agile software design and development. A storyboard consists of multiple, visualized scenes that paint a narrative of how an end-user will interact with a future system [101]. The use of a storyboard is to easily share the vision you have of an end-user interacting with your device, and providing initial UI concepts [102].
After reviewing the epics and user stories, it was clear that the purpose of the application was to enable youth to better self-manage their concussion through an educational and guidance-based approach that involved them recording data about their action plan and receiving feedback. This information recording will need to be done by the user on a consistent (daily) basis in order to provide the user with feedback on how the application perceives them to be doing. This consistent entry of data will be encouraged through a daily notification reminder that will be set at a time convenient for the user. Upon review of the feedback the application provides, the user can improve their decision-making and modify their action plan if necessary. Education and additional resources will also be accessible to the user for further support. This analysis of requirements aided in the storyboarding process and resulted in Figure 2.
Meet Andrew, who recently suffered a concussion during a soccer game.

"I want a way to create an action plan to self-manage my concussion, complete with education and feedback, using my phone!"

Andrew adds a Sleep goal, and gets educated on Sleep & Concussion.

"I think I'll try to avoid taking naps so I can sleep better, and read up on how concussion affects sleep."

Andrew receives a notification reminder from the NeuroCare app, and opens it.

"I am having a hard time sleeping, so I'll add a sleep strategy/goal to my to action plan and see if that helps."

Andrew then clicks on the Summary button to see how he's doing.

"Looks like I've been feeling pretty good the past few days, and this goal to stay hydrated is helping. Let's try some more nutritional goals."

Andrew adds a Nutritional Goal.

"Let's try to include healthy carbs in my diet, and see how that works out."

Andrew goes on with his day, and will check back in tomorrow.

"Okay, sweet. I'll try to complete all my goals today and check back in tomorrow."

Figure 2: Storyboarding sample
The storyboard (Figure 2) detailed the initial user workflow that was envisioned. The concussed youth would interact with the device for a minute or two, recording feeling information and goal completion information for their action plan, while perhaps reviewing feedback that the application was giving to them. With this feedback in mind, the user could go back into the application that same day or in the future, and modify the list of goals in their action plan if needed. This storyboarding process was useful in envisioning how a user might approach and interact with the mobile application while recording information, and also how the user might respond to summary information being shown to them. Storyboarding got the creative process started, and further design details were developed in an iterative development approach.

6.1.3 Iterative Prototype Development and Testing

After formulating an initial user workflow for the mobile application, design and development of the application began. The design, development and improvements to the prototype were carried out using an iterative and incremental development (IID) approach with the support of the design team and NeuroCare team (see section 3.6) members. Several iterations of informal evaluations were conducted with the design team throughout the development of the technology, and one evaluation was conducted with the NeuroCare team. Many research methods are employed during a product’s development life cycle including, focus groups, interviews, and design walkthroughs that were informally used throughout this prototype’s development [58, 59, 65].

The IID approach to software development is one where the development of a product is composed of several sequenced iterations, where each iteration is a self-contained development block consisting of analyzing requirements, code and UI design, programming, and function testing code [103]. Thus, each prototype version was assessed to see if it met the design requirements and principles identified for the technology (Table 3 and 4), and this resulted in improvements and recommendations to the design of specific features, user workflows, and the UI. Specifically, prototypes were iteratively module (unit), function, and system tested. Module testing involved testing each unit of code, and was carried out as each component was being developed [104]. Function testing checked if the program’s components behaved correctly according to specifications (Table 3 and 4) [104]. Function testing took place after each
component was implemented, and had been unit tested. System testing was used to ensure that all components of the system combined to deliver the desired results [104]; this type of testing took place after all function and unit testing was complete. During testing, the test cases included all aspects of the application that were identified as critical for use, and edge cases were also tested. For example, one test case was to test that the system allowed the user to select a goal for a specified period of time, and an edge case involved checking if the application would function correctly if the user added all the available goals. This testing took place iteratively throughout the development of the technology until a satisfactory design was achieved. Latency testing was also conducted iteratively throughout technology development to identify problematic areas in the application, and to improve the efficiency of the technology. The design team and persona of Andrew were referred to when an implementation, reduction, or improvement of a feature was to be made. The final, stable prototype presented for usability testing with end-users was grown throughout many iterations of adding and testing incremental functionality, feature by feature.

High-fidelity prototypes were created using proto.io, an online smartphone UI prototyping application, during the initial design phase. Proto.io allows users to create fully interactive prototypes that allow one to quickly emulate the look and feel of a mobile application idea [105]. Using this tool for quick prototyping, the designs of each of the key application features were created, as identified from the results of the epics and user stories discussed earlier. The design principles identified for this technology (Table 3) were used to guide the development of each feature of the technology throughout the development process. The UI of this prototype was initially influenced by the Concussion & You program toolkit’s wheel of health (Figure 3) found in the program’s work booklet, but the final UI used for the end-user usability study was quite different. Following the development of a high-fidelity prototype, the design team assessed the design, identified design changes to improve the usability and utility of the prototype, and this author implemented the recommended changes until a preliminary design was achieved. Once the preliminary design was identified, a fully functional Android application prototype was developed using this design as a guide; the design requirements, principles, epics, and user-stories guided the design and development of the technology. This Android prototype was iteratively assessed by the design team, and once by the NeuroCare team, using research
methods that included, informal focus groups, interviews, design walkthroughs, and group discussions.

![Image](image1.png)

(a)

![Image](image2.png)

(b)

**Figure 3. Influence of Concussion & You work booklet. (a) Concussion & You Visual Care Plan Wheel of Health. (b) Initial proto.io technology prototype**

### 6.1.4 Annual NeuroCare Team Meeting

The NeuroCare team meeting is an annual meeting that is attended by most members of the NeuroCare team grant (i.e. brain injury researchers, engineers, and health care professionals), and youth/adults with a history of concussion; these members provide feedback and guidance on current NeuroCare projects.

During an iteration of development, this author presented a functioning version of the smartphone application prototype to NeuroCare team members. At the beginning of the team meeting, this author provided the team a brief overview of the smartphone technology prototype. All team members were sitting at circular tables in groups of four to six. Each table was provided a list of tasks (Appendix A) to complete using the smartphone technology prototype; the technology prototype was installed on touch-screen laptops, so that each table could easily interact with the prototype. After each group completed the tasks provided, they were provided time to freely explore the prototype. Subsequently, the team took part in a group
discussion (informal focus group) with this author to discuss the usability and utility of the prototype; usability issues were identified, and design changes were recommended. Overall, the group was satisfied with the technology’s UI, and features. At the end of the group discussion, each member completed a brief survey to provide further feedback, and suggestions to improve the prototype. The survey can be found in the Appendix B. The results from the group discussion, and survey were used to identify usability issues, and design changes that could be incorporated in the technology. The identified usability issues, and appropriate design changes were implemented.

6.2 Development Details

6.2.1 Android

A single mobile platform on which to create the mobile application needed to be decided on, as supporting the design and development of the application on more than one mobile platform was not feasible for a one-person development team (this author). As of the fourth quarter of 2015, Google’s Android Operating System (OS) was the leader in mobile OS market share, with an 80.7% share, while Apple’s iOS was next at a 17.7% market share [106]. This drove the design team to agree on designing and developing an Android prototype application for the end-user usability study. A smartphone application was developed for Android’s Nexus 5 smartphone, which runs the Android OS developed by Google Inc. [107]. This system was designed using Android Studio 1.5.1, Java 1.7, Nexus 5 emulator, and Android SDK 23 (Android 6.0 APIs). Android Studio 1.5.1 is the official integrated development environment (IDE) for Android application development [108]. Android Studio’s features include, a powerful code editor, developer tools, fast and feature-rick emulator, and GitHub integration [108]. Java is the main programming language used by Android Studio for the Android OS [108], and was used to develop this application prototype. In addition, the commonly used Android 6.0 application program interfaces (APIs) were used to develop this technology. Some external libraries were also used, with permission, to develop this technology which are the opencsv-3.7 [109], material-calendar view [110], and android-floating-action-button [111] libraries.
6.2.2 Mobile Application Color Scheme

The mobile application was based around the Concussion & You program, and was created in partnership with Holland Bloorview’s Concussion Centre. To keep the mobile application’s color within the color theme of Holland Bloorview, the primary and secondary colors of the application were chosen to be those of Holland Bloorview Corporate; the corresponding colour codes were identified using the Holland Bloorview color template available on an internal website. The primary color was chosen to be HEX #1979be and the secondary color was chosen to be HEX #53bb50, shown in Figure 4.

![Figure 4: Mobile application (a) primary, (b) secondary colors](image)

6.2.3 Menu Navigation within the Mobile Application

The navigation of a mobile application is essential, as it guides the user through different parts of the application [95]. A good navigation design should be intuitive and predictable, with new users being able to navigate an application with ease [95]. Our initial prototype (Figure 5b) had a menu on the main screen of the application, with a navigation button to the summary page on the bottom of the screen, and a navigation button to educational information at the top of the screen. However, it is recommended to use a sidebar navigation menu where important destinations within the application are shown and less important destinations are excluded [95]; this would ensure the UI is kept simple, which is a key design requirement for this technology; this was the navigation design that was implemented. Determining the important and less important destinations was an iterative process that was decided upon through iterative evaluations. Initially, the separate destinations of the application were determined to be a:
1) Screen where the user can record how they feel today.

2) Screen where the user can see the current goals within their concussion recovery self-management plan.

3) Screen where the user can see goals that are available to be added to their concussion recovery self-management plan.

4) Screen with concussion education and online resources

5) Summary screen with feedback on their concussion recovery self-management plan

6) Screen with the contact information of concussion experts

7) Screen where a notification reminder can be set

8) Screen explaining how to use the mobile application

In early evaluations of this design, three observations were made. The first was that the goals available to be added to a concussion recovery self-management plan (3) did not need to be in a separate location from the screen that listed the current goals within the concussion recovery self-management plan (2). Instead, screens (2) and (3) would be integrated together. The second observation was that information regarding concussion education and online concussion resources were different enough in presentation that they would have their own, separate screens. The final observation was that important destinations could be split into two distinct groups: destinations that aided self-management actively through action (1, 2+3, 5, 7) and destinations for aiding self-management passively through information (4, 6, 8). The initial and final designs are shown in Figure 5a and Figure 5b, respectively.
6.2.4 Home Screen

The home screen of an application is the first screen that is seen when the application is launched. It was decided that this screen would be a page that asks the user how they feel. The main use of this application was to enable concussed youth to self-manage their concussion to holistically feel better, and therefore this simple question of “How Am I Feeling Today?” is an important one that needs to be answered. This application is designed for pediatric concussion management, and therefore a design choice was made to allow the user to answer this question by clicking one of five smiley faces, as seen in Figure 6. This design choice was made because visual scales have been shown to work better with children and youth than numbers or words [96].
Figure 6: Visual scale of feelings. From left to right, the meanings of each smiley face are ‘Awful’, ‘Bad’, ‘Okay’, ‘Good’, and ‘Great’ respectively.

For record keeping, a calendar showing how the user felt on previous days is also shown, as seen in Figure 7a. This calendar was originally always visible to the user, but an evaluation with the design team recommended that the calendar not be shown if the user has not answered the “How Am I Feeling Today?” question for the day. A persistent calendar was seen as a tool that could bias the user’s answer; the user could look at their previous emotional history before answering the “How Am I Feeling Today?” question for the day. Once the calendar is visible, the user can click on a date to bring up a dialog box that lists the goals on that day that were completed (green text), not completed (red text), and not answered regarding completion (grey text), as seen in Figure 7b. The placement of this history information regarding goals in the concussion recovery self-management plan and their completion status was experimental.
Figure 7: Feelings calendar. (a) Calendar displaying how the user felt on past days, and a prompt to head to the goals page. (b) User can see what goals were done on a specific day by clicking on the appropriate calendar date.

From the user story for this feature, the main function of this page was to record how the user was feeling for the day. The next page the design team wanted the user to navigate to was the concussion recovery self-management plan page to review their list of goals. Therefore, when the user answers the “How Am I Feeling Today?” an Android Toast notification [112] prompts the user to navigate to the “My Goals” page. This navigation guides the user through the short and concise primary workflow that was originally envisioned. This Android toast is shown in Figure 7a, and can be ignored or discarded by swiping it away.
6.2.5 Concussion Recovery Self-Management Plan

Each user creates a personalized action plan that will aid them in self-managing their concussion. This action plan consists of a set of goals that the user aims to complete on a daily basis to holistically feel better. Initially, this action plan is empty as seen in Figure 8a, and the user is encouraged to add a goal using the ‘+’ button on the lower-right side.

When clicked, the ‘+’ button displays five other ‘+’ buttons pertaining to the five categories of goals that were identified during the requirements phase, as seen in Figure 8b. Originally, the primary ‘+’ button navigated the user to a single list of all goals from all categories, but after a usability evaluation by the design team, this was determined to be an excessive amount of information for the concussed youth to decipher on one screen. Therefore, a design change was made to split up each category of goals into separate lists.

![Figure 8: My Goals page. (a) Empty My Goals page, with no currently active goals. (b) User can choose from a selection of Sleep, Nutrition, Energy, Relaxation, and Social goals by clicking on the appropriate button.](image)

Once a ‘+’ button relating to a goal category is clicked on, the user is navigated to a list of available goals pertaining to that category, as shown in Figure 9. Each item in the list has the
goal name, and recommended goal duration stated. Action plans are typically one or two weeks long, and modifications to specifics of the action plan are made after this time [34, 90]. For the purpose of this usability study, the default recommended goal duration for each goal was set to one week.

Figure 9: Available Goals Layout – This screen shows a list of available Social goals that the user can choose from and add to their action plan. Similar pages exist for the other goal types.

Once a goal is clicked, a description page for this goal is displayed to the user. This page gives a detailed and concise description of what the goal entails, and asks how long they would like the goal to be and for an excerpt of how the goal will be accomplished. The user then adds the goal to their action plan by clicking “ADD GOAL”. This page is shown in Figure 10.
Figure 10: Adding a goal - The description page of a goal, where the user can (a) set the duration of the goal, and (b) state how they will accomplish the goal.

Once a goal is added to the action plan, it will show up in the My Goals page, as seen in Figure 11. The user is tasked with answering the question “Did you complete this goal today?” daily, for as long as a goal is within the action plan. The user answers this question by giving a thumbs up or thumbs down to the question. A visual is used to answer the question because visuals have been shown to work better with children and youth than words [95]. It is expected that the user may not always complete a goal, and it was important for the application’s design to give words of encouragement when a goal is not completed [34].
Figure 11: My Goals page with active goals - An action plan with 4 goals, and completion statuses recorded for each goal. When the completion status of each goal has been recorded, the user is prompted to head to the Summary page.

The user can also click on a goal on the My Goals page and be navigated to a page that gives a description of the goal, how they set out to accomplish the goal, and a calendar showing the days that the goal was available and completed (green dot), not completed (red dot), or the completion status was unknown (grey dot). This feature (Figure 12) is for informational purposes and reviewing records. If the user deemed that the goal is not useful in their concussion recovery self-management plan, the goal can be removed by clicking the “DELETE” button.
Figure 12: Viewing an active goal - The description page of a currently active goal, with a calendar showcasing the completion status of the goal using colored dots – green as completed, red as incomplete, grey as unknown completion status.

A user can add multiple goals to their concussion recovery self-management plan, and will be tasked with answering the “Did you complete this goal today?” question for all of them on a daily basis. Once all goals in the action plan have answered this question for the day, the main purpose of this user story is complete. The design team determined the next task in the user workflow would be for the user to review the summary page and use the information presented to make more informed decisions on their self-management journey. Therefore, when the user answers the “Did you complete this goal today?” question for all goals on the My Goals page, an Android Toast notification prompts the user to head over to the Summary page and review the information presented. This Android toast is shown in Figure 11, and it can be ignored or discarded be a swiping gesture.
6.2.6 Summary Page

The summary page gives the user feedback on how they are doing in their concussion recovery. This page is intended to improve the decision-making of the user in regards to their concussion recovery self-management plan. The summary page is not updated until the user has used the mobile application for a duration of three days, which the design team deemed as a sufficient duration to gather information and supply feedback. Thereafter, the summary page is updated as new information becomes available. The design of this page was improved after an evaluation by the design team, as seen in Figure 13. The initial design displayed all summary information to the user, and was deemed excess and confusing. The finalized design allows the user to selectively pick which information they would like to see in that moment using an accordion UI design element, and is cleaner from a usability perspective.

![Initial Summary Page](a) ![Finalized Summary Page](b)

Figure 13: (a) Initial and (b) finalized Summary page designs

The first set of data shown on the Summary page is the top three goals that make the user feel their best, shown in Figure 14a. This information is determined by correlating the feeling data and goal completion data that the user has been recording into the application each day. The correlation was done using a scoring system to determine which goals make the user feel best,
where each smiley in the “How Am I Feeling Today?” scale was assigned a value: ‘Awful’ as 1, ‘Bad’ as 2, ‘Okay’ as 3, ‘Good’ as 4, and ‘Great’ as 5. For each goal, the respective feeling values on each day the goal was completed are summed up and averaged. The goals with the top three scores are determined and shown to the user. It is important to note that this is a rudimentary correlation that can result in false-positives and false-negatives, but for the purpose of the formative usability study it was sufficient. This feedback is shown to the user to let them know which goals seem to be helping them feel their best, and enabling the user to make an informed decision if they were to modify their action plan.

