Equitable Digital Health Design and Implementation: Understanding Diverse Needs and Perspectives Regarding the Use of Mobile Technology to Provide Clinical Support for Health Behavior Change

By

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Abstract

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Background: Digital health is a broad, multidisciplinary field that uses technology to deliver and enhance health care. Within the digital health landscape, mobile health (mHealth) has become one of the largest sectors of digital health, with mHealth interventions accounting for a majority of digital health interventions. This dissertation focuses on mHealth interventions designed to provide clinical support for health behavior change to patients. Despite there being countless mHealth interventions targeting a wide variety of health behaviors and concerns, insufficient user engagement and low acceptance of mHealth continue to hinder the field's growth. As such, a greater emphasis on understanding predictors of user engagement and individual acceptance of technology is necessary. Many of these predictors are influenced by socio-demographic factors, access to technology, digital literacy, health literacy, human resources, and environmental factors. Although one of the goals of mHealth has always been to expand access to care and reduce health disparities, at present, mHealth is often implemented inequitably and without sufficient consideration of their intended users' circumstances. Thus, further research gathering the perspectives of low-income individuals, racial and ethnic minority populations, immigrant populations, those in low-resource service settings, and other underserved populations is necessary so mHealth interventions can be tailored to their needs and preferences.

Methods: This dissertation contributes to equitable digital health design and implementation by exploring the needs and preferences of diverse individuals intended to benefit from mHealth interventions. Additionally, it provides key insights into creating engaging, helpful, and culturally responsive health behavior change content and designing accessible, inclusive, and user-friendly mobile platforms for individuals with varying technology familiarity and digital literacy. The first paper of this dissertation describes use of an implementation strategy designed to improve low-income ethnic minority patients' engagement with and adherence to treatment within a public healthcare system. The implementation strategy consisted of a text messaging adjunct that sent patients mood rating messages, therapeutic content messages, and treatment and medication reminders to improve patient attendance at group therapy for depression. Descriptive statistics, inferential statistical tests, content analysis, and thematic analysis of qualitative

feedback were conducted to explain the mechanisms of change behind this text messaging adjunct and determine what types of text messages were most effective at eliciting patient engagement. The second and third papers of this dissertation employ qualitative thematic analysis of interview data collected from key digital health stakeholder groups, with a focus on immigrant populations and racial and ethnic minority groups, to explore the utility, value, and appropriateness of mHealth interventions designed to provide clinical support for health behavior change. The second paper utilizes interview responses from intended users of mHealth to provide recommendations for designing and improving mHealth interventions that encourage healthy lifestyle behaviors and decrease the risk of chronic disease, while the third paper explores medical providers' views of mHealth applications as they relate to patient health behavior change and provider workflow and responsibilities.

Results: Across the three papers, individuals generally held positive views of mHealth programs designed to support health behavior change. mHealth interventions that delivered encouraging content and messages that uplifted mood, increased motivation, related to individuals' health goals, provided directive content, offered suggestions and feedback, and connected individuals to support from providers or community were received most positively and assisted individuals in implementing health behavior changes. Provider recommendations were an important way for individuals to gain awareness of mHealth interventions that can benefit their health, and individuals were much more likely to initiate use of an mHealth intervention when it was recommended by their providers. Individuals appreciated interventions that provided highly tailored health plans that took into account their health needs, limitations, and available resources and supports. Across all three studies, inconvenient timing and frequency of text message or app notification delivery often lowered individual acceptance of mHealth. Other key barriers noted included insufficient personalization of health behavior change plans and health reminders, limited support for technology use, and lack of culturally responsive content and recommendations that aligned with cultural preferences and social circumstances.

Conclusions: While a plethora of apps exist for various health issues, there are numerous barriers that continue to impede mHealth use and adoption. Rather than continuing to expand the digital health market, a key focus of the mHealth sector should be on improving existing apps and platforms to offer more inclusive content and features that address diverse users' needs. The reach of mHealth can be furthered by developing more culturally relevant content, incorporating multilingual support, and partnering with medical providers, healthcare organizations, and insurance companies to increase awareness of mHealth programs. Platforms need to put forth evidence-based content and recommendations, maintain robust privacy and security measures, and improve timing and relevance of text messages and app notifications. Just-in-time adaptive interventions and machine learning approaches like reinforcement learning may be a useful way to optimize the content and delivery of text messages. Findings from this study contribute to our understanding of how to design mHealth programs to both supplement standard healthcare provision and act as standalone behavioral change interventions. This dissertation highlights the significance of including diverse users and medical providers in design, implementation, and evaluation processes in order to put forth equitable interventions that are widely applicable in different contexts and address the needs and preferences of users of varying levels of advantage, especially underserved populations. This dissertation contributes to the field's understanding of how to utilize mHealth to expand access to health care and reduce health disparities.

Dedication

This dissertation is dedicated to my grandfather, Y. Y. Kuo, 郭淵源,
whom I lovingly called 東東, and to my dog, Peanut.

東東, your relentless determination, hard work, vision, and belief in me made it possible for me to stand here today, graduating with my doctoral degree. Thank you for laying the groundwork for me to create my own path and pursue educational and professional opportunities that align with my passions. Your love and pride in me have always been one of my biggest motivations, and you are forever my inspiration. It's been the honor of a lifetime being your granddaughter, and I will continue to strive to make you proud in all that I do. You are deeply loved and missed, but know that your spirit and legacy will continue to live on in everything that I do.

With the deepest love, respect, and gratitude,
婷婷

Peanut, my heart, my soul dog, I wish more than anything that you were still here by my side, but in the 7.5 years we were lucky enough to spend together, you were my everything. You are, and forever will be, in my heart, so very loved.

Love always,
Tiff

Table of Contents

Abstract 1
Dedication i
Table of Contents ii
Background 1
Mobile Applications for Health Behavior Change 1
Defining mHealth 1
Health Behavior Change 2
User Engagement with mHealth 3
Defining Engagement 3
Predictors of Engagement 3
Barriers to Engagement 4
Implementation Science 5
Definition and Scope 5
Implementation Strategies and Outcomes 6
Barriers to Equitable Implementation 7
Biases and Underrepresentation 8
Problem Statement 9
Dissertation Overview 9
Paper 1: Utilizing Text Messages to Improve Patient Adherence to Group Therapy for Depression: Guidelines for Designing a Text Messaging Adjunct for Use as an Implementation Strategy 12
Background 12
Study Overview 13
Methods 16
Results 18
Discussion 29
Conclusion 32
Paper 2: Understanding how Mobile Apps for Health Behavior Change are Selected and Adopted: Qualitative Analysis of Interviews with Target Users through a UTAUT Lens 33
Background 33
Methods 35
Results 39
Discussion 52
Conclusion 59

Paper 3: Exploring Medical Providers' Perspectives on the Utility and Value of Mobile Apps for Health Behavior Change: Qualitative Analysis of Interviews 61
Background 61
Methods 63
Results 64
Discussion 79
Conclusion 82
Concluding Chapter 83
Policy Implications 87
References 89
Appendix A: Ethics and Human Subjects Protection Statement 100
Appendix B: Interview Guide 101

Background

Digital health is a broad, multidisciplinary field that uses technology to deliver and enhance health care. Digital health is defined as "the use of information and communications technologies in medicine and other health professions to manage illnesses and health risks and to promote wellness" (Ronquillo et al., 2022). Key goals of digital health include improving access to health care, streamlining the healthcare system, improving quality of care, lowering the cost of health care, and providing more tailored and personalized care for patients (Ronquillo et al., 2022). Digital health products and services are designed with one or more of the following objectives in mind: 1) improve the quality of outcomes; 2) improve population health; 3) improve the patient experience; 4) improve the provider experience; and 5) address health disparities (Ronquillo et al., 2022). Over the years, digital health has evolved to include many different platforms and forms of delivery, including mobile health, telehealth, telemedicine, wearable devices, and health information technology (Värri, 2020).

Mobile Applications for Health Behavior Change

Within the digital health landscape, mobile health (mHealth) has become one of the largest sectors of digital health. mHealth interventions now account for a majority of digital health interventions, as they can be used and adapted for a variety of purposes (Värri, 2020). There are points throughout this dissertation where I discuss specific mHealth interventions, which can also be understood to be digital health interventions, as mHealth falls under the broader category of digital health.

Defining mHealth

mHealth is defined as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices" (WHO Global Observatory for eHealth). mHealth's functionality can be divided into four key domains: 1) clinical support; 2) health worker support; 3) remote data collection; and 4) helplines (Bashshur et al., 2011). Within clinical support, mHealth may be used to provide patients with psychoeducation or health education, deliver interventions, enable self-monitoring and self-management of health conditions, ensure continuity of care, improve clinical outcomes through behavior change, and increase patient compliance with treatment (Rowland et al., 2020). As for health worker support, mHealth may be used to expedite workflow, support clinical diagnosis and decision making, facilitate communication amongst providers, or deliver provider assistance, training, or technical support (Olla & Shimskey, 2015). Mobile phones can also collect and transmit individual and aggregate data quickly and at low cost, thus enabling remote data collection in service of individual and population health (Akter & Ray, 2010). Finally, helplines are a basic form of mHealth consisting of a phone number that individuals call to gain access to health services such as phone consultations, counseling, and information on medications, care options, and clinic availability (Mathieu et al., 2021).

mHealth can facilitate more efficient and effective patient care, improve quality of services, integrate resources, and enable widespread, real-time access to up-to-date medical knowledge and information (Ammenwerth et al., 2003). It is seen as an important resource and tool for health services delivery and public health due to its ease of use, broad reach, and wide acceptance (WHO Executive Board, 2018). Mobile-based solutions, especially SMS and smartphone applications, have been designed to improve health access, literacy, knowledge, and behaviors across many contexts and target groups (WHO Executive Board, 2018). These

contexts include medically underserved areas and health professional shortage areas. Target groups include individuals of lower socioeconomic status, racial and ethnic minority groups, individuals with lower literacy (e.g., reading literacy, health literacy, technology literacy), and rural communities. In 2015, there were over 7 billion mobile telephone subscriptions across the world, 70% of which were in low- or middle-income countries where people were more likely to have access to a mobile phone than to clean water or electricity (WHO Executive Board, 2018). As of 2024, 98% of Americans own a cell phone of some kind, and 91% of Americans own a smartphone (Pew Research Center, 2024). Given the high phone ownership rates across a range of demographic groups and geographic locations, mHealth has tremendous potential to revolutionize healthcare delivery, services, and systems for all (Fiordelli et al., 2013).

Health Behavior Change

In this dissertation, I focus primarily upon mHealth interventions designed to provide clinical support for health behavior change to patients. Health behavior change can be understood as a two-part process that involves developing an intention to change health behaviors based on self-beliefs (behavioral intention), followed by self-regulation for planning, initiating, and maintaining the behavior over time (actual health behavior change) (Schwarzer, 2001). The behavioral intention results from sufficient motivation, while the actual health behavior being adopted and maintained depends upon volition and self-regulatory efforts.

