Usability Testing of a Mobile Health Physical Activity Application for People with an Inflammatory Bowel Disease: Mixed Methods Study

by

Cameron Trim
Bachelor of Arts, Western University, 2019

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We acknowledge and respect the Lək^{w}əŋən (Songhees and X^{w}sepsəm/ Esquimalt) Peoples on whose territory the university stands, and the Lək^{w}əŋən and W̱ SÁNEĆ Peoples whose historical relationships with the land continue to this day.

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Abstract

Background: Living with an Inflammatory bowel disease (IBD) implies a lifelong burden of physical and mental health complications to diagnosed individuals, even when in a quiescent disease state. The prevalence of IBD within industrialized nations is increasing worldwide, and the associated economic cost is substantial. Physical activity (PA) has the potential to improve systemic symptoms for people with an IBD without risk of exacerbating disease activity. Despite this, the recommended amount of PA is often not met within the IBD population. Fatigue is a common systemic symptom of IBD which can affect participation in PA. Just-in-time adaptive interventions (JITAI) can be delivered using mobile health (mHealth) apps and can provide tailored support for behaviour change. These types of interventions have the potential to offer a scalable solution to help increase PA levels for people with an IBD while tailoring to a person's fatigue level. Using the IDEAS framework, a mHealth JITAI app with the aim of increasing PA levels of people with an IBD has been developed; however the usability and acceptability of the app remains unclear.

Objective: This study aims to evaluate the usability and acceptability of a JITAI app, IBD-Move, among individuals living with an IBD.

Methods: This mixed-methods study involved two cycles of 4 participants (n = 8) and was conducted at the University of Victoria. Participants were asked to complete five tasks, 1) login and read through the introductory module, 2) read through the Chapter 1 module, 3) add a PA goal, 4) complete a PA session, and 5) track the PA using the app. During the study, participants 1) completed the baseline questionnaire on demographics (e.g., age, sex, social economic status) and experience with smartphones, 2) attempted to complete the five goal-oriented tasks, listed above, while performing the Think-Aloud protocol, and 3) responded to the mHealth app

usability questionnaire (MAUQ) and answered semi-structured interview questions. Usability measures included task completion rates, efficiency (i.e., completing a task with minimal steps), and qualitative use feedback. The framework analysis method and usability problem taxonomy were used to identify themes of usability problems, as identified from Think-Aloud task completion and interview.

Results: Quantitative results showed that task completion rates improved from Cycle 1 to Cycle 2, though Tasks 3 (Add Goal) and 4 (complete PA Session) sustained relatively lower rates of completion in Cycle 2 and demonstrated the highest inefficiencies of screen transitions. Usability scores improved in both *Ease of Use* (MAUQ) (Cycle 1 (M[SD]) = 1.93 [0.52], Cycle 2 (M[SD]) = 1.45 [0.21]) and *Interface and Satisfaction* (MAUQ: Cycle 1 (M[SD]) = 1.98 [0.42] to Cycle 2 (M[SD]) = 1.15 [0.14]). *Usefulness* scores, used to measure acceptability, also improved (MAUQ: Cycle 1 (M[SD]) = 2.88 [0.82] to Cycle 2 (M[SD]) = 1.67 [0.85]). Constructs of the Theoretical Framework of Acceptability were met with unanimous agreement in Cycle 1, however the constructs *Perceived Effectiveness* and *Self-efficacy* were not fully agreed during Cycle 2. Qualitative analysis identified 12 consolidated usability problems for Cycle 1 and 13 for Cycle 2, with the most severe problems in Task 2 (read Chapter 1), Task 3 (Add Goal), and Task 4 (Complete PA Session), primarily related to *Visualness* and *Task-mapping* classifications of UPT.

Conclusion: IBD-Move demonstrated high usability and acceptability, with its tailored approach to physical activity and content well-received. Key refinements were made from Cycle 1 to Cycle 2; text was adjusted, instructions were added, and technical errors were fixed, though challenges in Tasks 3 and 4 remained. Further adjustments to the app will be made in preparation

for a future feasibility study, evaluating IBD-Move's effectiveness for improving physical activity levels and health outcomes.

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Dedication

I would like to dedicate this thesis to all the family and friends that have been pivotal in my academic life. From my mom influencing my decision to pursue a degree in Kinesiology to the stellar Amanda Willms who laid much of the foundation for this project, I thank you all.

Chapter 1

1.1 Background

Inflammatory bowel disease (IBD) is increasingly prevalent within industrialized nations, and Canada is among the countries with the highest prevalence in the world, with an estimated 725 people per 100,000 diagnosed as of 2018 (Kaplan et al., 2019; Kaplan & Windsor, 2021). Characterized by chronic inflammation of the digestive system, the onset of IBD involves a lifelong burden to an individual's health and wellness (Strober et al., 2007). There are two major classifications of IBD: ulcerative colitis (UC) and Crohn's disease (CD). UC is presented as inflammation which ulcerates the mucosa and sub-mucosa of the colon, whereas CD involves inflammation, structuring, and/or penetrating disease that can manifest anywhere along the gastrointestinal tract. Active disease can bring on intense symptoms ranging from mild discomfort to severe pain and can sometimes require hospitalization and surgery to remove the affected area of the bowel (M'koma, 2022). Though IBD is a chronic disease, patients can achieve a quiescent state termed remission, where inflammation caused by active disease is reduced or resolved, along with associated symptoms (Bernstein, 2015; Bryant et al., 2014). Despite being in remission, physical and psychological side effects such as pain, fatigue, and depression often persist and can contribute to a decreased quality of life relative to healthy individuals (Mancina et al., 2020).

Regular physical activity (PA) has been reported to be an effective strategy in improving numerous physical and mental health outcomes for persons with an IBD, without incurring added risk of disease relapse (Baker et al., 2022). A review of 28 articles by Davis et al. (2022) found beneficial impacts of PA on quality of life, fatigue, mood, stress, cardiorespiratory fitness, and body composition for people with an IBD. These benefits were found across a wide variety of

low and moderate intensity modalities, the most common being walking and running. Despite the benefit of physical activity, people with an IBD have been shown to engage in less PA than healthy individuals (Agrawal et al., 2021; Qalqili et al., 2021). One factor that may be responsible for this discrepancy is fatigue, a prominent symptom of IBD, and reported barrier to PA (Chan et al., 2014). A lower overall physical fitness and intensity of PA engagement has been shown for persons that experience fatigue (Vogelaar et al., 2015). Inactivity may be in part due to a "vicious circle" of fatigue, identified as a lack of PA which contributes to increased fatigue, thus making PA engagement even less likely (Beck et al., 2013). Thus, a dose-response approach to PA for IBD has been recommended by previous literature (Davis et al., 2022), wherein individuals can gauge their PA engagement to prevent exacerbation of fatigue.

Mobile health applications (mHealth apps) using a just-in-time adaptive intervention (JITAI) approach may have the potential to bridge this gap. Having gained substantial traction for their ability to provide scalable and personalized healthcare services (Wang et al., 2014), JITAI is a type of mHealth intervention wherein the app content is tailored and presented based on the participant's momentary needs. JITAI includes limiting support that is not beneficial and providing the appropriate amount of support at the right time to capitalize on the intention to engage in a desired behaviour, such as PA (Nahum-Shani et al., 2018). Tailored mHealth apps have been shown to be effective at increasing PA behaviour (Davis et al., 2020), and even more beneficial for persons living with chronic medical conditions such as diabetes, cancer, chronic obstructive pulmonary disease, and coronary heart disease (Mönninghoff et al., 2021). Despite the potentially beneficial outcomes of PA for IBD (Davis et al., 2022), there is currently a lack of tailored mHealth apps that provided PA advice to persons with an IBD. Delivering content using

this more tailored approach may help users learn to appraise the barrier of fatigue for success in achieving an active lifestyle.

I developed IBD-Move, a JITAI mHealth app, with the intention of improving PA levels for people with an IBD. In the app, users are presented with a daily PA session based on their current level of fatigue. Users can also set goals, track activity, and read through weekly text modules. The text modules cover information grounded in the Multi-Process Action Control framework, a behaviour change theory that has shown successful implementation for previous mHealth apps (Willms et al., 2023). I developed the app using the IDEAS (integrate, design, assess, and share) framework, a standardized method of creating digital health interventions (Mummah et al., 2016). IBD-Move is now at a stage of development where usability and acceptability testing should be evaluated. Thus, this study aims to examine the usability and acceptability of a JITAI mHealth app (IBD-Move) for increasing PA levels among physically inactive people with an IBD.

1.2 Research Objectives

1) To evaluate the usability of a JITAI mHealth app (IBD-Move) among physically inactive individuals living with an IBD,
2) To evaluate the acceptability of a JITAI mHealth app (IBD-Move) among physically inactive individuals living with an IBD.

1.3 Hypotheses

1) Based on usability testing, I hypothesized that participants would find IBD-Move usable based on the following thresholds:
    a) Task Completion Rate per Participant at 70% (Ramadan et al., 2019).
    b) Task Completion Rate per Task at 70% (Ramadan et al., 2019).
    c) Efficiency, defined as task completion at or below an additional three screen transitions from the shortest path. (Fernandez et al., 2012).
    d) mHealth App Usability Questionnaire (MAUQ) score (< 2.5/7) for items "Ease of Use" and "Interface and Satisfaction".
2) Based on acceptability testing, I hypothesized that participants would find the JITAI-IBD app acceptable based on the following thresholds:
    a) MAUQ score (< 2.5/7) for item "Usefulness".
    b) A majority of participants (>50%) will respond positively to interview questions regarding the seven constructs of the Theoretical Framework of Acceptability (Oldham et al., 2023).

1.4 Significance of Study

This project is one of the first to incorporate the use of JITAI and PA into the management of IBD. This study adds to the growing body of literature dedicated to progressing the development of mHealth apps for helping support the management of chronic, non-communicable diseases. Determining the usability and acceptability of IBD-Move can help improve care provided to individuals living with IBD.

1.5 Assumptions

1. Participants would respond to the questionnaire items and interview questions accurately and honestly.
2. Participants have the intention to engage in more PA.

1.6 Limitations

1. Limited context – The controlled environment wherein data collection would take place may not fully represent the real-world context of mHealth app usage.
2. Short Duration - The short duration wherein data collection would take place may not accurately represent the long-term usage patterns or experiences of users.
3. Hawthorne Effect – Participants may alter their behaviour during usage of the mHealth app as a result of being observed by a researcher (Berkhout et al., 2022).
4. Subjective Evaluation – This study relies on subjective measures which can be influenced by participants' biases, expectations, or social desirability.
5. Selection Bias – Participants may already be motivated to improve PA levels as is evident by their participation in the study.

1.7 Operational Definitions

1. Inflammatory bowel disease – chronic inflammation of the digestive tract. Two major classifications include:

a. *Ulcerative colitis* – inflammation which ulcerates the mucosa and sub-mucosa of the colon.

b. *Crohn's disease* – inflammation, structuring, and/or penetrating disease that can manifest anywhere along the gastrointestinal tract.

2. Physical Activity – any bodily movement produced by the skeletal muscles that require energy expenditure above resting levels.
3. Application (app) – software designed to operate on a mobile device.
4. Usability – "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" (International Organization for Standardization, 2018).
5. Acceptability – "a multi-faceted construct that reflects the extent to which people delivering or receiving a healthcare intervention consider it to be appropriate, based on anticipated or experiential cognitive and emotional responses to the intervention" (Sekhon et al., 2017).

Chapter 2

2.1 Introduction to IBD

Inflammatory bowel disease (IBD) is characterized by chronic, cytokine-driven inflammation of the digestive tract. The exact cause of IBD remains unknown, though it is widely considered that genetic predisposition interacts with environmental factors to influence the onset of the disease (Strober et al., 2007). There are two major classifications of IBD that this study will focus on: Crohn's disease (CD) and Ulcerative Colitis (UC). UC is presented as inflammation which ulcerates the mucosa and sub-mucosa of the colon, whereas Crohn's disease involves inflammation, structuring, and/or penetrating disease that can manifest anywhere along the gastrointestinal tract. The most frequently diagnosed individuals with CD are women and young adults between the age of 20 to 30, whereas UC is more commonly diagnosed in older adults and this distribution is even among sex (Kaplan et al., 2019).

Canada's population has among the highest worldwide incidence and prevalence of persons living with an IBD (Kaplan & Windsor, 2021; Ng et al., 2017). In 2018, the prevalence of IBD in Canada was 270,000, and the prevalence is expected to increase to 403,000 by 2030 (Kaplan et al., 2019). A systematic review of population-based data on worldwide IBD epidemiology revealed incidence rates in North America for CD and UC to be between 6.30 to 23.82 and 8.80 to 23.14 per 100,000 people, respectively (Ng et al., 2017). Interestingly, Nova Scotia held the highest incidence rates for both CD and UC in North America (Ng et al., 2017). Incidence rates of IBD in industrialized countries are now stabilizing following their rapid increase throughout the 20th century. Though incidence rates are stabilizing, a relatively low mortality rate for IBD results in a pattern of compounding prevalence that is being seen in industrialized nations across the world (Kaplan & Windsor, 2021).

Since the diagnosis of CD or UC is usually not life-threatening, adequate access to healthcare allows the diagnosed individual to live a long, fulfilling life. However, challenges arise for an individual living with an IBD, which can severely limit their quality of life. Active inflammation can bring on feelings of severe abdominal pain, fatigue, and other debilitating symptoms which impact one's daily functioning. Debilitation due to disease results in indirect costs such as loss of wages to sick days and disability, premature retirement, and out-of-pocket costs for complementary and alternative medicine. The estimated total of these indirect economic costs of IBD in Canada was $1.29 billion in 2018 (Kuenzig et al., 2019). Thus, there is a need for cost-effective strategies to provide supportive, long-term health care to attenuate the progression and prevent the relapse of active IBD.

The following sections explore the pathology of IBD, focusing on chronic inflammation driven by cytokines and the notable differences between CD and UC. Physical activity (PA) is examined as a complementary treatment, with evidence suggesting benefits for quality of life, fatigue, and mental health, though optimal PA modalities remain unclear. Barriers to PA, such as disease activity, fatigue, and psychological factors, are identified, alongside challenges in delivering in-person PA programs. Mobile health (mHealth) is proposed as a scalable solution, with, just-in-time adaptive interventions (JITAI) offering tailored support. The development of the IBD-Move app, grounded in behavioral theory, is outlined, emphasizing the need for usability and acceptability testing to ensure successful implementation for users with an IBD.

2.2 Pathology of IBD

Chronic gastrointestinal mucosal inflammation is a key characteristic of IBD (Zhou & Liu, 2017). Initiation of the immune response is mediated by local receptors within the gastrointestinal mucosa. Toll-like receptors and nucleotide-binding oligomerization-domain

protein–like receptors identify antigens from the mucosa and subsequently produce cytokines (Ho et al., 2020; Phillipson & Kubes, 2011). The cytokines allow plasma proteins and neutrophils to enter the mucosal environment, wherein neutrophils release granules, proteases, and oxidants to ensure an inflammatory environment is created (Phillipson & Kubes, 2011). These contents of the neutrophil act on the local area of the mucosa, producing damage beyond what would be required to destroy the target antigens. In healthy conditions, once the target antigens are removed, the inflammatory environment would cease, and resolution would begin. However, in IBD, there is excessive production of pro-inflammatory cytokines interleukin (IL)-1β, IL-6, IL-23, and tumor necrosis factor-alpha (TNFα) because of increased local signalling (Friedrich et al., 2019). Neutrophils, therefore, do not undergo apoptosis and instead continue to exhibit pro-inflammatory properties. Particularly, TNFα has been labelled a critical inflammatory mediator in the progression of both UC and CD (Sands & Kaplan, 2007; Van Deventer, 1997). The pro-inflammatory environment associated with IBD influences major systemic issues, leading to physical and mental health complications.

Inflammation of CD is generally associated with T-helper 1 (Th1) dysfunction and involves excess IL-12/IL-23 and interferon-γ/IL-17 production. CD primarily occurs in the small and large intestines, although the entire gastrointestinal tract is susceptible to inflammation. Commonly reported symptoms of CD include abdominal pain, diarrhea, rectal bleeding, weight loss, and fatigue (Strober et al., 2007). These symptoms are also commonly present in UC, though UC presents itself differently (Kaur & Goggolidou, 2020). Specifically, UC primarily affects the large intestine and is driven by excess IL-13 production through dysfunction of Th2. UC tends to be more superficial than CD, as only the mucosa and submucosa are affected, resulting in ulceration of the epithelial wall of the large intestine (Fuss et al., 2004).

Treatment avenues for IBD is dependent on multiple factors and can involve many different disciplines of healthcare. An overview of pharmacological, dietary, surgical, and complementary treatments is presented in Appendix A. Physical activity (PA) is categorized as a complementary and alternative medicine for IBD. The following section provides an overview of the pathophysiological mechanisms describing effect of PA for IBD and beneficial effects on lifestyle outcomes that have been associated with being more physically active.

2.3 PA Outcomes for IBD

Regular PA has been suggested to have positive effects on the IBD population. A meta-analysis that combined inflammatory biomarker data from 5 studies revealed no significant differences in any variable of interest between exercise and control groups (Baker et al., 2022). Exercise upregulates the production of anti-inflammatory myokines without a systemic increase in pro-inflammatory cytokines, such as TNFα and IL-1β (Pedersen, 2018). IL-6 as a myokine is known for its anti-inflammatory properties; particularly, IL-6 has been shown to inhibit TNFα and IL-1 production (Pedersen & Febbraio, 2008) (Schindler et al., 1990). Furthermore, IL-6 upregulates the activity of anti-inflammatory cytokines (IL-10 and IL-1ra) involved in the signalling and mediation of other cytokines (Pedersen & Febbraio, 2008). IL-15 is also an important anti-inflammatory myokine upregulated post-exercise. IL-15 protects against the accumulation of visceral fat and has been shown to reduce the negative effects of TNFα for people with Type-2 Diabetes (Sánchez-Jiménez & Alvarado-Vásquez, 2013). Working together, myokines IL-6 and IL-15 exert their anti-inflammatory effects systemically through the up/downregulation of mediatory cytokines involved in the production of visceral fat.

Research on PA's association with IBD is growing but still limited relative to other non-communicable diseases. Yet, current literature suggests PA can provide numerous health benefits

and, importantly, PA is safe for people with an IBD. A systematic review and meta-analysis by Baker et al. (2022) supported the use of multiple types of exercise in the complementary treatment of IBD, concluding that exercise does not increase inflammatory markers of IBD. A review of 28 studies by Davis et al. (2022) deemed low-moderate intensity PA safe for adults (>18 years) and identified benefits to quality of life (QoL), fatigue, and mental health as outcomes of PA. The exact modality and quantity of PA differed among the studies, making an estimate of ideal PA prescription difficult to conclude. These outcomes are further discussed in the subsections below.

2.3.1 Physical Activity Effects on Quality of Life

QoL is a common subjective measure to assess person-related experiences with IBD. Davis et al. (2022) reviewed 7 studies that examined PA's influence on a person with an IBD's subjective QoL. Overall, results indicated QoL has a direct positive relationship with PA; those with more reported PA had increased QoL compared to those with less or no PA reported (Davis et al., 2022). Several studies used the inflammatory bowel disease questionnaire (IBDQ), an internationally recognized valid and reliable measure that recognizes a higher score to be related to greater health-related QoL for people with an IBD (Pallis et al., 2004). There is somewhat contradictory evidence for the relationship between PA and IBDQ scores in the current literature. One study of 158 participants found those who participated in more PA during their leisure time had higher IBDQ scores ($k = 0.212$, $p = .018$), whereas participants performing a higher frequency of "sweat-inducing exercise" per week had lower IBDQ scores ($k = –0.228$, $p = .011$). In another study consisting of 91 participants, longer durations of vigorous PA (between 6-9METs), measured with accelerometers, were positively correlated to IBDQ scores ($r = 0.235$, $p = .029$)(Wiestler et al., 2019). Early experimental trials have given evidence for PA as the

predictor of higher QoL. A pilot single-arm study consisting of 148 female IBD patients engaged in an 8-week progressive resistance training regime showed significant improvements in QoL based on IBDQ scores (p = .0001) and isometric quadriceps strength (p = .0001) (de Souza Tajiri et al., 2014). A pilot randomized-controlled trail (RCT) of 36 male and female adults with a mildly active or in-remission IBD confirmed the feasibility of 12 weeks of both high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) using a cycle ergometer. Based on IBDQ scores, QoL was found to increase immediately following the intervention for both groups (HIIT, 184 to 186; MICT, 181 to 192), though statistical significance was not assessed (Tew et al., 2019). These pilot trials provide evidence of people with an IBD being able to tolerate strenuous PA without degenerating QoL. Full-scale interventions are needed to confirm the positive effect of PA on QoL.

2.3.2 Physical Activity Effects on Fatigue

Fatigue is of major concern for patients with an IBD. In a survey study of Crohn's and Colitis UK members (n = 918), fatigue was identified as the most commonly reported problem (42%) for people who felt negatively about exercise and the most prevalent barrier (68%) for those who felt positively about exercise (Chan et al., 2014). Lower levels of fatigue have been correlated with higher levels of PA, and decreased fatigue has been observed in people who started an exercise program (Davis et al., 2022). The following statement from one participant of a qualitative study (Beck et al., 2013) examining the effect of fatigue in female IBD outpatients gives substance to the interaction between PA and fatigue:

> *"Yes, I used to be an active runner. However, I simply do not... Ever since this fall, I have not been able to get up off the shitty couch. Although I know it will give me more energy…"* (p. 6)

This cyclical pattern of degenerating fatigue with physical inactivity, is contrasted by the upward spiral that two other participants of the same study noted, wherein constant engagement in PA increased their energy levels. A pilot study involving IBD patients in a quiescent disease state found significant improvements in fatigue and health-related QOL following a 12-week aerobic and resistance training exercise program; however, the lack of a control group limits these findings (van Erp et al., 2021). In a cross-sectional study examining fatigue in people with IBD, fibromyalgia, and healthy controls, fatigue was shown to involve a combination of physical and psychological factors in a person's life (Olive et al., 2020). This study found that two out of three significant IBD correlates (pain-catastrophizing, depression, sleep) to fatigue were psychological, suggesting psychological therapy could be effective in managing fatigue as a symptom of IBD. This is congruent with the observed effectiveness of mind-body exercise techniques mentioned in Baker et al. (2022).