![Figure 14: Top 3 goals and overall feeling feedback. (a) The top goals that make a user feel their best. (b) The user’s overall feeling-level the past week.](image)

Next, the user sees how they’ve been feeling the past seven days (Figure 14b) in the form of a smiley and textual information. This calculation is determined by averaging how the user has been feeling the past seven days, by assigning a value to each smiley on the “How Am I Feeling Today?” scale: ‘Awful’ as 1, ‘Bad’ as 2, ‘Okay’ as 3, ‘Good’ as 4, ‘Great’ as 5. This is information the user can use to review how they have been feeling, and contains encouragement
text if they have not been feeling well. It is also a record for the user’s physician or other healthcare providers to gauge how the user has been feeling, holistically, in the past week.

The next data point displayed is the number of goals the user should aim to complete, shown in Figure 15a. This data point is calculated by taking a weighted average of the average number of goals completed on the days the user is feeling okay (weight of 1), good (weight of 2), and great (weight of 4), rounded to the resultant’s floor. This calculation gives exponentially greater weight to goals that were completed on days where the user felt their best. The data point is provided to improve the user’s decision-making in any modifications to their concussion recovery self-management plan, and the user is encouraged to use this data point.

![Figure 15: Recommended goal, and number of goals. (a) The recommended number of goals for the user. (b) A goal the user’s healthcare professional recommends for them.](image)

Next is a recommendation for the user to try a goal that has not been attempted, or has not attempted recently. This item is shown in Figure 15b. A list of recommended goals is compiled by the user’s physician and put into a circular priority queue, and this recommendation is based off that queue. This recommendation is to enable the user to add doctor-recommended goals to their concussion recovery self-management plan. For the purpose of the initial prototype, the feature for a doctor to create a patient-specific list of recommended goals was not implemented.
due to time constraints. This recommended goal list was pre-compiled and static for the purpose of the initial prototype and usability study with end-users.

The last item on the Summary page is a list of actions the user can take to improve the road to recovery from concussion, shown in Figure 16. These actions were recommended by the healthcare professionals on the design team. The act of asking questions and sharing progress with the physician are recommended so that the user can gain insight into their concussion recovery and increase communication between the user and the physician. This can improve patient health outcomes, particularly emotional health and symptom resolution [81]. The act of connecting with family and friends is recommended to expand the support network of the adolescent user during their concussion recovery [113].

![Figure 16: Next steps feedback - Next steps that the user can take to improve their road to recovery. There is an emphasis to share, ask, and connect.]

6.2.7 Notification Reminders

Mobile phone text message reminders may improve outcomes in a healthcare setting [94]. A page where the user can set a daily reminder to be reminded to use the mobile application can be seen in Figure 17.
The user sets a time to be reminded daily of using the mobile application, and a notification reminder will be shown at the set time, seen in Figure 18a. Furthermore, every seven days from the first use of the mobile application, the user will receive a notification encouraging them to review the summary page and make modifications to their concussion recovery self-management plan if necessary, seen in Figure 18b.
Figure 18: Notifications - The (a) daily and (b) weekly reminders the smartphone application sends.

6.2.8 Concussion Education and Online Resources

The educational resources portion of the mobile application was originally in a single location, but it was decided that the presentation of concussion education content and the online concussion resource content was different enough to warrant separate pages. The concussion education page cleanly displays information that is listed in the Concussion & You educational booklet, as seen in Figure 19a.
The online resources page is seen in Figure 19b. It is a straightforward list of online concussion resources, complete with the title of the resource and a webpage link to the resource. This page requires the user to have an internet connection to view the linked webpages.

6.2.9 Contact Concussion Experts and “Using NeuroCare”

The design team at the Holland Bloorview Concussion Center (HBCC) also wanted an accessible way for a user to be able to contact concussion experts. This resulted in a “Contact Concussion Experts” page, as seen in Figure 20a. A description of what the HBCC is and how the professionals at HBCC can help concussed youth is included. The contact information for a concussion helpline and e-mail is also included. The mobile application’s prototype name was chosen to be “NeuroCare”. A “Using NeuroCare” page was included to give the user a description of how to use this application, and how it can work for them. This page is seen in Figure 20b.
Figure 20: Contact and Use pages. (a) The “Contact Concussion Experts” page to contact HBCC professionals and (b) the “Using NeuroCare” page to gain direction on how to use this app.

6.3 Final Prototype

The fully function prototype was developed as outlined above. The software development included designing and developing software to include the specific features, functions, and content that the design team identified are required to aid youth in managing their concussion. The software development required the development of many components, which included the following: prompts/alerts, database, summary page to display useful data, UI design, and selectable goals. The information architecture (Figure 21), and software architecture (Figure 22) of the final prototype are shown below.
Figure 21: Final prototype information architecture

This application’s information architecture is shown in Figure 21; the application’s Menu icons are shown near the top of Figure 21, which shows this application has a total of eight main sections. These sections are divided into two distinct groups: destinations that aid self-management actively through action (i.e. Feelings, My Goals, Summary, and Set Reminder pages) and destinations for aiding self-management passively through information (i.e. Concussion Library, Resources, Using NeuroCare, and Contact Experts). The arrows show how each screen is linked to the Menu, and how screens are linked to other screens within the
application; the arrows indicate how a user could navigate through the different screens of the application. A key design principle (Table 3) for this technology required that navigation through the application should be intuitive, simple, and demand minimal engagement from the concussed youth; to ensure this the number of screens per section was kept to a minimum, and the depth to which users could navigate in each section was also minimized. Instead, more elements were provided on a single page, to reduce the need to navigate to different screens. For example, the summary page includes five sections, as shown at the bottom of Figure 21, and all the sections can be displayed by clicking on the arrow on the right of the section. This type of screen display provides the user with all the information they need, but only shows the detailed information if the user demands it. In addition, key design features for this technology also included that it should guide the user through the application, and require minimal constant engagement. The user of this application would be asked to complete a set of tasks daily, and these tasks are the following: select how you are feeling today on the “Feeling page”, go to the Goals page and select the competition status of each goal, then navigate to the Summary page to check your progress. This application provides the user an alternative path to complete all the required (i.e. daily) actions through the use of Android Toast notification [112], which prompt the user to navigate to the next required page. This alternative path is indicated by the red arrows in Figure 21 which guides and enables the user to complete the required actions using a short and concise workflow that requires minimal user engagement.
Figure 22: Final prototype software architecture

Figure 22 shows an overview of this application’s software architecture, which describes the structure and behavior of the application. In order for this technology to be useful in helping youth manage their concussions it was important to include all the required features and functions identified by the design team (Table 3 and 4) in this technology; e.g. required features included data recording, feedback, and educational features. Thus, software components were developed to receive/send data from/to the UI, design UIs, store and retrieve collected user data,
send users prompts/reminders, and provide useful information to the user in order to help them better manage their concussion. To develop these features the commonly used Android 6.0 APIs were used. Some external libraries were also used, with permission, to develop this technology which are the opencsv-3.7 [109], material-calendar view [110], and android-floating-action-button [111] libraries. The UI (front end) design involved developing layout files using the Extensible Markup Language (XML), and some parts of the UI were also developed programmatically using Java. The back end of the application involved the development of many classes that included, Activity and Fragments classes (e.g. Active Goals Fragment). The database to store user data was developed and is managed using the SQLite database management classes, which are included in the Android 6.0 APIs. The database development involved the creating many tables including, the Active Goals, Available Goals, and History tables. The basic system behavior involves the user using the UI provides an input, and then the back end uses the Database Handler class to read or write to the database, and then the back end modifies the front end to display the appropriate output for the user.

The design and development of the fully functional smartphone prototype for the self-management of pediatric was discussed in detail in this chapter. Chapter 7 describes the evaluation of this smartphone technology prototype through usability testing with end-users; the fourth phase of the user-centered design involves evaluating a prototype.
Chapter 7

7 Usability Study

Research Objective 2: Evaluate the usability of this technology, and identify usability issues with this technology.

A usability study with end-users is an important aspect of UCD, as it can reveal usability issues stemming from bad design, poor page layouts and navigation, inefficient task flows, and unclear language [57, 58]. Collecting measurable quantitative and qualitative usability data is an essential UCD technique [57, 58]. Technologies with inadequate consideration of the needs of the intended users are difficult to learn, will be misused or underutilized, and will ultimately fail to accomplish objectives originally set out [55]. To ensure usability of the developed prototype, usability testing with end-users should be conducted. There are many research methods used to assess the usability of a technology [58, 59, 65]; common usability evaluation methods include lab-based usability studies, usability benchmarking, questionnaires, and interviews [26, 58, 59, 65].

Lab-based usability studies are one of the most commonly used research methods used to assess a product’s usability [58, 59, 65]. Formative lab-based usability testing is a widely used usability testing approach that is iterative in nature [58, 59]; the goal of this testing is to make improvements in design before releasing the product [58, 59]. This includes, identify and diagnosing problems, making and implementing recommendations, and then re-evaluating the product [58, 59]. A formative lab-based usability study was conducted with the fully functional smartphone prototype. This study involved the completion of tasks, using the think aloud protocol, questionnaires, and an exit-interview.

The following chapters describe the methodology, execution, and results of the usability study of the smartphone technology prototype developed (see Chapter 6). Four pilot studies were conducted to refine the experimental procedure and setup for the usability study. Ethics approval for this study was obtained from the Bloorview Research Institute’s Ethics Board, and administrative approval was received from University of Toronto’s Ethics Board; REB No. 16-632.
7.1 Usability Study Setup and Procedure

7.1.1 Location

Usability tests were conducted at either Holland Bloorview Kids Rehabilitation Hospital (fourth floor, conference meeting room), Crescent School (an independent elementary and secondary boys school in Toronto, Ontario that teaches youth from Grades 3 to 12 [114]), or at the healthcare professional’s place of practice. The studies were conducted in a quiet room, with a table, at least two chairs, a voice recorder, the mobile application prototype installed on an Android smartphone (LG Nexus 5), and a smartphone screen recorder installed on the Android phone.

7.1.2 Participants

In formative usability studies, the most significant usability findings are observed with the first five participants [87, 115]. This usability study consisted of the primary and secondary end-users of the smartphone technology. For the purpose of this usability study, participant recruitment closed when a total of 14 participants were reach: 7 youth with a history of concussion within 10 to 18 years of age, and 7 health care professionals involved with concussion assessment, management, or research. Recruitment of currently concussed youth was not possible because it was neither feasible nor safe to test this technology with youth currently suffering from a concussion. A summary of the participant groups, number of participants, and inclusion/exclusion criteria are briefly described in the Table 10.

Table 10: Summary of participant groups

<table>
<thead>
<tr>
<th>Participant Group</th>
<th>Youth</th>
<th>Healthcare Professionals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Participants</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>
Inclusion Criteria
1. 10-18 years-old
2. Have had a concussion in the past two years.
3. Are not symptomatic (not experiencing any post-concussion symptoms)
4. Have recovered from the concussion

Exclusion Criteria
1. Less than 10 years old or greater than 18 years old
2. Have not used smartphone applications
3. Non-English speaking
4. Experiencing Post-Concussion Symptoms
5. Physical, visual, or cognitive issues that preclude participant from being able to use smartphone technology in the traditional way (i.e. hand disability, visually impaired)

To participate in this study, participants had to be fluent in English in order to comfortably read the tasks/scenarios, and provide written and oral feedback for the questionnaires and exit-interviews, respectively. In addition, youth participants must have had a concussion within the past two years to ensure they would be able to recall, with reasonable accuracy, their experience with a concussion. Also, youth participants were required to have recovered from their concussion, and have zero existing post-concussion symptoms, to participate in the study.

Participants were excluded if they had any physical, visual, or cognitive problems that may have precluded them from being able to use the technology in the traditional way; the main objective of this study was to evaluate the usability of this technology, and this technology was developed for individuals that do not have any of the aforementioned disabilities.

Youth participants were recruited from past participants of NeuroCare (phase 1) who had sustained a concussion, and had consented to be contacted for additional studies; they were contacted via email (Appendix C). Health care professionals from Holland Bloorview Kids Rehabilitation Hospital were recruited through team meetings. This author attended two meetings, the Brain Injury Rehab Team (BIRT) meeting and the Persistent Concussion Clinic Team meeting, where the author introduced the research study, and asked potential interested
participants to contact the author via email for further details and/or to participate in the study. In addition, both youth and health care professionals were recruited through recruitment flyers (Appendix D) placed at the University of Toronto Rehabilitation Science Building, Holland Bloorview Kids Rehabilitation Hospital, and on Holland Bloorview’s webpage (Appendix E). Lastly, youth and health care professionals were recruited from Crescent School.

7.1.3 Obtaining Consent

The usability tests were 1-on-1 with the study coordination (this author) and the participant; each usability study took approximately 30 to 45 minutes to complete. At the beginning of each study, this author introduced the participant to the test environment, and the process of the usability testing. The participant was informed that they would be observed, the session would be audio recorded, and the smartphone screen would be recorded for the purpose of further analysis and documentation. Then, the participant was provided with a copy of the information letter and consent form (Appendix F), walked through both documents, and given as much time as required to review the form or ask questions. If the youth participant’s agreed to participate in the study, they were asked a few questions to assess their capacity to consent (Appendix G). After the participant had completed the consent form, they were asked to complete a demographics questionnaire (Appendix H).

7.1.4 Demographics Questionnaire

The demographics questionnaires for the two participant groups (youth and health care professionals) were customized for each group, and can be found in Appendix H in-sequence for youth and healthcare professionals. Youth were asked questions regarding their concussion history and experience with managing concussion(s), while healthcare professionals were asked about their involvement in concussion assessment, management or research. Both participant groups were asked basic demographics questions, and asked to share their perception of concussion knowledge and management in Canada. Participants were asked to answer questions using a 7-point Likert scale (1 – strongly disagree, 7 – strongly agree), and open-ended comments. After completing the demographics form, the participant was introduced to the think aloud approach.
7.1.5 Think aloud approach

The participant was explained the process of “thinking aloud”, i.e. providing continuous commentary, while operating the smartphone technology, with the help of a short video describing the process (Appendix I). The short video explained to the participants how they should vocalize their thoughts about their underlying thinking, i.e. their opinions, attitudes, feelings, perceptions, and assumptions, behind their interactions with the smartphone technology. The participant was reminded that if they required help at any time during the usability study, they could ask for assistance, and that the usability study was testing the smartphone technology and not the participant [116]. The Guidelines for Usability Testing with Children, and the Practical Guide to Usability Testing were both used to guide this author in providing unbiased assistance, and prompts if the participants were not thinking aloud [116]. To ensure that that time on task data would not be substantially affected by the participant’s thinking aloud comments, the participants were asked to hold any longer comments for after the task was complete [59]; the participant was provided with other instructions for this study as outlined in Appendix J. Then, the participant was given the Android smartphone with the fully functional prototype to be tested pre-installed. The participant was asked to perform a series of tasks using the smartphone technology; a total of eleven tasks were completed.

7.1.6 Tasks

An essential requirement for conducting usability studies is that the participants must attempt tasks that are indicative of what eventual end-users will need or want to do with the technology [58, 59]. However, due to time and resource constraints it is not possible to test every possible task that the end-users can do with the technology. Thus, the tasks selected for this study were those that probed potential usability problems, tasks that are difficult to recover from if done wrong, and tasks that eventual users will perform with the technology [58, 59, 64]. Dumas and Redish state that a good task for a usability study is a task that “has the potential to uncover a usability problem”. In this study, participants were asked to complete ten essential tasks, and one bonus task, with the smartphone technology. Some tasks were best described as scenarios [58, 59, 64]: a scenario makes a task more realistic by providing information, motivation, or a fictional background for the task [58, 59, 64].
The tasks for this study were developed, and ordered such that they would be representative of how a concussed youth could use the smartphone application to self-manage their concussion. The tasks were chosen, so that they would be indicative of the tasks both user groups would need to understand, or complete with the technology. Thus, the tasks completed by both participant groups, i.e. youth and health care professionals, were identical; each task is summarized in Table 11. The usability issues or technology features that each task attempted to investigate are listed on the right of Table 11 and Appendix K.

Table 11: Usability test tasks - The usability issues or technology features that each task attempted to investigate are listed on the right.

<table>
<thead>
<tr>
<th>Task</th>
<th>Feature(s) Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Using the visual scale: enter the application, and answer the “how are you feeling today” question with OKAY using the visual scale.</td>
</tr>
<tr>
<td>2</td>
<td>Finding and adding a goal on the My Goals page: add a specific “Social” goal to the action plan for a duration of one week.</td>
</tr>
<tr>
<td>3</td>
<td>Setting a reminder: set a reminder 1 minute from the current time.</td>
</tr>
<tr>
<td>4</td>
<td>Responding to the reminder notification: respond to the notification reminder that was set in Task 3. HASHA</td>
</tr>
<tr>
<td>5</td>
<td>Using the visual scale and using the prompt (i.e. toast notification): answer the “how are you feeling today?” question with GOOD. Then, use the prompt to go from Home screen to the My Goals page.</td>
</tr>
<tr>
<td>6</td>
<td>Setting goal competition status and using the prompt (i.e. toast notification): set the completion status for goals on the My Goals page, and use the prompt to go from the My Goals page to the Summary page.</td>
</tr>
<tr>
<td>7</td>
<td>Finding and adding the recommended goal: add the physician-recommended goal on the “Summary” page to action plan for a duration of 2 days.</td>
</tr>
<tr>
<td>8</td>
<td>Deleting a goal from the action plan: delete the “Social” goal originally added in Task 2.</td>
</tr>
<tr>
<td>9</td>
<td>Setting goal completion status and using the prompt (i.e. toast notification): set completion status for goals on the My Goals page, and use the prompt to go from the My Goals page to the Summary page.</td>
</tr>
<tr>
<td>10</td>
<td>a) Finding concussion education information: find the “concussion myths versus facts” educational page.</td>
</tr>
</tbody>
</table>
The flow of the tasks was in-line with the user workflow that was originally envisioned: the user would record how they feel for the day, add a goal(s) to their self-management plan and state the completion status of the goal(s), then review the feedback that the smartphone technology provides, and modify the self-management plan accordingly. Each task was explained to the participant, and the study coordinator reminded the participant to think aloud while performing the task. If at any point the participant was having difficulty with the task at hand, the study coordinator provided assistance or prompted the participant as necessary. After the participant completed all the tasks, they were given up to 10 minutes to freely use the application in order to form an opinion on the application.