Health behavior change emerged as a field of study largely due to its pivotal role in chronic disease prevention and intervention. Chronic diseases such as cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes are the leading causes of death, responsible for 74% of all deaths globally (World Health Organization, 2023). They tend to affect individuals over long periods of time and result from a combination of genetic, physiological, environmental and behavioral factors. They differ from infectious diseases in that they are strongly influenced by behavior: daily habits and lifestyle are major contributors to their development and course. An important way to control chronic diseases is to focus on reducing the modifiable behavioral risk factors associated with these diseases. As such, health behavior change interventions emerged to encourage individuals to engage in healthy lifestyle behaviors (e.g., increased physical activity, balanced diet, sufficient sleep, medication adherence) and reduce unhealthy behaviors (e.g., smoking, substance use, risky sexual activity), with the goal of preventing chronic disease and early mortality and improving overall health and well-being.

Mobile apps are increasingly being used to deliver health behavior change interventions for chronic conditions, as they can be designed to target a wide variety of health issues, patient groups, and behavioral change strategies to maintain and improve patients' health. A systematic review mapping mHealth research over one decade revealed that 63% of mHealth studies focus on chronic conditions, with an additional 19% of studies focusing on illness prevention and overall wellbeing (Fiordelli et al., 2013). Mobile apps support active user interaction and passive collection of a variety of health data on lifestyle behaviors such as physical activity, mobility, sleep, and social interaction (Milne-Ives et al., 2020). Additionally, they allow for self-management of conditions, health promotion, communication, remote monitoring, data gathering, improvement of adherence behaviors, training, and education (Fiordelli et al., 2013).

User Engagement with mHealth

Defining Engagement

The success of mHealth interventions depends largely upon sufficient user engagement. As such, it is important to first understand what constitutes engagement. There is no clear consensus in the digital health literature on the definition, conceptualization, or operationalization of engagement with digital interventions for health behavior change (Amagai et al., 2022; Perski et al., 2017). This is likely because digital health interventions have a foundational basis in multiple fields, including behavioral science, computer science, and human-computer interaction, each of which operates under different epistemologies, research contexts, objectives, and perspectives. Within computer science and human-computer interaction, engagement has typically been understood as a subjective experience of focused attention, intrinsic interest, enjoyment, and immersion, which depends heavily upon the entertainment and usability of the interactive technology. By contrast, in behavioral science, engagement is conceptualized as a behavior, specifically the usage of interventions (including frequency and duration) and the depth of usage (e.g., use of specific intervention content or features). This conceptualization emerged due to the finding that only a small fraction of those who download and try a digital health intervention will continue using that intervention over a sustained period of time. At the same time, there is an understanding that users can move dynamically between stages of engagement, disengagement, and re-engagement over time, thus suggesting that engagement is also a process of linked behaviors. To cross-cut these fields' definitions, Perski et al. (2017) proposed a two-part definition of engagement with digital interventions for behavior change as "the extent (e.g. amount, frequency, duration, depth) of usage and a subjective experience characterized by attention, interest and affect." I adopt Perski's definition in this dissertation and use engagement to refer to an individual's usage behavior of an intervention based on their subjective experience of what it feels like to interact with that intervention. It is important to note that in the literature, engagement is often captured by many different terms such as adoption, retention, adherence, compliance, and completion (Amagai et al., 2022), so these terms will, at times, also be used.

Common methods of measuring engagement with mHealth interventions include phone and app usage data (including frequency and duration of usage), surveys, qualitative feedback, app-collected data (active or passive), and data from synced devices (e.g., activity trackers). A systematic review of mobile apps for health behavior change found that different measures tend to be used to capture different components: subjective experience operationalized as affective and cognitive engagement is primarily captured with qualitative methods; small-scale behavioral engagement with specific components of the digital intervention tends to be captured by app use data; and large-scale behavioral engagement with target health behaviors is most often captured by self-report, questionnaires, and app tracking (Milne-Ives et al., 2023). This emphasizes the importance of using mixed methods to fully assess the different components of engagement. As such, this dissertation integrates qualitative feedback, self-report of phone and app usage, and app-collected data to understand individuals' subjective experiences of interacting with mHealth interventions and describe the multifaceted nature of user engagement behavior.

Predictors of Engagement

mHealth interventions, by design, require user involvement and self-management, and sufficient engagement in a program can directly produce behavior change, with high engagement users experiencing more clinical improvement than low engagement users (Torous et al., 2020).

When it comes to predicting engagement, some factors relate more to the design and usability of the technology itself, while others have to do with individual factors and alignment with users' needs. Many different models have been proposed to explain individual acceptance of technology. A basic conceptual framework underlying this class of models can be found in Figure 1 (Venkatesh et al., 2003). An in-depth review of these models found that there are seven constructs that are significant direct determinants of either intention to use or actual use of technology: performance expectancy, effort expectancy, social influence, facilitating conditions, attitude toward using technology, self-efficacy, and anxiety (Venkatesh et al., 2003).

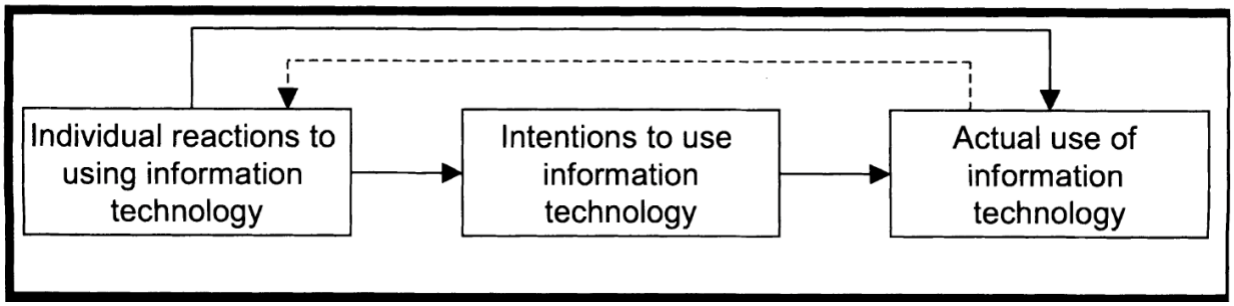

Figure 1: Basic Concept Underlying User Acceptance Models.

Most theories and models that inform and explain digital health engagement and acceptance are agency centered, as they primarily focus on the individual and interpersonal elements of digital health acceptance, with individual attitudes, behaviors, and motivations being at the core of theoretical analysis. They are useful for helping us understand factors related to user engagement, as they explain the processes involved in people making decisions about behaviors they need to alter. The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) is one such model and serves as a guiding conceptual framework for this dissertation. The UTAUT will be explained in further detail in the second paper of this dissertation and used to explain predictors of technology adoption and user engagement.

Barriers to Engagement

Despite there being an extensive field of literature exploring the various factors that influence engagement, insufficient user engagement and acceptance continues to be high (Wu et al., 2007). A past study showed that over 50% of available mHealth apps are downloaded less than 500 times and 80-90% of downloaded apps are used only once before being deleted (IMS Institute for Healthcare Informatics, 2013). The last-reported 30-day user retention rate of mHealth apps stood at 47% (IMS Institute for Healthcare Informatics, 2015) and the 90-day retention rate at 27-30% (Birnbaum et al., 2015). These low usage rates are not due to lack of demand, as national surveys have revealed that up to 66% of Americans are interested in mHealth apps and wearable devices, and studies conducted in healthcare settings have shown that 90% of patients are interested in digital health interventions to improve their health (Ranney et al., 2012). Rather, low usage is due to a complex interplay of factors including, but not limited to, lack of personalization for individuals' health and behavioral characteristics, poor timing of intervention delivery, lack of evidence of intervention effectiveness for particular groups, and lack of attention paid to users' needs, skills, and perspectives (Birnbaum et al., 2015). While part of the failure rate has to do with the technology itself, the other part can be attributed to non-

technical factors, with failures often resulting from insufficient user acceptance of the technology (Wu et al., 2007).

A systematic review conducted on patient acceptance of consumer-centered health information technologies revealed that 71% (67/94) of major variables associated with consumers' acceptance of health information technologies were individual factors including socio-demographic factors, education level, prior experience using computers, digital literacy, health literacy, and other health- and treatment- related variables (Or & Karsh, 2009). Many of these factors significantly affect individuals' performance expectancy and effort expectancy. For example, lower health literacy and digital literacy are significantly associated with lower performance expectancy and effort expectancy across all mHealth apps, which subsequently leads to significantly lower use of mHealth among those with low health and digital literacy, as compared to those with adequate health and digital literacy (Mackert et al., 2016). Environmental factors, including the social climate and the environment surrounding the technology's use, are also significantly associated with individuals' acceptance of health information technologies (Or & Karsh, 2009), despite not being primary constructs within technology acceptance models.

A greater emphasis on exploring social influences and contexts as determinants of use and tailoring mHealth interventions to individual and group needs and circumstances is necessary. To increase the success of mHealth, it is crucial to determine how and why technology adoption differs by social groups, which is one factor that ultimately leads to disparities in health outcomes. The field of implementation science can help to explain technology dissemination and implementation processes and elucidate areas where mHealth interventions are currently falling short in reaching their target populations.

Implementation Science

Definition and Scope

Implementation science is defined as the study of methods and strategies to promote the adoption and integration of research findings and evidence-based interventions into policy and practice to improve the quality and effectiveness of health services (Eccles & Mittman, 2006). There are two major goals of implementation science: 1) to produce insights and generalizable knowledge regarding implementation processes and identify barriers and facilitators across multiple levels of context; and 2) to develop reliable implementation strategies for enhancing facilitators and overcoming barriers and facilitate the widespread uptake of those strategies (Bauer & Kirchner, 2020).

Implementation is understood to be closely related to adoption, as it depends upon many of the same factors that influence initial adoption decision and assimilation (Greenhalgh et al., 2004). One understanding of implementation is that it is the early usage activities that follow the adoption decision (Greenhalgh et al., 2004). Another definition is that implementation is the collection of processes designed to get an intervention into use by and within an organization, the gateway between an organizational decision to adopt an intervention and actual routine use of that intervention (Damschroder et al., 2009). The adoption decision is influenced by the processes of diffusion and dissemination, both of which are methods of spreading an innovation. In diffusion, the spread of an innovation is unplanned, informal, decentralized, and primarily horizontal or mediated by peers. In contrast, dissemination is a more active process in which the spread of an innovation is planned, formal, centralized, and propagated through vertical hierarchies. The connection between diffusion, dissemination, adoption, and implementation is illustrated in Figure 2.