2.3.3 Physical Activity Effects on Mental Health

Maintaining good mental health is vitally important to people living with IBD. Beyond preserving energy for optimal daily living, there is evidence that symptoms of depression or anxiety are associated with recurring disease activity (Mikocka-Walus et al., 2016). Further evidence from a longitudinal study indicates symptoms of depression and anxiety increase over time for people with an IBD; the same study showed an increased odds (OR = 2.70; 95% CI, 1.15–6.34) of active disease with exacerbated depression symptoms (Marrie et al., 2021). A possible mechanism for this interaction involves dysregulation of the hypothalamic-pituitary-adrenal (HPA) axis when individuals experience psychological stress. A resultant misbalance of pro- and anti-inflammatory cytokines can lead to the exacerbation of disease activity in IBD (Baker et al., 2022).

PA as a complementary treatment for IBD has shown effectiveness in bolstering mental health outcomes in several studies (Davis et al., 2022). A randomized controlled trial (n = 29) assessed the effect of a Breath-Body-Mind-Workshop which taught breathing techniques, movement coordination with breathing, and meditation versus an educational seminar control group which educated participants on topics related to managing their disease (Gerbarg et al., 2015). Both groups initially received 9 hours of their respective intervention, then continuing education throughout the 26 weeks of the study. Baseline, 6-week, and 26-week measurements were taken on anxiety, stress, and depression (among other measurements) using the Beck Anxiety Inventory (Fydrich et al., 1992), Beck Depression Inventory (Wang & Gorenstein, 2013), and Perceived Stress Questionnaire (Levenstein et al., 1993). Anxiety symptoms showed statistical improvement following 6 weeks of the workshop and all three psychological indices were found to significantly improve at 26 weeks within the IBD group, no significant differences within the control group were found. Appropriate PA intervention has shown merit in reducing the negative impact of poor mental health for people with an IBD; examining ways to make PA interventions widespread and easily accessible for the IBD population may be a next step in progressing this type of complementary treatment.

Understandably, people may reduce their engagement in PA after receiving a diagnosis of IBD. This does not mean a sudden dislike of PA occurs, on the contrary, those diagnosed with an IBD have been shown to feel positively towards PA as a complementary treatment method (Gatt et al., 2019). IBD simply presents overwhelming barriers for the IBD population, which influences activity behaviour. A goal for ongoing IBD healthcare should be to introduce, or reintroduce, a physically active lifestyle to people with IBD and thus reap the benefits of physical actvity. However, engaging in PA presents challenges, even for a healthy individual. An

important step towards creating an effective intervention program is understanding the barriers and facilitators to PA for people with an IBD.

2.4 Barriers to PA

Five studies were identified that measured subjective views of PA in people with IBD, revealing multiple correlates. Fatigue, disease activity, abdominal pain, urgency, and psychological factors were reported to have affected PA participation in people with an IBD (DeFilippis et al., 2016; Fagan et al., 2021; Greenley et al., 2018; Lamers et al., 2021; Tew et al., 2016). All were cross-sectional studies, four of which used exclusively questionnaire data, and one used a combination of questionnaire and semi-structured interviews to collect data (Lamers et al., 2021). The sample populations for each study were somewhat heterogeneous, with four studies having sample parameters of above 18 years of age (DeFilippis et al., 2016; Fagan et al., 2021; Lamers et al., 2021; Tew et al., 2016), and one under 18 years of age (Greenley et al., 2018). One study recruited using social media, 3 recruited from gastroenterology outpatient clinics, and 1 recruited from an email database of people with an IBD. This section aims to provide an overview of the most influential antecedents to PA for IBD by synthesizing information from each of the identified studies.

Fatigue

Fatigue was investigated in all 5 of the studies, each one citing fatigue as a prevalent barrier to PA engagement. Firstly, Tew et al. (2016) found a significant correlation (r = -0.127) explaining the relationship between total PA and fatigue. Second, Greenley et al. (2018) found a significant correlation between perceived sports impairment and fatigue (r = 0.563). When controlling for disease activity in Greenly et al (2018), it was found that fatigue explained most of the shared variance (5.8%, p<.001) in the final model of perceived impairments towards

exercise participation. DeFilippis et al. (2016) and Fagan et al. (2021) found that fatigue was the most common barrier (36% and 34%, respectively) in both of their study populations. Out of the 14 interviewees in Lamers et al. (2021), 6 reported they are often too fatigued to exercise.

Disease Activity

Disease activity was investigated in 4 of the 5 studies, and each of these studies concluded that active disease was negatively associated with PA engagement. Specifically, Tew et al. (2016) and Greenly et al. (2018) found significant negative correlations ($r = -0.228$ and $r = –0.496$, respectively) such that PA engagement decreases with increased disease activity. Fagan et al. (2021) found that people with active disease (80%) report higher levels of perceived barriers compared to those in remission (54%). Finally, using semi-structured interviews, Lamers et al. (2021) also found that participants retrospectively viewed exercise as being more difficult to participate in when their disease activity was higher.

Abdominal Pain

Abdominal pain was mentioned in all 5 of the studies. In Greenly et al. (2018), abdominal pain had a smaller association ($r = 0.509$) with the perceived impairment of exercise participation than fatigue but was still significant. Tew et al. (2016) did not relate abdominal pain to PA levels but found abdominal pain to be the most common reason (55%) for PA avoidance among their population. DeFilippis et al. (2016) and Fagan et al. (2021) also noted abdominal pain as a commonly perceived barrier to PA (6% and 20%, respectively). Fear of exercise-induced abdominal pain was mentioned by 3 of the 14 interviewees in Lamers et al. (2021).

Urgency

The urgency of needing to use the toilet during PA was mentioned as a barrier in 3 of the 5 studies. Tew et al. (2016) found that 61% of the participants who reported their IBD had

impacted their PA engagement felt urgency was a barrier to PA. Fagan et al. (2021) found 13% of their whole study population cited urgency as a barrier to PA engagement. Urgency was the most prevalent factor for the interviewees in the study by Lamar et al. (2021), wherein 9 of the 14 participants felt they needed to have a toilet nearby while engaging in PA.

Psychological Factors

Psychological factors, namely depression and anxiety, were mentioned in 2 of the 5 studies. Tew et al. (2016) found both depression ($r = -0.287$) and anxiety ($r = -0.120$) to have a significant relationship with total PA. Greenly et al. (2018) found that depression ($r = 0.409$) and anxiety ($r = 0.425$) are significantly associated with an individual's perceived impairments toward exercise. No other studies compared psychological factors to PA habits or perceptions.

2.4.1 Challenges with In-Person PA Delivery

Delivering an in-person PA program poses reach, scalability, cost, and tailoring issues. The accessibility of care would be limited should PA programs for people with an IBD only be available in certain areas. Particularly for those in rural communities, commuting to an in-person PA session presents the participant with increased time commitment, a consistent barrier to PA in healthy individuals (Felicia Cavallini et al., 2020). In-person PA interventions are limited to the target participants in their area and the size of the facility, should the program need to reach more people, greater expenses are required. With over 270,000 people in Canada who have an IBD (Kaplan et al., 2019), PA intervention should be delivered in a way that can be reasonably scaled to reach the target population. Each location the PA program is delivered incurs a cost that includes but is not limited to the facilities, hiring qualified exercise professionals, and equipment. These costs are usually reflected in the resultant price of the program, which presents a selection bias for higher-income participants who can pay to participate (O'Regan et al., 2020). Should an

in-person PA intervention for IBD become available and scaled nationwide, tailoring the program to individual needs within a group setting requires much more time and resources, further adding to the aforementioned barriers (Bethancourt et al., 2014).

2.5 mHealth for PA and IBD

Mobile health (mHealth) is the application of mobile and wireless technology to yield positive health outcomes (WHO Global Observatory for eHealth., 2011). Praised for their scalability, mHealth interventions have given rise to a new method of cost-effective, widespread program delivery (Wang et al., 2014). Given that 88.1 percent of Canadians over 15 years of age own a smartphone (Statistics Canada, 2021), the potential reach of mHealth apps is vast. IBD is more prominent in industrialized societies; since this population generally has greater access to mobile devices, the means match the ability to provide healthcare through a mHealth medium.

A recent systematic review and meta-analysis by Mönninghoff et al., (2021) showed small to moderate effects of mHealth interventions for increasing PA among 4 outcome measures: walking (standardized mean difference (SMD) 0.46, 95% CI 0.36-0.55; $p<.001$), moderate-vigorous PA (MVPA) (SMD 0.28, 95% CI 0.21-0.35; $p<.001$), total physical activity (SMD 0.34 95% CI 0.20-0.47; $p<.001$), and energy expenditure (SMD 0.44, 95%CI 0.13-0.75; $p=.01$). These effects decreased but maintained significance after follow-up within 6-months for walking (SMD 0.26, 95%CI 0.09-0.42; $p=.002$), MVPA (SMD 0.20, 95% CI 0.05-0.35; $p=.008$), and total physical activity (SMD 0.53, 95% CI 0.13-0.93; $p=.009$). For walking (SMD 0.25, 95% CI 0.10-0.39; $p=.001$) and MVPA (SMD 0.19, 95% CI 0.11-0.27; $p<.001$) the effects further decreased but maintained significance beyond 6 months. Effect sizes were increased when moderating for at-risk and sick populations, indicating higher effectiveness of PA mHealth interventions for these populations. The results of this synthesis of randomized controlled trials

provide the strongest evidence of the efficacy of mHealth interventions to increase PA to date, yet Mönninghoff et al., (2021) identified a high risk of bias and large heterogeneity for their results.

As of 2018, there were only 56 apps developed to aid IBD management available for download in Android and Apple stores (George & Cross, 2020). Current mHealth apps for IBD management focus primarily on remote patient monitoring, which constitutes monitoring and reporting patient experiences with their disease (Atreja et al., 2018). Symptom diaries, medication reminders, nutrition logs, and providing disease-related information are the most common features of current apps (George & Cross, 2020). IBD apps have shown benefits and no drawbacks relating to education, QoL, quality of care, medication management, and treatment adherence (Yin et al., 2019). Despite the beneficial effects of PA for IBD and persons with an IBD participating in less physical activity than peers without disease, there is no history of or currently available mHealth initiative for persons with an IBD to improve their PA habits.

2.5.1 Tailoring PA for Fatigued IBD Patients

Tailoring can be defined as gathering or assessing information from a person to develop and deliver individualized intervention components. Unlike a one-size-fits-all approach, individualized strategies consider a person's characteristics, needs, preferences, and context. In the systematic review by Davis et al. (2022), a tailored approach to PA programming is recommended for people with an IBD. Tailored interventions aim to increase PA participation by addressing specific needs of the population group (Ma et al., 2021).

The most convincing empirical PA advice for fatigued individuals with an IBD lies within a pilot RCT by van Erp et al. (2021). Fatigue was found to significantly improve (p =

.001) in adult IBD patients based on a change in Checklist Inventory Strength-Fatigue (Vercoulen et al., 1994) survey score from 105 (± 17) to 66 (± 20) points following a 12-week personalized cardiovascular and resistance training exercise program. Twenty-five participants of this study performed 30 minutes of aerobic training on an indoor exercise bicycle, cross-trainer, or treadmill at 65-80% of the participant's maximum heart rate, as determined through a cardiopulmonary exercise test. This was immediately followed by 30 minutes of circuit resistance training of which, the weight was set to 40-60% of the participant's maximum ability for one repetition; this was re-measured every 6 training sessions.

In the qualitative study mentioned earlier by Beck et al. (2013), the women interviewed mentioned a cycle of fatigue that can arise from remaining inactive: not experiencing improved energy from exercise because they are too energy-depleted to exercise. Fatigue is a vital influential barrier to physical activity for people with IBD (Chan et al., 2014), so it should be a prime consideration when presenting PA advice. To overcome the barrier of fatigue, individuals should be presented with a dose of PA they can confidently engage in while avoiding exacerbation of fatigue. Ideally, the dose would be incorporate personal fitness factors, as exemplified by van Erp et al. (2021).

2.5.2 Just-In-Time Adaptive Interventions

Just-In-Time Adaptive Interventions (JITAI) is a concept used in healthcare and behavioural science to describe an approach to providing individualized support and treatment. The goal of JITAI is to deliver adaptive interventions to individuals when they are most needed and receptive to change, rather than on a pre-determined schedule (Nahum-Shani et al., 2014). These adaptive interventions, in addition to being timely, incorporate an element of individualization that captures information about the user in hopes to maximize engagement with

the system. This approach aims to increase the effectiveness and efficiency of treatments by tailoring them to the user's specific needs and circumstances. JITAI has been used in a variety of health and behavioural domains, including substance use, mental health, physical activity, and medication adherence (Etminani et al., 2021; Kazemi et al., 2018). Wang & Miller (2020) conducted a meta-analysis comparing the health behaviour outcomes of JITAI interventions compared to waitlist control and non-JITAI interventions. Both waitlist control (Hedges g = 1.65) and non-JITAI (g = 0.89) interventions were shown to be not as effective in changing health behaviours as JITAI interventions (Wang & Miller, 2020).

A JITAI intervention focussed on increasing PA could be an acceptable and particularly useful approach for individuals with IBD because it can fulfill the need for dose-response programming. Provide tailored, real-time support and feedback, considering the individual's current symptoms and activity levels.

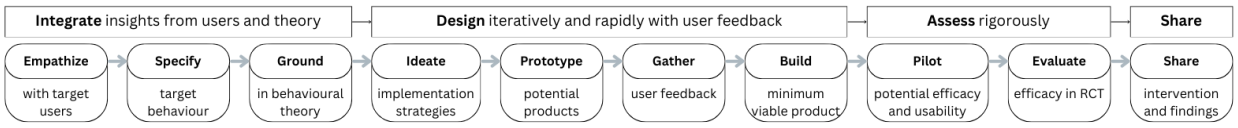
2.6 Development of the IBD-Move App

mHealth interventions can receive criticism for a lack of theory-based development and design. The IDEAS (Integrate, Design, Assess and Share) Framework (see Figure 1) originated from a team aiming to create an intervention, Vegethon, to increase vegetable consumption in older adults (Mummah et al., 2016). Following the proven efficacy and user acceptability, the researchers, designers, and engineers of Vegethon refined their process into the 10-step, 4-stage framework used to direct the creation of effective digital health interventions (Mummah et al., 2016). One such example of the IDEAS framework's effectiveness for PA behaviour change was published by Liu et al. (2019), wherein a multidisciplinary team described their design process of a web-based intervention using the Multi-Process Action Control Framework (M-PAC) to promote PA for inactive adults. A web-based PA intervention using M-PAC had never been

created before, so the team structured their action plan based on the IDEAS framework to coordinate efforts into a manageable, logical sequence to ensure action items were completed promptly. Liu et al. (2019) concluded that using the iterative design process increased the quality of their web-based intervention. The IDEAS framework has also been used to aid the successful development of a mHealth financial incentive PA intervention for people with chronic hypertension (Willms, 2021). This mHealth app progressed to a feasibility trial, wherein Willms et al. (2022) confirmed the feasibility of the app they had created using the IDEAS framework, with a 95% retention rate and positive subjective experience from participants.

Figure 1

Stages and Phases of the IDEAS Framework



Note. adapted from Mummah et al. (2016).

The first stage of the IDEAS framework, Integrate, involves understanding the needs of the target population, aligning their needs with an appropriate health behaviour change, then identifying a behavioural theory to help guide the development of the intervention (Mummah, Robinson, et al., 2016). The Design stage instructs researchers to undergo an iterative process of idea creation, testing, and gathering feedback from users to eventually build the first iteration of the intervention. Stage three, Assess, puts this minimally viable product to the test, as the researcher(s) first evaluate user acceptability through analysis of user data, questionnaires, and interviews. Following confirmation of usability, a full-scale randomized controlled trial should be conducted to assess the effect of the intervention on the health behaviour identified in stage one along with related health behaviours, any mediators or moderators of the interaction, and

further user feedback. The final stage urges the researcher(s) to consider various dissemination strategies when introducing the intervention to the public (Mummah, Robinson, et al., 2016).

The following sub-sections describe the process of creating IBD-Move, the proposed mHealth app, following the first stage within the IDEAS framework.

Phase 1: Empathize with Target Users

The first step of the IDEAS framework involves collecting data to gain a deeper understanding of user needs to identify an issue that can be met by intervention. Participants of qualitative research have explained feeling of unable to participate, a lack of knowledge and confidence, and a lack of advice from medical professionals leading to avoidance of PA (Jones et al., 2023). Survey data has identified that persons with an IBD regard PA as beneficial (80.5%, *n*=158) and sensible (71.8%, *n*=158) (Chae et al., 2016) and would be interested in receiving personalized advice for an exercise program (94%, *n*=190) (Gettigan Mc et al., 2022). Fatigue was identified as a prominent, modifiable barrier to PA by the cohesion of quantitative (DeFilippis et al., 2016; Fagan et al., 2021; Greenley et al., 2018; Tew et al., 2016) and qualitative (Beck et al., 2013; Lamers et al., 2021) research mentioned in previous sections of this literature review. Thus, the identified target user for IBD-Move is a person with an IBD that experiences fatigue and would like to receive personalized PA advice regarding their unique condition.

Phase 2: Specify Target Behaviour

Including a more specified target behaviour is important to better define the purpose of the intervention and outcomes by which it will be judged. In the context of IBD-Move, the broad goal to “increase PA” is further specified based on the Canadian 24-hour Movement Guidelines for Adults Aged 18 Years and Older (Ross et al., 2020). By the end of IBD-Move, users will be

encouraged to increase their PA to at least 150 minutes of moderate-vigorous PA per week, incorporate muscle strengthening activities at least twice per week, and accumulate several hours of light PA per day.

Phase 3: Ground in Behavioural Theory

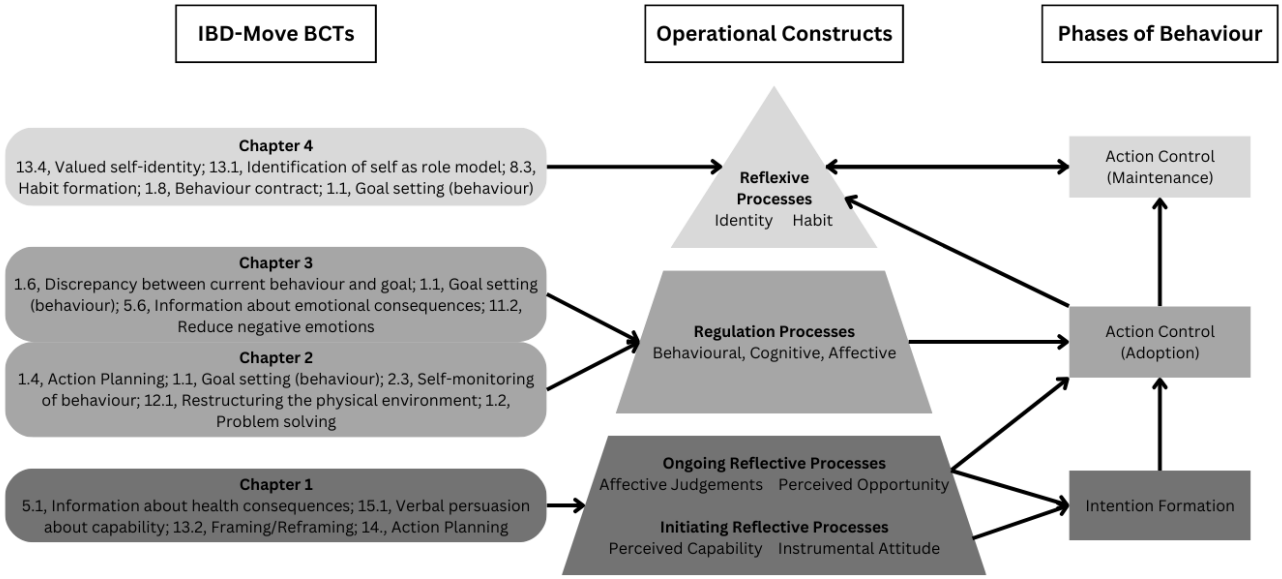
The M-PAC framework (Rhodes, 2017) was chosen as basis for structuring IBD-Move because it is designed to provide a pragmatic approach to PA intervention. M-PAC describes the process of intention formation to sustaining behaviour. Intention formation has traditionally been regarded as the most important factor influencing PA participation (Rhodes & Yao, 2015). M-PAC differs in that it describes intentions, while still crucial, as only a piece of the matrix describing overall PA behaviour change (Rhodes, 2021). The disparity between having an intention to engage in a behaviour and carrying out said behaviour is called the "intention-behaviour gap". Results from a recent systematic review and meta-analysis (N=29,000) quantified the intention-behaviour gap for PA behaviour at 47.6% among all the reviewed studies, and even higher (53.7%) among high-quality studies (Feil et al., 2023). Therefore, despite persons with an IBD demonstrating interest in receiving advice for a PA program (Gettigan Mc et al., 2022), appropriate measures should be taken to provide support as this intention translates to action.

Behaviour change techniques (BCTs) are utilized throughout all four chapters of literary content as mechanisms to support progression along the M-PAC framework. BCTs are the observable, replicable, and irreducible components of an intervention that are designed to actively facilitate a change in behaviour (Michie & Johnston, 2013). A taxonomic list of 93 different BCTs was developed by Michie et al. (2013) to better inform and validate the techniques used in behaviour change interventions. Several BCTs are proposed within each

construct of the M-PAC framework (Rhodes, 2017), which have been adapted for use within IBD-Move. Four chapters of text material, delivered subsequentially at the beginning of each week of the intervention, will guide the user through the hierarchical constructs of M-PAC, from intention formation to action control adoption, then action control maintenance. Figure 2 illustrates the theoretical progression through M-PAC and the BCTs used relative to each chapter of IBD-Move.