7.1.7 Post-test questionnaires and exit interview

After the participant had tested the smartphone technology, two questionnaires were administered to the participant (Appendix L) to assess the perceived usability and utility of the smartphone technology. After completing the questionnaires, the participant was invited to take part in a semi-structured exit-interview (Appendix M) to share comments and opinions on the smartphone technology. The participant answered questions regarding the prototype’s usability and utility, discussed problems encountered while completing the assigned tasks, and clarified key comments or behaviors exhibited during the think aloud protocol.

7.2 Measures

ISO 9241-11 (1998) defines usability as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use [58, 59, 63]. There are many different measures of usability that can be used to assess a product [58, 59, 64]. The measures used to evaluate the usability of this smartphone technology prototype are summarized in Table 12 below.
Table 12: Measures used to assess usability

<table>
<thead>
<tr>
<th>Measures</th>
<th>Effectiveness</th>
<th>Efficiency</th>
<th>Satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Task Success</td>
<td>1. Time on task</td>
<td>1. Overall satisfaction</td>
</tr>
<tr>
<td></td>
<td>2. Errors per task (type, frequency)</td>
<td></td>
<td>(likability, pleasure, comfort, trust)</td>
</tr>
<tr>
<td>Purpose</td>
<td>-To identify the tasks which can/cannot be completed without errors.</td>
<td>-To measure how quickly the user can</td>
<td>-To measure how satisfied the user is with the</td>
</tr>
<tr>
<td></td>
<td>-To identify the common types of errors experienced by the user.</td>
<td>perform each task.</td>
<td>technology.</td>
</tr>
<tr>
<td></td>
<td>-To understand the parts of the system which need to be re-designed/modified.</td>
<td>-To understand the parts of the system</td>
<td>-To understand how the system can be modified to</td>
</tr>
<tr>
<td></td>
<td></td>
<td>that may need to be modified to reduce</td>
<td>improve user satisfaction.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the amount of time it takes to complete.</td>
<td></td>
</tr>
<tr>
<td>Procedure</td>
<td>-During usability testing each of the measures was recorded on a chart (using</td>
<td>-During usability testing the study a</td>
<td>-The SUS questionnaire measures the overall</td>
</tr>
<tr>
<td></td>
<td>pen and paper).</td>
<td>smartphone screen recorder was used,</td>
<td>usability, which includes overall satisfaction.</td>
</tr>
<tr>
<td></td>
<td>-During the exit-interview the participant was asked to elaborate on the</td>
<td>and the timestamps on the recordings</td>
<td>-The general questionnaire administered will also</td>
</tr>
<tr>
<td></td>
<td>types of errors and issues they faced, and what was causing the errors (i.e.</td>
<td>were used to identify the time on task.</td>
<td>measure the perceived satisfaction.</td>
</tr>
<tr>
<td></td>
<td>missing information or misleading text)</td>
<td>-The total time per task will be</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>recorded on a chart (using pen and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>paper)</td>
<td></td>
</tr>
</tbody>
</table>

7.2.1 Objective usability

The effectiveness of this prototype was evaluated by measuring the number of tasks that were completed successfully (task success) by the participant, and the number of errors encountered during each task (errors per task) [58, 59, 63]. Task success is a commonly used metric to measure how effectively users are able to complete a given set of tasks [58, 59].

To measure the efficiency of the technology, the time it took the user to complete each task (time on task) [58, 59, 63] was recorded; it is important to ensure that time is measured
accurately and consistently [58, 59, 64]. Thus, this author marked the start of each task as the time when the participant was told to start attempting the task; this author said “1, 2, 3, and go” before every task, and the participant was asked to start attempting the task as soon as they heard the “go” command. The end time was marked as the time when the participant said “I am done”; waiting for the participant to say they are done is important, so that detectable usability issues do not go unidentified [58, 59, 64].

7.2.2 Perceived Usability and Utility

Questionnaires and interviews are user experience research methods that are commonly used in usability studies to collect qualitative and quantitative data regarding user preferences, perceived usability and utility [54, 58, 59, 65].

*Questionnaires*: Participants were asked to complete a demographics questionnaire at the beginning of this study, and two questionnaires at the end of the study. The purpose of the pre-test questionnaire was to collect background information, including the participant’s experience with managing concussion(s), and their perceptions of concussion knowledge and management in Canada. There were two post-test questionnaires both focused on measuring the prototype’s usability; the SUS [67] was issued first, and was followed by a general post-session questionnaire focused on usability and utility [59, 117].

User satisfaction can be measured by the extent to which users have achieved their pragmatic and hedonic goals, and ISO/IEC CD 25010.2 suggests the following types of measures: likability, pleasure, comfort, and security [63]. For example, pleasure, a measure of satisfaction, can be measured by asking the user how attractive or aesthetically pleasing they found the system. The perceived usability and satisfaction of a product can be evaluated by having the user complete the SUS [59, 67]. The SUS consists of 10 questions, and uses a five-point Likert-scale answering scheme, to get a reliable and robust evaluation of a product [59, 67, 68]. The SUS is a validated, and reliable questionnaire [59, 67]. Research has shown that the SUS questionnaire provides a reliable measure of the perceived usability of a system with small sample sizes (i.e. 8 to 12 users) [67, 69]. This survey has been widely used for a variety of research projects and evaluations in industry due to its easy of use and reliability [59, 67, 68]. Thus, an adapted version of the SUS questionnaire was used to measure the overall perceived
usability, and overall satisfaction of the technology [67]. The SUS questionnaire was modified to be more youth-friendly (uses lay language), and customized for assessing a smartphone technology.

Rubin and Chisnell defined usefulness as “the degree to which a product enables a user to achieve his or her goals, and is an assessment of the user’s willingness to use the product at all” [32, p.4]. Usefulness is an important dimension of usability, and a non-useful product is likely not be used [32, 58]. Thus, an adapted version of a utility questionnaire that was developed and validated by Davis was used to understand the perceived usefulness of this technology [118]. This utility questionnaire was included in this study’s general questionnaire. This general questionnaire also included some questions to assess perceived satisfaction to compliment the SUS score, and better understand technology satisfaction. The questions pertaining to satisfaction that were included in the general questionnaire were adapted from the Usefulness, Satisfaction, and Ease of Use questionnaire [59, 119].

Exit-interview: After completing the questionnaires, the participant was invited to take part in a semi-structured exit-interview (Appendix M); follow-up interviews are commonly used in usability studies where the researcher meets with the participants one-on-one to discuss in detail what the participant thinks about a specific topic in question, discuss usability issues, and clarify comments or behaviors exhibited during the usability study [26, 65]. This exit-interview was adapted from [59, 117-119, 138], and it allowed the participant to share comments and opinions on the smartphone technology, answer questions regarding the prototype’s usability and utility, discuss any problems they encountered while completing the assigned tasks, assist in clarifying and resolving usability issues, and to clarify key comments or behaviors exhibited during the think aloud protocol.

7.3 Data Collection

All usability testing sessions were audio recorded, and a smartphone screen recording application, AZ Screen Recorder [120] available on Android’s application store, was used to record the smartphone screen; this included recording screen clicks and navigation to aid in identifying usability issues. During each study, this author sat beside the participant, and observed their actions with the technology. This author recorded, using pen and paper,
performance metrics such as task success, the time on task, and number of errors. In addition, this author recorded any issues the participant faced while using the technology, including issue frequency, type, and severity. During the exit-interview, the participant’s responses were recorded on paper.

A summary of the data collected during the usability study is provided below:

- Demographics questionnaire
- Performance metrics
  - Task success
  - Time on task
  - Number of errors
- Posttest questionnaire
  - SUS questionnaire
  - Utility questionnaire
- Semi-structured exit-interview
- Issues (severity and frequency)

The primary outcome measures were the task success, time on task, errors, and SUS scores. The secondary outcomes were the usability issues, unnecessary actions, assists, and responses to the utility questionnaire and exit-interview.

### 7.4 Data Analysis

A usability test generates a substantial amount of data about a small number of participants, including data on performance measures from pre- and post-test questionnaires, audio recordings, and the test coordinator’s written notes. The goal of a usability test is to find the usability problems with a product. A useful technique for handling a large amount of data from several sources is triangulation [64]. Triangulation involves looking at multiple sources of data together to find the usability issues with a product. For example, a large number of errors, long task times, deviations from the critical path, and the participants’ comments may all point to the same usability issue. Triangulating enables the usability tester to find, and better understand the key usability issues [64]. The triangulation approach includes, tabulating and summarizing the
quantitative data, looking for trends and surprises in the data, examining the data for problems, using statistics, and organizing the problems by severity [64].

In this study, data analysis involved using the triangulation approach [58, 59, 64] to identify the key usability issues with the smartphone technology prototype. Descriptive statistics (e.g. frequencies) were used to analyze all performance data collected in this study that included, task success, time on task, errors, unnecessary actions, and assists. Data for these measures, and data from questions involving a yes/no option or rating scale (closed-ended questions) were analyzed using frequency counts/percentages, such as the number of errors that occur during a task. Time on task data was analyzed using a measure of central tendency (i.e. mean). For performance measures, descriptive statistics were used to identify if the performance metrics were consistent with the hypotheses (see Chapter 4), to look for trends and surprises in the data, and to identify the severity and location of usability issues with the system. For example, a high frequency of errors and assists indicates a problematic task [58, 59, 64]. This performance data identified the tasks that indicated the presence of one or more usability issues. Subsequently, the data from think aloud, exit-interviews, screen recordings, and questionnaires for the tasks/questions indicating usability/utility issues were examined to identify the cause of, and possible solutions for the issues using the approach described by Dumas and Redish [64]. The frequency/percentage of participants that experienced, or made comments about a particular usability/utility issue and the issue were recorded; in addition, similar usability/utility concerns, and recommendations mentioned by participants to resolve specific issues were grouped to develop a list of recommendations, which are described in detail in the next section. The SUS questionnaire was analyzed using the procedure described by Brooke [67]; descriptive statistics (i.e. measures of variability, and central tendency) were also used to analyze the SUS scores and demographics data. The details of how the usability data was analyzed are further described in the next section.

### 7.5 Results

The data collected in this study was triangulated to identify the key usability issues of this technology, and recommendations were provided to resolve identified usability issues. Usability data saturation was achieved with the completion of four usability studies with youth, and two
studies with healthcare professionals; all key usability issues were identified with the first six studies. The results of the data analysis, and procedure are described next.

7.5.1 Demographics

A total of 14 participants were recruited for this study: 7 youth with a history of concussion, and 7 healthcare professionals. The health care professionals included, 2 neuropsychologists, 2 occupational therapists, 2 school nurses, and 1 physical medicine and rehabilitation physician. The healthcare professionals in this study were all female (100%) with a mean age of 42.9 years (SD 15.7); the mean years of work experience in their current role was 9.6 years (SD 7.3 years). The mean youth age was 12.7 years (SD 1.9 years), and 71% (5/7) of youth were female. All youth had sustained one concussion within the past 18.9 months (SD 4.7 months). The majority (4/7) of the youth were assisted in managing their concussions by the occupational therapists at Holland Bloorview’s Concussion Centre; one of the four youth that was supported by the Concussion Center also received support from a sports medicine physician. The three youth that did not receive care from the Concussion Center, received concussion management support from their family physician, and two of three youth also received assistance from other physicians. Youth and health care professionals were asked about their perceptions of concussion management through a few questions on the demographics form. When health care professionals were asked if they find that all youth in Canada are given enough information to manage their concussion, 86% (6/7) of the health care professionals either disagreed, or strongly disagreed with the statement; one health care professional slightly disagreed with the statement. When asked if they find all health care professionals in Canada manage pediatric concussion in a consistent manner, 100% of the health care professionals disagreed or strongly disagreed with the statement. Youth were asked despite the help they received from health care professionals, if they felt confused about what they should do to manage their concussion; 71% (5/7) youth participants either agreed, or strongly agreed with the statement. All (100%) youth participants selected that they either own, or have daily access to, a smartphone and tablet. All (100%) of health care professionals selected that they either own, or have daily access to, a smartphone; four of seven health care professionals selected that they either own, or have access to, a tablet.
7.5.2 Performance measures

The data collected through usability testing was analyzed, beginning with task performance metrics, and followed by the questionnaire results. There were three key performance measures collected during each task the participant performed:

- Task success or failure
- Assists, errors, and unnecessary steps while completing a task
- Time on task

7.5.3 Task Success

Task success is the most widely used performance metric; if a user cannot complete a given task, then there is likely a problem with the technology. Thus, to measure how effectively participants were able to complete tasks with the technology, task success was measured. Figure 23 shows the percent of participants that successfully completed each task.

![Percentage correct, by task](image)

**Figure 23: Task success rates - Percent of participants who successfully completed each task.** The tasks instructed the participants to do the following: Task 1: select “how are you feeling today” using the visual scale; Task 2: add a Social goal to the action plan; Task 3: set a reminder; Task 4: respond to the reminder; Task 5: select “how are you feeling today” using the visual scale, and use the toast notification to navigate; Task 6: set completion status for goals,
and use the toast notification to navigate; Task 7: find and add the recommended goal; Task 8: delete a goal; Task 9: set completion status for all goals, and use the toast notification to navigate; Task 10: (a) find concussion education information, and (b) navigate to the Home screen; and Task 11: review and comprehend feeling and action plan history.

Figure 23 shows that the majority of participants completed most tasks successfully. However, a few participants were not able to successfully complete tasks 3, 4, 9, 10b, and 11. To provide context:

- Task 3 - Instructed participants to set a reminder that would remind them to use the application on a daily basis.
- Task 4 - Instructed participants to find and respond to the reminder set in Task 3.
- Task 9 - Instructed participants to mark the completion status of goals in their action plan, and navigate to the summary page.
- Task 10b - Instructed participants to go to the home screen of the application, without explicitly telling them which screen was the home screen.
- Task 11 - Instructed participants to identify how they were 1) feeling on the previous (simulated) day, and 2) what goals they had set on the previous (simulated) day.

It is possible for participants to successfully complete a task while still having difficulty with said task. To identify tasks that participants had difficulty with, task success was organized into three levels: task completion without problems, task completion with problems, and task failure. Problems were deemed to have occurred if:

- there were errors made by the participant before task completion
- assistance provided by the study coordinator to aid in task completion
- and/or participants exceeded the minimum number of actions required for each task

Errors and assists indicate effectiveness; both are useful in pointing out particularly confusing parts of a technology [58, 59, 64]. The number of actions exceeding the minimum number of actions required for a task is indicative of the efficiency of a technology [58, 59, 64]. Figure 24 shows the percentage of participants that completed a task with zero problems (green), with one or more problems (blue), and task failure (red).
Figure 24 shows that despite the low number of task failures, participants did face some problems while using the technology. Importantly, taking one or more actions than the minimum number of actions required to complete a task was considered a problem; however, in many cases participants only took one additional action, which may point to a low severity usability issue. Figure 24 provides further evidence for the existence of usability problems for tasks 3, 4, 10b, and 11, which is evident by the high percentage of participants (>43%) that completed these tasks with one or more problems. However, despite the one task failure that occurred for task 9, the majority of participants (79%) completed the task with zero problems. Thus, task 9 may point to a low severity usability issue. In addition, Figure 24 depicts that there may be usability issues with all the tasks, but their severity is unknown.

7.5.4 Frequency of problems per task

To further examine the severity of usability issues for each task, the total number of assists, errors, and extra actions across all 14 participants was examined. Participants were provided assists only when the participant was having a considerable amount of difficulty with a task, thus any task that required assists should be examined further for high severity usability issues. Errors were defined as any action that caused the participant to deviate from the path to
successful completion; errors may point to low or medium severity problems. Actions were the number of steps the participant took that exceeded the minimum number of actions required for each task; actions without accompanying errors or assists may point to low severity problems, but actions accompanied with errors or assists are likely indicative of a high or medium severity usability issue. Figure 25 shows the frequency of assists (red), errors (orange), and actions (yellow) for each task; these problem types were tallied up across all 14 participants, regardless of task completion.

![Frequency of problems, by task](image)

**Figure 25: Frequency of assists, errors, and actions per task, across all 14 participants**

First, the tasks that resulted in task failures are discussed. Figure 25 shows that a significant number of assists were provided to participants for task 4, and some assists were provided for task 10b and task 11. This indicates a severe usability issue with task 4, and moderate usability issues with tasks 10b and 11. One task failure occurred for task 3 (Figure 23), for which zero assists were provided and only a few errors occurred. However, many actions were taken that
exceeded the minimum number of actions required for task 3; this may point to a minor usability issue. One failure also occurred for task 9 (Figure 23), but there were zero assists required, only 3 errors, and 5 unnecessary actions across 14 participants, further indicating that task 9 may be a minor usability issue.