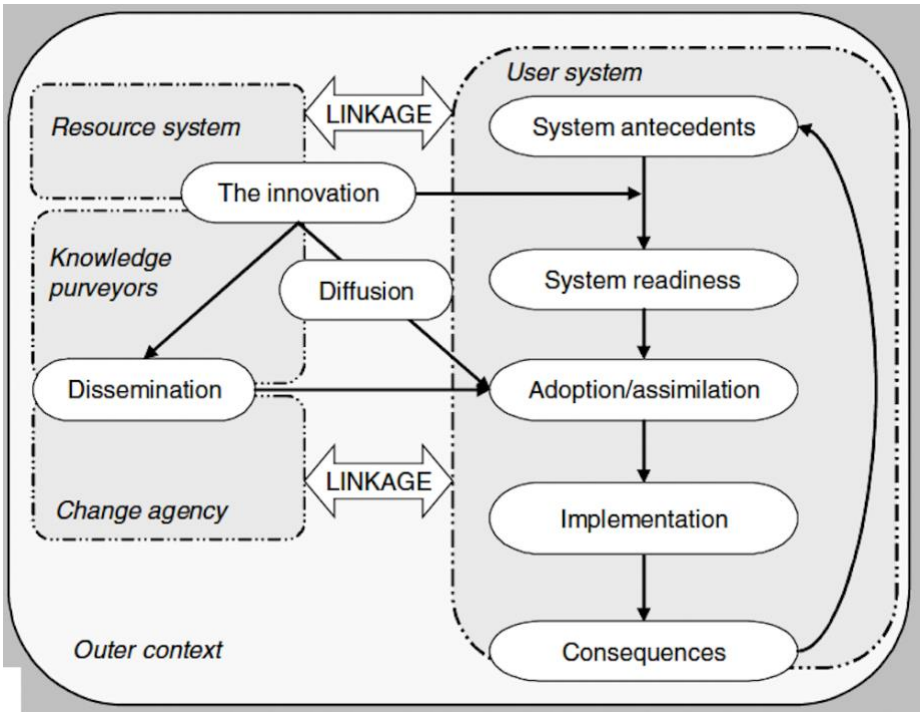

Figure 2: A conceptual model for the determinants of diffusion, dissemination, and implementation of innovations.

Whereas the literature looking at predictors of mHealth engagement focuses primarily on the technology system's antecedents and readiness as key determinants of adoption and assimilation, implementation science looks at the process as a whole, including a consideration of outer contexts and their influence on technology spread and adoption. Barriers to implementation can arise at multiple levels of delivery, and implementation science offers a structure for analyzing how each contextual layer (patient, provider, organization, healthcare system, sociocultural, policy, etc.) affects implementation outcome (Odeny, 2021).

Implementation Strategies and Outcomes

Developing strategies to overcome barriers to implementation and improve intervention uptake is a high research priority (Proctor et al., 2013). There has been a growing body of literature centered on identifying, developing, and testing implementation strategies, which can be defined as methods or techniques designed to enhance adoption of a clinical intervention or health promotion activity (Curran et al., 2012). Implementation strategies are the "how to" component of changing healthcare practice, explaining the specific means or methods behind intervention adoption, implementation, and sustainment (Proctor et al., 2013).

Implementation strategies target one or more implementation outcomes, including acceptability, adoption, appropriateness, feasibility, fidelity, implementation cost, penetration, and sustainability (Proctor et al., 2011). Implementation strategies can be discrete or multifaceted. Discrete strategies are single-component strategies, whereby a singular action or process is undertaken in service of a particular implementation outcome (e.g., provider training to target fidelity). Multifaceted strategies involve combining multiple discrete strategies to

address multiple outcomes, levels of delivery, or barriers to change (e.g., provider training, technical assistance, patient education to target adoption and fidelity). Implementation strategies target complicated processes within interpersonal, organization, and community contexts, and they must be developed or selected in a context-specific way so they can address relevant barriers to uptake.

Barriers to Equitable Implementation

The translation of research into practice, impact, and policy has historically been slow and inequitable (Glasgow et al., 2019). Many interventions that have been implemented have failed at achieving broad and equitable impact, as participants of these health promotion activities have often been those who need them the least (e.g., the "worried well" and the more advantaged groups) (Glasgow et al., 1999). A systematic review exploring the implementation of telehealth and mHealth interventions for chronic disease management found that there are a variety of factors that can prevent interventions from being delivered to the populations they are intended to reach (Fowe, 2021). When it comes to the technology itself, key barriers include device usability challenges, lack of usability testing, poor fit between the intervention and intended users, difficulties with installation, and high costs of technology. Users experience difficulties installing and accessing the intervention and find many processes to be time consuming or have to change existing duties and routines to accommodate the intervention. Outer context is also important, as external policy and incentives, patient needs and resources, and organizational partnerships and connections often influence the availability and accessibility of the intervention. Some barriers to implementation include lack of population-specific knowledge and skills, lack of end-user training, and lack of adequate technology and poor telecommunications infrastructure in rural areas that are traditionally much more economically disadvantaged than their urban counterparts. Additionally, within organizations, lack of fit, lack of training, technical challenges, and inadequate technology infrastructure (e.g., poor connectivity) limit use of the intervention. Failure to assess the unique needs and characteristics of the recipient population prior to implementation leads to implementation challenges that prevent interventions from reaching their target populations.

There are certain populations in particular that mHealth interventions have historically struggled to reach (Liu & Schueller, 2023). Digital interventions often do not work well for racial and ethnic minority groups, gender minority groups, and individuals with accessibility considerations. Although consistency in technology presentation and function allows delivery of evidence-based interventions with treatment fidelity, it also hinders adaptability, which is most likely to impact marginalized groups that have cultural and language differences that require adaptation, thus impacting their ability to benefit from the intervention. Along the same lines, key factors related to individual characteristics include technology access and literacy, both of which often look different in racial and ethnic minority groups and lower socioeconomic status groups. Limited access to technology and limited digital health literacy impact the ability to use and benefit from digital interventions, and underserved populations tend to be more greatly affected. High-speed broadband internet is not widely available throughout the US, and given that most mHealth interventions rely on connectivity, individuals in areas with poorer connectivity have an inherent disadvantage despite often needing these interventions the most. Additionally, lower-income communities and rural areas are more likely to experience difficulties implementing mHealth interventions due to a lack of resources. There must be enough effectiveness data from studies conducted with the target populations to warrant these

settings investing in implementing new technology, but that data often does not exist due to the lack of diversity in populations involved in research studies, with most digital health research being conducted with young and middle-aged white individuals (O'connor et al., 2016).

mHealth interventions have the potential to significantly expand healthcare access and improve healthcare quality, but their impact depends on whether they are actually used, which depends on successful implementation. Currently, there are more barriers facing implementation with underserved populations, and these barriers must be addressed to ensure that those populations are also able to benefit from mHealth interventions. Some populations require specific accommodations to be able to navigate the technology, and developing population-specific guidelines and protocols that consider their needs and engage them early on is crucial to successful implementation.

Biases and Underrepresentation

When studying the design and implementation of mHealth interventions, it is also important to keep in mind that biases, stereotypes, and prejudices often pervade algorithms governing mHealth technologies (Figueroa et al., 2021). Many mHealth applications as they currently stand reinforce social marginalization and exclude certain groups from digital health spaces on the basis of race, ethnicity, age, gender, socioeconomic status, education level, etc. (Doukani, 2021). mHealth technologies that are advertised to help everyone often rely heavily on the use of data accumulated from clinical trials where white males have historically been overrepresented (Hendl et al., 2019). For example, some mHealth interventions supposedly designed to be used by all exclude functions relating to non-male health – functions pertaining to the bodily processes of women, transgender, and non-binary individuals (Hendl et al., 2019). The lack of diverse representation within this space results in poorer quality of care for marginalized groups, as well as the deprioritization of their unique health issues (George et al., 2018).

A related concept that has emerged when discussing underrepresentation within digital health is health data poverty, defined by Ibrahim et al. (2021) as "the inability for individuals, groups, or populations to benefit from a discovery or innovation due to insufficient data that are adequately representative" (p. 260). There are systematic differences in the quantity and quality of health data representing different individuals, groups, and populations, leading to disparities in health data. Vulnerable and underserved populations have been starkly underrepresented in clinical trials, which inform the evidence-based interventions used in implementation studies (Baumann & Cabassa, 2020). For example, a review of clinical trials conducted in the U.S. between 2001 to 2010 for common mental health disorders found that racial and ethnic minorities accounted for only 19% of the total sample, with some minority groups representing less than 1% of the total sample (Santiago & Miranda, 2014). Meanwhile, white, healthy, middle- to upper-class males continue to be disproportionately represented in research, leading to datasets that underrepresent key population segments and data-driven interventions that are effective for a small segment of the population but ineffective, and at times, even harmful, for the rest (Ibrahim et al., 2021). Health data poverty, combined with lack of research using representative samples, can lead to the exacerbation of existing health inequities. To counter this, mHealth interventions need to be guided by scientific evidence regarding different manifestations of health conditions and symptoms in diverse population groups (Hendl et al., 2019) and be able to perform across populations and settings. mHealth developers must be able to tailor apps without reinforcing harmful social norms or stereotypes. Additionally, researchers need to increase representation in the enrollment and engagement of vulnerable populations in

clinical trials (Baumann & Cabassa, 2020), evaluating interventions with study samples that are representative of the intended user population.

Problem Statement

There is a significant need for more representative research to ensure that mHealth interventions are able to reach their target populations and deliver the intended benefits. One of the goals of mHealth has always been to expand access to care and reduce health disparities (Gorski et al., 2016; Ronquillo et al., 2022; Rowland et al., 2020), but there is potential for mHealth to further amplify disparities in access (Baum et al., 2012) and exacerbate social inequalities (Sawert & Tuppat, 2020). At present, mHealth is often implemented inequitably (Gustafson et al., 2023), and many mHealth applications have been implemented without sufficient consideration of their intended users' circumstances, including the social and healthcare systems into which they are being placed, thus resulting in technical, social, and economic barriers that impede mHealth systems' success and growth (Gorski et al., 2016; Hadjiat, 2023; Wu et al., 2007).

Differential access to technology, health and digital literacy, skills, human resources, and enabling environments can maintain and exacerbate social inequalities and further leave behind the social groups that are most in need of health care by offering unequal amounts of benefit to groups of people with different levels of advantage in society. At present, many users who are part of socially disadvantaged groups are not receiving the full health benefits promised by these technological advances (Mackert et al., 2016). There have been few improvements in the health outcomes of individuals of lower socioeconomic status and individuals of racial and ethnic minority groups especially (Stowell et al., 2018). Instead, it is often the individuals and groups who already had greater resources to begin with and were already able to access care within traditional models of health care delivery who gain earlier access to technology and benefit more from the technology (Rogers, 2014). Thus, inequitable implementation of technology can lead to the gap between social groups widening, and more disadvantaged groups being left further and further behind.

Dissertation Overview

Further research investigating the impact of interventions for low-income racial and ethnic minority populations and other underserved populations in low-resource service settings is necessary to address health equity issues (Glasgow et al., 2013). Some evidence-based interventions have been found to be effective at reducing inequities in healthcare delivery, but these interventions are rarely implemented in community settings serving vulnerable populations (Baumann & Cabassa, 2020). Additionally, enrollment in interventions among racial and ethnic minority populations tends to be much lower than among white individuals. For example, in the case of national enrollment in self-management education and support programs for diabetes, only 13.2% of individuals enrolled were Hispanic or Latino, while 86.8% were non-Hispanic, and only 13.1% enrolled were black, while 64.6% were white (Jacobs et al., 2024). There is a need for more research that focuses on using implementation strategies to enhance the uptake of evidence-based interventions in community settings and with racial and ethnic minority populations. The first paper of my dissertation will address this need by describing use of an implementation strategy for improving low-income ethnic minority patients' engagement with and adherence to treatment within a public healthcare system. The implementation strategy entails a text messaging adjunct designed to support and improve patient attendance at group

therapy for depression. The following research questions regarding the text messaging adjunct will be answered:

1) What types of text messages are most likely to elicit a response from patients?
2) What impact do text messages have on patients' knowledge, skills, intentions, and decision processes?
3) What do patients find most helpful and valuable about a text messaging adjunct?
4) What barriers do patients experience when interacting with a text messaging adjunct?