Figure 2

Structure of IBD-Move using M-PAC and BCTs



Chapter 1 of IBD-Move aims to bolster reflective processes to solidify the intention to exercise. M-PAC posits intention formation is based on the synthesis of four reflective processes, which can be further split into two categories: initiating and ongoing (Rhodes, 2017). Initiating reflective processes include instrumental attitude (expected benefits) and perceived capability (self-perception of ability), which contribute exclusively to the formation of intention. Ongoing reflective processes include affective judgements (expected pleasure) and perceived opportunity (evaluation of social and environmental conditions), which are factors that affect both intention

formation and the likelihood of action adoption. Thus, this chapter intends to affirm the belief that people with an IBD should be physically active by providing positive information regarding outcome expectancies and task self-efficacy. Users will be asked to think about what they find pleasurable about physical activity and when they can fit it into their schedule.

Chapter 2 and Chapter 3 of IBD-Move introduce regulation processes and provide strategies to support the enactment of regular PA. Regulation processes consist of behavioural, cognitive, and affective regulation techniques that aim to support the translation of intention to action adoption (Rhodes, 2017). More efficacious interventions use regulation processes that focus on the behavioural experience rather than the distal outcomes a user wishes to see (Locke & Latham, 2006; Rhodes, 2021). As such, Chapter 2 aims to keep the user engaged in the process of performing PA by delivering prospective BCTs such as goal setting, restructuring the physical environment, and self-monitoring. Chapter 3 introduces reactive BCTs that allow the user to critically appraise their PA experience and make changes to their plan for PA engagement as necessary. By synthesizing BCTs from Chapter 2 and 3, the user will have learned a cyclical process of planning, appraisal, and re-planning, which can be used endlessly in the pursuit of maintaining PA (Rhodes & Sui, 2021).

Chapter 4 of IBD-Move intends to educate the user on what constitutes an identity and habit, how they contribute to PA maintenance, and how they are formed. Identity and habit are reflexive processes described within the M-PAC framework as the consequence of repeated behaviour enactment wherein each contributes to a selection bias that facilitates PA enactment (Rhodes, 2017, 2021). These constructs cannot be taught, they are natural occurrences that happen over time. To ensure sustained PA behaviour, an individual must continue to practice regulation processes over a long enough period to form an identity and habit (Rhodes & Sui,

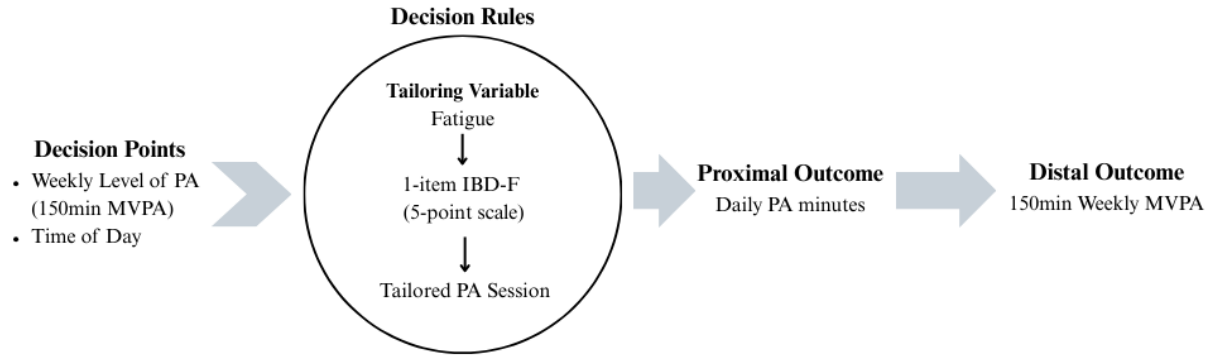
2021). Once a PA identity and habit are formed, reflective and regulatory processes are smaller predictors of PA behaviour (Caldwell et al., 2018; Rhodes & Sui, 2021).

2.6.1 JITAI Tailoring for IBD-Move

The IBD-Move app employs a JITAI framework to personalize physical PA recommendations based on real-time fatigue levels, aiming to improve adherence and effectiveness. Figure 3 illustrates the key components of the JITAI feature, including decision points, tailoring variables, decision rules, and outcomes (Nahum-Shani et al., 2018). The decision points for IBD-Move are weekly level of PA and a prespecified time of the day (based on user input). If the user does not have 150 minutes of PA reported within the specified week, the JITAI module will be delivered, and a notification will be sent to the user. If the user has reached 150 minutes of activity, no JITAI module will be delivered. Decision rules are based on the tailoring variable is self-reported fatigue, assessed via the IBD fatigue self assessment scale (IBD-F) (Czuber-Dochan et al., 2014), where users rate their current fatigue on a 5-point Likert scale. Exercise recommendations are dynamically adjusted based on fatigue. None, low, and moderate fatigue triggers progressively shorter Mixed Exercise sessions (20, 15, or 10 minutes), combining aerobic and resistance training with adjustable intensity. High and extreme fatigue shifts to gentler Active Mobility or Breathing and Mindfulness routines. The target proximal outcome of IBD-Move is increasing daily active minutes of PA, which aims to promote adoption and maintenance of the distal outcome, meeting 150 minutes of weekly MVPA.

Figure 3

Conceptual Model of JITAI Feature for IBD-Move



Note. Adapted from Nahum-Shani et al. (2018)

2.7 Usability and Acceptability Testing for mHealth

2.7.1 Usability Testing

Usability is an important determining factor for the success of mHealth apps as it aids researchers in developing interfaces for goal-oriented tasks that users can achieve in easy and efficient ways (Baharuddin et al., 2013; Harrison et al., 2013). Mobile app usability has been shown to predict a user's intention and continued use, two important constructs for the continued longevity of a system (Hoehle & Venkatesh, 2015). The International Organization for Standardization defined 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" (International Organization for Standardization, 2018). This definition has been cited consistently in research examining the empirical usability of mHealth apps, with various quantitative and qualitative methods developed with the purpose of quantifying and describing the usability of mobile technologies (Zapata et al., 2015).

Among existing usability studies for mHealth apps providing a PA intervention, a main concern is the lack of methodological rigour and reliance on a single method for data collection (El-Gayar et al., 2013; Fontecha et al., 2023). Reviews within the field call for multiple methods of usability testing within a single study and the need for standardized analysis procedures to produce higher quality mHealth app functionality assessments (Lyles et al., 2014; Zapata et al., 2015). Usability researchers have found success using multi-method approaches to collect qualitative user data coupled with structured data analysis using approaches such as Framework Analysis and the Usability Problem Taxonomy (UPT) (Fontecha et al., 2023; Georgsson & Staggers, 2016).

Using a Multimethod Approach

A combination of testing methods provides deeper insight into usability problems and increases the validity and reliability of the findings (Green et al., 2015). Usability studies using a multi-method approach to data collection find that each test employed can identify unique user issues, or at the very least, support the existence of a previously identified issue (Fontecha et al., 2023; Georgsson & Staggers, 2016).

Three common methods of usability testing for mHealth apps are (1) the Think Aloud protocol, (2) semi-structured interviews, and (3) usability questionnaires. Think Aloud was developed by Ericsson and Simon (1993) and elicits real-time subjective data of the user's cognitive processes during a task by having the participants the vocalize their thoughts while recording their use of a system. This data collection method provides a direct report of the user's experience complemented with observations of how they interact with a system. A limitation of the Think-Aloud method is the inability for participants to reflect on their experience, as feedback occurs in real-time. By contrast, semi-structured interviews evaluate users' feelings and

perceptions regarding their experience using the system through open-ended questions, which creates the opportunity to reflect on how their needs could be better met (Zapata et al., 2015). While a useful tool to gain deeper insight into participant thoughts and feelings, the retrospective nature of semi-structured interviews makes them sensitive to recall bias. Questionnaires are often used following system use to collect subjective data on user experiences by asking specific questions, such as the Psychometric Evaluation of the Post-Study System Usability Questionnaire (Lewis, 1992), the System Usability Scale (Bangor et al., 2008), or the mHealth App Usability Questionnaire (MAUQ) (Zhou et al., 2019). Questionnaires are useful to gather overall measures of a particular usability construct but lack depth to explain why the result occurred. The conjunction of these three methods gives a well-rounded approach to usability evaluation, one which considers the direct, in-real-time experience along with retrospective feelings associated with the user's interaction with a system. This study uses all three methods described above to collect rich and measurable data related to app usability.

Framework Analysis for Qualitative Data

Usability evaluations are sometimes criticized because they lack consistency between qualitative data analysis procedures, such as those collected from Think-Aloud and semi-structured interviews. Besides ensuring a rigorous analysis, standardized methods can be more easily replicated for future research. Framework Analysis originated as a framework for analyzing qualitative data in political science and has since been adopted with verified effectiveness in health and mHealth research (Gale et al., 2013; Georgsson & Staggers, 2016). There are five distinct stages to Framework Analysis: (1) familiarizing oneself with the data, (2) identifying themes or a framework to be used, (3) indexing and applying the framework to the data, (4) charting the data and (5) mapping and interpretation. Framework Analysis is useful in

compartmentalizing the qualitative data, allowing multiple researchers, including those with little qualitative research experience, to easily interpret, audit, and contribute to the analysis (Ward et al., 2013).

The Usability Problem Taxonomy is to be used in conjunction with Framework Analysis. The original article by Keenan et al. (1999) presents a taxonomy framework for classifying usability problems in software engineering. It provides a hierarchical approach to categorize and analyze these problems, intending to improve software usability and user experience. The authors argue that by organizing usability problems into meaningful categories, it becomes easier to identify and address them effectively.

Since their inception, Framework Analysis and the Usability Problem Taxonomy qualitative data analysis methods have been adopted into mHealth research for the usability of diabetes self-management systems. The first iteration of Framework Analysis and the Usability Problem Taxonomy analysis for mHealth was performed by Georgsson and Staggers (2016) and was concluded to have a substantial benefit. The use of a multi-method approach consisting of Think Aloud usability testing protocol, post-test interview, and post-test questionnaire. This gave ample opportunity for unique usability problems to be discovered by any of the three testing methods and for triangulation of problems that occur more frequently. A more recent usability study by Fontecha et al., (2023) revisited Framework Analysis and the Usability Problem Taxonomy as methods of data analysis for a diabetes mHealth system and web platform. A multimethod approach was also used in this study; however, a heuristic evaluation of the systems was used (individual assessment by interface and content experts) instead of a post-test interview. In both studies, authors reported the Framework Analysis and Usability Problem Taxonomy methods to result in easily defined, fine detail usability problems, able to be easily

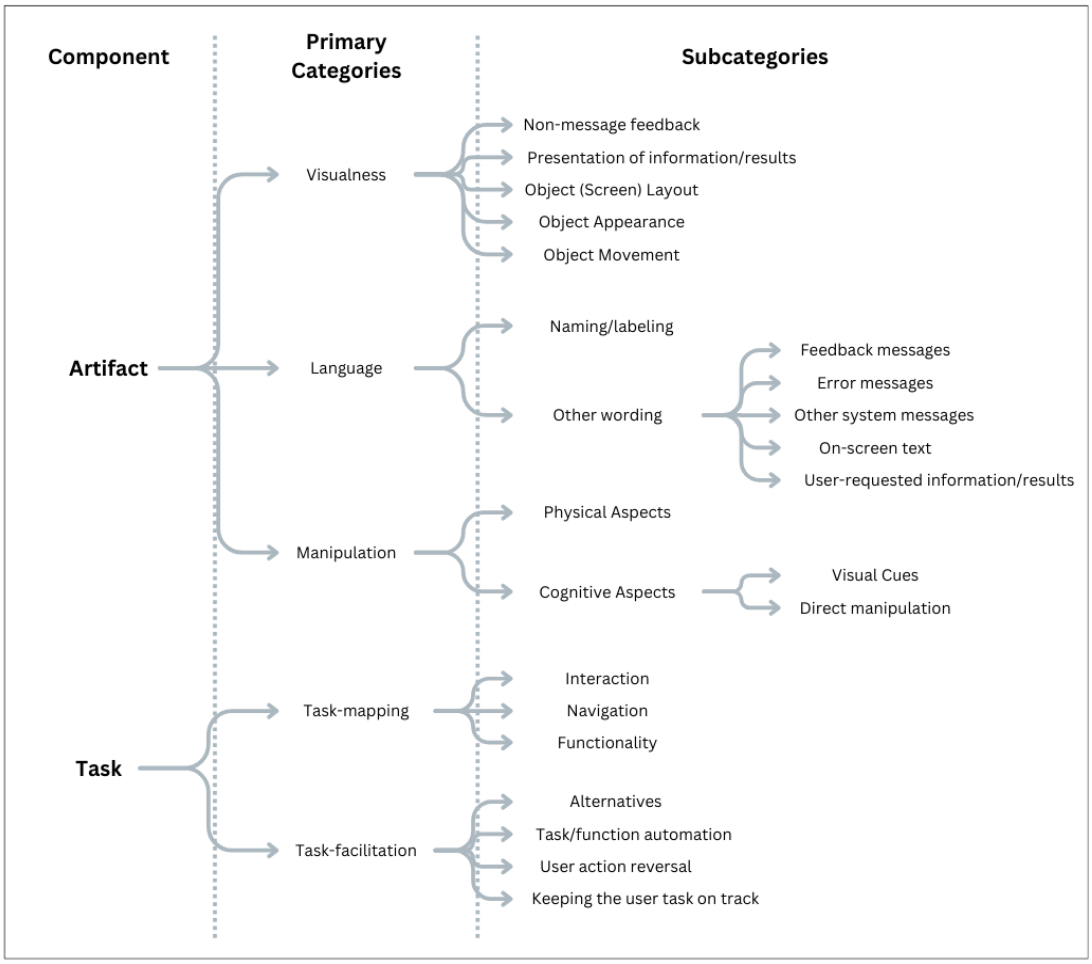
categorized based on occurrence (number of participants reporting the problem) and severity rating.

Usability Problem Taxonomy Classifications

There are two main components of usability problems according to the Usability Problem Taxonomy: artifact and task. Artifact components encompass problems that occur when a user interacts with the interface of a system. There are three primary categories of artifact components (*Visualness*, *Language*, and *Manipulation*), which can be further classified by 16 sub-categories. Figure 4 provides a visual representation of the components of the Usability Problem Taxonomy and their respective categories.

Figure 4

Structure of the Usability Problem Taxonomy



Note. Adapted from Keenan et al. (1999).

Task components relate to problems that occur when a user moves through a task within the system. There are two primary categories of task components (task-mapping and task-facilitation), which can be further classified by seven sub-categories. Investigators must attempt to classify problems into both the task and artifact components of the Usability Problem Taxonomy; therefore, one usability problem always has two classifications. Full classification within a component occurs when a user problem can be defined by the deepest level within a sub-category. Partial classification is when a user problem can only be defined by a category not

at its deepest level within a component. Null classification is given to problems that cannot be defined by a category of a given component. Null or partial classifications do not detract from the importance of usability problems, they simply help to better define the problem, with the understanding that usability problems can have elements of both task and artifact components. A severity rating is then applied to prioritize each problem for subsequent changes to the mHealth system. This study uses UPT to give each usability problem an artifact and task classification, which will map the most common pain-points for reference in future app development.

2.7.2 Acceptability Testing

Acceptability captures thoughts and emotional reactions participants have to an intervention. The degree to which interventions are viewed as acceptable by users and other stakeholders influences both engagement and effectiveness, ultimately predicting adoption (Greenhalgh et al., 2017). Several evaluation methods have been conducted in previous studies, as researchers continue to recognize the value of acceptability as a necessary component to successful digital interventions. The following section will provide an overview of acceptability testing for digital health interventions and conclude with the rationale for methods used in this study.

Acceptability testing can be conducted at various stages during intervention development. A measurement of acceptability can be taken before a participant engages in an intervention (prospective), during the intervention (concurrent), and after (retrospective). Prospective assessments are hypothetical in nature, evaluating initial thoughts and feelings the user has regarding acceptability of the idea. To perform prospective assessments, a prototype or description of the intervention is given to the user, giving researchers insight into user

perceptions during intervention design (Materia & Smyth, 2021). Concurrent and retrospective assessments aim to measure actual acceptability, and how it may fluctuate throughout ongoing engagement with the system. These stages of acceptability can be measured quantitatively and qualitatively, using various methods that have been adapted to fit the needs of individual research needs. Questionnaires, qualitative surveys, semi-structured interviews, focus groups and Think-Aloud are among the most used methods to collect acceptability data for healthcare interventions (Nadal et al., 2020). These methods and their application are discussed below.

Quantitatively, questionnaires can be used to collect data on dimensions of acceptability that are modeled according to theoretical frameworks (Brook et al., 2021). However, these questionnaires are often developed custom to each study, identifiably due to a lack of standardized tools for acceptability testing of healthcare interventions (Nadal et al., 2020). Despite this challenge, there are studies that have managed to satisfy the need for a standardized measure of acceptability. The MAUQ (Zhou et al., 2019), traditionally used to measure usability of mHealth apps, has been used to gather a measure of acceptability for a PA mHealth app for people at risk of hypertension (Willms et al., 2023). Questions within the section *Usefulness* were given a mean score among all participants and used to evaluate retrospective acceptability. While this quantitative measure is limited to a rudimentary and incomplete definition of acceptability, it gives the mHealth app a measurement from a validated tool which can be used for comparison in subsequent iterations. To quantitatively evaluate multiple dimensions of acceptability, custom questionnaires based on the Theoretical Framework of Acceptability (TFA) (Sekhon et al., 2017, 2022) have been used in previous healthcare intervention research (Keyworth et al., 2021; Renko et al., 2020). However, the TFA has more frequently been used as a tool to qualitatively evaluate healthcare interventions.

The TFA conceptualizes acceptability as “a multi-faceted construct that reflects the extent to which people delivering or receiving a healthcare intervention consider it to be appropriate, based on anticipated or experiential cognitive and emotional responses to the intervention” (Sekhon et al., 2017). There are seven key facets that are thought to represent the construct of acceptability: *affective attitude, burden, ethicality, intervention coherence, opportunity cost, perceived effectiveness, and self-efficacy* (definitions presented in Table 1). For the purposes of evaluation, the more facets a user considers an intervention has met, the more acceptable the intervention is. Facets of the TFA have been mapped to semi-structured interview questions to measure retrospective acceptability following the use of an mHealth app aimed at reducing alcohol consumption (Oldham et al., 2023). In an interview context, participants were able to give their initial impression (positive or negative) and explain their response further. This approach allowed for detailed feedback on each specific facet of the TFA, resulting in a comprehensive evaluation of acceptability. To evaluate concurrent acceptability, the Think-Aloud method can be used, wherein the user is told to speak their thoughts during usage of the system (Breathnach et al., 2020). Acceptability themes are inductively generated, then deductively mapped according to facets of the TFA. In summary, the TFA provides a robust framework for assessing acceptability through its seven key facets, enabling both retrospective and concurrent evaluation methods to comprehensively capture users' cognitive and emotional responses to healthcare interventions.

Table 1

Facets within the Theoretical Framework of Acceptability

Construct	Definition
Affective Attitude	How an individual feels about taking part in an intervention.
Burden	The perceived amount of effort that is required to participate in the intervention.
Ethicality	The extent to which the intervention has good fit with an individual's value system.
Intervention Coherence	The extent to which the participant understands the intervention, and how the intervention works.
Opportunity Costs	The extent to which benefits, profits, or values must be given up to engage in an intervention.
Perceived Effectiveness	The extent to which the intervention is perceived as likely to achieve its purpose.
Self-efficacy	The participant's confidence that they can perform the behaviour(s) required to participate in the intervention.

Note. Facets of the Theoretical Framework of Acceptability from (Sekhon et al., 2017)

To address the need for effective interventions for individuals with IBD, the current study evaluates the usability and acceptability of the IBD-Move app, a JITAI mHealth app designed to overcome the barrier of fatigue to improve PA levels for users with an IBD. The following methods section outlines a multi-method approach to assess usability and acceptability, ensuring the core functionalities are tested and the app content aligns with user needs and expectations.

Chapter 3

3.1 Study Design

This is a mixed method study used a task-based and summative evaluation of human-computer interactions (Yen & Bakken, 2012). Usability testing was conducted in-person, over two cycles with each session lasting one hour. I made improvements of the app after first cycle of usability and acceptability testing. Ethics approval was obtained from the Human Research Ethics Board at the University of Victoria (UVic) through the UVic Research Administration Information System (23-0337). Written informed consent was obtained from all the participants.

3.2 Participants

Participant inclusion criteria included the following: 1) not meeting the 24-hour Movement Guidelines of 150-minutes of moderate-vigorous PA per week, as measured by physical activity vital sign questionnaire upon screening (Ball et al., 2016; Ross et al., 2020), 2) having been diagnosed with an IBD for over 1 year, 3) participants' IBD was in remission, as confirmed by self-report, and 4) participant was between the ages of 19-64 years old. Participants who could not read and write English were excluded from the study. To recruit participants, this study utilized aid from external organizations. External organizations included the Crohn's and Colitis Society of Canada, the UVic campus, REACH B.C. and gastroenterologist clinics. Participants were offered a $15 gift card as incentive for completing the study.