Task 5 and 7 had a 100% success rate, but still exhibited some issues. Task 5 had one assist was provided, and a miniscule number of errors and unnecessary actions occurred. Therefore, this task is not likely to point to a usability issue, but the cause of the assist was still investigated. However, Task 7 resulted in 9 errors, and many unnecessary actions were taken; task 7 may point to a usability issue.

7.5.5 Time on task

To better understand the amount of effort (efficiency) with which participants completed each task, time on task was also measured (Figure 26); the faster the user completed a task, the lower the amount of effort required to complete a task, thereby offering an overall better experience. However, as discussed earlier, the number of unnecessary actions performed for a task is also indicative of the efficiency of a technology [58, 59, 64]. Therefore, it is possible for a task to have a fast completion time, but still require a high amount of effort. Although participants were asked to think aloud during this usability test, time on task data was still collected; however, using a concurrent think aloud protocol may impact task completion time. However, a good solution is to ask participants to “hold” any longer comments until after a task is completed [59]; this solution was used to ensure task completion times were as accurate as possible while using the think aloud protocol. Figure 26 depicts the mean task completion times for each task.
It was hypothesized that each task would take less than two minutes to complete; this hypothesis was confirmed. Figure 26 reveals that the mean time on task for each of the tasks was less than 77 seconds while using the think aloud protocol. Actual mean task completion times may have been faster had we not used the think aloud approach. It is important to note that the amount of work and time required for each task was not expected to be equal. The tasks of adding a goal to the action plan (tasks 2 and 7) were expected to take much longer than the other tasks, and that is what is seen in Figure 26. However, setting and responding to a notification reminder (tasks 3 and 4) was not expected to take as long as Figure 26 shows, which points to a usability issue. This is further supplemented by the problems seen with tasks 3 and 4 in sections 7.5.3 and 7.5.4. Learnability, an essential component of usability, could be measured for two features of the application: adding a goal to the action plan (tasks 2 and 7), and navigating to the summary page after setting the completion status of all goals within the action plan (tasks 6 and 9). Figure 26 shows that in both sets of tasks, the time on task between tasks decreased. However, because the tasks were not completely identical, this author is hesitant to comment on the learnability of the features mentioned. After analysis of the time on task measure for the remaining tasks, the times looked reasonable and did not warrant further investigation.

Figure 26: Mean completion times per task, in seconds
7.5.6 Usability issues

As discussed, some tasks led to task failure, requiring assists, errors, and/or unnecessary actions. The tasks were analyzed, beginning with the tasks that indicated high severity issues, followed by medium and low severity issues. Problem severity was rated according to the definitions listed in Table 13 [58, 59, 64]. The next section discusses the high severity issues in detail, and briefly summarizes the identified moderate and low severity issues.

Table 13: Usability issue severity rating definitions

<table>
<thead>
<tr>
<th>Severity</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Any issue that leads directly to task failure. This type of issue significantly impacts effectiveness, efficiency, and satisfaction.</td>
</tr>
<tr>
<td>Medium</td>
<td>Any issue that causes significant task difficulty, but does not lead to task failure. This type of issue impacts effectiveness, and likely impacts efficiency and satisfaction.</td>
</tr>
<tr>
<td>Low</td>
<td>Any issue that frustrates a participant, but does not cause task failure. This type of issue may only reduce efficiency and/or satisfaction slightly, if at all.</td>
</tr>
</tbody>
</table>

To investigate a task for usability issues, data from multiple sources was triangulated; this author reviewed many sources of data, including audio recordings, screen recordings, participants’ comments during the think aloud protocol, questionnaires, and exit-interview data. Triangulating multiple sources of data enabled this author to find and better understand the usability issues, and provide recommendations to resolve the usability issues. According to the usability issue rating definitions, tasks 3, 4, 9, 10b, and 11 indicate the presence of high severity usability issues: all these tasks produced one or more task failures. Task 4 produced two task failures, and tasks 3, 9, 10b, and 11 resulted in only one task failure each.
Usability issue 1 - Task 4

In task 4, participants were instructed to find a reminder that they had been previously asked to program in task 3. However, many participants had difficulty finding the reminder, since they attributed a reminder to something that would pop-up in the middle of the smartphone’s screen, emit a sound (“ringing”), and state that it is a reminder explicitly. 4 of the 14 participants were able to find the reminder without any assistance, and interestingly all 4 of these participants were youth; no health care professional was able to find the reminder without assistance. This may suggest that youth may be more comfortable using smartphone technology reminders than health care professionals. The participants struggling with the task were provided an assist where this author asked the participants “What if we called it a notification?”. This lead to one participant finding the reminder, but 9 of the 10 remaining participants required another assist in order to complete this task and 2 failed to complete it. The reminder is shown in Figure 27a. If the user is using their smartphone, then this reminder appears as a notification that is indicated by the NeuroCare brain logo at the top right of the notification bar. In order to access this reminder the user must swipe down to reveal the notification center Figure 27b. If the user exits the phone, they can view the reminder in the lock screen notification view (Figure 27c). Most participants were able to find the reminder when they were taken out of the phone to the lock screen. However, the participants were still unsure if this was the “reminder” they had programmed earlier.
Figure 27: Usability Issue 1 - (a) The NeuroCare reminder shown in the top right-hand side of the notification bar. (b) The reminder shown in the notification center. (c) The reminder shown in the lock screen notification view.

**Recommendation for improvement:** Analyzing the data pertaining to this task, specifically the exit-interview, it was identified that the participants understood that this was a message sent by the NeuroCare application, but they were not sure if this was the “reminder” they were asked to locate. However, this author worked with the participants who had difficulty finding this reminder to identify a solution. It is recommended that the reminder explicitly state that it is the daily reminder that can be programmed within the application. For example, the message inside the reminder could state the following: “Your daily reminder: How are you feeling today?”. This may clear up confusion regarding the use of this reminder notification.
Usability issue 2 - Task 10b

For task 10b, participants were asked to go from the concussion library (Figure 19a) to the main screen of the application (Figure 6). Only one participant, a healthcare professional, was unable to complete this task successfully. Also, three participants (all healthcare professionals) required one assist each in completing this task. All youth participants successfully completed this task with zero assistance and unnecessary actions; one youth participant made one minor error, which was self-corrected. This suggests that youth may have a more intuitive understanding of what the “main screen” of an application is; it is generally the first screen when an application is opened. During think-aloud, many youth participants commented that they believe the “How Am I Feeling Today?” page is the main screen, since the application first opened up to this page. However, most (71%) health care professionals were not sure which screen was the “main screen” of the application.

Recommendation for improvement: Many participants attempted to click the NeuroCare brain logo in the menu (Figure 5b); participants thought that clicking this button should take them to the main screen. Also, participants were attempting to look for a “home” icon to locate the main screen of the application. The home screen of this technology was the “How Am I Feeling Today?” page. To ensure participants can easily recognize that this is the main page, a “home” icon can be used to replace the current “smiley” icon for the “How Am I Feeling Today?” page. Also, the brain logo should be programmed such that when it is clicked, it takes the user to the main screen of the application.

Usability Issue 3 - Task 11

Task 11 was considered a “bonus” task, since it was a last minute addition to the technology. The main purpose of including this task in this study was to gauge interest, facilitate discussion, understand if the feature would be useful, and thus whether this feature should be developed further. During this task participants were asked to (a) find out “how they were feeling” yesterday, and (b) find out what goals they completed or did not complete yesterday according to the application. This feature was detailed in Section 6.2.4, and Figure 7. All participants were able to figure out “how they were feeling” yesterday (Figure 7a) according to the application, but some participants had trouble finding which goals they completed or didn’t complete
yesterday (Figure 7b); two health care professionals, one youth required an assist, and one youth (Y6) failed to complete the task successfully. Seven of fourteen participants assumed that the goals history would be on the goals page, or the summary page. However, after providing an assist directing the participant to the Feeling page, where the goal history was located, most participants were able to find the goals history on the Feeling page. The participant that failed to complete this task was unable to find the goals history.

**Recommendation for improvement:** Reviewing screen recordings and exit-interview data, it was identified that participants were confused about the location of the goals history; the participants expected the goals history to be located on the goals page. However, when participants were asked if they thought it was useful to see their goals history in the feelings calendar, 100% agreed. Thus, to ensure users can easily find their goal history it is recommended that the goal history be added to the goals page, or the summary page. Most participants expressed that they liked the calendar view, so it is recommended that the calendar format still be used to display the goal history.

**Usability Issue 4 - Task 3**

Task 3 asked each participant to set a reminder for one minute in the future. This required the participants to navigate to the “Reminders” page and set the reminder using a clock-face (Figure 17). A single failure occurred for this task, but many unnecessary actions were performed across all participants. Analyzing the exit interviews data, it was identified that the current clock-face was not intuitive, and was too complex for participants. Three health care professionals, and one youth made a single error while completing this task; the error was that each of these participants were unable to set the time to exactly one minute in the future, but the three health care professionals were able to set the reminder to within fives minutes of the requested time. However, one youth (Y4) was unable to set the time to within five minutes of the requested time; Y4 believed that the clock-face would only allow setting a reminder in five-minute intervals.

**Recommendation for improvement:** During the exit-interview, most participants mentioned that they identified more with a scrollable time picker, and had difficulty using the clock-face time picker. One health care professional (HCP4) mentioned that the current clock-face might
require a lot of cognitive effort. Thus, to minimize the cognitive effort required to use this technology, and improve usability, the current clock-face should be replaced with one that is similar to the time picker shown in Figure 28.

![Figure 28: Usability Issue 4 - (a) Current design and (b) recommended change to setting a reminder](image)

Usability Issue 5 - Task 9

Task 9 asked participants to set the completion status of all the goals in their action plan (My Goals page), and then use the prompt that pops up to navigate to the Summary page. This feature is shown in Figure 11. As discussed earlier, even though this task produced one task failure, there were a total only one error, and two unnecessary actions taken by other participants. Furthermore, zero assists were provided for this goal. The one participant failure came from Y4, who performed all the correct actions for the task: Y4 set the completion status of all goals to complete, and used the pop up to navigate to the Summary page. However, the task asked the participants to stop at the Summary page; Y4 assumed the summary page was the
Goals page, and stopped at the Goals page. However, of all the participants only Y4 made this error, so this error indicates a minor usability issue, if any. Analyzing the screen recordings, and the other sources of data it is not clear why Y4 believed the Goal page was the Summary page. It could be that Y4 believed the task was asking them to go to the “Goals Summary” page, but no such page exists. Considering all data sets through triangulation, the actual cause of the error is unclear. Thus, further testing is required to identify if this outlier is an anomaly or an indicator of a real usability issue, and what design changes, if any, need to be implemented.

Further analyzing tasks that had low to medium severity usability issues, the following recommendations to improve the design of the smartphone technology were developed.

Table 14: Medium to low severity usability issues

<table>
<thead>
<tr>
<th>Feature</th>
<th>Problem</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended goal</td>
<td>There is no “ADD” button in the recommended goal’s section (Figure 15b), on the Summary page. Some participants said they were unsure if clicking on the goal would add the goal, even though it did.</td>
<td>Make it clear that the goal can be added directly from this recommended goal section. One recommendation would be to add text beside the goal that says “ADD GOAL”.</td>
</tr>
<tr>
<td>Goal Completion Icons</td>
<td>The thumbs-up (complete) and thumbs-down (not complete) icons for each goal were confusing to some participants (Figure 11). Some participants thought these icons were used to indicate whether the participant liked or disliked a goal.</td>
<td>Change these icons to other icons, such as a checkmark (complete) and ‘X’ (not complete). Another option is replace the current icons with a box that can be checked off.</td>
</tr>
<tr>
<td>Adding a goal</td>
<td>When adding a goal to their action plan, participants had to set the duration of the goal and state how they would accomplish it. Participants thought that after stating how it would be accomplished, and clicking the “check-mark” on the keyboard (Figure 10b, bottom-right), the goal would be added.</td>
<td>The button to add the goal was called “ADD GOAL” (Figure 9b, top-right). Changing the location of this “ADD GOAL” button to the bottom of the screen (underneath how the user will accomplish the goal) may improve the efficiency with which a user is able to locate the button.</td>
</tr>
<tr>
<td>Deleting a goal</td>
<td>When asked to delete a goal, participants began trying to “swipe” a goal on the My Goals page.</td>
<td>Swiping elements to the left is a common UI tactic, to indication item deletion or archiving. This should be implemented in this application as well.</td>
</tr>
<tr>
<td>Menu Icon</td>
<td>One healthcare professional did not recognize the menu icon (Figure 6, top-left), and therefore did not instinctively use it to navigate throughout the application.</td>
<td>The “hamburger” icon for a menu is a universal design element in mobile applications. To mitigate a lack of knowledge in icon recognition, and of features of the application in general, a short tutorial on how to use the application should be developed.</td>
</tr>
<tr>
<td>Visual Scale for Feelings</td>
<td>Cognitively, it may be hard to figure out which “smiley” corresponds to which type of feeling (Figure 6).</td>
<td>Add text underneath each smiley, indicating what each one represents in general.</td>
</tr>
</tbody>
</table>

### 7.5.7 System Usability Scale (SUS) questionnaire

To develop a better understanding of the perceived usability of this technology, the posttest questionnaires were analyzed. Research has shown that the SUS questionnaire provides a reliable measure of the perceived usability of a system with small sample sizes, 8 to 12 users [67, 69]; Thus, this questionnaire was used for this study; the results from the SUS questionnaire are shown in Figure 29.
Scores above 68 (SD 12.5) indicate above average usability [67, 69, 68]. The mean SUS score for this study was 81.9 (SD 11.3), indicating that, on average participants were highly satisfied with the usability of this smartphone technology prototype. Bangor et al. proposed an adjective rating, and school grading scales to facilitate interpretation of the SUS scores [121]. According to these scales an SUS score of 81.9 corresponds a grade of “B”, and to usability that is between “good” and “excellent”.

To investigate if there were discrepancies in SUS scores between user groups, the mean SUS scores were calculated for both groups (Figure 30). The mean SUS score for youth was 87.5 (SD 8.5), whereas the mean SUS score for health care professionals was 76.4 (SD 11.5). SUS scores for 86% (6/7) of youth were equal to or above 82.5; one youth participant’s SUS score was 72.5. However, SUS scores for only 43% (3/7) of healthcare professionals were equal to or above 82.5. Furthermore, two healthcare professionals gave scores of 65 and 60, which is considered below average. There is a small, significant correlation between age and SUS scores showing that SUS scores decrease as age increases [121], which may partially explain the lower SUS scores among healthcare professionals. To better understand the discrepancies between SUS
scores between health care professionals and youth, key responses to the general questionnaire were analyzed.

**Figure 30: Mean SUS scores per user group (+/- SD)**

### 7.5.8 General Questionnaire

The general questionnaire included questions focused on perceived satisfaction and utility. The purpose of this questionnaire was to obtain preliminary feedback on the utility of the technology to facilitate discussions on how to improve the utility of this technology. Two versions of this questionnaire were developed: one for youth, and one for health care professionals. This questionnaire was appended to the SUS questionnaire to form one continuous survey. The general questionnaire ranged from 12 (youth version) to 14 (health care professional version) questions in length. The questions pertaining to the perceived satisfaction ranged from 4 to 5 questions, and the remaining questions were focused on assessing perceived utility. To assess technology satisfaction, the participants were asked a few questions pertaining to satisfaction. These questions asked participants to rate their agreement with the following statements: I am satisfied with this app, the interface of this app is pleasant, it was fun to use, I would
recommend it to a friend, and I would use this app if I had a concussion in the future. Key results from the questionnaire are describes next.

In this posttest questionnaire, youth participants (n=7) were asked that in the hypothetical case they experience another concussion in the future, if they would use this application; 71% (n=5) strongly agreed that they would use this application, and the remaining participants agreed (n=1), and slightly agreed (n=1). When youth and health care professionals were asked if they would recommend this application to a concussed youth, 100% (n=7) of youth agreed (1/7 slightly agreed), and (n=4) health care professionals agreed that they would recommend this technology to concussed youth. However, (n=3) health care professionals did not agree that they would recommend this technology; one (HCP6) health care professional neither agreed nor disagreed (i.e. neutral), one (HCP4) slightly disagreed, and one (HCP2) disagreed. To better understand these three ratings, the open-ended responses, if available, were reviewed. HCP6 stated that they did not know enough about the application to recommend it. HCP4 was concerned that using the technology (i.e. screen time), and the amount of reading/cognition involved may exacerbate symptoms. HCP4 also mentioned that if a youth were to have to choose between spending allowed screen time on this application versus school work, they would recommend the functional task over the use of this application. A concern among some (2/7) health care professionals that did not agree or slightly agreed to recommend this application, was that recommending this application meant they were recommending screen time to concussed youth; this was associated with the fear that extended screen time could lead to exacerbation of symptoms. However, most (4/7) health care professionals stated that they would still recommend this application to concussed youth.