Individuals intended to benefit from mHealth interventions have traditionally been excluded from design and implementation processes despite holding valuable perspectives and insights. Additionally, the acceptance of mHealth apps remains poorly studied outside the context of clinical trials and app usability studies (Breil et al., 2019), and there is a lack of research on mHealth acceptance and adoption, particularly within vulnerable and underserved populations. There is a need to elicit the perspectives of intended users who have the most stake in implementation outcomes, as interventions will be able to advance population health in an equitable manner only when intended users are involved in design and implementation processes and share decision-making power and influence with other key stakeholders (Damschroder et al., 2022). Thus, the second paper of my dissertation will gather and center the voices of intended users of mHealth interventions, with a focus on immigrant populations and racial and ethnic minority groups, to better understand the barriers and facilitators that impact user selection and adoption of mHealth interventions for health behavior change. Key questions that will be answered through this paper include:

1) What do individuals prioritize in their search for a suitable mobile app for their health needs?
2) What factors influence whether individuals adopt an mHealth app and continue to use it over time?
3) What features of mHealth apps are most helpful and desirable for individuals?
4) What barriers impede mHealth app use and adoption?

Another important stakeholder group that is often under involved in mHealth design and implementation is medical providers. Medical providers have tremendous influence over patients' health care and health decisions but are rarely involved in designing, testing, implementing, or evaluating mHealth interventions, which are increasingly being utilized in healthcare provision. It is important to elicit providers' perspectives regarding the field of mHealth and their insights into how to improve technology for patient and provider use, especially as mHealth becomes more and more integrated into mainstream clinical care. As such, the third paper of this dissertation will explore providers' views of existing mHealth apps and their utility and value to patients and providers, as well as features and content that providers would like to see further developed in mHealth apps to improve their appropriateness for patient care and patient use. The following research questions will be answered:

1) What are providers' views of existing mHealth apps and their utility and value to patients and providers?
2) What are the primary deciding factors for whether providers would recommend an mHealth app to patients for health behavior change?

3) What features and content would providers like to see further developed in mHealth apps to improve their appropriateness for patient care and patient use and increase the likelihood of providers recommending mHealth apps to patients?

Through a three-paper model, this dissertation aims to inform more equitable design and implementation of mHealth interventions for health behavior change by exploring diverse individuals' needs and preferences when engaging with mHealth. This dissertation contributes to the field's understanding of how to develop and implement mHealth interventions such that they are widely applicable in different contexts and address the needs and preferences of users of varying levels of advantage, especially underserved populations. Ultimately, the goal is for this work to lead to a greater understanding of the unique needs and cultures of different populations and communities, a more critical analysis of current approaches to designing and implementing mHealth interventions, and a deeper commitment to enhancing social inclusion in mHealth.

Paper 1: Utilizing Text Messages to Improve Patient Adherence to Group Therapy for Depression: Guidelines for Designing a Text Messaging Adjunct for Use as an Implementation Strategy

Background

Depression is a mental health disorder that can significantly impact function and quality of life, and it is the leading cause of disability worldwide (World Health Organization, 2017). Psychotherapy is an effective treatment for depression, and research has shown that higher dosage of psychotherapy via increased patient engagement leads to improved mental health outcomes (Kazantzis et al., 2016; Neimeyer et al., 2008). However, a primary challenge of mental health treatment is sustaining patient engagement and preventing dropout (Lutz et al., 2018). This is particularly true in racial and ethnic minority groups and socioeconomically disadvantaged groups (Stowell et al., 2018), as they have been shown to utilize services at lower rates (Alegría et al., 2008) and engage to a lesser extent once in treatment (Organista et al., 1994). Given this, there is a need for implementation strategies that target patient attendance, engagement, and retention, especially in low-income populations and racial and ethnic minority groups.

As of 2024, 98% of Americans own a mobile phone of some kind, and 91% of Americans own a smartphone, with almost all phones having SMS text messaging capabilities (Pew Research Center, 2024). Given high phone ownership rates across a range of demographic groups, there is tremendous potential for mobile technology to be used as an implementation strategy for improving patient adherence to psychotherapy. Prior research has found that mobile technologies benefit the delivery of psychotherapy, as patients who received mobile technology to supplement treatment demonstrated improved outcomes as compared to patients who did not receive any form of mobile technology (Lindhiem et al., 2015). Using mobile technology as a supplement to treatment can enhance the delivery and effectiveness of treatment. Specifically, text messages have been shown to increase session attendance (Figueroa et al., 2021) and the time that patients stay in psychotherapy (Aguilera et al., 2017). However, beneficial effects and therapeutic gains associated with such technology rely on sufficient engagement, as studies have also shown that low patient engagement with mobile interventions over time reduces their effectiveness (Fleming et al., 2018; Short et al., 2018) and patients' likelihood of experiencing clinical improvement (Torous et al., 2020). Thus, research is needed on ways to make messaging adjuncts more engaging. The content of text messages is one of the most important determinants of their success, and prior research has found that specific words, personalization, caring sentiments, polite text, and texts that enhance connectedness between patient and provider are characteristic of successful messages (Berrouiguet et al., 2016). This study identifies specific words that are important and relevant to treatment for depression and discusses how message type and format affect patient engagement.

This study focuses on text messages sent to and from low-income English- or Spanish-speaking patients receiving services at an urban safety-net hospital to inform understanding of the types of text messages that resonate with socioeconomically disadvantaged groups and racial and ethnic minority populations, as these groups tend to be disproportionately affected by mental health issues and experience worse outcomes (Stowell et al., 2018). Health equity researchers have pointed to a need for the field of implementation science to identify, develop, and test implementation strategies that can support the adoption of evidence-based interventions in vulnerable communities (Baumann & Cabassa, 2020). This study provides guidance and

recommendations on how to use text messaging adjuncts as an implementation strategy to improve patient adherence to psychotherapy in underserved populations.

Study Overview

The main purposes of this study are to explain the mechanisms of change behind a text messaging adjunct and to identify text messages that resulted in high response rates so as to increase the likelihood of patient engagement with text messaging adjuncts. The MoodText intervention was used as a basis for addressing these study aims (Aguilera et al., 2017). The MoodText intervention was previously evaluated in a nonrandomized controlled trial where patients receiving services at an urban public hospital were assigned to one of two study conditions: group cognitive behavioral therapy (CBT) for depression or the same treatment with the addition of a text messaging adjunct (Aguilera et al., 2017). During the clinical trial, patients participated in a weekly CBT group based on the Building Recovery by Improving Goals, Habits, and Thoughts (BRIGHT) manual for depression (Miranda et al., 2006). The manual consists of four modules focusing on cognitive restructuring (thoughts), behavioral activation (activities), interpersonal relationships (people), and healthy behaviors (health). The group was designed to run over 16 continuous weeks, with group sessions offered weekly. Patients were enrolled in the groups on a rolling basis between January 2014 and August 2016. The text messaging adjunct was found to be an effective strategy for promoting sustained engagement in treatment and reducing attrition, as patients who were enrolled in the text messaging adjunct stayed in group therapy significantly longer (median of 13.5 weeks before dropping out) than patients not enrolled in text messaging (median of 3 weeks before dropping out).

The research team continued to implement the MoodText intervention after the initial clinical trial, and in the subsequent phase of the study, which took place between September 2016 to September 2020, all patients were enrolled in the text messaging adjunct. Enrollment once again took place on a rolling basis, with patients starting the 16 weeks of therapy at different points in time, thus resulting in patients receiving text messaging content in different orders. This paper uses data from the second phase of the study, with the focus being on patient engagement with the text messaging adjunct.

Description of the Text Messaging Adjunct

Over the course of the intervention period, patients received six types of automated text messages: 1) a daily mood rating prompt, with feedback 20% of the time based on their mood ratings; 2) a daily thematic module-based message to supplement live group therapy material; 3) optional daily medication reminders; 4) a weekly reminder to attend group psychotherapy; 5) a monthly prompt to provide feedback on the texting intervention, and 6) a monthly opt-out message to terminate message delivery, if desired.

Mood Rating Prompts. Daily mood rating prompts were designed to promote mood-monitoring and increase awareness of mood and mental state, both of which are important elements of depression treatment. Each day patients were asked to rate their mood on a scale from 1 to 9, with 1 indicating worst mood and 9 indicating best mood. Patients were also invited to explain the rationale behind their provided mood rating. Examples of patient responses include:

- "9 – just finished some self-care, with a massage, chiropractic service and acupuncture. Looking forward to bed."

- "Today I say 6. I am feeling better and getting some work done, so onward and upward. Enjoying a Saturday that's rainy and quiet."

Patients were given feedback on their mood ratings a random 20% of the time they sent a mood rating. For example, if they provided a low mood rating, they might receive a supportive response with a tip for improving their mood.

Thematic Module-Based Messages. Module-based messages were sent daily to reinforce and supplement the theme of that week's group CBT session. A total of 112 messages were developed for the texting adjunct, with 28 messages in each of the four categories defined by the BRIGHT manual: 1) Thoughts; 2) Activities; 3) People; 4) Health. Messages varied in their content and format, with some messages containing a statement (e.g., fact, tip, reminder) and others containing a question. These messages were gain framed, focusing on increasing capability, opportunity, and motivation and helping patients build skills. Examples of module-based messages include:

- "[[first_name]], think about your day. Can you think of a thought that lowered your mood? How could you change it so it doesn't affect you as much?" (Thoughts message)
- "Short and long term goals give us motivation and reasons to get better. What are your goals?" (Activities message)
- "[[first_name]], remember good communication is the key to improve your relationships and improve your mood." (People message)
- "There are many benefits to exercising. When will be the next time you exercise?" (Health message)

Group Therapy Reminders. Patients received an appointment reminder via text message once per week at 7 P.M. the evening before their scheduled group psychotherapy session. These messages prompted patients to give a direct reply as to whether they planned to attend group psychotherapy the following day: *[[first_name]], are you coming to group tomorrow?*

Feedback Prompts. Patients received one of four feedback messages each month to assess their satisfaction with the text messaging adjunct:

1) What is the most positive part of receiving these text messages?
2) What do you not like about receiving the text messages?
3) Can you give an example of a message you would like to receive when you are feeling down?
4) When you have not responded to the text messages, it was because:

Text messages were provided in patients' preferred language (either English or Spanish), and text message content was designed to not exceed a sixth grade reading level to ensure accessibility for those with lower levels of education and reading literacy. Text messages were automatically delivered on a predetermined schedule through a text messaging platform that allowed providers to schedule automated and real-time message delivery, track their patients' progress over the course of treatment, and monitor responses to text messages between therapy sessions. Patients received text messages throughout the duration of the 16-week group therapy period and for up to six months afterwards.

This study examines patients' responses to text messages, analyzes differential response rates to the various types of text messages delivered, and identifies components of the text messaging adjunct that were most successful and desirable, as well as barriers to engagement. Additionally, the mechanisms of change behind this text messaging adjunct are elucidated to further knowledge on effective implementation strategies to keep patients engaged in live treatment over time. The following key research questions will be answered:

1) What types of text messages are most likely to elicit a response from patients?
2) What impact do text messages have on patients' knowledge, skills, intentions, and decision processes?
3) What do patients find most helpful and valuable about a text messaging adjunct?
4) What barriers do patients experience when interacting with a text messaging adjunct?