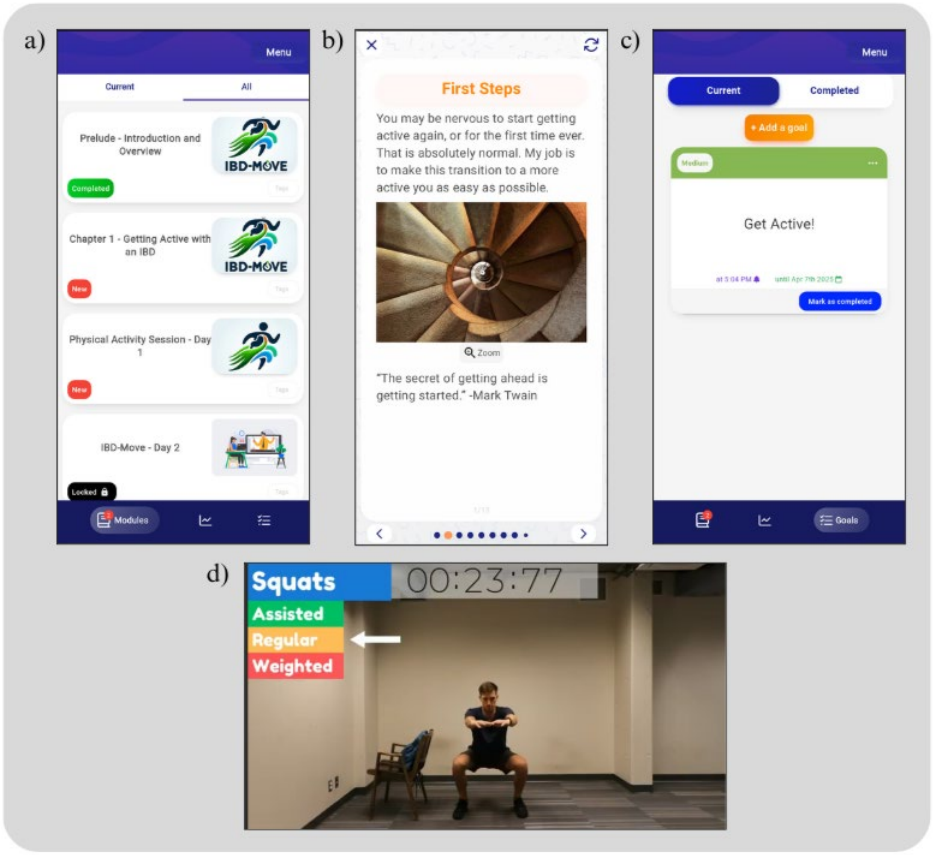
3.3 JITAI IBD mHealth App

The mHealth intervention was created using Pathverse, an app development software from the Digital Health Lab at UVic. Pathverse is a platform for researchers to develop mHealth

interventions entirely through a graphical user interface, with no software programming required (Liu et al., 2022). Pathverse can be downloaded through either the AppStore or Google Play. Sample screenshots of the app are shown in Figure 5 below.

Figure 5

Screenshots of the IBD-Move App



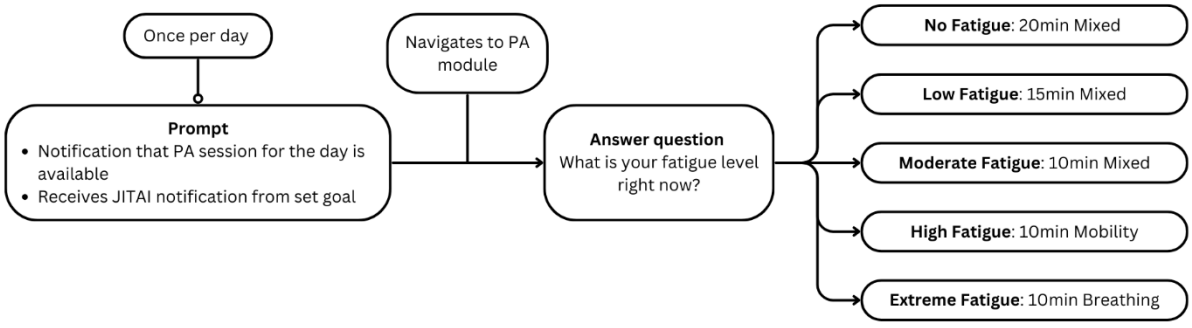
Note. General screenshots of the IBD-Move app, a) homepage, b) a slide from Chapter 1, c) goal setting page, and d) physical activity video

The overall objectives of the IBD-Move program are to introduce regular PA and support the maintenance of PA. The literary content of IBD-Move is delivered in four chapters, using behavioural change techniques informed by the Multi-Action Process Control framework (Rhodes, 2021). The chapters aim to progressively bolster reflective processes of behaviour

(Chapter 1), introduce methods of self-regulatory behaviours (Chapter 2 and 3), and support the formation of reflexive processes of behaviour (Chapter 4). The user is assumed to have the intention to exercise, seeing as they have registered for and started using the app. As such, behavioural intervention is aimed at capitalizing the user's predeveloped intention by immediate initiation of action and support towards maintenance of action throughout the 4-weeks. Only the Prelude and Introduction (Orientation) and Chapter 1 were used for testing in this study. The content for these chapters can be found in Appendix B. If users have accumulated less than 150 minutes of weekly MVPA on the given day, a PA session module is delivered which is tailored based on their current fatigue level. The decision tree to access the JITAI PA session is illustrated in Figure 6. This JITAI feature aims to improve the proximal outcome of daily PA engagement, with the distal outcome of reaching at least 150 minutes of MVPA per week.

Figure 6

JITAI Decision Tree



PA advice follows the Canadian 24-Hr Movement Guidelines in IBD-Move. To achieve a dose-response-oriented program, the app provides a PA routine based on the user's fatigue at the time of intervention. The app is designed to assessed participants fatigue daily using a self-report questionnaire and delivers a PA session relative to their level of fatigue. The PA session can be

accessed by the user daily at any time, with a reminder notification being sent at a time they have previously chosen as their most ideal time to be active. Recommended exercise routines are delivered according to item 1.1 from the IBD-F (Czuber-Dochan et al., 2014): “What is your fatigue level right now”, wherein users answer based on a 5-item Likert scale. No fatigue, low Fatigue, and moderate fatigue responses deliver a “Mixed Exercise” session of 20-minute, 15-minute, and 10-minute durations, respectively. Mixed Exercise incorporates aerobic and resistance exercises into one session and provides three levels of difficulty for each exercise, so the user can gauge their ability in real time to participate with their preferred level of intensity. Fatigue level 4 delivers a 10-minute “Active Mobility” routine, and fatigue level 5 delivers a 10-minute “Breathing and Mindfulness” routine; these routines consist of 5 exercises practiced for 2 minutes each. A detailed outline of the exercise sessions and their integration with Pathverse can be found in Appendix C.

This study did not test notification feature from the app based on the decision point of weekly PA levels, which is the initiating component of the JITAI feature. This was outside the scope of a task-based usability test due to time constraints and the logistical challenge setting the notification during the testing session.

3.4 Procedure

Qualified participants were invited to attend in-person usability testing at the UVic. The study procedure was explained to the participants, which consisted of the following: 1) complete the baseline online questionnaire on demographics (i.e., age, sex, education), IBD diagnosis, and user experience with smartphones, 2) carry out five tasks while performing the “Think-Aloud” protocol, 3) provide usability and acceptability feedback following testing.

After completing the baseline questionnaires, participants were asked to complete a series of five tasks. These tasks were designed to simulate real-life interactions and test the core functionalities of the app. In **Task 1: Complete Orientation**, they logged into the app and navigated to the "Introduction and Overview" module to review its content. In **Task 2: Read Chapter 1**, participants accessed and completed the "Chapter 1 – Getting Active with IBD" module, including answering embedded survey questions. In **Task 3: Add Goal**, they recorded a new physical activity goal by selecting "+ Add a goal" in the "Goals" section and saving their entry. In **Task 4: Complete PA Session**, participants first completed the "Day X – Fatigue Questionnaire" to report their daily fatigue score, then accessed and followed along with a guided exercise video. Lastly, in **Task 5: Track Activity**, they logged their completed physical activity in the "Trackers" section under "Exercise Logging." The tasks and accompanying cues for participants are displayed in Table 2.

Table 2

Goal Oriented Tasks

Task	Description	Cue
1. Orientation	Participants open the app, logs-in using their details provided via email from the researcher (login information will be provided at the time of testing as well). Participant navigates to the study "IBD-Move" to reach the "Modules" page, then opens and reads through the "Introduction and Overview" module.	Login using your username and password, then navigate to and read through the "Introduction and Overview" module.
2. Chapter 1	Participants encounter "Chapter 1 – Getting Active with an IBD", click to open the module, navigate through the content, answer survey questions when they are presented, and navigate back to the "Modules" page when complete.	Complete the module "Chapter 1 – Getting Active with an IBD".
3. Add Goal	Participants record their physical activity goals. They navigate to the "Goals" page and select "+ Add a goal". They fill out the appropriate sections and select "Save".	Add a new physical activity goal.

4. PA Session	Participants are ready to engage in physical activity for the day. They select the "Day X – Fatigue Questionnaire" to report their daily fatigue score, then navigate back to the "Modules" page to access their PA video module. The participant opens the module and navigates to the video. The participant follows along with the video and returns to the "Modules" page.	You would like to begin exercising. Complete your daily fatigue questionnaire, then access and complete your physical activity video.
5. Track Activity	Participants want to record the activity they just completed. They navigate to the "Trackers" page and then to the "Exercise Logging" tab to select "+ Log an exercise". Participants follow the prompts and select "Save".	Add the activity you just completed to your "Trackers" page.

These tasks guided the user toward testing the core-functionalities of the app. Specifically, the app provides educational content on exercising with IBD, allows users to access their responses to chapter questions, and offers a tailored daily exercise routine based on fatigue levels. Additionally, it supports physical activity behaviour tracking, including frequency, intensity, type, and time, and facilitates goal setting to help users work toward achieving 150 minutes of moderate-to-vigorous physical activity per week. While Pathverse offers additional app functionalities, these features were the primary focus for assessing IBD-Move's usability.

Participants were not provided any training prior to or during the usability testing to avoid any bias. Users were encouraged and reminded to speak their thoughts during app interaction to reveal their raw experiences, reactions, and thoughts while completing the modules. The Think-Aloud procedure during tasks were critical to understanding participants' thoughts and detecting any usability issues (Jaspers et al., 2004). A video recording of the testing procedure was taken from an angle where just the screen of the mobile device can be seen. The device used to record participants was a Canon EOS 80D DSLR, and to record audio, a RODE

wireless GO was used. The interaction trial was transcribed using Echo360 automatic speech recognition service (Echo360, n.d.) for data analysis.

3.5 Usability Evaluation

Task completion rates were used to measure the accuracy and completeness in which users achieved the specified tasks (Inal et al., 2020). The researcher kept track of completed tasks during the session by manually checking off each task as they are completed using their own task list. Failed tasks were recorded if the researcher needed to aid the participant to completion. Specifically, the following measures were calculated retrospectively through video playback:

1. Task Completion Rate per participant (TCR_p) is calculated using the following equation: TCR_p = (number of tasks completed successfully / total number of tasks undertaken) × 100 (Ramadan et al., 2019).
2. Task Completion Rate per task (TCR_t) per task is calculated using the following equation: TCR_t per task = (number of participants who completed successfully / total number of participants) × 100 (Ramadan et al., 2019).
3. Distribution of Task Success (DTS) according to three possible levels of achievement: (1) No Errors, participants completed with ease (i.e., without any errors or difficulties); (2) With Error, completed with at least one error or difficulty and (3) Did Not Complete, needed researcher assistance to complete the task.

Efficiency was measured to determine the level of resource use required for participants to achieve specified goals in relation to accuracy and completeness (Inal et al., 2020; Rochat et al., 2022). Specifically, efficiency was calculated based on the average time on tasks and number of screen transitions per task. Each task start time will be marked by a verbal cue: “Start” and completed with a verbal cue: “End”. The think aloud method may inflate the time to complete

each task, however this inflation should be balanced because each participant is being asked to complete tasks while thinking aloud. Number of screen transitions was assessed using a recording of the participant's phone, by counting the number of screen transitions they had between the "Start" and "End" of each task. A screen transition was defined as a complete change of state during screen navigation. For example, a keyboard coming up on the screen to allow input of text to a text box would not be considered a screen transition, because the text box is part of the same screen state. The optimal number of screen transitions (shortest path to task completion) was compared to the actual number the participant used to complete the task.

Ease of use and interface and satisfaction were evaluated using the mHealth App Usability Questionnaire (MAUQ) (Zhou et al., 2019); this mHealth evaluation tool is deemed valid and reliable against the System Usability Scale (Bangor et al., 2008) and Post-Study System Usability Questionnaire (Lewis, 1992), two commonly used usability questionnaires for mHealth research. There are four versions of the MAUQ, the one used in this study is for "Standalone mHealth Apps Used by Patients". Ease of use was evaluated using statement (S) 1-S5, and interface and satisfaction using S6-S12. These items were evaluated on a 7-point Likert scale (1, strongly agree; 7, strongly disagree).

Global usability per task was evaluated using the Single Ease Question (SEQ), chosen for its ease of use, validity, and reliability in comparison with other measures of post-task usability (Olsen et al., 2009). The SEQ: "Overall, this task was:" was answered on a 7-point Likert scale (1, very easy; 7, very difficult) following the completion of each of the five tasks.

A net promoter score (NPS) was used to assess user loyalty as an extension of usability following the completion of all five tasks. Each participant will be asked to answer the following question on a 7-point Likert scale: 'How likely is it that you would recommend this app to a

friend or colleague?" (1 – Extremely Unlikely, 7 – Extremely Likely) (Mandal, 2014). Participants who select an answer from 1-4 were considered detractors, 5-6 were considered passives, and 7 were considered promoters (Reisenwitz, 2017).

The Think-Aloud method was used while the participants completed tasks to collect qualitative data relating to concurrent app use. This was achieved by the researcher consistently reminding the participant to speak their mind during usage. The standard prompt to encourage thinking aloud during periods of silence was "please think aloud", although the researcher could change the prompt relative to the situation. For example, if the participant was noticeably confused, the researcher would prompt by asking "was that confusing?".

Semi-structured interviews were conducted after the participants complete the assessment by the primary researcher to collect qualitative data regarding usability. Questions asked during the semi-structured interview with a participant included questions not covered by MAUQ but are relevant to app development, or topics the primary researcher would like the participant to elaborate on. Examples of questions include: "Was it easy to navigate through the app?" and "Were you able to move through the app efficiently?". See Appendix E for the full interviewer question guide.

3.6 Acceptability Evaluation

Acceptability data was collected alongside usability data using the same methods. Specifically, usefulness as a global quantitative measure of acceptability was assessed using S13-S18 of the MAUQ (Willms et al., 2023). This item was evaluated on a 7-point Likert scale (1, strongly agree; 7, strongly disagree). The Think-Aloud method was used to collect qualitative acceptability data during task completion. Semi-structured interview questions were structured

according to the Theoretical Framework of Acceptability, with one question being used to assess each of the seven facets. For example, *affective attitude* was assessed by asking: "How much did you like the IBD-Move app?", and *ethicality* was assessed by asking: "Do you think anyone could use this app?".

3.7 Sample Size

Sample size requirements were based on empirical usability testing recommendations and sample size recommendations specifically for mHealth apps (Kushniruk & Patel, 2004; Zhao & Lal, 2020). These sources indicate that two or three cycles of 4-5 participants are sufficient to reach data saturation. This study performed two rounds of usability testing, with changes made between rounds based on participant feedback.

3.8 Data Analysis

The video from each Think-aloud task was analyzed to provide the researcher with quantitative measures of usability, such as effectiveness and efficiency. Quantitative data on group demographics and outcome measures was entered and analyzed using JASP Version 0.19.3.

Qualitative analysis involved the researcher theming the Think-aloud tasks and semi-structured interviews retrospectively according to Framework Analysis. For usability analysis, the combination of Framework Analysis and the Usability Problem Taxonomy allows for the aggregation of user-identified problems (as identified via Think-Aloud and interview) into easily differentiated usability problems, without sacrificing detailed individual feedback from data collection (Fontecha et al., 2023; Georgsson & Staggers, 2016). Artifact and task classifications within the Usability Problem Taxonomy were deductively determined for each usability problem

identified by inductive framework analysis. For acceptability analysis, themes derived from Framework Analysis were mapped according to the seven facets of the Theoretical Framework of Acceptability. The stages of Framework Analysis and how it must be applied by the researcher to data analysis is explained in Appendix F.

Chapter 4 Results

4.1 Participants

A total of eight participants completed the study and Table 3 describes the general characteristics of the participants (Cycle 1: $n = 4$, Cycle 2: $n = 4$). Five males and three females took part in this study. All participants of this study identified as a white person, with a mean (SD) age of 31(14.1) years. Four of the participants held a college degree, two a High School degree, one a bachelor's degree, and one a Graduate degree or higher. Four participants indicated making less than $20,000 annually, three responded between $75,000 and $99,999, and one did not answer. There was an even number of participants who were diagnosed with either Crohn's Disease or Ulcerative Colitis. Participants reported a mean (SD) daily smartphone use of 3.6 (0.7) hours. Five participants owned an iOS(Apple) device as their personal smartphone, whereas three participants owned Android smartphones.

Table 3

Participant Characteristics

Variable	Cycle 1 (n = 4)	Cycle 2 (n = 4)	Total (n = 8)
Sex, *n* [%]			
Male	2 [50]	3 [75]	5 [62.5]
Female	2 [50]	1 [25]	3 [37.5]
Gender, *n* [%]			
Man	2 [50]	3 [75]	5 [50]
Woman	2 [50]	1 [25]	3 [50]
Age in years, M (SD)	33.3 (20.2)	28.8 (6.3)	31 (14.1)
Ethnicity, *n* [100]			
White	4 [100]	4 [100]	8 [100]
Education, *n* [%]			
High School	1 [25]	1 [25]	2 [25]
Bachelor's degree	1 [25]	-	1 [12.5]
College Graduate	2 [50]	2 [50]	4 [50]
Graduate Degree or higher	-	1 [25]	1 [12.5]
Income, *n* [%]			
Prefer not to answer	1 [25]	-	1 [12.5]
Less than $20,000	2 [50]	2 [50]	4 [50]
$75,000 to $99,999	1 [25]	2 [50]	3 [37.5]
IBD Diagnosis, n [%]			
Crohn's Disease	2 [50]	2 [50]	4 [50]
Ulcerative Colitis	2 [50]	2 [50]	4 [50]
Personal Smartphone Type, n [%]			
IOS (Apple)	3 [75]	2 [50]	5 [62.5]
Android	1 [25]	2 [50]	3 [37.5]
Daily Smartphone Usage in hours per day, M (SD)	3.8 (1.0)	3.5 (0.6)	3.6 (0.7)

Note. M, mean; SD, standard deviation.

4.2 Usability Evaluation

4.2.1 Task Completion Rates

Five participants achieved a 100% Task completion rate per participant (TCR_p), but three did not (Table 4). Only one participant in Cycle 1 scored below the TCR_p threshold of <70%. No participants scored below <70% TCR_p in Cycle 2.

Table 4

Task Completion Rate per Participant

	Participants	TCR_P
Cycle 1	P01	100%
	P02	80%
	P03	100%
	P04	60%
Cycle 2	P05	100%
	P06	80%
	P07	100%
	P08	100%

Note. TCR_P, Task Completion Rate per Participant.

Task completion rate per task (TCR_t) generally improved from Cycle 1 to Cycle 2 (Table 5). However, Task 3 (Add Goal) still had a TCR_t of 75%, whereas all other tasks reached 100% in Cycle 2. The improvement of TCR_t is pronounced by a fewer number of tasks that were unable to be completed by participants in Cycle 2, although more tasks were completed with errors. Namely, Task 3 (Add Goal) and Task 4 (Complete PA Session) each had three participants have an error prior to completion of the task in Cycle 2.

Table 5

Task Completion Rate per Task and Distribution of Task Success

Task #	Cycle 1				Cycle 2			
	TCR_t	DTS (n = 4)			TCR_t	DTS (n = 4)		
		No Errors	With Error	DNC		No Errors	With Error	DNC
Task 1 (Orientation)	75%	3	0	1	100%	4	0	0
Task 2 (Chapter 1)	100%	1	3	0	100%	3	1	0
Task 3 (Add Goal)	75%	1	2	1	75%	0	3	1
Task 4 (PA Session)	75%	2	1	1	100%	1	3	0
Task 5 (Track Activity)	100%	4	0	0	100%	3	1	0
Total Frequency	-	11	6	3	-	11	8	1

Note. TCR_t, Task Completion Rate per Task; DTS, Distribution of Task Success; DNC, Did Not Complete.

4.2.2 Efficiency

Cycle 2 had three of five tasks take more time to complete than Cycle 1. Task 2 (Read Chapter 1) took the longest amount of time for participants to complete among both cycles. Task 3 (Add Goal) had the greatest difference in screen transitions, defined as complete changes in screen states during navigation, in Cycle 1, and Task 4 (Complete PA Session) had the greatest difference in Cycle 2. Task 3 (Add Goal), Task 4 (Complete PA Session), and Task 5 (Track Activity) all had differences in screen transitions above the threshold of three for both Cycle 1 and Cycle 2. Table 6 presents all efficiency data for both Cycle 1 and 2.

Table 6

Average Time and Screen Transitions to Complete Tasks

Task #	Cycle 1				Cycle 2			
	Mean Time (s) [SD]	Screen Transitions			Mean Time (s) [SD]	Mean Screen Transitions [SD]		
		Optimal	Mean Actual [SD]	Difference		Optimal	Mean Actual [SD]	Difference
Task 1 (Orientation)	316 [56]	14	15 [1]	1	264 [75]	16	19 [2]	3
Task 2 (Chapter 1)	455 [141]	22	23 [1]	1	378 [153]	20	21 [1]	1
Task 3 (Add Goal)	176 [77]	4	17 [10]	13	204 [132]	4	11 [9]	7
Task 4 (PA Session)	62 [27]	9	16 [8]	7	107 [56]	9	20 [9]	11
Task 5 (Track Activity)	77 [28]	3	8 [5]	5	80 [37]	3	10 [5]	7

Note. SD, Standard Deviation; s, seconds

4.2.3 mHealth App Usability Questionnaire

Ease of Use and Interface and Satisfaction

The MAUQ was used to quantitatively analyze the global Ease of Use and Interface and Satisfaction for IBD-Move. Ease of Use (mean [SD]) improved from Cycle 1 (1.93 [0.52]) to Cycle 2 (1.45 [0.21]). Interface and Satisfaction scores also improved from Cycle 1 (1.98 [0.42]) to Cycle 2 (1.15 [0.14]).