Health care professionals and youth were asked if this technology would be useful in helping youth self-manage their concussion. 86% of participants agreed (9/14 agreed, and 3/14 slightly agreed) that this technology would be useful in helping youth self-manage their concussion; one youth (Y4) neither agreed nor disagreed, and one health care professional (HCP2) disagreed. Analyzing the open-ended answers from the questionnaire revealed that Y4 thought it would be hard for youth to remember to set goals and change how they feel everyday; however, reviewing the task success and errors data revealed that Y4 failed to complete task 3 (i.e. setting a daily reminder). Thus, this data suggests that the youth was unable to understand that the technology
provided daily reminders, and that this may have led to the youth’s neutral rating for this question. However, improvements in the notification reminder feature have been discussed earlier, and should be implemented. HCP2 provided no explanation for their choice to disagree with the utility of this application. However, during the exit-interview, HCP2 did mention that they believed the technology would be useful in helping youth self-manage their concussions if the technology tracked post-concussion symptoms, and somehow tied symptoms with the goals. The post-concussion symptom scale can be included in this application, and a feature that combines goals and symptoms can also be implemented to further assist youth in managing their concussion. However, it will be important to consider the extra amount of screen time a concussed user will need to spend using the application.
Chapter 8

8 Discussion and Future Directions

This research described the development, and evaluation of a smartphone technology for the self-management of pediatric concussion. A fully functional smartphone technology prototype was developed, and a usability study was completed to evaluate this technology. In Chapter 7, usability issues with this technology were identified, and actionable recommendations were provided to resolve the issues; these issues should be resolved to improve the usability of the technology. Furthermore, some overarching issues, and corresponding recommendations to further improve this technology are discussed next.

The mean SUS score of 81.9 (SD 11.3) for this smartphone technology suggests that this technology is highly usable, and this SUS score confirms hypothesis 1; the SUS score is much higher than 68. Sauro looked at the relationship between SUS scores and the “Net Promoter Score”. The “Net Promoter Score” asks individuals how likely they are to recommend a product to a friend or colleague [122]. Sauro found that individuals who rate a product with an SUS score of 82 (+/- 5) tend to be “promoters” for the product [122]. Thus, the mean SUS score for this study of 81.9 suggests that people are likely to be “promoters” of this technology, so they are likely to recommend this technology to their friends or colleagues. More importantly, the high and consistent SUS scores provided by youth (87.5, SD 8.5) suggest that they are more likely to be promoters of this technology, than health care professionals (76.4, SD 11.5). These results are in contrast to the SUS scores of a recently proposed intervention for pediatric concussion management titled SMART. This intervention was tested with 4 child/parent pairs, and the mean SUS of this web-based technology was 84 [44]; however, the mean child score was 81 (SD = 22.8), while the mean parent score was 89 (SD = 10.7) [44]. These scores suggest that the features and design of that technology resonated better with older adults than children. In addition, the large standard deviation in youth SUS scores indicates that some youth perceived the usability of this technology as below average. However, the results from this study showed that all youth perceived the usability of this technology as high, and are likely to be “promoters” for this technology. In addition, these results suggest that the features and design of this technology resonated better with youth than older adults, as opposed to the results for the SMART intervention which suggested the technology resonated better with older adults. To
better understand the discrepancy between SUS scores among health care professionals and youth, key responses to the general questionnaire were analyzed. In the general questionnaire, youth and healthcare professionals were asked if they would recommend this application to a concussed youth. 100% (n=7) of youth agreed (1/7 slightly agreed), and (n=4) health care professionals agreed that they would recommend this technology to concussed youth. However, (n=3) health care professionals did not agree that they would recommend this technology; one (HCP6) health care professional neither agreed nor disagreed (i.e. neutral), one (HCP4) slightly disagreed, and one (HCP2) disagreed. These results support Sauro’s claim that individuals with SUS scores of 82 (+/- 5) tend to be “promoters” for the product, and are more likely to recommend the product. To better understand these three ratings, the open-ended responses, if available, were reviewed. HCP6 stated that they did not know enough about the application to recommend it. HCP4 was concerned that using the technology (i.e. screen time), and the amount of reading/cognition involved may exacerbate symptoms. HCP4 also mentioned that if a youth were to have to choose between spending allowed screen time on this application versus school work, they would recommend the functional task over the use of this application. A concern among some (n=2) health care professionals that did not agree or slightly agreed to recommend this application, was that recommending this application meant they were recommending screen time to concussed youth; this was associated with the fear that extended screen time could lead to exacerbation of symptoms. This may be due to the fact that the best-practice guidelines recommend a period of physical and cognitive rest following a concussion [20]. However, the ideal duration for this rest period is unknown [4], the benefits of this rest period have not been validated [4], and it is unclear whether physical and cognitive rest aid concussed youth in recovery [123]. In addition, findings from recent studies suggest that prolonged rest post-concussion is associated with increased risk for the development of secondary problems [123-125]; these secondary problems include, anxiety/stress, physical deconditioning, irritability, social isolation, and depression [4, 126]. Furthermore, it is unknown the extent to which youth adhere to the recommendations for physical and cognitive rest [127]. However, further development for the mobile technology should aim to demand lower cognitive effort to ensure the technology can be safety used by concussed youth. Nevertheless, the usability study instructed participants to complete a series of tasks sequentially, which could have led to a high perceived cognitive workload; whereas, concussed youth would only be expected to complete a subset of these tasks everyday. Concussed youth would be expected to complete tasks 1, and 5
everyday; these tasks ask youth to come into the application, select how they are feeling, then go to their goals page and state the completion status of the goals in their action plan. In addition, the youth can view their Summary page, which is also a part of task 5. According to the task completion times (Figure 26), these tasks required less than 25 seconds to complete in total. At the end of every week, youth would be asked to perform task 2, or task 7: these tasks ask youth to add a new goal. These tasks take approximately 70 seconds to complete for each goal. Thus, youth would be expected to use this technology for less than one minute on a daily basis, and less than two minutes at the end of each week; this suggests that this technology requires lower effort per day compared to other concussion management interventions [32, 44]. For example, during the usability study for the SMART intervention, analyzing the time-on module data revealed that a mean of 49 minutes was spent on completing 6 of the 8 modules (2 modules were missing timing data), and there was a total number of 103 web pages across the 8 modules [44]. However, to evaluate how safely this technology can be used by concussed youth, and to reduce healthcare professional anxiety in recommending this smartphone technology, further work should include the analysis of perceived physical and cognitive workload. Future work should evaluate the cognitive effort required to use the technology, and compare it to other activities youth take part in during concussion recovery to reduce physician anxiety in recommending this technology. A useful tool for evaluating perceived workload is the NASA Task Load Index (NASA-TLX) questionnaire [128]. NASA-TLX is widely used and validated questionnaire [128] that can help to assess the perceived workload required to use this technology. This questionnaire should be administered after participants have had the opportunity to use the technology; for example, the questionnaire can be administered following a usability study. In addition, further research is needed to trial this technology amongst a cohort of concussed youth to determine if the technology exacerbates post-concussion symptoms. Nevertheless, most (4/7) health care professionals stated that they would still recommend this application to concussed youth.

As discussed, recommending screen time to youth was a common concern among healthcare professionals, since cognitive and physical rest is recommended following a concussion. Thus, further development for the mobile technology should aim to demand lower cognitive effort to ensure the technology can be safety used by concussed youth. To reduce the amount of cognitive effort required for youth to use this technology many steps can be taken. For example,
resolving the identified usability issues with this technology can reduce the amount of time, frequency of errors, and the amount effort that is required to use a technology; the usability issues of this technology can be improved by applying the recommendations provided in Chapter 7. The Hierarchy of Intervention Effectiveness is a theory or tool for risk management that suggests technological interventions are more reliable and effective, than interventions targeted at human behaviour for mitigating errors [129, 130]. According to this theory, the most effective technological interventions are those that apply “forcing functions” and “constraints” [129, 130]. Forcing functions force the user to perform tasks by reducing the degrees of freedom the user has while using the technology. In addition, “computerization” and “automation” are also considered effective technological interventions [129, 130]. So, adding forcing functions, and automating, can reduce the number of decisions, and actions a user can make when using a technology, and this can reduce the amount of overall effort required to use this technology. This tool can be used to redesign some of this technology’s features to reduce the amount of effort, mitigate errors, and overall to improve the usability of this technology. Thus, this technology’s features can be redesigned such that the youth would need to make fewer decisions, and fewer actions while using this technology by applying forcing functions, and automating. For example, when a youth comes into the application, and selects how they are feeling, the application can automatically present the Goals page to the user. This can be followed presenting a prompt that asks youth to select which goals they have completed, and following this the summary page can be presented automatically. This would be different from the way the application currently assists the youth. As discussed in chapter 6, this technology provides youth Android Toast notifications [112] that prompt the user to navigate to the different pages in the application. This navigation guides the user through the short and concise primary workflow that was originally envisioned. This Android toast is shown in Figure 7a, and can be ignored or discarded by swiping it away. During the study participants were asked if they thought these notifications provided suggestions, or mandatory actions; there was no consensus between youth and health care professionals on whether these notifications were mandatory, or recommended a suggested next step. However, all participants believed these notifications were useful and made the application easier to use, since they did not need to go back into the Menu to navigate to different pages in the application. These Toast notifications provide youth with guidance on their next steps, but they rely on the youth responding to the notification. As discussed, using forcing functions, and automation, to refine some of this technology’s features
can reduce the number of decisions, and actions, that youth would need to make while using this technology. Reducing the number of decisions, and actions, may reduce the rate of errors, increase efficiency, and increase the effectiveness with which this technology can be used. This may help reduce the amount of cognitive and physical effort required to use this technology, which may reduce physician anxiety in recommending this technology to youth. Overall, applying forcing functions, and automating, alongside other types of error mitigation interventions described by the Hierarchy of Effectiveness can help to improve the usability of this technology.

During the usability study some participants mentioned that an introductory video, or a “tour” of the application would have made using the application easier; participants mentioned that once they knew where everything was located in the application, they were able to easily navigate through the application. Specifically, health care professionals voiced that having an explanation of how this application could help concussed youth, would be a beneficial addition to the introductory video. Introductory videos, and application “tours” are commonly included in applications to teach the user how to effectively use the application, bring specific parts of the application to the users attention, and explain the benefits of using it. It may be beneficial to add to this application an introductory video with a concussion expert explaining why and how this application can help concussed youth in their recovery. In addition, an application “tour” should be included in this application, which takes the user through the various features of the application to improve the usability of the application. An application “tour” is a form of training provided to the user to reduce the likelihood of errors, and improve the efficiency and effectiveness with which a technology is used. Training is one type of intervention described in the Hierarchy of Intervention Effectiveness [129, 130]; according to this tool, training is not considered the most effective type of intervention for mitigating errors, but it is suggested that training-based interventions are of some value [129, 130]. May and Deckker suggested that providing training improves a users’ understanding of concepts and the implications of actions, and consequently reduces the incidence of omissions made by users [131]. Thus, a short training video, or application “tour” may reduce the rate of errors, and thereby improve the usability of this technology.
Data sharing features were identified as desirable during requirements analysis (Chapter 5), and during the usability study many participants mentioned that having a feature to share their recovery data with a healthcare professional would be useful. Unfortunately, the functionality to share progress with a healthcare professional was not developed in time for this usability study, but this functionality should be added to the application. The conceptualized idea for this feature is to have a “Share your progress” tab on the menu that could be used to share all relevant information with the youth’s healthcare professional via e-mail. This information would include the entire tabulated history of the youth’s action plan of goals, the entire tabulated history of feeling-related information, and summary information similar to, but more in depth, then what the concussed youth sees on the Summary page. This information would be sent in the CSV file format, for easy consumption for healthcare data analytics.

The International Classification of Functioning and Health (ICF) integrates the physical, mental, and social aspects of an individual’s health condition [89, 132]; this tool is commonly used by rehabilitation therapists [89]. Like the ICF, this smartphone technology incorporates all aspects of a person’s life instead of solely focusing on their diagnosis, and provides a holistic view of an individual. In this study, some healthcare professionals mentioned that in their practice they had been focusing solely on the youth’s symptoms, and had not been asking youth how they are feeling overall. The health care professional’s voiced that the Feeling page of this technology would provide them the opportunity and prompt them to ask the youth how they have been doing overall, thereby lead to a change in the manner in which they manage concussion.

Overall, healthcare professionals mentioned that the Feeling page was a useful part of the application. However, it was suggested that the Feeling page not be the main page of the application, or there be two versions of this application available: one version for acute concussion, and another version for persistent concussion. Healthcare professionals mentioned that they were more worried about the persistent youth, who had not recovered within the first 28 days following their concussion. The professionals also mentioned that the symptoms of these youth do not change very much over time, so asking these youth about their symptoms is counter-productive; according to these healthcare professionals, little to no change in symptoms led to the youth feeling depressed and helpless. Zasler et al. discussed that if symptoms persist, than focusing on symptoms might be counter-productive [133]. However, the best-practice guidelines solely relies on youth self-reporting their symptoms to guide return to activity [20].
In addition, one of the only currently proposed concussion management interventions, other than the Concussion & You program, asks youth to complete the PCS scale daily [44]. However, this technology does not focus on symptoms rather it focuses on how the youth is doing holistically. Some healthcare professionals were concerned that if the youth is not feeling better, then the Feeling page may not be very motivating for those youth. For the persistent concussed youth population, it may be beneficial to change the main page of the application to the Goal page, or Summary page. Another option would be to create a new main page which provides quick links to the other pages of the application, so that the youth do not see the Feeling page as soon as they enter the application. However, the Feeling page may be a good choice for the main page for youth who are recovering quickly from their concussion, but since there is no way of currently knowing which youth will have persistent symptoms, it may be beneficial to create one version of the application that anticipates a persistent concussion. Nevertheless, healthcare professionals and youth mentioned that the Feeling page was a useful part of the application that provided a comprehensive summary of how the youth is doing holistically.

During this study, when asked how this technology could be made more useful, the majority of healthcare professionals, and some youth, mentioned it might be useful to have the PCS scale in this application. This was an expected finding, since the best-practice guidelines heavily rely on youth self-reporting their PCS to guide their recovery [20]. This scale was initially included in the design requirements for this technology, but due to limited time this feature was not implemented. It may be beneficial to add this scale to this technology. In this study, there was little to no consensus among healthcare professionals on how often the youth should be prompted to complete the PCS scale, but most healthcare professionals mentioned they would like youth to fill out the scale as often as possible. For example, one healthcare professional mentioned they would like youth to complete the PCS scale every day, and another professional mentioned they would like data on PCS every few days. This supports the current literature on concussion management that shows there is a lack of standardization in the management of pediatric concussion in Canada. Thus, many points would need to be considered before implementing this scale including, how often youth should be asked to input their PCS, whether youth should have access to the results, and the impact this feature may have on the cognitive and physical effort required to use this application.
As discussed, this study supports the current literature that shows a lack of standardization in the management of pediatric concussion: there was little to no consensus on how often youth should complete the post-concussion symptom scale. There was also a lack of knowledge observed in pediatric concussion management. For example, a healthcare professional mentioned that the information available in the “Concussion Library” would be useful for healthcare professional to know; the information provided in the “Concussion Library” is based on the best-practice guidelines and expert knowledge, which is information that ideally would be provided to concussed youth by their healthcare professionals. In this study, healthcare professionals were asked about their perceptions of pediatric concussion management on the demographics form. When asked if they find all health care professionals in Canada manage pediatric concussion in a consistent manner, 100% of the health care professionals disagreed or strongly disagreed with the statement. When healthcare professionals were asked if they find that all youth in Canada are given enough information to manage their concussion, 86% (6/7) of the health care professionals either disagreed, or strongly disagreed with the statement; one health care professional slightly disagreed with the statement. These results are consistent with the literature which has shown that there is a lack of standardization, and that significant gaps exist in the management of pediatric concussion in Canada [16-19].

In this study, participants were asked to provide information on the ownership, or access to, a smartphone and tablet, and 100% of participants either own, or have daily access to a smartphone. This supports the findings from the recent Pew Internet & American Life Project that indicate that mobile phones have become the primary communication tool for the majority of adolescents in the United States [50, 51]; 75% of 12 to 17-year-olds now own mobile phones [51]. Both youth and healthcare professionals have shown interest in this technology; most (4/7) health care professionals stated that they would recommend this application to concussed youth. In addition, 100% of the youth participants agreed that they would use this technology if they were to suffer another concussion in the future, and 100% said they would recommend this technology to others. This suggests that this smartphone application may be an accessible, and feasible intervention for concussed youth.