Building a Causal Pathway Model

As a way to illustrate the mechanisms of change behind this text messaging adjunct, a causal pathway model will be proposed using Lewis et al.'s (2018) approach. Causal pathway models represent relationships between variables and outcomes within a specific context, thus allowing researchers to empirically test whether implementation strategies operate via the theorized mechanisms and how much variance in outcomes can be explained by those mechanisms. Building causal pathway models can advance theory development about implementation processes by specifying hypotheses and allowing those hypotheses to be tested and refined. A causal pathway model will be built based on results of the above research questions to illustrate how a text messaging adjunct can be used as an implementation strategy to improve attendance in group psychotherapy.

Specifying and Reporting Implementation Strategy

When conducting research on implementation strategies, strategies should include a full description of their components and how they should be used (Proctor et al., 2013). This paper follows Proctor et al.'s guidelines for naming, defining, and operationalizing implementation strategies. In naming the implementation strategy being used, this paper draws on the Expert Recommendations for Implementing Change (ERIC), a compilation of implementation strategy terms and definitions often used in mental health service settings (Powell et al., 2015).

Naming. The text messaging adjunct in this study can be thought of as a multifaceted implementation strategy that aligns with the discrete strategies of *promoting adaptability* and *intervening with patients to enhance uptake and adherence*. Promoting adaptability is defined as identifying the ways a clinical innovation can be tailored to meet local needs and clarify which elements of the innovation must be maintained to preserve fidelity. Intervening with patients to enhance uptake and adherence is defined as developing strategies with patients to encourage and problem solve around adherence.

Defining. The text messaging adjunct is defined as an automated text messaging platform that delivers mood monitoring, treatment content, and treatment reminder text messages to patients while they are participating in a clinical intervention for depression – group psychotherapy.

Operationalizing. Per Proctor et al. (2013), implementation strategies should be operationalized by detailing the actor, action, action targets, temporality, dose, and implementation outcomes addressed; a justification for use of the selected implementation strategies should also be provided. In this case, actors include the behavioral health providers who referred patients to therapy and enrolled them in the text messaging adjunct, as well as intervention developers who designed and sent text messaging content to patients via the automated text messaging platform. The action is sending patients mood monitoring, treatment content, and treatment reminder text messages throughout the duration of the intervention. The action target is at the level of the individual, and determinants include patients' knowledge, skills, ability, intentions, decision processes, and compliance. Treatment content-related text messages are intended to enhance patients' knowledge of therapy content, increase the application of skills learned in therapy sessions, improve their ability to engage in health-promoting behaviors, and influence decision processes related to attending treatment.

In terms of temporality, patients were enrolled in the text messaging intervention at the time of enrollment in group psychotherapy. Messages were automatically delivered to patients on a predetermined schedule and sent to patients throughout the 16 weeks of group therapy and for up to six additional months after terminating therapy, for a maximum length of 300 days. In terms of dose, mood monitoring text messages and treatment content-related text messages were sent daily throughout the intervention period and reminders to attend therapy were sent weekly. The implementation outcome associated with the strategy is patient adherence to treatment.

The use of text messaging adjuncts for facilitating treatment adherence can be justified through empirical evidence. Mobile technologies have increasingly been used to effect positive behavior change and improve adherence behaviors, especially in mental health (Fiordelli et al., 2013). Text messaging is a particularly appropriate form of mobile technology for underserved groups, as it is low cost, easy to access, and used pervasively as a form of communication across groups of different levels of advantage (Berrouiguet et al., 2016). In mental health care, text messages have primarily been associated with four uses: reminders, supportive messages, information provision, and self-monitoring. The delivery of reminders and supportive text messages can make patients feel supported and close to the group, make sessions seem more immediately relevant, strengthen therapeutic alliance, and increase the likelihood that they will attend sessions or re-engage with psychotherapy if absent for a period of time, thus improving treatment attendance and adherence. Additionally, the delivery of information provision and self-monitoring text messages during treatment can prompt greater engagement in psychotherapy homework and more frequent application of skills learned in therapy sessions, thus leading to improved clinical outcomes. Text messaging has been linked to improved treatment adherence, higher treatment attendance, and greater satisfaction with health care services (Figueroa et al., 2021; Lindhiem et al., 2015), thus making it a suitable implementation strategy for implementing a psychotherapy intervention.

Methods

Participants

Data for this study came from text messages sent to and from the 63 English- or Spanish-speaking patients who participated in the MoodText intervention between September 2016 to September 2020. These patients were predominantly low-income Latinx patients recruited from primary care clinics in the public health care system in the county of San Francisco. Patients

were referred to a behavioral health clinician by their primary care provider when there were concerns about depression due to patient endorsement of depressive symptoms or a positive screen based on the 9-item Patient Health Questionnaire (PHQ-9), a commonly used depression measure in healthcare settings. The behavioral health clinician provided a referral to the weekly CBT group if a patient met the following inclusion criteria: age ≥ 18 years, English- or Spanish-speaking, ownership of a mobile phone with SMS text messaging capabilities, and a diagnosis of depression as based on the PHQ-9. Exclusion criteria were: active suicidal ideation with a plan, active severe psychosis, and comorbid substance use disorders.

Research Question 1: What types of text messages were most likely to elicit a response from patients?

The focus of this question was on the thematic module-based messages, as those messages varied in content and format each day, whereas the mood monitoring message remained the same each day it was sent out during the study. Descriptive statistics were generated to compare response rates of different module-based messages. Inferential statistics were used to look at the following categorical variables: CBT message category (activities, health, people, thoughts), message format (question vs statement), and question type (open-ended vs closed-ended). Chi-square tests of independence were conducted to determine whether there was an association between type of message and response rate. Statistical significance was calculated at the 5% level.

Content analysis was also used to identify keywords present in the thematic module-based messages that elicited higher response rates. The 2022 version of the Linguistic Inquiry and Word Count (LIWC) text analysis software (LIWC) (Pennebaker et al., 2007) was used to systematically conduct word-by-word content analysis, calculate frequency of words, and generate themes and patterns based on pre-established word categories. LIWC functions by processing text, comparing each word in the text to over 100 lists of dictionary words, and calculating the percentage of total words in the text that match each of the dictionary categories (Pennebaker et al., 2007). Each dictionary in LIWC consists of a list of words, word stems, emoticons, and other verbal constructions that reflect a psychological category of interest such as cognitive processes, social affiliation, and positive emotions. Most of the LIWC output variables are percentages of total words within a text that match each of the dictionary categories.

Research Question 2: What impact did the text messages have on patients' knowledge, skills, intentions, and decision processes?

Patient responses to the CBT module messages were input into LIWC to understand patients' psychological state when interacting with the text messages and to describe the mechanisms of change behind the text messaging adjunct. Text messages received in Spanish were translated into English via a translation software and checked by the author for accuracy before grouping all patient text messages into one file and importing patient responses to CBT module messages into LIWC. LIWC was used to identify words that were most commonly found in patients' responses to the thematic module-based messages. Additionally, the summary measures generated by LIWC were used to understand patients' thought processes as they received and responded to text messages sent by the text messaging adjunct. LIWC contains four summary measures: Analytical Thinking, Clout, Authenticity, and Emotional Tone. Each of these measures are algorithms derived from LIWC variables grounded in empirical research (Pennebaker et al., 2007). The measures are represented as standardized scores that have been

converted to percentiles. These summary measures were helpful in contextualizing how patients received and interacted with the text messaging adjunct – e.g., the degree to which they engaged with the text messaging adjunct formally (Analytical Thinking), confidently (Clout), honestly (Authenticity), and positively (Emotional Tone). Finally, LIWC was also used to calculate percentages of total words within patients' responses that matched different dictionary categories such as cognition, social processes, affect, perception, time, lifestyle, health, etc. to better understand what patients were thinking about as they responded to the text messages.

Research Question 3: What did patients find most helpful and valuable about a text messaging adjunct?

Qualitative analysis of patient responses to the monthly feedback questions was conducted to provide insight into how the text messaging adjunct was generally perceived by patients, how the text messaging adjunct made patients feel, and whether the text messages resulted in increased positive emotion, motivation, or desire to change behavior. To highlight the characteristics that contributed most to the text messaging adjunct's success, a thematic analysis approach was applied to analyzing patient responses to the feedback question: "What is the most positive part of receiving these text messages?" Thematic analysis is a qualitative method for systematically identifying and organizing insight into patterns of meaning across a data set to make sense of shared meanings and experiences (Braun & Clarke, 2012). Codes were generated inductively directly from the data through open coding. The coded data were then reviewed to identify areas of similarity and overlap between the codes and generate broad themes in relation to the research question.

Research Question 4: What barriers did patients experience when interacting with a text messaging adjunct?

To identify barriers to engagement with the text messaging adjunct and provide guidance for further optimizing text messaging adjuncts beyond this study, patient responses to two feedback questions were analyzed: "What do you not like about receiving the text messages?" and "When you have not responded to the text messages, it was because…?" The same thematic analysis approach discussed above was applied to this research question.

Results

Patient Characteristics

Of the 63 patients enrolled in the study, 52 opted to receive text messages in Spanish and 11 in English. Almost all of the patients remained enrolled in the text messaging adjunct for the entirety of the MoodText intervention, with only two patients opting out prematurely (one at three weeks in and one at one week in). Patients were predominantly female (72.6%) and born outside of the United States (76.7%). The mean age was 51.6 (SD=12.7). Education levels varied, with 49.1% lacking a high school diploma or equivalent. See Table 1 for patient characteristics.

Table 1: Patient demographics.

	Percent (N)
Gender	

Female	72.6% (45)
Male	27.4% (17)
Nativity	
US-born	23.3% (14)
Foreign-born	76.7% (46)
Native Language	
English	23.7% (14)
Spanish	69.5% (41)
Portuguese	1.7% (1)
Tagalog	1.7% (1)
Arabic	1.7% (1)
Russian	1.7% (1)
Highest level of education completed	
Primary school	8.5% (5)
Middle school	18.6% (11)
Some high school	22.0% (13)
High school graduate or GED	8.5% (5)
Some college or technical school	35.6% (21)
College graduate	3.4% (2)
Graduate degree	3.4% (2)

Research Question 1: What types of text messages were most likely to elicit a response from patients?

CBT Message Category. There were 28 unique text messages for each of the four CBT message categories (Activities, Health, People, Thoughts), thus totaling 112 unique thematic module-based messages that were sent out to patients. The response rate across all thematic module-based messages was 32.5%. CBT messages in the Thoughts category had the highest response rate at 35.4%, followed by the Activities category at 32.4%, then the People category at 31.0%. Messages in the Health category had the lowest response rate at 30.0% (see Table 2).

Results of a Chi-square test of independence showed that there was a statistically significant relationship between CBT message category and response rate ($\chi^2 = 9.39$, df = 3, $p = 0.025$). Post hoc testing was conducted to determine which pairs of the four CBT message categories were significantly different from one another with respect to their response rates. Separate Chi-square tests were run for each of the six pairwise comparisons using the Bonferroni-adjusted p-value of 0.008. The difference in response rate between Thoughts and Health messages was the only pairwise comparison that was statistically significant ($\chi^2 = 7.66$, df = 1, $p = 0.006$).