4.2.4 Single Ease of Use Question and Net Promoter Score

Single Ease of Use Question

The SEQ was used to determine how difficult participants found each task to complete (Table 7). Participants tended to find tasks more difficult to complete in Cycle 2 than Cycle 1. Only Task 4 (complete PA Session) had a more favourable SEQ score for participants of Cycle 2. Task 3 (Add Goal) was rated most difficult to complete among participants of both Cycle 1 and 2.

Table 7

Single Ease of Use Question

Task #	Cycle 1 Mean [SD]	Cycle 2 Mean [SD]
Task 1 (Orientation)	1.00 [0]	1.25 [0.50]
Task 2 (Chapter 1)	1.50 [0.58]	2.00 [0.82]
Task 3 (Add Goal)	2.50 [1.00]	4.25 [0.92]
Task 4 (PA Session)	2.00 [0.82]	1.50 [0.58]
Task 5 (Track Activity)	2.00 [0]	2.00 [0.82]

Note. SD, standard deviation.

Net Promoter Score

Participants of Cycle 1 gave the IBD-Move app a better NPS than participants of Cycle 2. Cycle 1 had one participant as a promoter and the rest passive for a NPS of 10. In Cycle 2, one participant was a promoter, one was a detractor, and the other two were passive for a NPS of 0.

4.2.5 Usability Problems

A total of 62 issues were uncovered among eight participants over two cycles of testing (Appendix G). Think-Aloud task testing detected 43 of the issues and the post-testing interview uncovered 19. These issues were consolidated into 12 usability problems for Cycle 1 and 13 usability problems for Cycle 2 (Appendix H) which could be classified by the task they appeared in and assigned severity level (Table 8).

Table 8

Usability Problems and Severity Levels per Task

Task #	Cycle 1		Cycle 2	
	# of Problems	Average Severity	# of Problems	Average Severity
Task 1 (Orientation)	2	1.50	2	1.00
Task 2 (Chapter 1)	4	2.00	3	2.33
Task 3 (Add Goal)	3	3.00	3	2.67
Task 4 (PA Session)	2	3.00	2	2.50
Task 5 (Track Activity)	1	2.00	3	1.67

Most Severe Usability Problems

Problems ranking among the highest severity level are presented in Table 9. Cycle 1 revealed two unique problems of severe (3) importance, while Cycle 2 revealed one unique problem of critical (4) importance. Three problems were persistent through both cycles, two of critical importance and one of severe importance. These problems were analyzed according to the task they were present and are described below.

Table 9

Most Severe Usability Problems

Usability Problems	Cycle Occurrence	Task #	Place of Occurrence	UPT Classification		Severity
				Artifact	Task	
Keyboard covers the submit button in Chapter 1 survey, making it difficult to submit survey and move on. In one case, participant clicked the 'X' button, deleting their survey answer, then continued with the task unknowingly.	Cycle 2	2	Chapter 1 Module	Visualness -> Object (screen) layout (FC)	Task-mapping -> Interaction (FC)	4
Trouble finding Physical Activity session from Home Page. Participants were scrolling directly past the module that delivers the session.	Both	4	Home Page	Visualness -> Object Appearance (FC)	Task-facilitation -> Keeping the user task on track (FC)	4
Unable to see written text in "Goal Title" text box until after screen transition.	Both	3	Goals Page	Visualness -> Non-message feedback (FC)	Task-mapping -> Functionality (FC)	4
Trouble finding goals page from the home screen. One participant suggested the icons should be labelled with text.	Both	3	Home Page	Visualness -> Object Appearance (FC)	Task-mapping -> Navigation (FC)	3
Repeat question #1 on Chapter 1 survey. *Fixed after cycle 1*	Cycle 1	2	Chapter 1 Module	(NC)	Task-mapping -> Interaction (FC)	3
Repeat question #2 on Chapter 1 survey. *Fixed after cycle 1*	Cycle 1	2	Chapter 1 Module	(NC)	Task-mapping -> Interaction (FC)	3

Note. UPT, Usability Problem Taxonomy; FC, Full Classification; PC, Partial Classification; NC, Null Classification.

Task 2 (read Chapter 1) resulted in three of the most severe usability problems. Each of these problems were related to the survey questions, delivered twice throughout the module. In Cycle 1, each of the surveys would present twice to each participant, which caused confusion for

the participants and resulted in unnecessary screen transitions to complete the task. These two problems were labeled under the UPT as a *Null Classification* in the artifact component and *Task-mapping, Interaction* in the task component; both were fixed by the development team at Pathverse prior to Cycle 2 beginning. In Cycle 2, the problem of critical importance occurred during both surveys, where the keyboard to enter the participant response would cover the survey's submit button. At best, this would add another step to completion for the participant and at worst, caused the participant to skip the survey altogether by pressing the visible "X" button. This problem was classified under the UPT as *Visualness, Object (screen) layout* in the artifact component and *Task-mapping, Interaction* in the task component.

The problem of critical importance during Task 3 (Add Goal), occurring in both cycles and arose when users attempted to type their goal title into the text box. Despite seeing the visual feedback of typing from the keyboard, the text box would not present any text before pressing submit. This caused users to attempt inputting their goal title multiple times, each time being unable to preview the text they would write. Within UPT, the artifact component of this problem was *Visualness, Non-message feedback* and under the task component, *Task-mapping, Functionality*. The severe problem noted during Task 3 (Add Goal) arose from users simply attempting to navigate to the goals page. The icons that represent the goals page and the tracker page were not immediately intuitive to users, causing them to press random buttons until finding the correct place. The artifact component of this problem was labelled *Visualness, Object Appearance* and the task component labelled *Task-mapping, Navigation.* One user suggested keeping the text that appears on the icon once in the goals page, to clearly direct the participant to their desired destination.

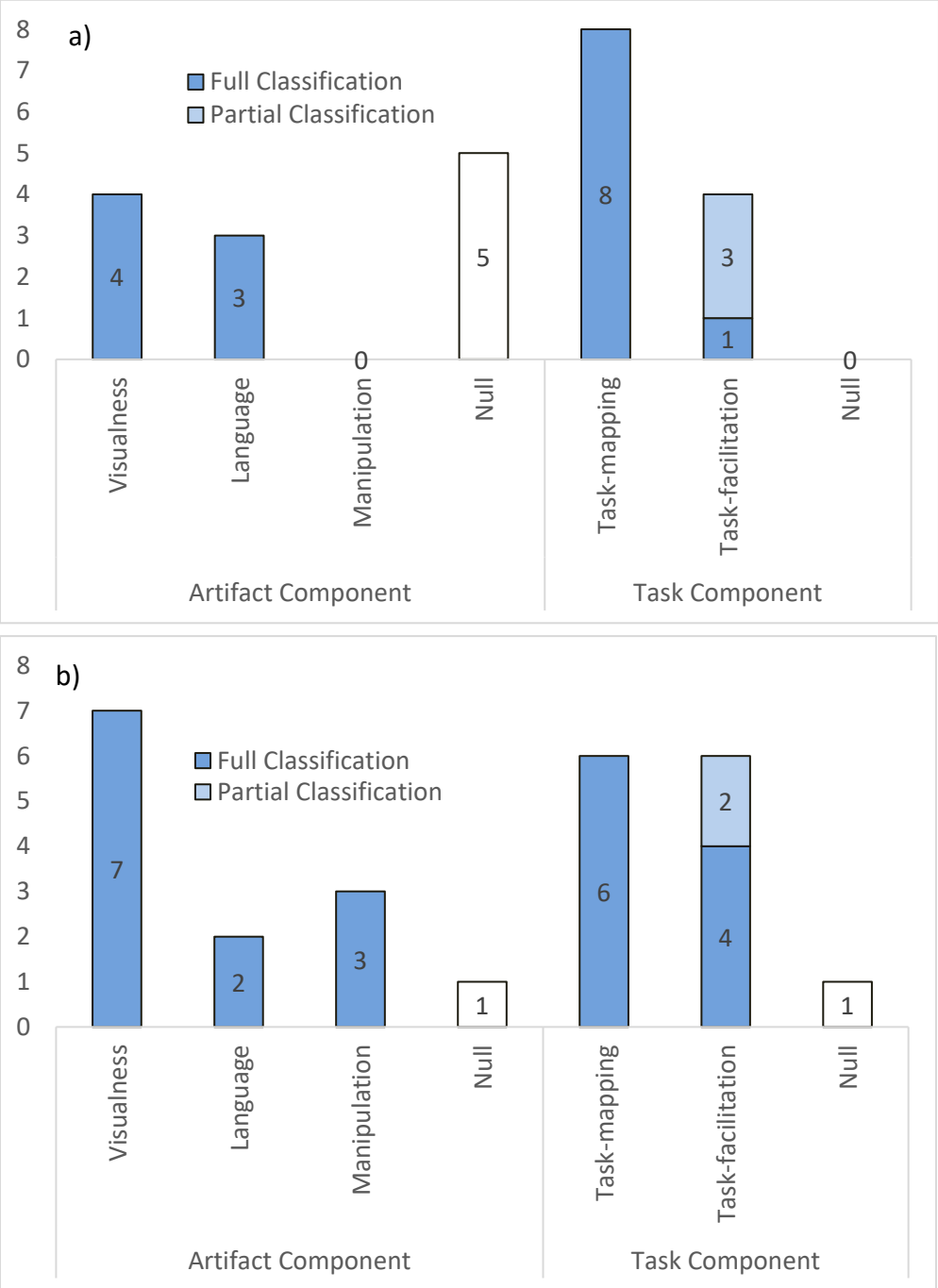
Task 4 (complete PA Session) resulted in one critical usability problem present among both cycles; users were unable to find the physical activity session from the home page when prompted to do so. Users who had difficulty with this task would scroll or swipe directly past the desired module, then navigate to other areas of the app, including the goals page or the trackers page. One participant mentioned the module title was different than what the researcher was asking for. The cue for Task 4 asked the participant to complete the fatigue questionnaire then access the physical activity video, despite them being found in the same module. No other participants had specific mention of confusion. UPT artifact classification for this problem was *Visualness, Object Appearance* and task classification was *Task-facilitation, Keeping the user task on track.*

Usability Problem Taxonomy Classifications

Figure 7 presents the frequency of distributions for primary classifications within the artifact and task components in the UPT for Cycles 1 and 2. *Visualness* represented the most full classifications within the artifact component for both cycles, indicating participants had difficulty with how the app displayed the user-interface objects. Most participants within Cycle 1 had problems related to *Task-mapping*, meaning the problems arose from how the tasks are structured on the system. In Cycle 2, the same number of problems were related to *Task-facilitation* as *Task-mapping*, meaning the system had equal trouble with directing the user along the task pathway and delivering the task in an easy-to-understand structure.

Figure 7

Frequencies of Usability Problem Taxonomy Classifications



Note. Distribution of the Usability Problem Taxonomy classifications per usability problem are separated between Cycle 1 (a) and Cycle 2 (b).

4.4 Acceptability Evaluation

4.4.1 Usefulness

The MAUQ was used to quantitatively assess the global Usefulness of IBD-Move. Usefulness (mean [SD]) improved from Cycle 1 (2.88 [0.82]) to Cycle 2 (1.67 [0.85]).

4.4.2 Theoretical Framework of Acceptability Facets

Facets of acceptability were assessed through yes/no interview questions (Table 10), then were encouraged to explain their reasoning. The full responses that participants gave relating to facets of the TFA can be found in Appendix I. Participants of Cycle 1 were found to unanimously agree that IBD-Move satisfied all seven facets. Participants of Cycle 2 unanimously agreed on five of the seven facets, apart from *Perceived Usefulness/Effectiveness* and *Self-efficacy*. The threshold of >50% was reached in every construct except for *Self-efficacy* in Cycle 2.

Table 10

Interview Responses for Facets of the Theoretical Model of Acceptability

Accessibility Facets	Cycle 1 (n = 4), n [%]	Cycle 2 (n = 4), n [%]
Affective Attitude	4 [100]	4 [100]
Perceived personal usefulness/ perceived effectiveness	4 [100]	3 [75]
Burden	4 [100]	4 [100]
Ethicality	4 [100]	4 [100]
Opportunity costs	4 [100]	4 [100]
Self-efficacy	4 [100]	2 [50]
Intervention coherence	4 [100]	4 [100]

Note. Responses were collected in a yes/no format. Further explanation for the participant response is not displayed in this table.

4.4.3 Acceptability Themes

Participants expressed thoughts, feelings, and concerns throughout testing and post-testing that were related to the acceptability of IBD-Move. This data is presented in Table 11 and can be used to inform future development of the app.

A vast majority of accessibility themes were identified from the text module content (Introduction and Overview, Chapter 1). Participants tended to comment on the content present in the text modules, wherein eight themes were identified regarding the perceived usefulness, relatability, and readability of content. These comments criticizing the content of text modules, indicating some slides should further explain or provide examples to support the available information, the information presented may be stressful for a user's mental health, and the text modules would be skipped altogether if users were using the app out of a research context. The most frequently mentioned theme identified throughout testing was the PA session being too physically demanding. Further comments about the physical activity session include one participant feeling that 10 minutes was a good amount of time to be active for, and another participant feeling there were not enough options from the fatigue questionnaire.

Table 11

General Acceptability Themes

TFA Construct	Description	Positive (+) or Negative (-)	Place of Occurrence	% of participants
Affective Attitude	Likes the idea of being able to set goals on the app	+	Introduction & Overview Module	13%
Affective Attitude	Agrees with Content. Slide "Make it Pleasurable"	+	Chapter 1	25%
Affective Attitude	Agrees with Content. Slide "Fitting it In"	+	Chapter 1	25%
Affective Attitude	Agrees with Content. Slide "Summary"	+	Chapter 1	13%
Burden	Felt like the content could potentially be harmful to an individual's mental health	-	Chapter 1	13%
Ethicality	Related to Content - Identified with "Physical Activity and IBD" slide	+	Introduction & Overview	25%
Ethicality	Would like to see mental health resources in the app	-	Chapter 1	13%
Ethicality	Related to Content - Identified with "First Steps" slide	+	Chapter 1	13%
Ethicality	Identifies with being affected by Fatigue and Stress, feels like PA could help. Slide "Benefits of PA"	+	Chapter 1	25%
Intervention Coherence	Content is easy to read and not too long	+	Chapter 1	13%
Intervention Coherence	Would like examples of exercises that are most helpful – Slide "Can You Exercise?"	-	Chapter 1	13%
Intervention Coherence	Expand on "reduces GI symptoms – Slide "Benefits of Physical Activity"	-	Chapter 1	13%

Opportunity Costs	The text modules were unimportant to the user, they would have skipped them in a real scenario	-	Chapter 1	25%
Perceived Effectiveness	Felt like the workout was too physically demanding	-	Physical Activity Video	38%
Perceived Effectiveness	Felt like there were limited options in the fatigue questionnaire	-	Fatigue Questionnaire	13%
Self Efficacy	10 minutes was a good amount of time to engage in physical activity	+	Physical Activity Video	13%

Note. TFA, Theoretical Framework of Acceptability.

4.5 Changes Made Between Cycles

Following the completion of Cycle 1 testing, several changes were implemented to improve the user experience and content clarity before proceeding to Cycle 2 (for screenshots depicting changes see Appendix D). However, some problems were unable to be fixed between Cycle 1 and 2, as more time and resources were required than were available. For Task 1 (complete Orientation), a simple adjustment of text was made to the “Weekly Lessons” slide adjusting the text positioning in the "Weekly lessons" section. Moreover, instructions were included to guide users on how to add goals and track activity, resulting in two new additional screen transitions. Task 2 (read Chapter 1) had small changes including the revision of pictures and text, and an app error that duplicated the two embedded surveys within the module was fixed, resulting in two fewer screen transitions. No changes were made to Task 3 (Add Goal). For Task 4 (complete PA Session), the title of "IBD-Move Day 1" was modified to “Physical Activity Session” to better align with what was being asked of the participant, and descriptions were added to exercise sessions to further define fatigue levels. No changes were made to Task 5 (Track Activity). These iterative changes aimed to refine the overall functionality and user engagement of the platform.

Chapter 5 Discussion

5.1 Summary and Interpretation of Findings

This study evaluated the usability and acceptability of IBD-Move, a JITAI mHealth app designed to support PA engagement among individuals with an IBD. The mixed methods approach provided a comprehensive understanding of the app's performance, combining quantitative metrics such as TCR, efficiency measures, and MAUQ scores with qualitative insights from user feedback.

The findings of this study partially supported the hypotheses outlined in Chapter 1. The first hypothesis indicated that participants would find the app usable based on task completion rates above 70% per participant (TCR_p) and per task (TCR_t). Further, the app would be efficient based on requiring equal to or less than three additional screen transitions per task. This was confirmed by the high TCR_p, with all but one participant achieving the threshold; high TCR_t, with all tasks achieving threshold; and favourable MAUQ scores, wherein both *Ease of Use* and *Interface and Satisfaction* scores remained below 2.50 among both cycles. However, the hypothesis that efficiency of task completion would be kept within three additional screen transitions per task above the minimum possible was partially challenged, as more screen transitions were observed in Task 3 (Add Goal), Task 4 (complete PA Session), and Task 5 (Track Activity), indicating room for improvement in streamlining navigation. The second hypothesis, which anticipated a high degree of acceptability based on a MAUQ *Usefulness* score below 2.50 and a majority of participants (>50%) responding positively to the seven facets of the TFA, was also mostly supported. MAUQ *Usefulness* scores for Cycle 1 were not favourable, however scores for Cycle 2 were. The TFA facets mostly met threshold, with the only exception being that of the construct *Self-efficacy*, which had a 50% approval rate in Cycle 2. Overall, the

study's findings provide actionable insights for further enhancing the IBD-Move app's design and functionality.

Usability

The IBD-Move app demonstrated strong usability, with most participants achieving a 100% TCR_p. Task 3 (Add Goal) yielded the most frequently problematic results among the quantitative analyses, having the lowest TCR_t, many errors, highest discrepancy of screen transitions in Cycle 1 and second highest in Cycle 2, and the highest score on the SEQ among both Cycles. Task 4 (complete PA Session) was unable to be completed by one participant, four others had difficulty, and had the highest discrepancy in screen transitions for Cycle 2, suggesting challenges. Efficiency metrics revealed that Task 2 (read Chapter 1) required the most time and actual screen transitions to complete among participants of both cycles, which is related to the high number of optimal screen transitions and time-consuming nature of the task (reading and commenting on literary content). This result may still suggest room for streamlining, especially since some participants felt they would not want to access the literary content in a real-life use-case. The MAUQ scores indicated high *Ease of Use* and *Interface and Satisfaction* of IBD-Move for both cycles, with scores improving from Cycle 1 to Cycle 2. The NPS suggested that participants were generally passive in their likelihood to recommend the app, with a small preference for participants in Cycle 1.

A total of 62 usability issues were identified and consolidated into 12 usability problems for Cycle 1 and 13 usability problems for Cycle 2. The most problems were located during Task 2 (read Chapter 1), but the highest severity of problems was in Task 3 (Adding Goal). Among UPT classifications, artifact components of usability problems were mostly classified under *Visualness*, and task components were classified under *Task-mapping*, which indicates the

problems with IBD-Move are related to how the user interface looks and how user tasks are structured within the system. These findings are consistent with studies that identify visual feedback and intuitive task flow as critical factors in mHealth app usability (Fontecha et al., 2023; Georgsson & Staggers, 2016).

The Pathverse platform has been used to develop and deliver a multitude of mHealth apps which have undergone various methods of usability testing (Cheung et al., 2024; Grieve et al., 2025; Jibb et al., 2023; Tang et al., 2025; Willms et al., 2023). Similar to the current study, these usability tests incorporated mixed methods for comprehensive examination of user feedback. Two of these studies (Jibb et al., 2023; Willms et al., 2023) conducted usability testing over multiple cycles. A Think-Aloud task or scenario-based test was conducted in each study, then followed by a semi-structured interview to collect qualitative data, with the exception of one study (Grieve et al., 2025) which conducted a task-based focus group to collect usage data. All studies used thematic analysis to analyze qualitative data, of which only two (Cheung et al., 2024; Jibb et al., 2023) used standardized procedures. One study coded usability problems derived from thematic analysis (Grieve et al., 2025) to a heuristic evaluation and assigned severity scores, which further defined the usability problems identified by testing. Quantitatively, most studies exclusively used validated questionnaires (mHealth App Usability Questionnaire or System Usability Scale) to assess usability. One study (Cheung et al., 2024) collected task success rate and task time data, and another (Grieve et al., 2025) study recorded expected and actual screen “taps” required to complete tasks, although this metric was not used to evaluate usability. The current study of IBD-Move synthesized many of the above methods used to assess mHealth apps developed using Pathverse, building on previous work in the field and providing foundation for future usability testing within the Pathverse platform.

Acceptability

IBD-Move was received as an acceptable intervention based on *Usefulness* scores on the MAUQ among participants of Cycle 2 but not Cycle 1. Conversely, facets within the Theoretical Model of Acceptability demonstrated high perceptions of acceptability among participants in Cycle 1 but not Cycle 2. The exceptions within Cycle 2 were *perceived personal usefulness/perceived effectiveness* and *self-efficacy*. These contradictory results underscore the need for further acceptability evaluation among future iterations of the IBD-Move app. Furthermore, participants expressed the tailored approach to promoting PA and relevance of literary content to the experience of IBD but expressed concerns about the physical demands of the activity sessions and need for further information and resources in the app.