This usability study provided valuable end-user feedback from both youth and healthcare professionals. A number of usability issues were identified, and recommendations to improve the design of the application were provided (see Chapter 7). Additionally, some
recommendations to improve the utility, safety, uptake, and overall design of the technology were provided (Chapter 8). An SUS score of 81.9 (SD 11.3) for this smartphone technology conveys high usability. This SUS score confirms hypothesis 1; the SUS score is much higher than 68, so this technology has high perceived usability. Hypothesis 2 was confirmed for all tasks except tasks 4; all tasks except task 4 had task success rates higher than 90%. Task 4 had a task success rate of 86%, but the usability issues that led to the reduced success rate for this task were discussed, and design changes to resolve these issues were provided. The frequency of errors for each task was lower than what was hypothesized; most tasks had a total error frequency of less than 11 errors, but task 4 had a total of 11 errors. It was hypothesized that each task would take less than two minutes to complete; this hypothesis was confirmed, and suggests this technology is highly efficient. As hypothesized, many low and moderate severity issues were identified, and less than 5 high severity usability issues were identified; a total of 4 high severity issues were identified. The results of the post-test questionnaires suggest that youth and healthcare professionals are open to using this application to self-manage a youth’s concussion, and feel that this technology would be useful in helping youth in managing their concussions. Overall, the results from the study suggest that this technology is usable, acceptable to users, and may be useful in helping youth self-manage concussion. However, further work should include the analysis of perceived physical and cognitive workload to evaluate how safely this technology can be used by concussed youth, and reduce physician anxiety in recommending this technology; for example, the NASA-TLX can be used to evaluate perceived workload. In addition, future work should include resolving the identified usability issues, implementing features that could improve utility, changing features to reduce cognitive workload, and then conducting a second usability study (phase 2).
Chapter 9

9 Limitations

There were several limitations in this study. This technology was tested in the lab with the researcher present in the same room. A limitation of this type of study is that the behaviours and performance of participants may be altered as a result of their awareness of being observed (i.e. the Hawthorne effect) [71]. The awareness of being observed may have led to better performance and a decrease in the number of observed errors [71]. Thus, it is important to not have any measurement methods that may be obtrusive to a usability study participant. For example, recording the screen of a mobile phone is common when performing a usability study of a mobile health technology, as is recording audio during the think aloud approach [69, 70]. The use of an external camera and external audio recording device can be used, but these methods are typically seen as obtrusive and further removes the study participant from a “real-world” setting [69, 70]. Instead, the mobile screen and think aloud audio can be recorded with the phone itself. It has been noted that some users still might find this method obtrusive, causing them to modify their task performance, positively improve behaviour towards the study facilitator, and limit the number of negative comments on the design [71]. However, this is the least obtrusive method of collecting data pertaining to mobile device interaction, and does not require any extra recording equipment other than the mobile device itself [69, 70]. In addition, although participants were asked to think aloud during this usability test, time on task data was still collected; however, using a concurrent think aloud protocol may impact task completion times, and may influence how individuals complete a tasks [59]. However, a good solution is to ask participants to “hold” any longer comments until after a task is completed [59]; this solution was used to ensure task completion times were as accurate as possible while using the think aloud protocol. In addition, Neilson states that participants quickly become very engaged in the test tasks, and forget that they are in a study [26]. Primarily, the quantitative performance metrics collected in this study were used to identify usability issues with the technology. All the data collected during this study was triangulated to identify the location of usability issues; thus, it is unlikely that any usability issues went unidentified due to this effect.
However, many different factors may influence how usability issues are identified, and Snyder provides a review of some ways that usability findings may be biased; she concludes that even though the bias cannot be completely eliminated, these methods are still useful [134]. The sources of bias in a usability study include, participants, tasks, artifact, environment, moderators, and expectations [59]. The tasks chosen for a study can have tremendous impact on what usability issues are discovered. Lindgaard and Chattratchart concluded that if participants are recruited carefully, than increasing the task coverage is more beneficial than increasing the number of users in identifying usability issues [135]. In this study, a wide range of tasks was used to uncover usability issues with this technology. Another possible source of bias are the participants, since each participant has a specific level of technical expertise, domain knowledge, and motivation [59]. For example, some participants are comfortable thinking aloud, and are comfortable in a lab setting, whereas others are not. All of the aforementioned factors can impact the type of usability issues that are identified. In addition, the number of participants in a study can impact the number of usability issues identified; according to Nielsen and Landauer 80% of usability issues will be identified with the first five participants. Thus, to increase the probability of identifying different types and all major issues, 14 participants with a wide range of technical expertise and knowledge were recruited for this study [87, 115].

Norgaard and Hornbaek found that many usability professionals come into testing with expectations on what are the most problematic areas of an interface, and this can lead to missing many other important issues [136]. However, this researcher conducted all usability studies before analyzing task specific usability data and conducted each study without a perceived notion of issues to reduce the possibility of missing any important usability issues.

As seen in the literature, performance anxiety may have had an affect on the behaviour of participants [137]. For example, some participants would make an error, and they would realize later that they made an error; realization of an error during the usability study may have caused the participants to feel stressed or anxious. To reduce the possibility or level of anxiety or stress, this researcher reminded the participants, before each task, that this study was testing the technology, not them.
This study recruited participants from Holland Bloorview Kids Rehabilitation Hospital, and the community. The youth participants of this study were drawn from youth that were able to travel to Holland Bloorview located in downtown Toronto, so this sample may not be representative of the general concussed youth population; the healthcare professionals were drawn from those that were able to travel to Holland Bloorview, or accommodate this researcher visiting their facility to complete the study. However, most (5/7) youth participants recruited in this study were from the past participants of NeuroCare (phase 1), and most (4/7) healthcare professionals that took part in this study were from Holland Bloorview; the majority (12/14) of participants were from Toronto, Ontario. In addition, the healthcare professionals and youth that chose to take part in this study may be more knowledge of concussion management, and be comfortable with using smartphone technologies. Thus, the results from this study might not be generalizable to the general concussed youth population, and may not be generalizable to the general healthcare professional population that manages concussion.

The study was conducted in English which limited the sample population to English speaking participants. This language barrier may have biased the study results since individuals who do not speak English living in Canada may have a different level of education, or may differ culturally from English speaking youth and healthcare professionals in regards to the way they perceive concussion, manage concussion, and use smartphone technologies. In addition, participants were required to have some experience using smartphones; this limited the sample population to participants who have had access to a smartphone, and who are able to use smartphones in the traditional manner. Thus, this technology barrier may have biased the study results: for example, including individuals who do not have experience using a smartphone in this study, may have led to different usability, and utility findings. In addition, the data from usability study was analyzed, and interpreted by this researcher to identify usability issues. This could have biased the study results, since this researcher may not have interpreted a participant’s comments as a participant may have intended them to interpreted [59, 69]. However, in order to reduce this bias, this researcher asked the participants to confirm all findings during the exit-interview, and used the recordings of the usability evaluation to enhance and clarify the findings.
There was a significant amount of data collected for this usability study, but due to limited time and resources not all the data was analyzed. This data should be analyzed in the future to further understand how to improve the utility and usability of this technology. However, the main usability data was analyzed, and the key research findings were discussed.
Chapter 10

10 Conclusion

Concussions can lead to a range of neurobehavioral deficits that include combinations of somatic, cognitive and emotional/behavioral symptoms [1]. These post-concussion symptoms can have significant impact on the functional participation of youth in daily activities, such as sports, school, family and social [2, 3]. Furthermore, concussions are a common injury among Canadian youth [2], but the large gaps that exist in the concussions management can lead youth receiving inconsistent and incomplete messages from their health care providers, consequently leading to poor health outcomes [16]. Thus, it is imperative that youth be provided with easy access to the best-practice concussion management strategies, and education developed by experts and leaders in concussion management. In addition, self-management is challenging for everyone, but the demands of self-management tasks may be particularly difficult for youth [50, 52]. Thus, an approach to enable self-management combined with continuous support and feedback is required for the concussed youth population. Given youths’ propensity for new technology and the fact that the majority of youth own mobile phones, mHealth interventions may provide important avenues to empower and engage youth to improve self-management skills and behaviours [50, 52]. There is a dearth of validated mHealth interventions developed specifically for the self-management of pediatric concussion. Thus, this research addressed this need to provide youth with an easily accessible self-management intervention by developing and evaluating a smartphone technology to aid youth in self-managing concussion.

This research described the development of an accessible concussion management intervention for concussed youth; a fully functional smartphone application prototype was developed. The results of the usability study suggest that this technology is highly usable; high SUS scores indicate high perceived usability, and high task success rates, a low number of errors, and fast task completion times suggest high objective usability. The results of the posttest questionnaires suggest that youth and healthcare professionals are open to using this application to self-manage a youth’s concussion, and feel that this technology would be useful in helping youth in managing their concussions. This research provides data on youth’s and healthcare professional’s perceptions of current concussion management; the results suggest there are large gaps in the way concussion is managed from both the youth’s and health care professional’s
perspectives. In this study, 100% of participants either own or have daily access to a smartphone, and both youth and healthcare professionals have shown interest in this technology; most (4/7) health care professionals stated that they would recommend this application to concussed youth. In addition, 100% of the youth participants agreed that they would use this technology if they were to suffer another concussion in the future, and 100% said they would recommend this technology to others. This suggests that this smartphone application may be an accessible, acceptable, and feasible intervention for concussed youth. Results from this study suggest that healthcare professionals are willing to recommend this technology to concussed youth, but there is a fear of recommending screen time that should be addressed. Thus, further work should include the analysis of perceived physical and cognitive workload to evaluate how safely this technology can be used by concussed youth, and reduce physician anxiety in recommending this technology; for example, the NASA-TLX can be used to evaluate perceived workload. In addition, future work should include resolving the identified usability issues, implementing features that could improve utility, changing features to reduce cognitive workload, and then conducting a second usability study (phase 2). Also, future work should trial this technology amongst a cohort of concussed youth to determine the effectiveness, and safety, of this technology as a concussion self-management tool/intervention.

This smartphone technology is expected to prevent delayed recovery, prolonged functional deficits, and more severe injuries, thereby reducing the duration and severity of post-concussion symptoms. Furthermore, this research is expected to improve the quality of life of youth by allowing the quick and safe return to daily activities, such as sports, school, family, and social activities. Overall, this technology is expected to help bridge the gaps in pediatric concussion management by 1) providing youth with expert informed concussion management strategies, 2) guiding youth in managing their concussion, and 3) enabling pediatric concussion researchers to better understand the concussion recovery trajectory, which will assist in the development of 4) more effective evidence-based best-practice guidelines for pediatric concussion management. For example, using this technology data can be collected anonymously and analyzed from a large sample size of patients to understand which concussion strategies are helpful in concussion recovery. Ultimately, this research may help bridge the gaps in the management of pediatric concussion through the development of a technology prototype that can enable and empower youth to self-manage concussion. In summary, this research resulted in the development of an
innovate smartphone technology prototype, and the results from this study suggest that this is a usable and acceptable technology that may be useful in helping youth self-manage concussion. This research provides brain injury researchers, concussion experts, and health care professionals with a smartphone technology prototype that is usable, acceptable to youth and healthcare professionals, and that can enable and aid youth in self-managing concussion. This study provides empirical data that can be used to improve the usability, usefulness, uptake, and safety of this and other technologies being developed for the management of pediatric concussion.
References


Appendices

Appendix A  NeuroCare Walkthrough Steps

The Main Screen is the “HOW ARE YOU FEELING” screen; this is the first screen the user
sees when they open the app.

PART 1: GOAL SETTING

1. CLICK the MENU icon (3 horizontal lines in the top-left side of the screen). This opens
   up the MENU.
   • This menu gives access to all the different parts of the app.

2. CLICK MY ACTIVE GOALS in the MENU
   • The app displays a message in the middle of the screen

3. CLICK on the ‘+’ button
   • Clicking this button takes you to a new page that displays all the available goals
     that the user can choose from.
   • Note: All the goals are placed in one of 4 categories, and each category has a
colour: Sleep (purple), Energy Conservation (yellow), Relaxation (pink), and
Nutrition (green)

4. CLICK on ANY of the GOALS
   • Clicking on a goal takes you to the GOAL’s DESCRIPTION page

5. CLICK on the pre-selected end date to change the end-date for this goal. SELECT a date
   and CLICK OK.
   • The end-date is preconfigured to 1 week from today’s date.

6. CLICK the line below “how will I accomplish this goal”, and WRITE how you plan to
   accomplish the goal using the keyboard

7. CLICK the SAVE goal button found in the top-right side of the screen
   • You have added the goal!

8. Now you are back at the MY ACTIVE GOALS and you should see the goal you just
   added here.

9. CLICK the THUMBS UP button in the goal you just added
   • Notice that the text to the right of the thumbs up changes to “goal completed”

10. CLICK on the GOAL you added. Now you should see the GOAL’S DESCRIPTION
     page. SCROLL down using the laptop mouse pad to see the entire page.
     • Note: What you entered for “how you will accomplish this goal” is shown here.
11. **SEE the CALENDER at the button of this page. NOTICE that the dates you selected for this goal show a DOT under them.**
   - The DOT is:
     - Grey: If goal completion is unknown
     - Green: If the goal was completed
     - Red: If the goal was not completed
   - Note: We clicked THUMBS UP thus, selected that the GOAL is COMPLETED for today, so you should see a GREEN DOT under today’s date, and GREY dots for the rest of the goal’s days.

12. **CLICK on the BACK arrow (top-left side of the screen) to go back to the main page.**

**PART 2: OTHER PARTS OF THE APP**

13. **CLICK the MENU icon (3 horizontal lines in the top-left side of the screen).**
   - This opens up the MENU. The menu gives you access to all the different parts of the app.

14. **CLICK on USING THIS APP**
   - This page will tell the user why they should use this app.

15. **CLICK the MENU icon again (3 horizontal lines, top-left of screen). Then, CLICK on HELPFUL RESOURCES**
   - This page lists some helpful resources for concussed youth and their parents.
     - **CAUTION: DO NOT CLICK WEBSITE LINKS. Clicking on the links opens up the corresponding website, but this will take a VERY LONG TIME as this is a simulated environment and not a real phone!**

16. **CLICK the MENU icon again (3 horizontal lines, top-left screen). Then, CLICK on CONTACT CONCUSSION EXPERTS**
   - This page will help the youth get in contact with the concussion experts closest to them; currently we are only displaying Holland Bloorview’s contact info.

17. **CLICK the MENU icon again (3 horizontal lines, top-left screen). And CLICK on SUMMARY.**
   - This page will help provide youth and/or health care professionals with a summary that can help them manage the concussion better.

18. **CLICK the MENU icon again (3 horizontal lines, top-left screen). And, CLICK on the CONCUSSION LIBRARY.**
   - Here we can put any information that can help kids throughout their concussion.

Now, you may give the group a few minutes to play around with the app before you ask them to comment on the important questions below.
Questions for the Group

Facilitator Note: Please focus on trying to get the group’s feedback for most importantly the Summary Page questions, and then the Prompt questions. This will be very important for further app development. Thank you.

Summary Page – Most important question for feedback

1. How can we use all the information we collect in this app to give meaningful feedback to a) the child and b) the health care professional to help them better manage concussion?

2. How can we display the information we are collecting in a meaningful way in the SUMMARY PAGE?

Prompts

3. How do we want to prompt the youth?
   a. When?
   b. How often?
   c. What should the prompt sound like? Or should it be a silent prompt that is just shown on the phone screen?

Once we have received good feedback for the above questions, please ask the group to comment on the following:

Concussion Library

4. What information could you recommend we add in this library to help kids with concussion?

Other Questions

5. Any other feedback or suggestions?
6. What do you like about the app?
7. What do you dislike about the app?
8. Anything confusing about the app?
Appendix B  NeuroCare Team Meeting Feedback Survey

NeuroCare Smartphone App

1. What do you like?

2. What do you not like?

3. Is there anything missing?

4. Any other feedback?
Appendix C  Recruitment Script for Past NeuroCare Participants

To: <email address of prospective interviewee>

From: <your email>

Greetings:

My name is Harminder Sandhu. I am a research student from the Concussion Research Centre at Holland Bloorview Kids Rehab. We accessed your email online from Holland Bloorview Concussion Labs past participant emailing list. You had previously given permission to be contacted for future relevant studies. That is why I am emailing you to see if you are interested in participating in a study that will test the usability and usefulness of a smartphone application (app) to help youth in self-managing concussion. This study will help us evaluate and improve the smartphone app so we can ensure we make a great app to help youth manage concussion.

You will be given a $10 gift card from Tim Horton’s for participating in this study. If the session is not completed for any reason, you will still receive the gift card.

If you are interested in participating please keep reading, however, if you do not want to participate you may close this email at any time.

Your decision to participate, decline, or withdraw from participation will have no effect on your current status or future relations with Holland Bloorview Kids Rehabilitation Hospital, or the Concussion Research Centre.

Let me tell you a little more about this study and how you can be involved. During the study you will be given a smartphone (Android) with the app we developed installed on the phone. You will be asked to fill out a demographics form, to use the app, complete a short questionnaire, and express and further suggestions for the app during the exit-interview. This study will take place at Holland Bloorview Kids Rehabilitation Hospital’s Concussion Research Centre (4+ floor), and the approximate time for the study is 30 minutes to 45 minutes. You feedback will be used to make sure we develop a great app to help kids manage their concussion.

If you are interested in participating, or if you have any questions please do not hesitate to send me an email or call me. I will make sure to reply within 48 hours.

Thank you for your time,

Harminder Sandhu, B.Eng., Master Student
Research Student, Concussion Research Centre
Holland Bloorview Kids Rehabilitation Hospital
Appendix D  Recruitment Flyers

RECRUITMENT FLYER FOR YOUTH

Participate in Research
Testing a Smart Phone App for Helping Youth Self-Manage Concussion

Principal Investigator:
Dr. Nick Reed, PhD, Occupational Therapist

Centre for Leadership in Acquired Brain Injury

ARE YOU A YOUTH WHO HAS HAD A CONCUSSION AND RECOVERED?
TEST A SMART PHONE APP!

What is this study about?
You will test an app we made for kids with concussion. This is the first app being made to help kids manage their own concussion in a fun way, so they can get back to activities they love faster and safer.

Who can participate?
We are looking for youth who:
• Are between 10-18 years old
• Have had a concussion
• Have recovered from the concussion

What's involved?
• Test a smart phone app
• Short questionnaire
• Short interview at the end
• Time of testing 30 mins to 45 mins (max)
• One visit to Holland Bloorview Kids Rehabilitation Hospital's Concussion Centre

Potential Risks?
Participating in this study is very low risk—you simply use an app and do a questionnaire.

Potential Benefits?
Your feedback will help us improve the app, so we can make a great app to help kids manage their concussion!

You will get a $10 gift card to thank you for your participation

Date Posted: July 23, 2016
Version Date: July 20, 2016

REB #: 16-632
Participate in Research
Testing a Smart Phone App for Helping Youth Self-Manage Concussion

Principal Investigator:
Dr. Nick Reed, PhD,
Occupational Therapist

Centre for Leadership in Acquired Brain Injury

ARE YOU A HEALTHCARE PROFESSIONAL?
INVOLVED WITH CONCUSSION?
TEST A SMART PHONE APP!
HELP THE YOUTH!