Message Format. Thematic module-based messages varied in their format. Some text messages contained only a statement (e.g., fact, tip, reminder), while other messages included a question. A Chi-square test of independence showed that there was a statistically significant relationship between message format and response rate ($\chi^2 = 65.80$, df = 1, $p < 0.001$). The

average response rate for messages with questions was 37.4%, while the average response rate for messages with only a statement was 26.4%, thus indicating that the inclusion of a question in a text message was significantly more likely to result in a response from patients.

Question Type. Of the text messages containing questions, some contained an open-ended question (e.g., H15: What are your goals to improve your health?), while others contained a closed-ended question (e.g., P20: What communication style did you use today: passive, aggressive or firm?). A Chi-square test of independence showed that there was a statistically significant relationship between question type and response rate ($\chi^2 = 10.10$, df = 1, p = 0.001). The average response rate for messages with a closed-ended question was 42.5%, while the average response rate for messages with an open-ended question was 35.7% (see Table 2), thus indicating that closed-ended questions were significantly more likely to result in a response from patients than open-ended questions.

Table 2: Response rates across categories.

Message category	Response rate across all messages	Proportion of messages containing a question	Response rate of all messages with a question	Response rate of messages with a closed-ended question	Response rate of messages with an open-ended question
Activities	32.4%	68.0%	37.1%	48.1%	35.6%
Health	30.0%	39.0%	33.9%	46.3%	32.6%
People	31.0%	50.0%	36.8%	42.4%	35.0%
Thoughts	35.4%	57.0%	40.2%	40.7%	39.7%
All categories	32.5%	54.0%	37.4%	42.5%	35.7%

Keywords. Thematic module-based messages with high response rates were input into LIWC to provide insight into keywords to include in text messages to increase the likelihood of patient interaction. There were 21 messages that had a response rate of 40% or higher: 7 in the Activities category, 4 in the Health category, 5 in the People category, 5 in the Thoughts category (see Table 3). The Word Frequencies test in LIWC revealed that the most commonly found words in those 21 messages were, in order of frequency: [first name], today, activity/activities, thought, mood, week, daily, better, health, healthy, improve, goals, positive, interactions, relationship, sleep, water.

Table 3: Messages with the highest response rates, in order of response rate.

CBT Message Category	Module Message	Response Rate
Activities	How many enjoyable activities did you do today?	54.5%
Thoughts	[[first_name]], think about your day. Can you think of a thought that lowered your mood? Is it worth it to focus on it so much?	54.5%
Thoughts	[[first_name]], can you think of a helpful thought from today?	54.1%

Activities	[[first_name]], what did you do today? How did it affect your mood?	52.0%
People	[[first_name]], how many positive social interactions have you had today?	50.0%
Thoughts	What is a thought that improved your mood today? Enjoy it!	48.7%
Activities	What pleasant activity do you plan to do this week?	48.1%
Health	Drinking water has a lot of benefits for your health. How many cups of water do you drink daily?	46.3%
Thoughts	Which thoughts make you stronger?	46.2%
Activities	[[first_name]], who can help you do a healthy activities?	46.0%
Activities	This week, were you able to do an activity that you enjoyed in the past?	45.5%
Activities	Short and long term goals give us motivation and reasons to get better. What are your goals?	45.0%
Activities	Were you able to do a new activity this week?	44.7%
Health	[[first_name]], how many hours did you sleep last night? Was that enough? What steps can you take to improve your sleep?	44.7%
People	How many positive interactions did you have today?	44.1%
People	If you have a bad or troubled relationship, what can you do to improve this relationship?	43.8%
People	Who are the people in your life that are good company? How can you better those relationships?	42.9%
Health	[[first_name]], what did you do today to take care of your health and well being?	42.9%
People	What communication style did you use today: passive, aggressive or firm?	42.4%
Health	[[first_name]], a healthy nutrition improves how our body functions daily and reduces the risks of diseases in the future.	42.1%
Thoughts	Can you think of a thought that didn't help you today? Is it true and balanced? Or is there a different way to view the situation?	41.7%

Research Question 2: What impact did the text messages have on patients' knowledge, skills, intentions, and decision processes?

Patient responses to the thematic module-based messages were input into LIWC to understand patients' psychological state when interacting with the text messages and to describe the mechanisms of change behind the text messaging adjunct. Examples of patient responses to text messages are provided in Table 4.

Table 4: Examples of module-based messages and patient responses.

Thoughts	Activities	People	Health
M: You are in control of your thoughts and how you view the world. R: Yes I am.	M: Do an activity that you enjoyed before or that you haven't done in a long time.	M: [[first_name]], who can you count on for practical support? (For example: ask to borrow money, ask	M: There are many benefits to exercising. When will be the next time you exercise?

	R: I went to the beach today.	for transportation, etc.) R: Social Worker, Paratransit	R: Sometime tomorrow.
M: [[first_name]], think about your day. Can you think of a thought that improved your mood? R: Somehow you guys always send a text that is relevant to my day! When I woke up very late, I was bleary and achy and just didn't want to do anything but go back to sleep, but I thought about what I accomplished yesterday and it gave me the strength to push through it so I could make a difference in getting rid of stuff! Still don't know what to do with 6 huge plastic bins of comics or a thousand LP's, but at least I am making some progress!	M: What things can you do to improve your mood? Start now! R: I am started! Slowly but surely! Today is cleaning day, laundry day, making real soup from scratch day! Busy and crossing things off the list--that's improving my mood! How bout a 7?	M: Who are the people in your life that are good company? How can you better those relationships? R: Good friends are good company and I am lucky to have so many! What I need is to figure out how to get together with them more often!	M: Start an exercise routine. Start by thinking about the exercise that you want to do, then where, how and when. R: I have dug out my old exercise pamphlets and want to get back to doing my knee exercises. I have been doing most of them fairly regularly, but lately I've been slacking on them, and doing only a couple of sets. So this is very timely! But I need to make a spot for doing some of them, Maybe moving some things around. And I need to set myself a schedule. This is a good plan--maybe a New Years resolution!
M: [[first_name]], think about your day. Can you think of a thought that lowered your mood? How could you change it so it doesn't affect you as much? R: Trying to take long and deep breath and count to 10.	M: [[first_name]], what did you do today? How did it affect your mood? R: Went to exercise class. I helped my mood by energizing me.	M: Who are the people that can give you emotional support? R: My Brother, my Sisters in law	M: [[first_name]], how can you accomplish the goals that you have for your health? R: Encourage myself to exercise, eat well and be around positive people.

M: Think about your day. Can you think of a thought that didn't help you? How can you balance your thoughts? R: Its not easy for me to think a thought if your feeling is not good. I will try to stay calm and comfort myself much as i can.	M: What pleasant activity do you plan to do this week? R: Working on an art project that will be a gift for my good friend's birthday. A lot of steps with drying time means it is going slowly. But it's going well and making me happy so far.	M: Hanging out with people who make you feel bad can lower your mood. R: That's why I don't do it! One good thing about being retired is you don't have to spend 8 hours a day with people who you don't care for!	M: Drinking water has a lot of benefits for your health. How many cups of water do you drink daily? R: I try to drink a gallon, and carry my water bottle everywhere. It's even more important for diabetics, so it's one thing I really work at.
M: What is a thought that didn't help you today? Can you give it less importance? R: Complaints from other people.	M: What new activity can you do to improve your mood? R: I am planning to attend the wellness program, other physical exercise.	M: How many positive social interactions have you had today? R: 3	M: For a treat, try having a little fruit or sugar-free dessert. R: Just had some grapes for dessert--still some sugar but it's OK. Now if I could get some sleep...elusive the past few days.
M: [[first_name]], use your positive thoughts as a tool when you feel down. R: One thing I used just today was my positive thought	M: What do you like to do? When is the next time you will do it? R: I like to go for walks when I can. Maybe I'll do it tomorrow if I feel well.	M: How can you meet new friends? Take the first step! R: I meet new friends as I attend 3 different exercise classes. Just have to make the time for one on one conversation.	M: How do you remember to take your medication? R: I set alarms on my phone. And some I have a backup alarm for, so I can't tell myself in a minute and then forget about it.

Some of the most commonly found words in patients' responses, in order of frequency, were: "thank" (including "thanks" and "thank you"), "today," "day," "blessings," "positive," "things," "better," "time," "afternoon," "work," "people," "walk," "trying," "god," "true," "life," "thoughts," "health," "friends," "mood," "right," "thought," "friend," "signed." These words appeared in text messages at least 40 times (see Table 5 for extended list).

Table 5: Words most commonly found in patient responses, in order of frequency.

Word	**Frequency (n)**	**Percent of Total Words (%)**
thank	154	1.88

today	147	1.79
day	124	1.51
blessings	108	1.32
positive	105	1.28
things	95	1.16
better	94	1.15
time	91	1.11
afternoon	75	0.91
work	66	0.80
people	64	0.78
walk	61	0.74
trying	60	0.73
god	57	0.69
TRUE	57	0.69
life	57	0.69
thoughts	56	0.68
health	55	0.67
friends	55	0.67
mood	50	0.61
right	48	0.58
thought	47	0.57
😍	45	0.55
thanks	43	0.52
friend	41	0.50
signed	40	0.49
healthy	39	0.48
eat	39	0.48
tomorrow	38	0.46
thinking	38	0.46
working	37	0.45
activity	37	0.45

feeling	36	0.44
give	35	0.43
change	35	0.43
iam	34	0.41
night	33	0.40
family	33	0.40
great	32	0.39
moment	30	0.37
happy	30	0.37
mind	30	0.37
helps	30	0.37
exercise	29	0.35
see	29	0.35
care	28	0.34
talk	27	0.33
walking	27	0.33
negative	27	0.33
son	27	0.33
hard	25	0.30
nothing	25	0.30
morning	25	0.30
best	24	0.29
sleep	24	0.29
person	24	0.29
eating	23	0.28
busy	23	0.28
yesterday	22	0.27
pain	22	0.27
difficult	22	0.27
making	21	0.26
improve	21	0.26

doctor	21	0.26
house	21	0.26
control	21	0.26
problem	21	0.26
problems	20	0.24

LIWC-22 summary measures were calculated based on patients' responses, with each of the four summary measures being a percentile ranging from 1 to 99. Analytical Thinking was rated 17.6, Clout rated 5.6, Authenticity rated 96.2, and Emotional Tone rated 94.3. Analytical Thinking is "the degree to which people use words that suggest formal, logical, and hierarchical thinking patterns" (Pennebaker et al., 2007). A high Analytical Thinking score tends to reflect more formal, logical, and hierarchal thinking, while a low Analytical Thinking score reflects more informal, personal, intuitive, and narrative thinking. Clout is "the relative social status, confidence, or leadership that people display through their writing or talking." A high Clout score suggests high expertise and confidence, while a low Clout score suggests a more tentative, humble, anxious style. Authenticity is a reflection of the degree to which a person is self-monitoring, self-regulating, or filtering what they are saying. Higher Authenticity scores are associated with more honest, personal, and self-disclosing text, while lower Authenticity scores are associated with more guarded, cautious, distanced discourse. Emotional Tone captures indications of both positive and negative tone. Higher Emotional Tone reflects a more positive, upbeat style, medium Emotional Tone (a number around 50) suggests either a lack of emotionality or different levels of ambivalence, and low Emotional Tone reveals greater sadness, anxiety, or hostility.