Previous mHealth apps developed using Pathverse have assessed acceptability in a similar manner to the current study. One study (Willms et al., 2023) also used the *Usefulness* scores of the MAUQ to quantitatively assess acceptability. Another study (Cheung et al., 2024) used the User Acceptance Questionnaire (Cheung et al., 2018), developed in a previous study by the same research team. User acceptance and acceptability were used interchangeably within this study, however the facets used to define user acceptance are in contention with the facets used to define acceptability in the current study. User acceptance was assessed based on *attitude*, *perceived ease of use*, *perceived usefulness*, *intention to use*, and *satisfaction*. Namely, *ease of* use and *satisfaction* are items that are generally used to define usability (Zapata et al., 2015) and as such, may cause confusion when also used to assess acceptability. The Theoretical Model of Acceptability was used in the current study to assess acceptability for its relevance and extensive use in healthcare interventions (Sekhon et al., 2017). Due to the clear differentiation the Theoretical Model of Acceptability makes between usability and acceptability, it is

recommended that this model is used in future acceptability assessments of mHealth apps developed with Pathverse.

5.2 Study Implications

The findings of the current study have several implications for the design, development, and implementation of the IBD-Move app and associated research. First, the usability problems should be addressed in future iterations of the app, preparing the app for a feasibility study. For example, during Task 3 (Add Goal), participants struggled to locate the goals tab due to unclear visual cues (*Visualness*) and navigation issues (*Task-mapping*). A fix could involve redesigning the interface to make the PA session more visually distinct and ensuring intuitive navigation pathways. Seeing as *Visualness* and *Task-mapping* were two prominent classifications of problems, future iterations of IBD-Move should focus on improving the visual representation of core app functions and optimizing task mapping within the system.

Second, the no-code mHealth development platforms can make it easier to improve the usability issues discovered in apps. Platforms like Pathverse provide an accessible way to develop and test app prototypes. Researchers can create and adjust an intervention independent of a development team, serving as an immense cost and time saving measure. The drawback, however, is a lack of flexibility for researchers to make changes to their app. Future intervention designs could incorporate other features available through Pathverse such as gamification. Gamification, through elements like progress tracking, rewards, and challenges, has been shown to increase motivation and adherence to health interventions by making the experience more interactive and enjoyable (Johnson et al., 2016; Tang et al., 2025).

Finally, the mixed-methods approach used in this study provides a robust and comprehensive evaluation by integrating quantitative metrics with qualitative insights, as is

recommended and used frequently in mHealth usability studies (Johnson et al., 2020; Zapata et al., 2015). This dual perspective allows for a deeper understanding of user experiences, capturing not only measurable outcomes but also the contextual nuances that influence app performance and the user experience. Additionally, conducting multiple cycles of testing allowed for improvements. Iterative processes lead to improved applications, as changes aimed at resolving one issue may inadvertently address or reveal others, fostering continuous refinement (Zapata et al., 2015). These methods can serve as a blueprint for other researchers developing mHealth interventions, particularly for populations with chronic conditions like IBD.

5.3 Strengths and Limitations of the Current Study

Strengths

The use of a variety of standardized usability testing (i.e. Think-Aloud method and UPT and FA) protocols and mixed methods design ensured rigorous data collection and analysis. The inclusion of individuals with IBD in the usability testing process ensured that the app's design and functionality were tailored to the specific needs of this population. An even number of people with Crohn's disease and Ulcerative Colitis participated in this study, aiding the case for generalization among the two distinct subgroups of IBD.

Limitations

The sample size (n = 8) was adequate for the purposes of this study, however with a larger sample size statistical comparisons between quantitative measures could be made, which would add greater insight to the usability metrics. Further, this study exclusively used subjective measures of usability testing, which threatens the reliability of the results due to participant bias and influence of the Hawthorne effect. Another limitation is a lack of ethnic demographic diversity of participants, limiting the generalizability of the findings. Moreover, the short

duration of the usability testing may not fully capture the long-term usability and effectiveness of the app, and the controlled environment of the testing sessions may not reflect real-world usage patterns. Finally, the timely aspect of IBD-Move's JITAI feature was not able to be tested in this study due to the logistical challenge of the participant needing to pre-set a time for the PA session module to appear.

5.4 Future Research Directions

The findings of this study highlight several areas for future research. Longitudinal studies are recommended to evaluate the long-term usability, effectiveness, and real-world application of IBD-Move. Future usability tests should also evaluate the JITAI feature in its entirety. Larger and more diverse sample size is needed to enable statistical comparisons and enhance the generalizability of results. Finally, a feasibility study is essential to assess the app's ability to improve physical activity levels and health outcomes, such as fatigue and disease activity, in individuals with IBD. These steps will strengthen the evidence base for IBD-Move and inform the development of more effective mHealth interventions for chronic disease management.

Chapter 6 Conclusion

The purpose of this study was to evaluate the usability and acceptability of IBD-Move, a JITAI-based mHealth app designed to support PA engagement among individuals with an IBD. The IBD-Move app consists of literary chapter content grounded in the M-PAC framework, with incorporated behavioural change techniques such as goal setting, activity tracking, and instructional PA sessions that are tailored to the user's momentary level of fatigue. Through a combination of qualitative and quantitative measures, it was determined that usability and acceptability were high among participants, with positive feedback on the app's tailored approach and relevance to the IBD experience. The iterative process of this usability study reinforced the importance of user-centered design in developing effective behaviour change interventions. By collecting input through a mixed-methods approach, this study provided valuable insights into the design and functionality of IBD-Move, identifying key areas for improvement. These findings have informed actionable recommendations for refining the app, ensuring it better meets the needs of its target users.

Quantitative results demonstrated improvements from Cycle 1 to Cycle 2, with higher task completion rates overall, though Tasks 3 (Add Goal) and 4 (complete PA Session) continued to exhibit errors and inefficient screen transitions. Several key refinements were made between cycles to enhance usability: for Task 1 (complete Orientation), text positioning in the "Weekly Lessons" section was adjusted, and new instructions were added to guide users in adding goals and tracking activity. In Task 2 (read Chapter 1), images and text were revised, and a technical error duplicating embedded surveys was fixed, reducing unnecessary screen transitions. For Task 4 (complete PA Session), the title was updated to "Physical Activity Session" for clarity, and exercise descriptions were added to better define fatigue levels. These

iterative changes contributed to improved usability scores in both *Ease of Use* and *Interface and Satisfaction*, as well as higher *Usefulness* scores. While some challenges remained, particularly in Tasks 2, 3, and 4 regarding *Visualness* and *Task-mapping*, the modifications made helped refine functionality and user engagement.

The development process used in this study has enhanced the quality of IBD-Move, laying a strong foundation for future iterations and scalability. By addressing the identified usability issues and incorporating advanced features such as gamification and AI chatbots, IBD-Move has the potential to become a more engaging and effective tool for promoting PA among individuals with IBD. This research underscores the value of iterative design and mixed-methods evaluation in creating user-friendly and impactful mHealth interventions, ultimately contributing to improved health outcomes for individuals living with chronic conditions.

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Appendix A

Treatment for IBD

Pharmacological

Pharmacological therapies most often used for the management of IBD are anti-inflammatory drugs and immunomodulators. 5-Aminosacilytes (5-ASA) are typically used to treat UC, and sometimes colonic CD (Bernstein, 2015). Although 5-ASA has proven benefits for patients with an IBD, its usefulness for both acute and maintenance stage treatment is sometimes minimal, notwithstanding some common (yet not serious) side effects and allergic reactions to the drug (Gisbert et al., 2002). Corticosteroid treatment can be more effective compared to 5-ASA in achieving remission when a patient is in acute stage IBD, however, they are known to have more severe long-term side effects. Concerns of toxicity and increased risk of infection make corticosteroids a short-term IBD solutions therapy (Bernstein, 2015). Maintenance of remission can be achieved by thiopurines, which have been proven effective for both UC and CD (Khan et al., 2011). Thiopurines are cost-effective, and have a low risk of side effects, leading clinicians to continue their prescription as a leading therapy (Bernstein, 2015). Anti-tumor necrosis factor (Anti-TNF) therapies are a relatively recent advancement in IBD therapy, now used commonly for acute and maintenance of both UC and CD. Combining the use of thiopurines and Anti-TNF agents is a common treatment practice, as it has shown greater efficacy in achieving remission without complications in both UC and CD (Frédéric Colombel et al., 2010; Panaccione et al., 2014).

Diet

Diet is an environmental factor that is theorized to have a great impact on the development and management of IBD. Recent epidemiological studies show incidence and prevalence of IBD is highest in industrialized nations, leading researchers to believe a connection

exists between IBD development and a more ‘Westernized’ lifestyle and diet (Kaplan et al., 2019; Ng et al., 2017). With regards to management of presently diagnosed IBD, dietary interventions aim to create a healthy enteric environment to limit inflammation caused by foods to induce remission or reduce relapse of IBD (Saha & Patel, 2023).

Several diets have been proposed as beneficial, however higher-quality intervention studies are needed to confirm the efficacy of diets among different demographics within the IBD population (Hou et al., 2014). Exclusive enteral nutrition (EEN) is a strategy that has shown low-quality evidence for inducing remission of pediatric and adult CD (Narula et al., 2018). EEN involves feeding exclusively through a nasogastric tube to administer a personalized formula of elemental (single amino acids), oligopeptide (approximately 4-5 amino-acid chains), or polymeric (whole food) diets. Low adherence to the EEN is a challenge due to the intolerable nature of the intervention. This has led to the development of more palatable nutrition strategies that use partial enteral nutrition (PEN), a plan that allows the regular ingestion of some foods while supplemented by a feeding tube. Early evidence suggests PEN may be just as efficacious and more tolerable than EEN, however more research is needed to confirm this comparison (González-Torres et al., 2022). Dietary interventions such as the simple carbohydrate diet, Low FODMAP (low in fermentable oligosaccharides, disaccharides, monosaccharides and polyols) diet, plant-based diets, and low-inflammatory diets allow the patient to ingest entirely solid foods and are thus preferrable to patients, however the efficacy of these strategies is not well understood and must be explored further using high-quality study methods (Saha & Patel, 2023).

Surgery

Surgical procedures are implemented when medical management fails, intending to remove affected areas of the bowel to resolve symptoms and minimize morbidity. The procedure

of choice for emergent operations of UC is a total or subtotal abdominal colectomy with end ileostomy, which aims to remove all or most of the affected colon while leaving opportunity for future reconstructive surgeries. The benchmark elective surgical option for UC is a total proctocolectomy with ileostomy, an established procedure which removes all the colon and rectum (Cohen et al., 2005). Surgical intervention for CD is more variable than UC, as multiple patient and disease factors influence the selection of a most-appropriate procedure (Hwang & Varma, 2008). For CD present within the small bowel, resection is the most common procedure, aiming to only remove affected portions and retain as much healthy bowel as possible. Resection is a point of contention for colonic CD, as evidence for total or segmental colectomy are a point of contention (Hwang & Varma, 2008). As the management of IBD improves, the risk of requiring surgery at 1-, 5-, and 10-years after diagnosis decreases over time, with risk being significantly lower in persons diagnosed after the year 2000 (Tsai et al., 2021).

Complementary and Alternative Medicine

Complementary and Alternative Medicine (CAM) refers to a diverse range of medical and healthcare practices, products, and systems that are used alongside or instead of conventional medicine. A longitudinal study of 309 respondents in Manitoba, Canada with an IBD found the most common CAM services used among their cohort were massage therapy (30%), chiropractic (14%) and physiotherapy (4%); and the most common products used were Lactobacillus acidophilus (probiotics) (8%), fish and other oils (5.5%) and glucosamine (4%) (Rawsthorne et al., 2012). While 74% of respondents had used a CAM over the 4.5 years, only 18% used one specifically to treat their IBD, implying this cohort mostly used CAM to treat other issues they were having.

A systematic review by Langhorst et al. (2015) identified experimental studies (26 RCT and 3 controlled trials) wherein the effect of a CAM was measured among a population with an IBD. Fifteen different herbs and botanicals were examined in 19 studies. Of the reviewed studies, some herbs and botanicals showed evidence for beneficial effects on IBD symptoms, such as wheatgrass juice, cannabis, and aloe vera gel, among others. The minimal evidence for any herbs and botanicals in particular warrants further study to draw conclusions on efficacy, dosage, and use as combination therapy. Langhorst et al., (2015) also reported on studies examining mind-body medicine; lifestyle modification, mindfulness-based interventions, hypnotherapy, and relaxation training, were all found to have one or more beneficial effects for the CAM used. Improvement of psychological factors following mindfulness-based stress reduction interventions was of special notice to Langhorst et al., (2015), as these interventions can reduce acute and prolonged perceived stress, which can be a predictor of disease activity.

Appendix B

IBD-Move Chapter Content

Prelude – Introduction and Overview

Main Objectives: Give background of the creator of the app content and what the user can expect from the app.

BCTs: 9.1. Credible Source

Content
1[Welcome to IBD-Move!] This is your app to learn how to use physical activity to improve your physical, mental, and emotional life living with an IBD.

2[My Name is Cameron] I created this program as part of a Master's Thesis to help people like myself get and stay active. With a Bachelor degree in Kinesiology and certification as an exercise professional, I have taught all kinds of people why and how to be physically active. / My work has included sports-specific and general movement literacy for youth, training specialized clients in a clinical setting, and creating group exercise programs for working adults with movement dysfunctions.

3[My Experience with IBD] In 2015, I was diagnosed with Crohn's disease. The abdominal pain was intense, and the fatigue left me feeling dreadful day after day. After trying several treatment avenues, I finally reached remission and found stable ground.

4[Physical Activity with IBD.] Throughout my experience with Crohn's, I noticed that managing to get up off the bed to move around a bit worked wonders for my physical, mental, and emotional health. / Being in a rut meant not moving for days, even weeks at a time because I felt incapable due to my disease. While in that state, it was difficult to remind myself that movement was not only good for my body, but it was what my body craved. However, even in remission, my Crohn's has lingering symptoms.

5[Supported by Science.] Being active is widely among current research as a way to improve the quality of life for people of all kinds. IBD is no different! A growing body of evidence has supported physical activity as being safe for those with an IBD and can improve many symptoms of the disease.

6[The Goal of IBD-Move.] Simply put: to get people struggling with an IBD more physically active for healthier and happier living. Now, healthy and happy living means something different for everyone, and so does getting active. IBD-Move aims to lead its users through the basics of physical activity, so at the end of the program, everyone realizes their own drive for being active and a way to find true joy in movement.

7[Weekly Lessons] There will be a text module available every week that will give you information on how to get and stay active, which will be presented in a slide format, like this Introduction module. We will cover all kinds of information relating to physical activity; when to do it, where to do it, why to do it, how to do it, and who to do it with!

8[Exercise Sessions] You will have one exercise session available to you each day. The neat thing about this program is that you can tell IBD-Move how fatigued you feel when you sign in, and the app will give you a physical activity session based on your current fatigue level.

9[Time to Begin.] Your first lesson is available! I hope you enjoy the program and please feel free to reach out should you ever feel stuck, demotivated, or need someone to talk to. Good luck and have fun!

Chapter 1 – Getting Active with an IBD

Main objectives: Bolster reflective processes to solidify the intention to exercise. This chapter intends to affirm the belief that people with an IBD should be physically active by providing positive information regarding outcome expectancies and task self-efficacy. Users will be asked to think about what they find pleasurable about physical activity and when they can fit it into their schedule.

BCTs: 5.1, Information about health consequences; 15.1, Verbal persuasion about capability; 13.2, Framing/Reframing; 14., Action Planning

Content

1[First Steps] You may be nervous to start getting active again, or for the first time ever. That is absolutely normal. My job is to make this transition to a more active you as easy as possible. / "The secret of getting ahead is getting started." -Mark Twain

2[Can You Exercise?] The short answer is yes. Some people living with IBD might avoid anything physically demanding for fear it might not be safe but, a great amount of support from academic literature suggests that physical activity is safe for people with an IBD and can even lessen some symptoms of IBD (Baker et al., 2022; S. P. Davis et al., 2022).

3[Benefits of PA] These are some of the beneficial impacts physical activity can have on people with an IBD:

- Increases overall quality of life
- Decreases stress
- Improves energy
- Improves sleep quality
- Reduces gastrointestinal symptoms
- Improves weight control
- Reduces physical and mental fatigue

Take a moment to reflect on your own experience. Are any of these areas where you would like to see improve?

4[You Are Capable!] People with an IBD often fall out of activity after getting their diagnosis, perhaps feeling unable to start again, and not knowing where to begin. If you are feeling this way, know that it is absolutely normal. / Research has shown that people with an IBD can feel this way, and then go on to make amazing strides of improvement for their physical and mental symptoms just by engaging in a physical activity program. You are no exception!

5[Make it Pleasurable] Humans are built to move. Many people even experience joyful feelings when getting active. Whether it is being able to join your friends in your favourite sport, trying new things without being limited, or just feeling good after a workout. / Throughout IBD-Move, you will get to know what healthy, active living means to you. Take a second to think about what you might like about physical activity.

6[*Survey Card*] What do you find pleasurable about being active?

7[Fitting it in] Ideally, we should set some time aside to perform some kind of physical activity many times per week. It doesn't have to be intense, heart-pounding exercise, just light stretching and body check-ins are all that is needed some days. Finding a time that works best with your schedule and natural energy levels is a good place to start. / Do not worry if you miss some days, or if some days just don't work for you. All you can ask from yourself is to try to fit it in when it makes sense for you.

8[The Ideal Time] Choose a time around any other routinely scheduled tasks for the day. Many people find success in exercising either before or after their workday. The idea is to find the time of day you would be most open to initiating activity. / If you tend to have more energy in the morning, choose to exercise before work. If you have more energy later in the day, choose to exercise after work. You may need to do some fine-tuning, but with time, you will find the time that works best for you.

9[*Survey Card*] When do you think would work best for you to fit in 10-20 minutes of daily activity? (You can always change this later!)

10[Summary] Engaging in regular physical activity can be an understandably daunting task for people with an IBD. Importantly, getting active has been shown to be safe, and can even provide numerous physical and mental benefits. / The key to being open to exercise is realizing the usefulness and joy that can come from it. Notice the positive effects getting active can have on your body and find the best time for you to practice regularly.

11[Next Chapter] We will go over some strategies to help you stay consistent with your exercising and some things to think about as you go about this lifestyle change.

Appendix C

IBD-Move Exercise Session Outlines

BCTs: 4.1, Instruction on how to perform the behaviour; 6.1, demonstration of the behaviour; 8.1, Behavioural practice and rehearsal

Questionnaire Modules

Module Details

Title: Day X - Fatigue Questionnaire

Keywords:

Description: Fill out your fatigue questionnaire here for IBD-Move to give you today's personalized exercise session.

Custom End Card

Title: Return to the Home Page

Description: That is where you will find the module that contains your personalized exercise video for today. See you there!

Release Date and Time

Date: X-1

Time: 12:00am

Notification Details

Title: IBD-Move - Day X, Available Now!

Body: Sign in when you are ready to exercise. Fill out the fatigue questionnaire to access your recommended routine.

Exercise Video Modules

Module Details

Title: ___ Fatigue Session - Day X

Keywords:

Description: Swipe to access your exercise routine for today in either video or pdf format.

Custom End Card

Title: Well Done!

Description: Be sure to add this activity to your Exercise Logging page. See you next time!

Set 1

Fatigue Level 5 / Breathing and Mindfulness / 10min

Supine Belly Breaths – 2min

- Lie on back with knees bent so feet are flat on the floor.
- Place one arm across chest, and the other across belly.
- Breathe deeply into abdomen, feel it expand your entire mid-section: front, sides, and back.
- Exhale slowly and with control.
- Switch arm positions and repeat.

Straight Leg Raise – 2min

- Lie on back with legs extended on the ground and arms slightly removed from sides.
- Push into the ground with arms and non-moving leg to create stability.
- Lift leg into the air, keep hips level with the ground.
- Hold at highest point for 3-5 seconds, then slowly lower.
- Switch and repeat for desired number of repetitions.

Overhead Extension – 2min

- Lie on back with legs extended on the ground and arms slightly removed from sides.
- Push into the ground with arms and non-moving leg to create stability.
- Lift leg into the air, keep hips level with the ground.
- Hold at highest point for 3-5 seconds, then slowly lower.
- Switch and repeat for desired number of repetitions.

Half Roll Rotations – 2min

- Lie on back with legs extended on the ground and arms slightly removed from sides.
- Push into the ground with arms and non-moving leg to create stability.
- Lift leg into the air, keep hips level with the ground.
- Hold at highest point for 3-5 seconds, then slowly lower.
- Switch and repeat for desired number of repetitions.

Prone Belly Breaths – 2min

- Lie on stomach with legs straight and hands stacked under your forehead.
- Feel your body's strength maintaining good posture, staying firm but not tense.
- Breathe in deeply through nose and into abdomen, feel it expand your entire mid-section: front, sides, and back.
- Exhale slowly and with control.
- Repeat at your own pace.

Fatigue Level 4 / Active Mobility / 10min

Bird-Dog – 2min

- Start in a quadruped position.
- Extend one leg behind you. Keep your hips level and squeeze your glute to lift.

- At the same time, lift your opposite arm. Keep your shoulders level and feel the movement originate from your shoulder blade.
- Inhale towards neutral, exhale towards extension.

Quadruped Rotations – 2min

- In a quadruped position, reach one arm under the other. Feel like you are pushing your shoulder through the gap.
- Hold for 3-5 seconds, breathe.
- Unravel yourself and reach upwards. Watch your hand as you rotate.
- Hold for 3-5 seconds, breathe.
- Repeat a few times then switch sides.

Child's Pose to Cobra – 2min

- In a quadruped position, rock your hips back to your heels. Relax your shoulders, lower your head and chest.
- To transition, rock forward so more weight is supported by your upper body. Keep shoulders back and down - and strong. Relax hips to the ground. Squeeze glutes, lift head.
- Repeat the transition between these poses while breathing throughout.