What is this study about?
You will test an app we made for kids with concussion. This is the first app being made to help kids manage their own concussion in a fun way, so they can get back to activities they love faster and safer.

Who can participate?
We are looking for healthcare professionals who are involved with concussion in any way (i.e. diagnosis, management, research)

What’s involved?
• Test a smart phone app
• Short questionnaire
• Short interview at the end
• Time of testing 30 mins to 45 mins (max)
• One visit to Holland Bloorview Kids Rehabilitation Hospital’s Concussion Centre or we can come to your place of practice to conduct the study

Potential Risks?
Participating in this study is very low risk— you simply use an app and do a questionnaire.

Potential Benefits?
Your feedback will help us improve the app, so we can make a great app to help kids manage their concussion!

You will receive a $10 gift card to thank you for your participation

Date Posted: July 22, 2016
Version Date: Sept 25, 2016

REB #: 16-632
Appendix E  Participate in Research Templates

PARTICIPATE IN RESEARCH TEMPLATE – FOR YOUTH

Holland Bloorview Kids Rehabilitation Hospital – Participate in Research Page

Evaluating the usability and utility of a smartphone technology to help youth self-manage their concussion

_Harminder Sandhu, Master’s student & Dr. Nick Reed, PhD, OT Reg. (Ont.)_

**TEMPLATE**

**Title:** Evaluating the usability and utility of a smartphone technology to help youth self-manage their concussion

**Call to action:** Are you a youth who has had a concussion and recovered? Test a smartphone app!

**Researchers:**
Harminder Sandhu (Master’s student), Dr. Nick Reed

**What is this study about:** You will test an app we have made for kids with concussion. This is the first app being made to help kids manage their own concussion in a fun way, so they can get back to activities they love faster and safer.

**Who can participate?**
We are looking for youth who:
- Are between 10-18 years old
- Have had a concussion
- Have recovered from the concussion

**What’s involved?**
- Test a smartphone app
- Short questionnaire
- Short interview at the end
- Time of testing 30 minutes- 45 minutes (max)
- One visit to Holland Bloorview Kids Rehabilitation Hospital’s Concussion Centre

**Potential Risks?**
Participating in this study is very low risk – you simply use an app and do a survey.
Potential Benefits?
Your feedback will help us improve the app, so we can make a great app to help kids manage their concussion!

You will receive a $10 gift card to thank you for your participation

Deadline: <When recruitment ends (TBD)>

Interested in Participating?
If you are interested in participating in this study or have additional questions, please contact Harminder Sandhu with your interest or questions, and we will get back to you shortly. Contacting us does not obligate you to participate in the study.
PARTICIPATE IN RESEARCH TEMPLATE – FOR HEALTH CARE PROFESSIONALS

Holland Bloorview Kids Rehabilitation Hospital – Participate in Research Page
Evaluating the usability and utility of a smartphone technology to help youth self-manage their concussion

Harminder Sandhu, Master’s student & Dr. Nick Reed, PhD, OT Reg. (Ont.)

TEMPLATE

Title: Evaluating the usability and utility of a smartphone technology to help youth self-manage their concussion

Call to action: Are you a healthcare professional? Involved with concussion? Test a smartphone app! Help the youth!

Researchers:
Harminder Sandhu (Master’s student), Dr. Nick Reed

What is this study about?
You will test an app we have made for kids with concussion. This is the first app being made to help kids manage their own concussion in a fun way, so they can get back to activities they love faster and safer.

Who can participate?
We are looking for healthcare professionals who:
• Are involved with concussion in any way (i.e. diagnosis, management, research)

What’s involved?
• Test a smartphone app
• Short questionnaire
• Short interview at the end
• Time of testing 30 minutes- 45 minutes (max)
• One visit to Holland Bloorview Kids Rehabilitation Hospital’s Concussion Centre or we can come to your place of practice to conduct the study

Potential Risks?
Participating in this study is very low risk – you simply use an app and do a survey.
Potential Benefits?
Your feedback will help us improve the app, so we can make a great app to help kids manage their concussion!

You will receive a $10 gift card to thank you for your participation

Deadline: <When recruitment ends (TBD)>

Interested in Participating?
If you are interested in participating in this study or have additional questions, please contact Harminder Sandhu with your interest or questions, and we will get back to you shortly. Contacting us does not obligate you to participate in the study.
Appendix F  Study Information and Consent Forms

Informed Consent Form to Participate in a Research Study
Flesch-Kincaid Grade level 7.5

Evaluating the usability and utility of a smartphone technology to help youth self-manage their concussion

Principal Investigator:
Dr. Nick Reed, PhD, MScOT, OT Reg. (Ont).
Clinician Scientist and Occupational Therapist
Concussion Research Centre
Bloorsview Research Institute, Holland Bloorsview Kids Rehabilitation Hospital
Rehabilitation Science Institute, University of Toronto
Associate Professor, Department of Occupational Science and Occupational Therapy
University of Toronto

Primary Study Contact & Co-Investigator:
Harminder Sandhu, B.Eng., MHSc Candidate 2016
Concussion Centre, Holland Bloorsview Kids Rehabilitation Hospital
150 Kilgour Rd., Toronto, ON M4G1R8
Study Funders: Ontario Brain Institute (OBI), Ontario Neurotrauma Foundation (ONF) and Canadian Institutes of Health Research (CIHR)

Dear Prospective Participant,

My name is Nick Reed. I am part of a research study at Bloorsview Research Institute at Holland Bloorsview Kids Rehabilitation Hospital that is testing a smartphone application (app) we are making to help youth self-manage concussion. Before agreeing to take part in this study, it is important that you understand how you will be involved. This consent form provides you with information to help you make an informed choice.

What is the study about?

We want to test a smartphone app we have developed to understand how we make this app better and more useful, so that it can help youth self-manage their concussion. We want to learn about how easy the app is to use, any problems people have while using the app, if this app will help
youth manage concussion, and overall how we can make the app better. This app will be tested by 10 youth (10-18 years-old), and by 10 health care professionals who are involved with concussion. Apps have helped youth with similar issues to concussion. We do not know if this app will be useful for youth with concussion because this is an early study. It will provide us with information to improve the smartphone app, and then do a larger study, where we will have youth use the device for a longer time and see if the app helps youth better manage their concussion.

**How will you be involved in the study?**

We would like to invite you to participate in this study. You must show me that you understand what you will have to do to take part in this study. If you cannot do this, you cannot participate in the study.

This is what you will be asked to do:

1. You will be asked to come to **Holland Bloorview for 1 visit**. This session will take approximately **30 minutes to 45 minutes** (max). This session will be a 1-on-1 session, with you and the study coordinator in the room. The session will be **audio recorded** so that we can re-listen to the audio to make sure we are able use all your feedback to make the app better. And, the smartphone application’s screen will be recorded to help us investigate the usability issues.
2. Before the testing begins, you will be asked to fill out a demographics form. You will be asked about your health, for example, history of concussion.
3. You will be given a smartphone with the app we want to test installed. You will be asked to perform some basic tasks on the application, such as switching between different screens, and returning to the home screen.
4. Then, you will be given time to freely use the app, so you can check-out any parts of the app you want to, and get a better idea of the whole app.
5. After this, you will be given a short paper and pencil questionnaire where you will be asked to rate the app, for example how did you like the app?
6. Then, you will be given time to give any last comments or suggestions for the app, and answer any questions the study conductor has during a short exit-interview.

**What will happen to my data?**

By providing consent to this study, you are agreeing that the data collected during this study will be stored electronically in a database developed and maintained by the Ontario Brain Institute (OBI). This database is known as Brain-CODE, and it will be stored in reputable facilities with high level security protocols. Brain-CODE will allow researchers to use the data collected in these collaborative studies to perform research and learn more about how concussion affects the brain.

Brain-CODE is an open-access database. This means that researchers and organizations outside this study can request access to data that has been stripped of information that can identify you.

**Are there any risks to doing the study?**

There are no risks to individuals participating in this study beyond those that exist in daily life. You will be simply using an app, and then doing a questionnaire, and exit-interview.
The results we gather from this study will be presented with the results from other participants as well. No identifiable information will be made available to the public. You still have your legal rights in the event of research-related harm, if you decide to take part in this study.

**Are there any benefits to doing this study?**

Although your participation in this research may not benefit you personally, it will help us understand how to make this app better, so that this app can help youth self-manage their concussion in the best and most fun way. Your feedback will be directly used to improve this app, and then the improved app will be tested in a larger study. The hope is that this technology will help youth understand what strategies they can use, and how they can use these strategies to get back to the activities they love in a faster and safer way. This app has the potential to reduce prolonged post-concussion symptoms, and further injury due to inappropriately timed return to activity.

**Payment or Reimbursement**

You will be given a $10 gift card from Tim Horton’s for participating in this study. If the session is not completed for any reason, you will still receive the gift card. Also, following study completion, you will be provided with educational resources about concussion management, such as info cards, and the Concussion & You book.

**Will anyone know what you say?**

All of the information we collect about you and your responses will always be kept private. During the study, your name will be replaced with a research identification number. This identification number is also private and the only people who have access to it are the research study team.

No information we collect will be made public that might identify you, unless required by law. For example, we have a legal duty to report suspected child abuse and potential harm to self or others.

If the results are published, your names will not be used. There is a possibility that our findings will be commercialized and you will have no ownership rights over the information. It is possible that a company or Holland Bloorview may get money from the sale of certain products in the future.

We will keep all of the information collected in a locked filing cabinet in the Holland Bloorview Concussion Centre. When data is placed onto the computers, a protected password will be applied to the files that only the researchers will know. We must keep the research data for 7 years. This is a requirement of the hospital. You do not give up legal rights due to research-related harm.

**How will my information be kept confidential?**

We wish to assure you that your privacy is very important to us. When you join the study, you will be given an ID number. Researchers will use this ID number to organize your data, instead
of your name or other information that can identify you directly. Any data collected for study purposes that could potentially identify you will be stored in a highly secure manner and never be released or disclosed in a form that could identify you. We will use tools that remove identifying information to the extent possible to minimize the risk of identifying you from the information we collect or release. This process will be applied to all data.

Holland Bloorview Kids Rehab and the OBI have entered into legal agreements to protect your data, and to set out the purposes for which this data will be collected, used, stored and disclosed. Steps have been taken to make sure your data are safe and the risk of identifying you is minimized. The OBI will continue to monitor these safeguards as new technologies evolve in order to limit any new risks to privacy.

**Who will have access to my information, and what will they see?**

Data collected through this study and stored in Brain-CODE will be available to researchers in this study. A list of these researchers and organizations can be found at http://bit.ly/15vPBTq.

Data from this study that has had identifying information removed to the extent possible may be shared with local, national and international researchers and organizations that are not part of this study. This open approach is being used by researchers internationally to better understand disease. Access to data by outside researchers or organizations will require a detailed plan for the use of the data, and approval from a research ethics board, as described in OBI’s Data Sharing Policy http://www.braininstitute.ca/Brain-CODE-governance. These researchers or organizations will be required to enter into an agreement with OBI that clearly states the safeguards that will be in place to protect that data, and the purposes for which this data may be collected, used, stored and disclosed.

OBI may take some of your data, combine it with data from many other people, and make it available to enhance the public’s awareness of research. We will use tools to remove identifying information from these combined data sets, making the risk of identifying you minimal.

**Do the investigators have any conflicts of interest?**

I (Principle Investigator, Dr. Nick Reed) and the other research team members have no conflicts of interest to declare related to this study.

**Do I have to do this?**

If you decide not to take part in this study, that is okay. If you decide to take part, but then at any time during the study you no longer want to participate, that is okay. Your decision to participate, decline, or withdraw from participation will have no effect on your current status or future relations with Holland Bloorview Kids Rehabilitation Hospital or the Concussion Research Centre.

You can withdraw from the study at any point. No new data will be collected or linked to other data from that point on. Upon your request, any data that has not been processed to remove identifying information will be destroyed. However, we are not able to remove any data that have
already been analyzed, processed to remove identifying information, or linked with other data for placement in Brain-CODE.

To withdraw from the study, contact Harminder Sandhu.

Further information about Brain-CODE is available at http://www.braininstitute.ca/Brain-CODE-governance.

**What if I have questions?**

Participants can contact me to explain anything that is not understood. You can also reach the Master’s student/study investigator, Harminder Sandhu.

If you have any questions about your rights as a research participant, please feel free to contact the Research Ethics Board at Holland Bloorview Kids Rehabilitation Hospital or by email.

Thank you for considering taking part with this research study.

Yours Truly,

Nick Reed, PhD, MScOT, OT Reg. (Ont.)
Clinician Scientist and Occupational Therapist
Concussion Centre
Bloorview Research Institute
Holland Bloorview Kids Rehabilitation Hospital

Harminder Sandhu, B.Eng, MHSc (c)
Research Assistant -Student, Concussion Research Centre
Holland Bloorview Kids Rehabilitation Hospital
150 Kilgour Rd., Toronto, ON, M4G 1R8
INFORMED CONSENT FORM – FOR YOUTH
HOLLAND BLOORVIEW KIDS REHABILITATION HOSPITAL

Re: Evaluating the usability and utility of a smartphone technology to help youth self-manage their concussion

Please complete this form below and return it to the researcher. You will receive a signed copy of this form.

By signing this form, I confirm that:

- Harminder Sandhu (Master's student/study investigator) explained this study to me and answered all of my questions.
- I read the attached Informed Consent Form dated _____________ and understand what this study is about.
- I understand the known risks and benefits of participating in this research study.
- I understand that I may drop out of the study at any time. My decision about taking part in the study will not affect the services I get at Holland Bloorview.
- I am free now, or in the future to ask questions about the study.
- I know that study records related to me will be kept confidential except as described in this form.
- I understand that information that identifies me or my family will not be shared with anyone without first asking my permission.
- I agree to participate in this study.

___________________________     _______________________      ________________
Participant’s Name (please print)  Signature       Date

I have explained this study to the above participant and have answered all their questions.

____________________________    ________________________    _______________
Name of Person Obtaining Consent  Signature         Date
Informed Consent Form to Participate in a Research Study
Flesch-Kincaid Grade level 7.5

Evaluating the usability and utility of a smartphone technology to help youth self-manage their concussion

Principal Investigator:
Dr. Nick Reed, PhD, MScOT, OT Reg. (Ont).
Clinician Scientist and Occupational Therapist
Concussion Research Centre
Bloorview Research Institute, Holland Bloorview Kids Rehabilitation Hospital
Rehabilitation Science Institute, University of Toronto
Associate Professor, Department of Occupational Science and Occupational Therapy
University of Toronto

Primary Study Contact & Co-Investigator:
Harminder Sandhu, B.Eng., MHSc Candidate 2016
Concussion Centre, Holland Bloorview Kids Rehabilitation Hospital
150 Kilgour Rd., Toronto, ON M4G1R8

Study Funders: Ontario Brain Institute (OBI), Ontario Neurotrauma Foundation (ONF) and Canadian Institutes of Health Research (CIHR)

Dear Prospective Participant,
My name is Nick Reed. I am part of a research study at Bloorview Research Institute at Holland Bloorview Kids Rehabilitation Hospital that is testing a smartphone application (app) we are making to help youth self-manage concussion. Before agreeing to take part in this study, it is important that you understand how you will be involved. This consent form provides you with information to help you make an informed choice.
What is the study about?

We want to test a smartphone app we have developed to understand how we make this app better and more useful, so that it can help youth self-manage their concussion. We want to learn about how easy the app is to use, any problems people have while using the app, if this app will help youth manage concussion, and overall how we can make the app better. This app will be tested by 10 youth (10-18 years-old), and by 10 health care professionals who are involved with concussion. Apps have helped youth with similar issues to concussion. We do not know if this app will be useful for youth with concussion because this is an early study. It will provide us with information to improve the smartphone app, and then do a larger study, where we will have youth use the device for a longer time and see if the app helps youth better manage their concussion.

How will you be involved in the study?

We would like to invite you to participate in this study. You must show me that you understand what you will have to do to take part in this study. If you cannot do this, you cannot participate in the study.

This is what you will be asked to do:

1. You will be asked to come to Holland Bloorview for 1 visit or if you are unable to come to Holland Bloorview, then the study coordinator will come to your place of practise to conduct the study. This session will take approximately 30 minutes to 45 minutes (max). This session will be a 1-on-1 session, with you and the study coordinator in the room. The session will be audio recorded so that we can re-listen to the audio to make sure we are able use all your feedback to make the app better. And, the smartphone application’s screen will be recorded to help us investigate the usability issues.
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Do the investigators have any conflicts of interest?

I (Principle Investigator, Dr. Nick Reed) and the other research team members have no conflicts of interest to declare related to this study.

Do I have to do this?

If you decide not to take part in this study, that is okay. If you decide to take part, but then at any time during the study you no longer want to participate, that is okay. Your decision to participate, decline, or withdraw from participation will have no effect on your current status or future relations with Holland Bloorview Kids Rehabilitation Hospital or the Concussion Research Centre.

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If you have any questions about your rights as a research participant, please feel free to contact the Research Ethics Board at Holland Bloorview Kids Rehabilitation Hospital or by email.

Thank you for considering taking part with this research study.

Yours Truly,

Nick Reed, PhD, MScOT, OT Reg. (Ont.)
Clinician Scientist and Occupational Therapist
Concussion Centre
Bloorview Research Institute
Holland Bloorview Kids Rehabilitation Hospital

Harminder Sandhu, B.Eng, MHSc (c)
Research Assistant -Student, Concussion Research Centre
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150 Kilgour Rd., Toronto, ON, M4G 1R8
INFORMED CONSENT FORM – FOR HEALTH CARE PROFESSIONALS
HOLLAND BLOORVIEW KIDS REHABILITATION HOSPITAL

Re: Evaluating the usability and utility of a smartphone technology to help youth self-manage their concussion

Please complete this form below and return it to the researcher. You will receive a signed copy of this form.