Other LIWC output variables were expressed in terms of percentages of total words within a text that matched each of the dictionary categories (see Figure 3). Over 27% of total words within patients' responses related to cognition, with about half of those words relating to cognitive processes. 11% of total words related to social processes, with half of those words being associated with social referents (e.g., family, friends) and the other half being associated with social behavior (e.g., love, care, say). 9% of total words expressed affect, with 84% of affect words being positive in tone. 7% of total words related to perception (e.g., motion, space, visual, auditory, feeling). 7% of total words included a reference to time, with the majority being focused on the present (e.g., today, now, I'm doing). 5% of total words related to drive, with achievement being the biggest drive, followed by affiliation. About 3% of total words were lifestyle related, including work, leisure, home, and religion. Another 3% of total words touched on health (physical health, mental health, illness, wellness, food).

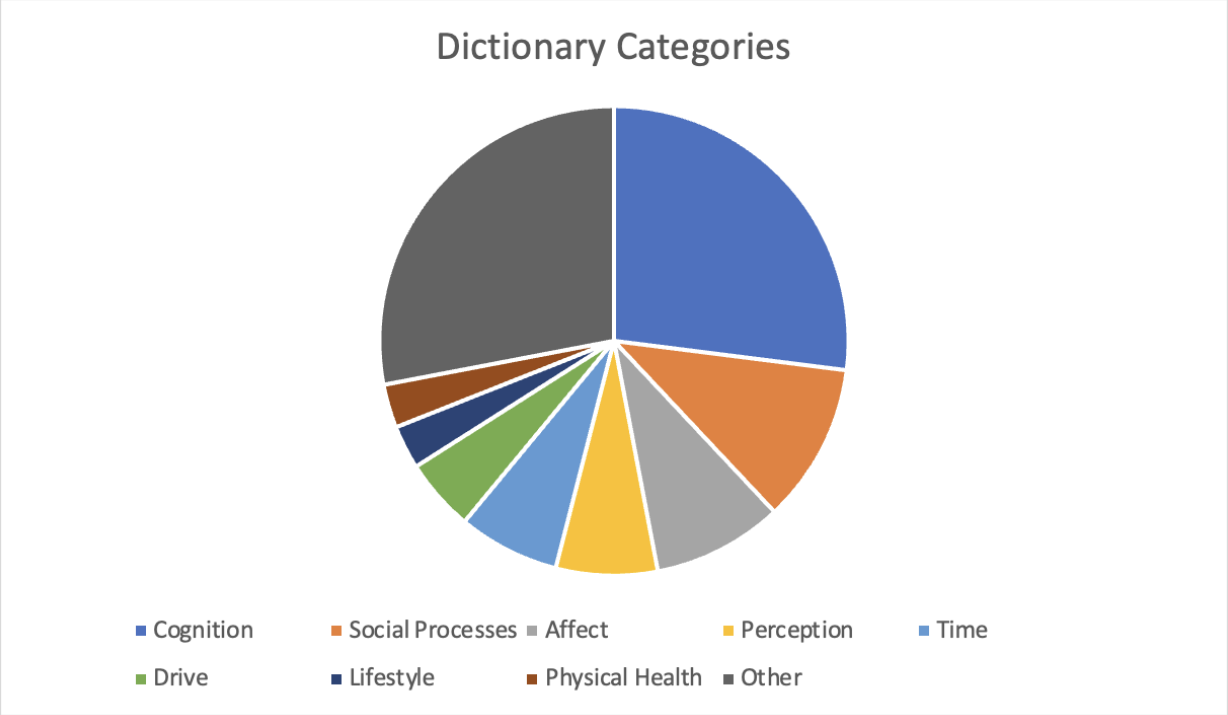

Figure 3: Percentage of total words in each LIWC dictionary category.

Research Question 3: What did patients find most helpful and valuable about a text messaging adjunct?

Patient responses to the first monthly feedback message 1 (*What is the most positive part of receiving these text messages?*) were analyzed to further provide context for the mechanisms of change behind the text messaging adjunct. Examples of patient responses are included in Table 6. General themes mentioned by patients were that the messages helped patients come up with positive thoughts, practice gratitude, think kindly about others, notice positive things in their lives, stay on track with their plans, keep busy throughout the day, enact skills learned in group therapy, gain self-confidence, broaden their perspective, and focus on key areas of their lives that they would otherwise not pay attention to. Additionally, they expressed that the text messages' supportive tone, positive reinforcement, and encouragement felt motivating. A couple patients explained that receiving a supportive, well-time message when they were feeling down helped to distract them from their negative thoughts and refocus their attention on a more productive thought, task, or activity. The text messages also served as reminders to patients to practice skills learned in group therapy sessions and apply them to their daily routines, relationships, and thought patterns. Multiple patients voiced that receiving text messages throughout the week made them feel cared for, supported by, and more connected to their providers between group therapy sessions. For some, this feeling of connection incentivized them to further engage with the therapy content throughout the week so they would have positive results to report back to their provider via the daily mood ratings. Patients shared beneficial impacts in their responses to the text messaging adjunct, reporting things like improved mood, reduced frustration with events outside their control, fewer negative thoughts, progress toward their goals, and healthier resolution of issues.

Research Question 4: What barriers did patients experience when interacting with a text messaging adjunct?

To assess barriers to interacting with the text messaging adjunct, patient responses to the following feedback messages were analyzed: "What do you not like about receiving the text messages?" and "When you have not responded to the text messages, it was because…" Examples of patient responses to these feedback messages are included in Table 6. The most frequently mentioned barriers to engaging with the text messages were being busy or occupied with another task; receiving the texts at an inconvenient time (e.g., while sleeping or at work); receiving too many text messages; missing the text notification; forgetting to respond; needing a break from therapy content; and not wanting to be on one's phone all the time.

Table 6: Examples of patient responses to feedback messages.

Feedback message: What is the most positive part of receiving these text messages?	*Feedback message: What do you not like about receiving the text messages?*	*Feedback message: When you have not responded to the text messages, it was because:*
The messages make me focus on some areas in my life that I would not normally think about	Sometimes they come when I'm busy doing something, and I forget to get back to it, because I don't have my phone with me all the time. Sometimes I need a break from it so I take it, so it doesn't seem to be a problem! Can't think of any others!	I didn't see the txt, I didn't have my phone, I was busy or I forgot.
They help me use positive thoughts. Not only for myself but to pass along to others.	Sometime I'm busy or I don't hear my phone.	I am sleeping resting that time I am so tired
Everything!! They keep me on track and make me try harder to feel better because I don't want to say today is only a two!! So I make a plan for how the day will go and I get more done. My friend said why don't you just say you feel great if that's how you want to be seen. But that's like a lie! I have to be truthful if I want it to work! It's just funny that I never even thought about being anything but truthful-- why even start the program if you weren't planning on being serious and	I can't think of anything! Really. The only issue is my reluctance to be tethered to my phone! So that reluctance leads to missing an occasional text or not getting to it in a reasonable amount of time. That's it! Can't think of anything good enough to even mention!	First of all I want to apologize because I haven't answered your messages but I feel fine and thank you.

honest, and what good effects would you be planning on getting?? Not me!!		
I was very thankful and happy coz you monitor what's in my mind and to help me out keep busy for respond this message	Nothing it means everything to me. Thank you and i appreciate it.	Busy doing other things
Thank you for sending me all the messages they have helped me resolve my negative thoughts and confront my problems in a positive way. Thanks a million for the unconditional support 🙏🙏🙏🙏🙏🙏	Everything is good, thank you. They help me.	I was spending time with my mom.

Discussion

Identifying Text Messages with High Response Rates

In designing text messaging adjuncts as an implementation strategy, it is important to know what messages resulted in higher engagement. Across the four CBT categories, messages in the Thoughts category had the highest response rate at 35.4%. Patients seemed to find cognitive restructuring exercises useful and were able to come up with examples of positive, negative, helpful, and harmful thoughts when prompted. Messages in the Health category had the lowest response rate at 30.0%, but this was likely due to the much lower proportion of Health messages that contained a question. Only 39% of Health messages contained a question, while over 50% of the messages in the Activities, People, and Thoughts categories contained a question. The inclusion of a question, especially a closed-ended question, in a text message was significantly more likely to result in a response from patients.

Results of the Word Frequencies test show that including the patient's name in text messages resulted in higher response rates. For example, two very similar questions were sent out to patients ("[[first_name]], how many positive social interactions have you had today?" and "How many positive interactions did you have today?), and the first message had a 6% higher response rate than the second (50% vs 44%), likely due to the inclusion of patients' first names. This aligns with past findings that message personalization is significantly associated with greater intervention efficacy (Head et al., 2013). Additionally, including a time frame or time specification (e.g., "today," "week," "daily") was helpful in eliciting engagement. These results indicate that the more specific the message is (e.g., closed-ended question with a time frame), the more likely patients are to respond. Words related to the four CBT categories (e.g., "activity," "thought," "healthy," "sleep," "interactions," "relationship") showed up repeatedly in messages, and when combined with certain words such as "mood," "better," "improve," "goals," and "positive," they tended to result in higher response rates.

Understanding the Mechanisms of Change behind the Text Messaging Adjunct

Three of the top five most frequently occurring words in patients' responses to the thematic module-based messages were "thank" (including "thanks" and "thank you"), "blessings," and "positive," suggesting feelings of gratitude toward the intervention and general positive feelings. The results of the four LIWC summary measures indicate that patients engaged

personally, intuitively, and informally with the text messaging adjunct (low Analytical Thinking). Their messages were honest, personal, and self-disclosing, and they responded in an open and unguarded manner (high Authenticity), thus indicating a high degree of trust in the intervention and little fear of judgment from their providers. At the same time, their speech was tentative and humble, lacking assertiveness (low Clout), perhaps signifying respect for their provider and reflecting cultural norms in communicating with professionals. A few patients mentioned feeling motivated to practice their therapy exercises so they would have positive results to report back to their provider, thus indicating a desire to be perceived positively by their provider. Overall, messages were very positive (high Emotional Tone), likely indicating improvement in overall wellbeing over the course of the intervention and positive feelings toward the intervention.

Over 27% of total words within patients' responses related to cognition, with about half of those words relating to cognitive processes, which aligns with the finding that CBT messages in the Thoughts category had the highest response rate at 35.4%. CBT messages in the Thoughts category mostly related to cognitive restructuring, and given the high occurrence of words related to cognition, the text messages were likely helpful in prompting reflection on negative thoughts and reframing thoughts to be more positive. About 11% of total words related to social processes, with half of those words being associated with social referents (e.g., family, friends) and the other half being associated with social behavior (e.g., love, care, say). These words were mostly used in response to CBT messages in the People category. Patients used messages related to the People category to reflect on individuals who are important to them and have been a source of support in their treatment. 5% of total words related to drive, with achievement being the biggest drive, suggesting that patients felt motivated when engaging with the text messages. Words related to achievement were mentioned frequently, especially in response to messages in the Activities category. This suggests that the Activities messages were successful in promoting behavioral activation and a desire to engage with and complete treatment successfully. Only 3% of total words touched on health (physical health, mental health, illness, wellness, food). This aligns with the result that messages in the Health category had the lowest response rate at 30.0%. Patients were not as motivated to engage with messages that asked them directly about health behaviors like their diet, water intake, sleep, and exercise.