Half-Kneeling Praise – 2min

- In a half-kneeling position, fold over your front knee.
- Explore movement in this position, tilt hips, nod head, and push hands into the ground. Hold position for 5-10 sec.
- Extend upwards and reach, maintaining balance and comfort during movement.

Half-Kneeling Ankle Mobility – 2min

- In an open half kneeling position, remain tall as you move your knee forward past your toes.
- Keep knee tracking in line with your toes or slightly outside.
- Hold at end range for 3-5 seconds, then return.
- Either perform another rep or switch sides and repeat.

Fatigue Level 3 / Mixed Exercise / 10min

Steps – 2min

Level 1 – Marching

Level 2 – Knee-ups

Level 3 – High-Knees

Punch Combo – 2min

Level 1 – Front Step

Level 2 – Knee

Level 3 – Kick

Mountain Climbers – 2min

Level 1 – Incline

Level 2 – Elbows

Level 3 – Hands

Squats – 1min

Level 1 – Assisted

Level 2 – Regular

Level 3 – Weighted

Superman's – 1min

Level 1 – Holds

Level 2 – YTWA's

Level 3 – Sweeps

Lunges – 1min

Level 1 – Assisted

Level 2 – Alternating

Level 3 – Split Squat

Push-ups – 1min

Level 1 – Pike

Level 2 – Kneeling

Level 3 – Regular

Fatigue Level 2 / Mixed Exercise / 15min

Steps – 3min

Level 1 – Marching

Level 2 – Knee-ups

Level 3 – High-Knees

Punch Combo – 3min

Level 1 – Front Step

Level 2 – Knee

Level 3 – Kick

Mountain Climbers – 3min

Level 1 – Incline

Level 2 – Elbows

Level 3 – Hands

Squats – 1min30sec

Level 1 – Assisted

Level 2 – Regular

Level 3 – Weighted

Superman's – 1min30sec

Level 1 – Holds

Level 2 – YTWA's

Level 3 – Sweeps

Lunges – 1min30sec

Level 1 – Assisted

Level 2 – Alternating

Level 3 – Split Squat

Push-ups – 1min30sec

Level 1 – Pike

Level 2 – Kneeling

Level 3 – Regular

Fatigue Level 1 / Mixed Exercise / 20min

Steps – 4min

Level 1 – Marching

Level 2 – Knee-ups

Level 3 – High-Knees

Punch Combo – 4min

Level 1 – Front Step

Level 2 – Knee

Level 3 – Kick

Mountain Climbers – 4min

Level 1 – Incline

Level 2 – Elbows

Level 3 – Hands

Squats – 2min

Level 1 – Assisted

Level 2 – Regular

Level 3 – Weighted

Superman's – 2min

Level 1 – Holds

Level 2 – YTWA's

Level 3 – Sweeps

Lunges – 2min

Level 1 – Assisted

Level 2 – Alternating

Level 3 – Split Squat

Push-ups – 2min

Level 1 – Pike

Level 2 – Kneeling

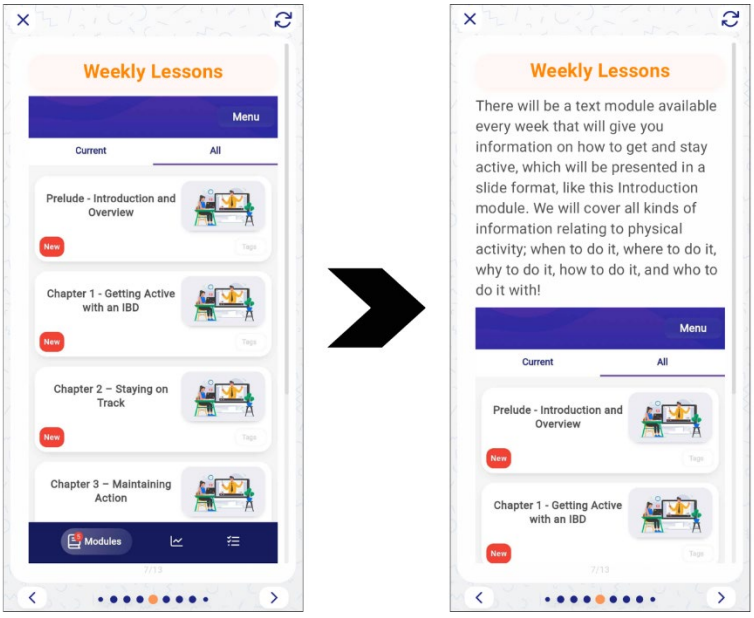
Level 3 – Regular

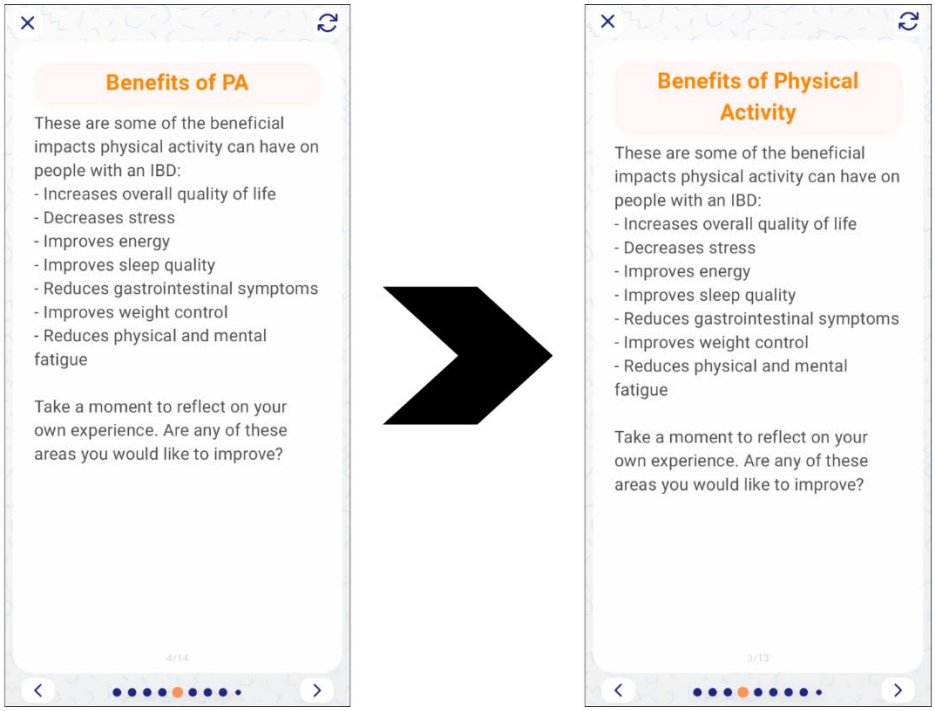
Appendix D

Changes Following Cycle 1

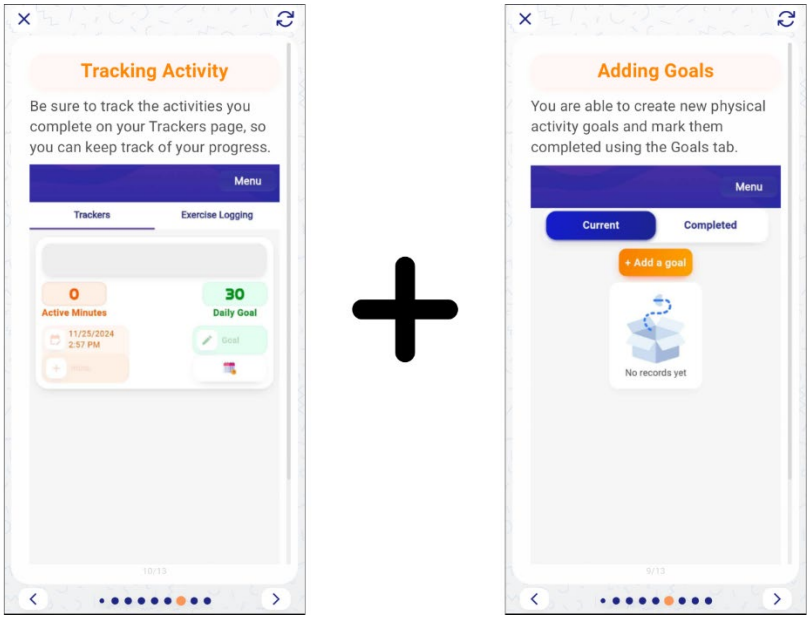
Task 1 (complete Orientation)

1. *Switch text position in "Weekly lessons"*



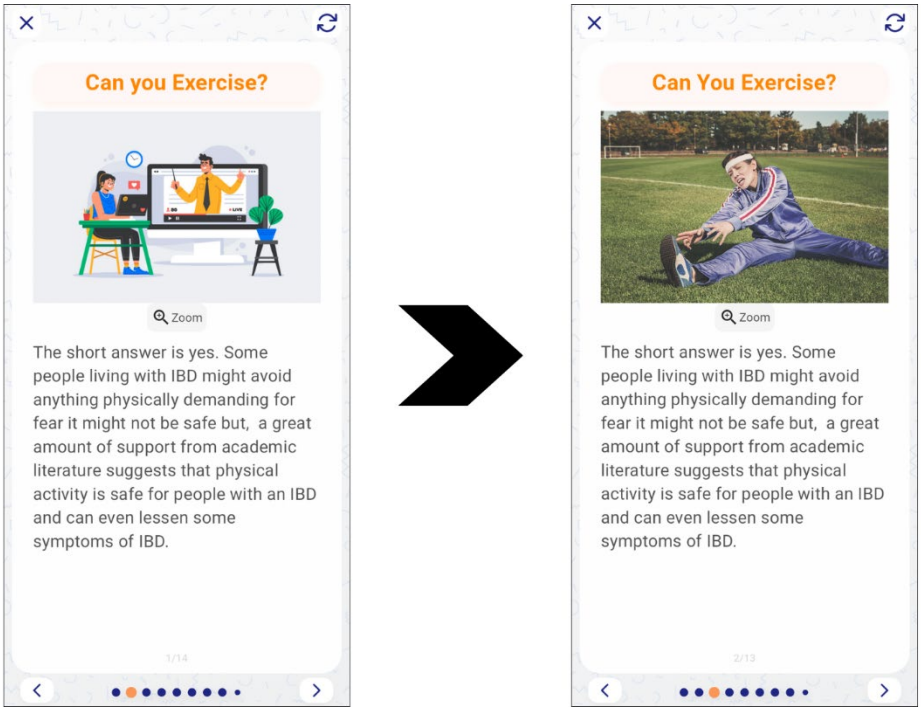


2. *Include instruction to find adding goals and tracking activity*

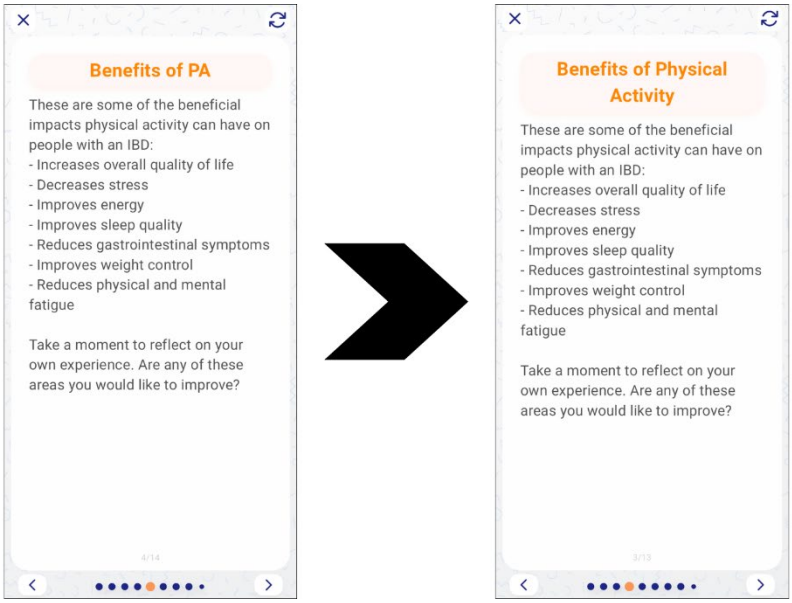


Task 2 (Chapter 1)

1. *Added missing picture to "Can you Exercise" slide*



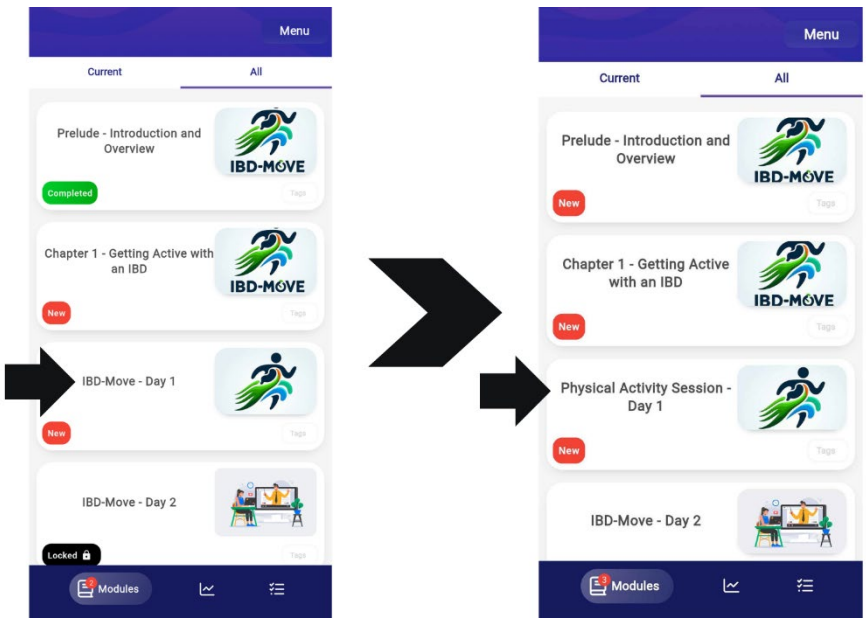
2. *Change PA to Physical Activity on "Benefits of PA" card*



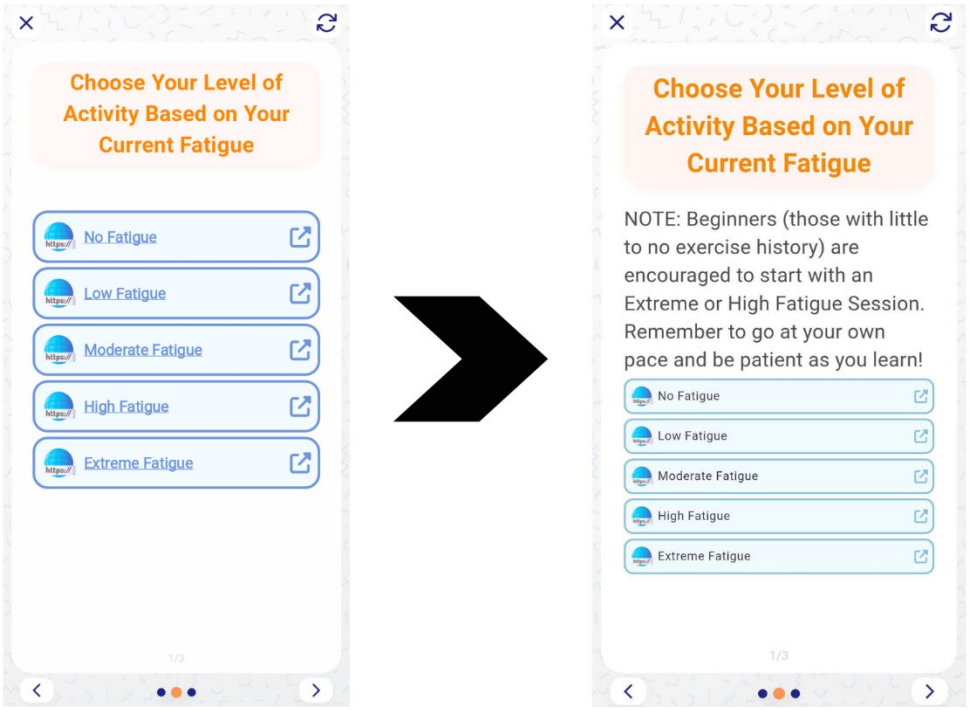
3. *Fixed questionnaire duplication (Unable to be visually represented)*

Task 4 (complete PA Session)

1. *Changed title of "IBD-Move Day 1" to "Physical Activity Session – Day 1"*



2. *Added description to exercise sessions (fatigue levels)*



Appendix E

Usability Questions

Q1: Is it easy to navigate through the app?

Q2: How easy was it for you to learn how to use the app?

Q3: Were you able to move through the app efficiently?

Q4: What lessons can you remember from Chapter 1?

Q5: Did you notice any errors while using the app?

Q6: Were you satisfied with how the app performed?

Acceptability Questions

Q7: How much did you like the IBDMove app? [Affective Attitude]

Q8: Do you believe that using the IBDMove app would help you get more physically active? [Perceived personal usefulness/ perceived effectiveness]

Q9: Did you find the IBDMove app time-consuming? [Burden]

Q10: Do you think anyone could use this app? [Ethicality]

Q11: Do you think using the IBDMove app would interfere with anything else important to you? [Opportunity costs]

Q12: How confident were you about using the IBDMove app? [Self-efficacy]

Q13: Was it clear to you how to use the IBDMove app and how it worked? [Intervention coherence]

Concluding Questions

Q14: Is there anything else you would like to add, or feel is important to say?

Appendix F

Framework Analysis

Stage 1: Familiarizing oneself with the data

The first step to Framework Analysis is for the researcher to become familiar with the data collected through the Think-Aloud tasks and interview transcriptions by reading the text results. This step does not have a standardized completion metric, the researcher moves to stage 2 when they feel comfortable with the data.

Stage 2: Identifying themes or a framework to be used

Themes were identified using triangulation of inductive and deductive analysis. Inductive analysis involves the researcher grouping data from all sources (Think-Aloud, interviews, and questionnaires) into themes based on their familiarity within Stage 1 of Framework Analysis. Deductive analysis involved grouping problems into themes defined by the Usability Problem Taxonomy. A list of inductively and deductively generated themes will then be synthesized. Usability problems that were identified by both methods still only count as one problem identified by the respective participant.

Stage 3: Indexing and applying the framework to the data

Usability problems identified using deductive reasoning were already classified under the Usability Problem Taxonomy. As such, this stage involves further classifying the unique usability problems as identified through inductive analysis under the Usability Problem Taxonomy. Full, partial, or null classifications (FC, PC, or NC) were given to all problems as an artifact component (Visualness, Language, and Manipulation) and a task component (Task-mapping and Task-facilitation). The severity of each problem were then rated according to the procedure described below.

Severity ratings were based on a procedure by Travis (2009), wherein three questions are asked to determine the severity of issues: (1) “Does the problem occur on a red route (the most consistent/critical user pathways)?”, (2) “Is the problem difficult for users to overcome?”, and (3) “Is the problem persistent (meaning the problem occurs repeatedly across the user interface)?”. Based on these questions, problems are defined as having a low, medium, serious, or critical influence on usability, where these classifications are decided based on the decision tree illustrated by Figure 5.

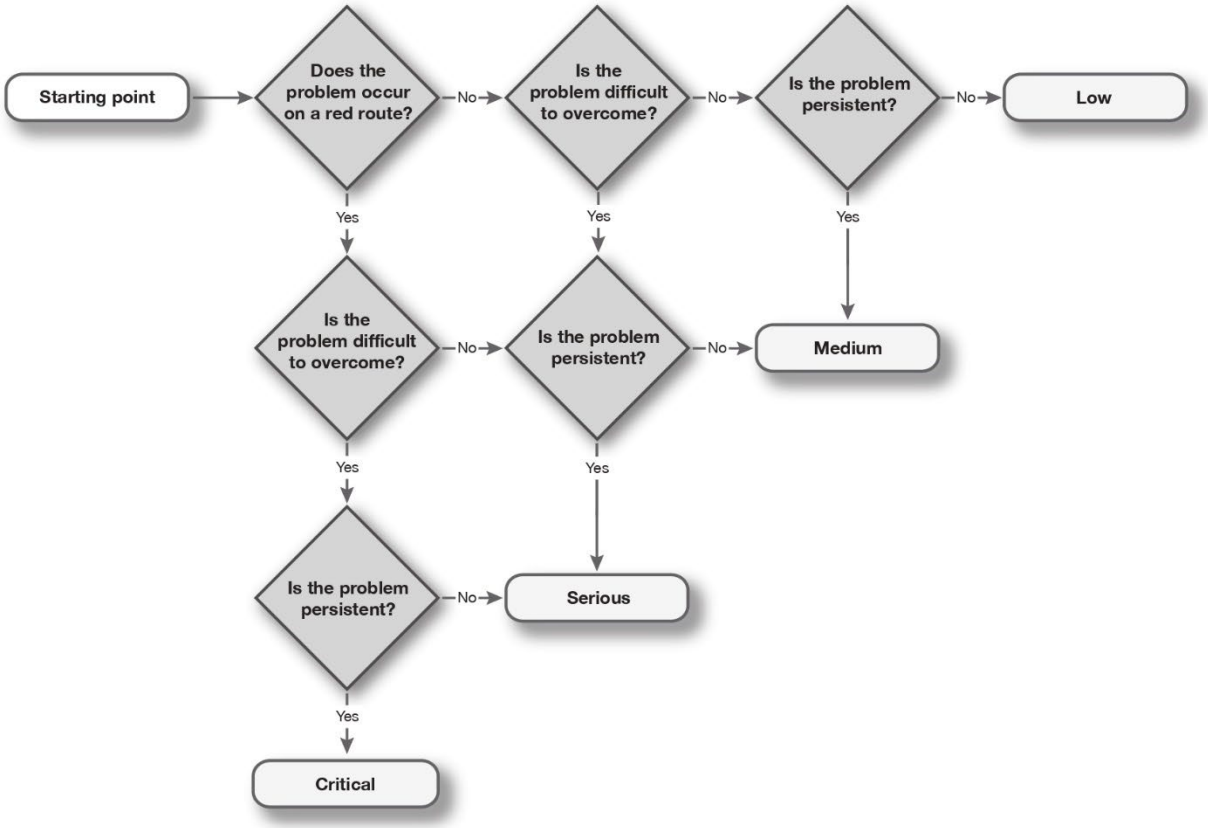
Stage 4: Charting the data

Usability problems were structured in a table indicating their place of occurrence within the app, Usabiltiy Problem Taxonomy classification, and severity level.