By signing this form, I confirm that:

- Harminder Sandhu (Master's student/study investigator) explained this study to me and answered all of my questions.
- I read the attached Informed Consent Form dated ______________ and understand what this study is about.
- I understand the known risks and benefits of participating in this research study.
- I understand that I may drop out of the study at any time. My decision about taking part in the study will not affect the services I get at Holland Bloorview.
- I am free now, or in the future to ask questions about the study.
- I know that study records related to me will be kept confidential except as described in this form.
- I understand that information that identifies my family or I will not be shared with anyone without first asking my permission.
- I agree to participate in this study.

_________________________     _______________________      ________________
Participant’s Name (please print)             Signature        Date

I have explained this study to the above participant/parent and have answered all their questions.

____________________________    ________________________    _______________
Name of Person Obtaining Consent  Signature         Date
Appendix G  Capacity Assessment Tool

Thank you for your interest in participating in this study. Have you had time to read over the email about the study and the consent form attached?

Note: if the participant indicates that they have not read the email and/or consent form, the participant will be given time to read the email and consent form and ask any questions they may have.

We just have a few questions for you so we can have a better idea of your understanding of the information provided in the email and the consent form.

Ask the following questions:

1. Who can be a part of this study?
2. Why do you think we are doing this study?
3. What will you do in the study?
4. Do you want to do all these things?
5. What if you start the study and decide you don’t want to do it anymore?
6. Who will know what you say?
7. Will I use your name when I write a report?
8. Do you have to do this?
9. What are some good things that might happen in this study?
10. Will taking part hurt you in any way?
11. Who can tell you more if you have questions?

If the youth cannot answer these questions due to needing clarification, the researcher will re-phrase aspects of the study to enhance understanding. If after attempts to make the study and its components clearer do not result in accurate answers from the potential participant, they will be excluded from the study.
Appendix H  Demographics Forms

DEMOGRAPHICS FORM –FOR YOUTH

Evaluating the usability and utility of a smartphone technology to help youth self-manage their concussion

Demographic Information Form

Participant ID Number _________________    Age ________    Sex ________

Date: _____________________

Concussion Information

Concussion History:   Yes □     No□

Number of Previous Concussions: _____     Most Recent Injury Date: ______________

1. Who helped you manage your concussion(s)? (Please choose all that apply)

☐ Family Physician
☐ Sports Medicine Physician
☐ Occupational Therapist
☐ Physiotherapist
☐ Neurologist
☐ Other: ____________________________

2. Even with the above person(s) helping me, I felt confused about what I should do to manage my concussion(s).

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Slightly Disagree</th>
<th>Neutral</th>
<th>Slightly Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Please Explain:

3. I feel I was given enough information to manage my concussion(s).
(Please circle one answer, and explain your choice)

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Slightly Disagree</th>
<th>Neutral</th>
<th>Slightly Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Please explain:
4. I find all youth in Canada are given enough information to manage their concussion? (Please circle one answer, and explain your choice)

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Slightly Disagree</th>
<th>Neutral</th>
<th>Slightly Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
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<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Please explain:

________________________________________________________________________

5. What did you find was the hardest part of managing your concussion?

________________________________________________________________________

6. Do you own a smartphone and/or a tablet, or have access to one daily? (Circle all that apply)

☐ Yes, a smartphone  ☐ Yes, a tablet  ☐ No
DEMOGRAPHICS FORM – FOR HEALTH CARE PROFESSIONALS

Evaluating the usability and utility of a smartphone technology to help youth self-manage their concussion

Demographic Information Form

Participant ID Number ____________________  Age ____  Sex ______

Date: ________________________

Concussion Involvement

1. What type of health care professional are you?
   - [ ] Family Physician
   - [ ] Sports Medicine Physician
   - [ ] Occupational Therapist
   - [ ] Physiotherapist
   - [ ] Neurologist
   - [ ] Researcher
   - [ ] Other: ______________________

2. How long have you been doing this work (e.g. 2 years and 6 months)?
   Answer:

3. How are you involved with concussion? (Please explain)

4. I find all youth in Canada are given enough information to manage their concussion? (Please circle one answer, and explain your choice)

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Slightly Disagree</th>
<th>Neutral</th>
<th>Slightly Agree</th>
<th>Agree</th>
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<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

   Please explain:

5. I find pediatric concussion is managed in a consistent and standardized manner by all health care professionals in Canada? (Please circle one answer, and explain your choice)

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Slightly Disagree</th>
<th>Neutral</th>
<th>Slightly Agree</th>
<th>Agree</th>
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<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

   Please explain:
6. What do youth find is the hardest part of managing their concussion?

7. Do you own a smartphone and/or a tablet, or have access to one daily?  
   (Circle all that apply)  
   □ Yes, a smartphone       □ Yes, a tablet  
   □ No
Appendix I  Think Aloud Demo Video

LINK TO “THINKING ALOUD” DEMO VIDEO:
http://www.nngroup.com/articles/thinking-aloud-demo-video/
Appendix J  Instructions for Think Aloud

**Briefing**

So, before we begin I wanted to let you know the phone screen and your voice will be recorded to help us make the app better. Once again we are not testing you, but we are testing the app. So, please feel free to mention exactly what you are thinking, and please do not worry about hurting our feelings. We need your honest feedback.

**Instructions**

Before we start, I have a few instructions for you:

1) I will say the task and ask you if you understand it, you can ask me to repeat it if you don’t understand. Once, I tell you the task, please wait for me to say Go then you may start the task!

2) Please say out loud when you feel you are done the task. Say “I am done”, this is very important for us, so please as soon as you think you are done say, “I am done”.

3) Wait when you are done the task for instructions from me! Please do not touch the app, until I say go again. (If needed) Please, take your hand off the phone and put them on the table.

4) Lastly, please remember to THINK OUT LOUD whatever you are thinking, what you are doing, and why you are doing it. If you are feeling confused or find something easy, then say that; if you hate something, or like something, then mention it; if you are thinking about pressing a button, then say it and why it’s your next step. If you are not speaking for a certain amount of time, I will remind you to continue to think aloud.

5) Please “hold” any longer comments for the time between tasks. When you are done a task then you can speak to me about any longer comments you may have.
Appendix K  Tasks

Task 1
A. Open the Neuro Care app.
B. SELECT that you are feeling OKAY today.
Say “I’m DONE!” as soon as you feel you have finished the task.
Wait for the next task; please do not touch the app until your next task.

Task 2
Imagine you are feeling lonely today. So, you want to set yourself a goal that will help you feel better.
A. On your goals page add a new SOCIAL goal to your goals.
B. Assume that you want to do this goal for 1 WEEK.
C. Make sure to fill in any information the pages ask for before adding the goal.
Say “I’m DONE!” as soon as you feel you have finished the task.
Wait for the next task; please do not touch the app until your next task.

Task 3
Imagine you want to set yourself a reminder that will remind you to come into this app every day.
A. Now go set yourself that reminder.
B. Change the reminder time to 1 MINUTE from now (insert current time here).
Say “I’m DONE!” as soon as you feel you have finished the task.
Wait for the next task; please do not touch the app until your next task.

Task 4
A. Now, find the reminder that the Neuro Care app sent you, on the phone.
B. Use the reminder to go into the app.
Say “I’m DONE!” as soon as you feel you have finished the task.
Wait for the next task; please do not touch the app until your next task.

Task 5
A. Change how you are feeling to GOOD.
B. Then, use the pop-up at the bottom of the page to go to your goals page.
Say “I’m DONE!” as soon as you feel you have finished the task.
Wait for the next task; please do not touch the app until your next task.

Task 6
A. Assume you have done all your goals today, check them off.
B. And, go to your summary page.
Say “I’m DONE!” as soon as you feel you have finished the task.
Wait for the next task; please do not touch the app until your next task.

Task 7
Imagine you want to find out which goal your doctor wants you to try next. Now,
A. Find the recommended goal.
B. Add that recommended goal to your goals.
C. Assume you want to do this goal for 2 DAYS.
D. Make sure to fill in any information the pages ask for before adding the goal.
Say “I’m DONE!” as soon as you feel you have finished the task.
Wait for the next task; please do not touch the app until your next task.

Task 8
A. Assume you no longer want to do your SOCIAL goal, delete it.
Say “I’m DONE!” as soon as you feel you have finished the task.
Wait for the next task; please do not touch the app until your next task.

Task 9
A. Assume you have done all your goals today, check them off.
B. And, go to your summary page.
Say “I’m DONE!” as soon as you feel you have finished the task.
Wait for the next task; please do not touch the app until your next task.

Task 10
Imagine you want to know some facts about concussion.
A. Find and open the page that discusses concussion myths versus facts.
B. Then, leave that page and go to the main screen of the app
Say “I’m DONE!” as soon as you feel you have finished the task.
Wait for the next task; please do not touch the app until your next task.

Bonus
Imagine you used this app yesterday; you filled out how you were feeling yesterday, and you set
yourself 3 goals yesterday. Now,
1. Find out how you were feeling yesterday. Then, say that feeling out loud.
2. Find out what goals you had set for yesterday. Then, say out loud which goals you completed
or didn’t complete yesterday.
Say “I’m DONE!” as soon as you feel you have finished the task.
Wait for the next task; please do not touch the app until your next task.
Appendix L  Questionnaires

The following participant questionnaire has been adapted from a validated client usability questionnaire to meet the needs of this mobile application for youth self-management study.

PARTICIPANT QUESTIONNAIRE FOR HEALTHCARE PROFESSIONALS

On a scale of 1 to 5 (1 being strongly disagree and 5 being strongly agree), how would you rate the following software criteria:

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
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<tbody>
<tr>
<td>1. I think that I would like to use this mobile app frequently</td>
<td>[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5</td>
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<tr>
<td>2. I found the mobile app unnecessarily complex</td>
<td>[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5</td>
<td></td>
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<tr>
<td>3. I thought the mobile app was easy to use.</td>
<td>[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5</td>
<td></td>
</tr>
<tr>
<td>4. I think that I would need assistance to be able to use this mobile app.</td>
<td>[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5</td>
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<tr>
<td>5. I found the various functions in this mobile app were well integrated.</td>
<td>[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5</td>
<td></td>
</tr>
<tr>
<td>6. I thought there was too much inconsistency in this mobile app. (i.e. inconsistent design, info, flow)</td>
<td>[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5</td>
<td></td>
</tr>
<tr>
<td>7. I would imagine that most people would learn to use this mobile app very quickly.</td>
<td>[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5</td>
<td></td>
</tr>
<tr>
<td>8. I found the mobile app very cumbersome/awkward to use.</td>
<td>[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5</td>
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<tr>
<td>9. I felt very confident using the mobile app.</td>
<td>[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5</td>
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<tr>
<td>10. I needed to learn a lot of things before I could get going with this mobile app.</td>
<td>[ ] 1 [ ] 2 [ ] 3 [ ] 4 [ ] 5</td>
<td></td>
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</tbody>
</table>

The following questions will be added to the SUS to further assess the usability and satisfaction of the system presented in this research proposal. These questions have been adapted from research that has looked at evaluating similar smartphone self-management applications, and from the USE Questionnaire: Usefulness, Satisfaction, and Ease of use Questionnaire.
11. This app was fun to use. (Please circle one answer)

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Slightly Disagree</th>
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</table>

12. I am satisfied with this app. (Please circle one answer)

<table>
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<tr>
<th>Strongly Disagree</th>
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13. The interface of this app is pleasant. (Please circle one answer)

<table>
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<tr>
<th>Strongly Disagree</th>
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14. If a youth had a concussion, I would recommend this app to him/her. (Please circle one answer, and explain your choice below)

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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Please explain:
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15. I find this app would be useful in helping youth self-manage their concussion. (Please circle one answer, and explain your choice below)

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<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
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Please explain:
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16. I find this app would be useful in helping youth with concussion communicate with their health care provider. (Please circle one answer, and explain your choice below)

<table>
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<tr>
<th>Strongly Disagree</th>
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Please explain:
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17. I find it is useful to have concussion management strategies in the form of simple goals that youth can try to complete every day?

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<th>Strongly Disagree</th>
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Please explain:

18. Using this app would enable youth to better self-manage their concussion. (Please circle one answer, and explain your choice below)

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<th>Strongly Disagree</th>
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Please explain:

19. Using this app would make it easier for youth to self-manage their concussion.

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Please explain:

20. If a concussed youth were using this app, I would find this app useful in helping me manage the youth’s concussion. (Please circle one answer, and explain your choice below)

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<tr>
<th>Strongly Disagree</th>
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Please explain:

21. If a concussed youth were using this app, the information collected and presented by this app (e.g. summary and Feeling pages) would enhance my effectiveness in managing the youth’s concussion. (Please circle one answer, and explain your choice below)

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<th>Strongly Disagree</th>
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Please explain:
22. What would you add to this app to make it more useful in helping youth self-manage their concussion?

__________________________________________________________________________________

__________________________________________________________________________________

23. What would you add to this app to make it a better tool for you, the health care professional, to help you better manage a youth’s concussion?

__________________________________________________________________________________

__________________________________________________________________________________

Do you have any final comments?

THANK YOU!
PARTICIPANT SATISFACTION QUESTIONNAIRE FOR YOUTH

On a scale of 1 to 5 (1 being strongly disagree and 5 being strongly agree), how would you rate the following:

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1. I think that I would like to use this mobile app often</td>
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<td>![Options] 1 2 3 4 5</td>
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<td>2. I found the mobile app unnecessarily difficult</td>
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<td>4. I think that I would need help to be able to use this mobile app.</td>
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<td>5. I found the many functions in this mobile app were well combined.</td>
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<td>6. I thought there was too much inconsistency in this mobile app. (i.e. inconsistent design, info, flow)</td>
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<td>7. I would imagine that most people would learn to use this mobile app very quickly.</td>
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<td>8. I found the mobile app very awkward to use.</td>
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<td>9. I felt very confident using the mobile app.</td>
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<td>10. I needed to learn a lot of things before I could get going with this mobile app.</td>
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The following questions will be added to the SUS to further assess the usability and satisfaction of the system presented in this research proposal. These questions have been adapted from research that has looked at evaluating similar smartphone self-management applications and from the USE Questionnaire: Usefulness, Satisfaction, and Ease of use Questionnaire.
11. The app was fun to use. (Please circle one answer)

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12. I am satisfied with the app. (Please circle one answer)

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13. The interface of this app is pleasant.

<table>
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14. If I experience another concussion in the future, I would use this app. (Please circle one answer)

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<th>Strongly Disagree</th>
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Please explain:

15. If a youth (e.g. a friend) had a concussion, I would recommend this app to him/her. (Please circle one answer, and explain your choice below)

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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Please explain:

16. I find this app would be useful in helping youth self-manage their concussion. (Please circle one answer, and explain your choice below)

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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Please explain:
17. I find this app would be useful in helping youth with concussion communicate with their health care provider. (Please circle one answer, and explain your choice below)

<table>
<thead>
<tr>
<th>Strongly Agree</th>
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</table>

Please explain:

18. I find it is useful to have concussion management strategies in the form of simple goals that youth can try to complete every day?

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</table>

Please explain:

19. Using this app would enable youth to better self-manage their concussion. (Please circle one answer, and explain your choice below)

<table>
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Please explain:

20. Using this app would make it easier for youth to self-manage their concussion.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
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Please explain:

21. What would you add to this app to make it more useful in helping youth self-manage their concussion?

Anything else you would like to say to us?
Appendix M  Exit-interview Guide

Introduction: Thank you for testing the concussion app, and completing the questionnaire.

Now I would like to ask you a few last questions, please know that you can leave at any time.

QUESTIONS LIST –FOR YOUTH PARTICIPANTS

1. What did you like about using the app?
2. What did you not like about using the app?
3. Are there any parts of the app that you found confusing or difficult to use/ understand?
4. During the usability testing, I noticed you were having some difficulty with (insert the issue(s) the participant had) during (explain the task they were asked to perform). Could you please explain what you were having difficulty with?
5. Now that you have used the app what changes would you suggest to improve it?
6. Do you find the (insert the section of the app you need to discuss) section of the app would be useful in helping youth self-manage concussion?
7. What could we add/change to/in this app to make it more useful in helping youth self-manage their concussion?
8. What apps do you frequently use?
9. Do you have any final suggestions or comments?

QUESTIONS LIST –FOR HEALTH CARE PROFESSIONALS

1. What did you like about using the app?
2. What did you not like about using the app?
3. Are there any parts of the app that you found confusing or difficult to use/ understand?
4. During the usability testing, I noticed you were having some difficulty with (insert the issue(s) the participant had) during (explain the task they were asked to perform). Could you please explain what you were having difficulty with?
5. Now that you have used the app what changes would you suggest to improve it?
6. Do you find the (insert the section of the app you need to discuss) section of the app would be useful in helping youth self-manage concussion?
7. What could we add/change to/in the app to make it more useful in helping youth self-manage their concussion?
8. What could we add/change to/in the app to make it a better tool for you, the health care professional, to help you better manage a youth’s concussion? What kind of information would be useful for you?
9. What apps do you frequently use?
10. Do you have any final suggestions or comments?

Conclusion: Thank you for answering all my questions, and for your time and feedback. Your feedback will help us make this app better. Thank you very much, and if you have any questions or concerns please contact me at any time.