Stage 5: Mapping and interpretation

Based on the resulting chart of data, the most prevalent problems were identified and interpreted concerning guidance for app development.

Decision Tree Depicting Level of Severity



Note. Adapted from Travis (2009).

Appendix G

Task Themes

Usability Positives

Task #1

Researcher Noted Positives

Good amount of text (not too long)	**2/8**
P02 - short and sweet. And I like how there's a photo. P04 - It's good. Yeah, I like how the um photos display with a bit of text. It's not too much text, but it's not too little as well.	

Easy to Follow	**1/8**
P02 - Awesome. I like how it's easy to follow	

Likes the support from science and shared personal experience	**2/8**
P02 - I like how it's supported by science and it's also shares personal experience. P07 - I like that you talked about your experience	

Likes zoom option for the photos	**2/8**
P02 - I like how there's a zoom option. P04 - OK, so this text, this is a little small, but I can clearly see the zoom button so you can like open it and read it, so it's pretty easy.	

Likes the individualization	**2/8**
P02 - Awesome. It seems individualized, which I like because everyone's different P05 - That's good that you can tell it how you're feeling that day. I think that's important.	

Likes swiping	**2/8**
P05 - I like the swiping. P07 - just personally, but I like how it vibrates when you slide	

Example slides in the Intro & Overview module are useful	**1/8**
P05 - I think this one's useful, uh, for like giving me an example of what it will look like.	

Clicking is Intuitive	**1/8**
P08 - clicking on it was pretty like intuitive even though it wasn't like click me to start like it just like, yeah, it felt natural	

Easy to read and follow module	**1/8**
P06 - I like the uh layout of it. It's certainly easy to follow. Yeah, it's easy to move around and the graphics are good.	

Task #2

Researcher Noted Positives

Likes the progress dots on the bottom	**2/8**
P06 - Oh I swipe too far. That's right. Uh, came back, which is nice. P08 - I like the like dots at the bottom that you can like see how far you're going along.	

Likes bullet form	**1/8**
P02 - I like how it's in bullet form.	

Likes the reassurance	**1/8**
P02 - I like how it's reassuring.	

Survey had participant reflect on delivered content	**1/8**
P07 - Yeah, I think it kind of like as soon as I click start survey I thought back to the things you had listed and I was comparing what one of those like really stood out to me and then also just personal experience	

Task #3

Researcher Noted Positives

Liked clock interface	**1/8**
P07 - Oh, this is cool. Yeah, that is super cool. Yeah, I know it works, no, that's super cool. I haven't seen anything like that before and it's uh. Oh wow, do you think it's the minutes in between	

Task #4

Researcher Noted Positives

Cues on the screen were useful – timer, colour coordination, framing	**3/8**
P02 - I like how there's cues on the screen like a little, it's not just like him saying it, it's also instructions on the screen. like how there's a timer as well and I like how you can rewind if you need to watch again. I like the color co ordination for kind of like, easier to, harder. And I like how you show the exercises in different angles by switching your body position. P04 - OK, I like the feedback. I see that the, uh, it tells me when it's done. It counts down. That's nice. Yeah, it's not, it's not difficult. I'm not like a big YouTube person, but this is quite simple to kind of follow. P08 - I think the camera framing and stuff is good.	

The noise at the end is useful	**1/8**
P07 - The noise at the end is useful. I didn't catch it the first time, but I think that kind of solves the first problem I had with the like, I didn't realize you had restarted	

Camera framing is good to follow along to	**1/8**
P08 - I think the like the camera framing and stuff is good	

Task #5

Researcher Noted Positives

Buttons are straight forward	**1/8**
P08 - The buttons seem fairly like straightforward.	

Usability Problems

Task #1

Researcher Noted Problems

Position of picture on “Weekly Lessons” slide confused participant	**2/8**
P01 - Oh, so these are just all the modules that I have to go through? OK. Yeah, it's a, I guess there's a blurb there. P04 - OK, so we'd finished the prelude introduction and overview. So yeah, text on the top for that one. I mean, I would have clearly figured it out, but someone perhaps a little less tech savvy might be like, excuse me, what?	

App crashed upon entering login details	**1/8**
P04 - Oh, it closed out. Whoop, it kicked me out again.	

Zoom straight into the picture instead of clicking	**1/8**
P05 - one thing I that would be good is if you could, well, I don't know if this is possible, but being able to just zoom in straight off here, I don't know if that's possible because I don't know, I just want to do that automatically. yeah, that might be another thing for some people who don't know how to use technology as much.	

Would like a zoom in a bit bigger on pictures with words	**1/8**
P06 - maybe a bit bigger on the, on the zoom. Yeah, just a little hard for me to read just because of the size.	

Task #2

Researcher Noted Problems

- Second question does not fit on Questionnaire card title

Repeat question #1 *Fixed after cycle 1*	**4/4**
P01 - I'm not sure how to answer this question P02 - Oh, did I already answer this one? P03 - The same question? P04 - Oh yeah, it popped us back to the other one. Yeah, yeah, OK, yeah, so it pulled us back to the other one.	

Repeat question #2 *Fixed after cycle 1*	**4/4**
P01 - Oh, yeah, asked me this question twice. I'll just answer it anyway because I don't know if it'll let me go forward. P02 – *No comment*	

P03 - I think it's asking the same question again. P04 - *completely missed this question because they went back after the repeated question* *Later* - Oh, I put in my answer and it. An error happened where it put it again, so I see, I see that that's an error

Opened wrong module due to title confusion	**1/8**
P04 - *researcher*: So this is actually the um this is the one we're not there yet.	

PA should be expanded to physical activity *fixed after cycle 1*	**1/8**
P04 - I probably would write physical activity. Acronyms can be a little more like physical activity brackets, PA.	

Keyboard covers the submit button in Chapter 1 survey, making it difficult to submit survey and move on. In one case, participant clicked the 'X' button, deleting their survey answer, then continued with the task unknowingly.	**1/8**
P05 - that's that part is kind of confusing when you go to submit it because I think that that's going to submit and then automatically close that, but then you have to click. P07 - for the survey when I was doing it, uh, I just clicked the X to close it and uh. I don't know, I was worried that it didn't say I completed or something. *survey did not save because he clicked X – keyboard was covering the "Submit" button*	

Completed module disappearing from the "Current" Tab confused participant	**1/8**
P07 - I was on to current so I swipe to the right and I mean, so I just looked at the first thing which is physical activity session day one, but chapter one was over there. Like it doesn't, it's not particularly hard, but if, if I'm looking at it, I did this first, the next thing I would imagine is that *gestures to module that comes after desired one*	

Button "Go to Main Menu" on Congratulations page could be bigger	**1/8**
P05 - this button could probably be slightly bigger, but that's just a small thing.	

Task #3

Researcher Noted Problems

- Pop-up keyboard blocks the text box for "new goal title"

Trouble finding goals page from the home screen (suggests small text beside button stays)	**5/8**
P01 - is it the for like this one here, day one? Uh, no. Oh, daily goal here. P02 - *clicked into exercise session module* I don't want the session, I want the, to make my own goal. It was a little harder to find how to make my own goal, but there wasn't too many buttons for me to click on to be able to find it. But maybe if the bottom buttons were labeled, it'd be easier to create my own goal. P04 - *clicked back into Chapter 1* P05 - *went to trackers page* OK. Uh, I don't remember. OK, I slightly remember that it's at the bottom, trackers. OK, yeah, I guess those could be like slightly better like labeled because I	

wasn't sure. *opened trackers page instead of goals, tracked an activity, then realized that was not the task* Oh add a goal, that's what you wanted me to do. P06 - *went to PA video* I hope I'm in the right spot. No. Don't know where I went to here. I think I've gone the wrong place again though. Oh God. In progress, begin. I think I screwed up your system here.

Unable to see written text until after screen transition	**4/8**
P01 - No, it's not wanting to save any of the written stuff. P03 - it does not like me putting anything in there. Oh, yeah? Yeah. Like if I was to just put in exercise and then go out, it gets rid of it. P06 - I can't see the keyboard. I'm getting feedback from the vibration on the keyboard that sounds like it's going in. P08 - The keyboard pops up in the way and then you can't see it, um, and it doesn't seem to be entering the thing	

Long loading screen after refreshing – researcher needed to close app and reopen	**1/8**
P02 - It is a long loading screen for, um, comes back. Well, maybe I shouldn't have refreshed it.	

Tried to click the entire box on "Priority" and "Deadline"	**1/8**
P08 - I think that for these two it might be more like intuitive just to click the whole panel.	

Task #4

Researcher Noted Problems

Trouble finding Physical Activity Session from Home Page.	**3/8**
P03 - The title of it was a little different from what you were asking for. *researcher asked to find fatigue questionnaire and access physical activity video* P04 - OK, I just gotta find it here. exercise logging, OK. Well, that's not what we're doing. Trackers, menu, not there. P05 - I somehow got lost here and I don't know where to go, so I'm gonna try pushing buttons. I really don't know where I'm going, but that's OK. I don't know where to find it. Mm mm mm Not here, not here.	

Did not hear instructions / unclear when to progress or regress exercises	**3/8**
P05 – "Was it clear that you could like um Like regress at any time like you pick one of the three." Oh, I didn't catch that. P07 - I didn't realize that the, the thing was starting again, but I think that might have been me not paying enough attention. When I'm doing the exercises, I'm focused on like my form and all that stuff. So maybe having like a noise between them, like from when you for example this one between the assisted the regular P08 - I think that you can still hear you, but during the times you're talking, like having the music fade down just a little bit might be nice, but like I think during the time that it's like it's like good to have like kind of like the music going	

App crashed when returning from YouTube *possibly due to an update the app had just undergone*	**1/8**
P04 – And it crashed again	

Task #5

Researcher Noted Problems

Doesn’t know what MVPA or LPA means	**3/8**
P04 - Type of exercise, MVPA or LPA, so. I don't know what that means. I click on it. Will it tell us light. Oh, light. Yes P06 - type of exercise, uh, I don't understand, uh, MP MVPA or LPA. P08 - I don't know what MVPA is	

Text box on “What exercise did you do” was difficult to see	**1/8**
P06 - Yeah, it was a little bit hard to find where I had to go.	

Scrolling on “How long, in total, did you exercise for?” not intuitive, needs visual cue	**1/8**
P08 - I wasn't exactly sure what it was prompting me for. It burst, um. I feel like if like. You know, sometimes it can be like kind of like a shaded thing that looks like it rolls, then it might be more intrinsic to like spin it, um, but yeah, once you move your finger over it, then it makes sense.	

Appendix H

Cycle 1 Usability problem descriptions and classifications

			% of participants detecting		UPT Classification		
Themes	Task #	Place of Occurance	Think-Aloud	Interview	Artifact	Task	Severity
Position of picture on “Weekly Lessons” slide confused participant.	1	Introduction & Overview Module	50%	-	Visualness -> Object (screen) layout (FC)	Task-mapping -> Interaction (FC)	1
App crashed upon entering login details. The next try was successful.	1	Login Screen	25%	25%	(NC)	Task-mapping -> Functionality (FC)	2
Repeat question #1 on Chapter 1 survey *Fixed after cycle 1*	2	Chapter 1 Module	100%	100%	(NC)	Task-mapping -> Interaction (FC)	3
Repeat question #2 on Chapter 1 survey *Fixed after cycle 1*	2	Chapter 1 Module	100%	100%	(NC)	Task-mapping -> Interaction (FC)	3
Opened wrong module due to title confusion	2	Home Page	25%	-	Language -> Naming/labeling (FC)	Task-facilitation (PC)	1
PA should be expanded to physical activity *Fixed after cycle 1*	2	Chapter 1 Module	25%	-	Language -> Naming/labeling (FC)	Task-facilitation (PC)	1
Trouble finding goals page from the home screen. One participant suggested the icons should be labelled with text	3	Home Page	75%	25%	Visualness -> Object Appearance (FC)	Task-mapping -> Navigation (FC)	3
Unable to see written text in "Goal Title" text box until after screen transition	3	Goals Page	50%	25%	Visualness -> Non-message feedback (FC)	Task-mapping -> Functionality (FC)	4
After refreshing Home page, the loading screen was persistant, causing the participant to close and re-open the app.	3	Home Page	25%	-	(NC)	Task-mapping -> Functionality (FC)	2
Trouble finding Physical Activity session from Home Page. Participants were scrolling directly past the module that delivers the session.	4	Home Page	50%	-	Visualness -> Object Appearance (FC)	Task-facilitation -> Keeping the user task on track (FC)	4
App crashed when returning from YouTube *possibly due to an update the app had just undergone*	4	Physical Actiivty Video	25%	25%	(NC)	Task-mapping -> Functionality (FC)	2
Doesn’t know what MVPA or LPA means	5	Trackers Page	25%	-	Language -> Naming/labeling (FC)	Task-facilitation (PC)	2

			% of participants detecting		UPT Classification		
Themes	Task #	Place of Occurance	Think-Aloud	Interview	Artifact	Task	Severity
Zoom straight into the picture instead of clicking.	1	Introduction & Overview Module	25%	-	Manipulation -> Physical Aspects (FC)	Task-mapping -> Navigation (FC)	1
Typo in module slides.	1	Introduction & Overview Module	25%	25%	Language -> On-screen text (FC)	(NC)	1
Keyboard covers the submit button in Chapter 1 survey, hiding the button to submit the survey. In one case, participant clicked the 'X' button, deleting their survey answer, then continued with the sceanrio unknowingly.	2	Chapter 1 Module	50%	50%	Visualness -> Object (screen) layout (FC)	Task-mapping -> Interaction (FC)	4
Completed module disappearing from the “Current” Tab disrupted user flow, as they had not yet learned that completed modules are erased from this tab.	2	Home Page	25%	-	Visualness -> Non-message feedback (FC)	Task-facilitation -> Keeping the user task on track (FC)	2
Button “Go to Main Menu” on Congratulations page should be bigger.	2	Chapter 1 Module	25%	-	Visualness -> Object Appearance (FC)	Task-mapping -> Navigation (FC)	1
Trouble finding goals page from the home screen. One participant suggested the icons should be labelled with text.	3	Home Page	50%	-	Visualness -> Object Appearance (FC)	Task-mapping -> Navigation (FC)	3
Unable to see written text in "Goal Title" text box until after screen transition.	3	Goals Page	50%	50%	Visualness -> Non-message feedback (FC)	Task-mapping -> Functionality (FC)	4
Tried to click the entire box on “Priority” and “Deadline” when adding a new goal.	3	Goals Page	13%	-	Manipulation -> Cognitive aspects -> Direct manipulation (FC)	Task-facilitation -> Alternatives (FC)	1
Trouble finding Physical Activity session from Home Page. Participants were scrolling directly past the module that delivers the session.	4	Home Page	25%	-	Visualness -> Object Appearance (FC)	Task-facilitation -> Keeping the user task on track (FC)	4
Did not hear instructions / unclear when to progress or regress exercises.	4	Physical Actiivty Video	75%	-	(NC)	Task-facilitation -> Keeping the user task on track (FC)	1
Doesn’t know what MVPA or LPA means.	5	Trackers Page	50%	-	Language -> Naming/labeling (FC)	Task-facilitation (PC)	2
Text box on “What exercise did you do” was difficult to see.	5	Trackers Page	25%	-	Visulness -> Object Appearance (FC)	Task-facilitation (PC)	1
Scrolling on “How long, in total, did you exercise for?” not intuitive, needs visual cue.	5	Trackers Page	25%	25%	Manipulation -> Cognitive aspects -> Direct manipulation (FC)	Task-mapping -> Interaction (FC)	2

Appendix I

Theoretical Model of Acceptability Themes

Affective Attitude

Participants expressed positive affect regarding IBD-Move	**8/8**
P01 - I really did like it and again I would use it again. the average person might not exercise as well as having the exercises laid out for them. Like, they could still be spending the time but they may not be managing their time efficiently. unless you have, like, the, the training, like, in exercise science, you know, I wouldn't know where to start. P02 – I enjoyed the app because it was reassuring. It gave like scientific and like you share it on your, your own experience. So it kind of, it was inspiring in that way and it was and made it so you could make your own goals and cater to your life. It was very individualized, which I liked. P03 – I actually really like it. It was good visuals, easy to read. And it was in terms of, like, the text and the pictures being used, like, too extravagant or like, fake awesome. P04 – I liked it. I thought it was, um, reassuring to like. You're not just um You know, like exercises for everyone and it's, you know, it's gonna, it's gonna be a helpful thing no matter where you are, and I think that's, that's good to hear. I mean, we, we know these things like intuitively like movement is good, but like reading about it as like specific to your demographic, like people with similar conditions found this helpful and you're like, oh, OK, you know, that's that's nice P05 - I liked it. I'd say I'd give it about a 7/10. P06 - A lot. I like it. I could see it being very functional and very usable. P07 - I would say. Like a 7 or an 8. P08 - Yeah, like I like the information and the ability to work through	

Perceived personal usefulness/ perceived effectiveness

Believed IBD-Move would improve their physical activity levels	**7/8**
P01 - Yes, I, I do. I, I think that it's, well, seeing that they're 10 minutes long of videos. even if you were to do, you know, 20 or 30 minutes, like, I mean, most people can, you know, put that aside every day or most days at least. even if you're only working, you know, the 10, you know, 20 minutes or, you know, whatever it is, you know, if you're actually doing, um, well laid out exercises that are beneficial, you know. I don't think you really need to spend, you know, 2-3 hours in the gym. P02 – Yes, I think it allows you to create a program or set time side that works for you to become more active. P03 – Yes. P04 – Oh yeah, for sure, yeah, for sure. Um, and I think it's something like you can do like in your living room, which is nice. You don't have to go, um, because that's another like barrier to exercise is like you have to, if you're going to go to a gym, well you have to get like, you have to drive there and like pay for it and all of like, you know. Get changed, and that takes a lot to even just get there, right, when you're there and all these like people around you, but if	

you can do it in your living room, well, that's pretty, that's very low, low barrier to doing it, right? It's right there. You don't need anything, it's to get started, and I think that's the getting started is the hard part. Especially if you have chronic health conditions. P05 - Probably, yeah, if I had like goals every day that I had to achieve, it would probably be better than just exercising when I feel like it helps. Um, Track habits, I guess, which is useful. P06 - I think it would help motivate, especially with the goals and stuff like that to be able to track. it would give you a way of reminding you and/or tracking. P07 - Yeah, totally. I really like the tracking section. That was very smooth to me, yeah, yeah, the tracking afterwards, like the time and then how hard I did it and stuff like that and it, it also was really like entering it was really easy and then looking at it after the fact it was really easy like it was all presented right there, which I liked.

Burden

There was no perceived burden to time while using the IBD-Move app	**8/8**
P01 - No, no. Like I said earlier, I mean, I think that everybody should be able to set aside that little bit of time every day or at least enough days of the week that it's worthwhile. P02 – No, I found it time effective. P03 – No. P04 – No, it was very quick to do what we were doing. P05 - No, I think it was pretty simple P06 - No, not at all P07 - No, there was no interruptions P08 - No, I wouldn't say it was time consuming. I think it was pretty quick to use.	

Ethicality

Believed anyone could use the IBD-Move app	**8/8**
P01 - Yes. I think it's even beneficial for people who don't have IBD. It's just a good way to, you know, get people active in general sense. P02 – I do. P03 – yeah. at the bottom, where you had, like, the tracker and to add goals and stuff. Like having, um, either the words saying that because the symbols might not be obvious for people on what it is P04 – Yeah, I think anyone, like any like age, like an elderly person could use it someone with like a low kind of understanding of tech could figure it out. P05 - I think anybody could, but yeah, they'd have to be taught a tutor or like yeah, better access to the tutorial if you need to review things and stuff P06 - I think so. I think I was thinking of my parents as an example. I think they could use it. It's fairly Fisher-Price-ish in that sense, very easy, very easy, not cluttered up or anything like that. P07 - yeah, totally, I think 100%. P08 - Yeah, I think so.	

Opportunity costs

IBD-Move would not interfere with anything else important to the user	**8/8**
P01 - No, I don't see why it would P02 – I don't think so because I think IBD-Move is designed to improve your quality of life so you can put time aside to make the app work for you in your life. P03 – No P04 – Nope. P05 – No P06 - No, don't think so. Not at all. P07 – No, I only really see benefits of using it P08 - No, I don't think so.	

Self-efficacy

User was confident in using the IBD-Move app	**6/8**
P01 - I was pretty confident. I mean, I think as long as you can use a phone, you should be able to use the app. P02 – I felt fairly confident about it. I feel like I'm not the most tech savvy person and I was able to navigate it well, which says a lot. P03 – one got the hang of things. It was pretty easy. P04 – Very confident, yeah. P07 - it's all pretty smooth P08 - Yeah, fairly confident, I would say.	

Intervention coherence

The IBD-Move intervention and how it worked was clear to the user.	**8/8**
P01 - Yes. P02 – Yes, it was, it was straightforward and I like how it was in modules because you knew how many two you like, saw how many modules there were. So you knew what to expect and what to complete. P03 – yeah, again, once I got the hang of it. P04 – Mhm, yep. P05 - Yeah, I think it'd be helpful and I think it made sense. It wasn't the most confusing thing I've ever done, so yeah, I've used way more, way more confusing apps P06 - I think so, yeah, if I was at home alone with it, I would have fumbled alone along and figured it out. I would have not given up. P07 - yeah, I think so. P08 - I think it was clear to me, yeah, especially like kind of going through the like progression that we did go through	