Responses to the monthly feedback questions suggested that most patients found the text messages satisfactory and engaging, thus suggesting sufficient usability and acceptability of the technology. They appreciated the text messages' supportive tone and felt motivated by the positive reinforcement and encouragement. About two-thirds of the patients noted that the number of text messages sent (i.e., the dose of the implementation strategy) was appropriate. Patients also expressed that they felt more supported, connected to, and cared for by their providers throughout the intervention due to this adjunct. Most patients found the content of the text messages to be helpful in reinforcing and practicing therapy content. When they were able to successfully practice a skill learned in therapy, for example, replacing a negative thought with a helpful thought, leaving the house to take a 10-minute walk, practicing assertive communication with a partner, they often noticed improved mood and self-esteem and felt motivated to continue treatment. This suggests that gain-framed messages were effective at increasing capability, opportunity, and motivation and promoting healthy behaviors.

Addressing Barriers to Engagement

Qualitative data from the monthly feedback questions revealed that lack of response to text messages was primarily due to inconvenient timing of message delivery. In the MoodText intervention, text messages were automatically delivered on a predetermined schedule (e.g., treatment reminders were sent once per week at 7pm the evening before group therapy sessions; thematic module-based messages were sent once daily at 8pm; mood rating prompts were sent once daily at random between 8am and 8pm). On certain days, patients could have received up to five text messages (a mood rating prompt, feedback in response, a module-based message, a medication reminder, and a treatment attendance reminder). Very few patients mentioned receiving too few text messages, thus suggesting that no more than five unique messages should be sent out daily. Some patients mentioned receiving too many text messages, which resulted in annoyance or even opting out of text messaging adjunct. In future interventions, researchers should consider assessing patients' preferences for text message delivery in terms of both timing and frequency at baseline. For example, patients could identify one or more preferred times to receive text messages every day. Additionally, they could decide whether they want to receive the programmed content all together in one message or in separate messages throughout the day. Some patients mentioned missing the text notification or forgetting to respond, so patients could also be asked whether they would like to receive reminder messages when they have not responded within a certain timeframe.

Building A Causal Pathway Model

To illustrate the mechanisms of change behind this text messaging adjunct, a causal pathway model was built using Lewis et al.'s (2018) approach. Figure 4 below depicts a causal pathway model for using a text messaging adjunct as an implementation strategy to improve attendance in group psychotherapy.

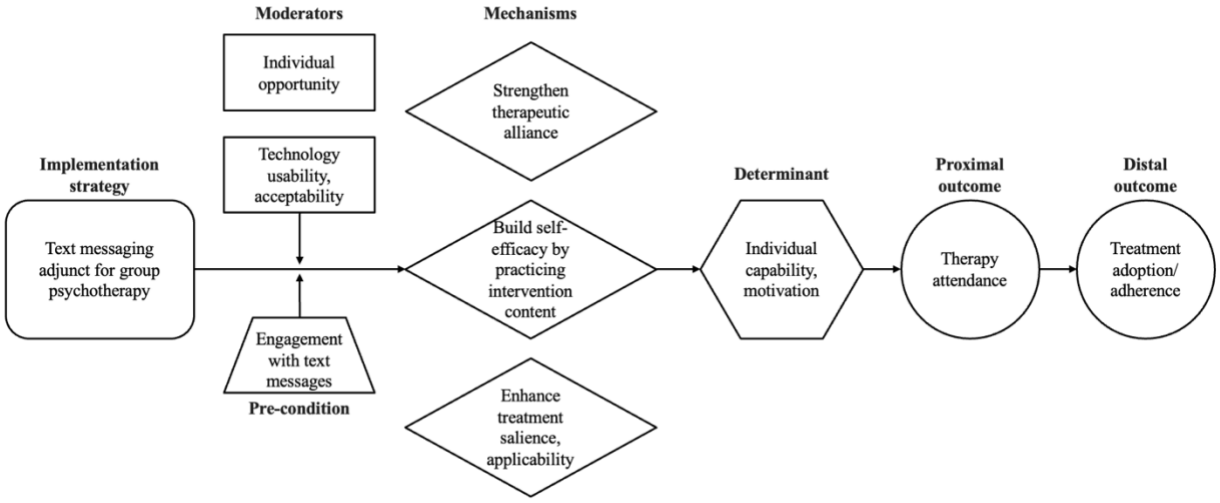

Figure 4: Causal pathway model for using a text messaging adjunct as an implementation strategy.

One mechanism of change behind the text messaging adjunct was strengthening therapeutic alliance between patients and their providers by making patients feel cared for, connected to, and supported by their providers between sessions, thus increasing their

willingness to attend group therapy and work with their providers. Responses to the feedback questions combined with the low Clout score on the LIWC summary measures also indicated that patients cared about their providers' perceptions of them, and as such, they were motivated to engage with therapy content delivered via thematic module-based messages so they could report improvements in mood and positive changes in behavior to their providers. Another way the text messaging adjunct prompted change was by increasing patients' self-efficacy by giving them opportunities to successfully practice therapy content outside of group sessions, thus influencing individuals' beliefs in their capability to improve their mental health. Finally, text messages enhanced treatment salience and applicability by reminding patients that skills learned in group therapy can and should be applied to different aspects of their lives, including daily activities, healthy behaviors, relationships, and thought patterns. Many patients reported beneficial results like improved mood, better coping abilities during difficult situations, increased exercise, reduced frustration with events outside their control, and progress made toward their goals, which increased their motivation to attend therapy so they could continue to experience positive gains. Patient satisfaction with message timing and frequency was linked to their engagement with the text messages and whether they stayed enrolled in the text messaging adjunct, thus suggesting that key moderators of the implementation strategy's effectiveness include individual opportunity to receive and respond to text messages and acceptability of text message delivery.

Conclusion

Overall, the text messaging adjunct was positively received, and patients were engaged with the messages. The CBT module-based messages were helpful in uplifting mood, reinforcing treatment content, reminding patients to practice skills learned in therapy, and helping patients feel connected to their providers throughout the week, thus explaining increased treatment attendance. Text messages should include a combination of closed- and open-ended questions, tips, suggestions, and personalized feedback for maximum impact. Key barriers to engaging with the text messages related to inconvenient timing and frequency of message delivery. Machine learning approaches like reinforcement learning may be a useful addition to optimize the content and delivery of text messages. Reinforcement learning can be used to personalize messages, identify keywords to include to increase engagement, select messages from categories that are most likely to prompt a response, and tailor the timing and frequency of message delivery. Findings from this study contribute to our understanding of how to design engaging text messages to supplement standard therapy, thus increasing the likelihood of treatment attendance.

Paper 2: Understanding how Mobile Apps for Health Behavior Change are Selected and Adopted: Qualitative Analysis of Interviews with Target Users through a UTAUT Lens

Background

Chronic illnesses such as diabetes, cardiovascular diseases, and cancers are the leading causes of death, responsible for 74% of all deaths globally (World Health Organization, 2023). Modifiable lifestyle behaviors like physical inactivity and unhealthy diet significantly increase the risk of chronic illness. Thus, solutions to reducing risk factors must include a focus on modifying health behavior. mHealth apps have the potential to provide highly tailored, customizable, and affordable plans for health promotion, and they are increasingly being used to deliver health behavior change interventions for the prevention and management of chronic conditions. One review found that approximately 82% of mHealth studies focus on chronic conditions, disease prevention, or wellbeing (Fiordelli et al., 2013).

Countless mHealth interventions for health behavior change exist, but at the same time, a large number of them have failed or have not been implemented as predicted (Gorski et al., 2016; Wu et al., 2007). A primary reason for this is that individuals intended to benefit from mHealth interventions have traditionally been excluded from design and implementation processes, resulting in the development of interventions that are not aligned with their intended users' needs and contexts, as well as challenges in implementing these interventions among groups and settings that experience different circumstances, constraints, and availability of resources (Brownson et al., 2022). For example, immigrant populations encounter significantly more challenges in using mHealth, and their ability to engage fully with these interventions is often impeded by language, cultural, and financial barriers, lack of insurance coverage, limited knowledge of available medical resources in their new host country and surroundings, limited access to culturally and linguistically competent healthcare services, and high costs of accessing mHealth interventions (Kim et al., 2024; Liu et al., 2025). Despite the potential of mHealth to reach underserved groups, few interventions have succeeded at achieving broad and equitable impact, as they have not reached or been tailored toward those who stand to benefit the most (Damschroder et al., 2022; Glasgow et al., 1999).

Within technology, there is often a pro-innovation bias, which assumes that innovations are good, adoption of innovations is advantageous for everyone, adoption rates should be increased as quickly as possible, and rejection or reinvention of an intervention is undesirable (Rogers, 1981). The reality is that not all innovations are universally useful and beneficial and as such, they may not be appropriate or desirable for some individuals (Gripenberg et al., 2012). In an ever-expanding landscape of mHealth interventions, it is important to take a step back to better understand what characteristics of existing mHealth interventions are serving users well and what issues remain unaddressed in their design and implementation before further pushing for the dissemination and adoption of these interventions. In particular, there is a need to elicit diverse user perspectives, including those of racial and ethnic minority groups and immigrant populations. To address that need, this study looks at mHealth design from the perspective of intended users, with an emphasis on racial and ethnic minority groups and immigrant populations, to better understand factors that affect mHealth app selection and use, features of existing mHealth apps that are most helpful and desirable for users, and barriers that continue to impede mHealth use and adoption.

Guiding Conceptual Framework

When trying to understand the various determinants of mHealth use and adoption, as well as the factors that facilitate or detract from an intervention's success, a technology framework is helpful. This study draws upon the Unified Theory of Acceptance and Use of Technology (UTAUT), developed by Venkatesh et al. (2003) to synthesize and unify the many theoretical models that seek to explain user acceptance of new technology. The UTAUT simplified the theoretical landscape by integrating key elements from an initial set of 32 main effects and four moderators posited by eight prominent models in the field into a unified model that incorporates four main effects and four moderators as determinants of use intention and use behavior. The UTAUT suggests that actual use of technology is determined by behavioral intention. The likelihood of technology adoption is a function of four key constructs: performance expectancy, effort expectancy, social influence, and facilitating conditions.

Performance expectancy is defined as the degree to which individuals believe that using the technology will enhance their job performance. This construct is considered the strongest predictor of behavioral intention and is based on whether the technology: 1) increases user productivity; 2) improves user job performance; 3) enhances user job effectiveness; and 4) is found useful in a user's job (Legris et al., 2003). Effort expectancy is defined as the degree of ease associated with use of the technology. This construct can be measured by the following items: 1) learning to operate the application is easy for users; 2) users find it easy to get the application to do what they want to do; 3) the application is flexible to interact with; and 4) overall, users find the application easy to use. Social influence is defined as the degree to which individuals perceive that influential members of society believe they should use the new technology. In other words, it is the idea that individuals' behavior is influenced by how they believe others will see them as a result of using the technology. Finally, facilitating conditions are defined as the degree to which individuals believe that there is existing organizational and technical infrastructure to support their use of the technology. The influence of each of these constructs on behavioral intention and usage is moderated by gender, age, experience, and voluntariness of use. Figure 5 illustrates how each of the moderators interacts with the constructs determined to predict behavioral intention to use technology and actual technology use (Venkatesh et al., 2003).

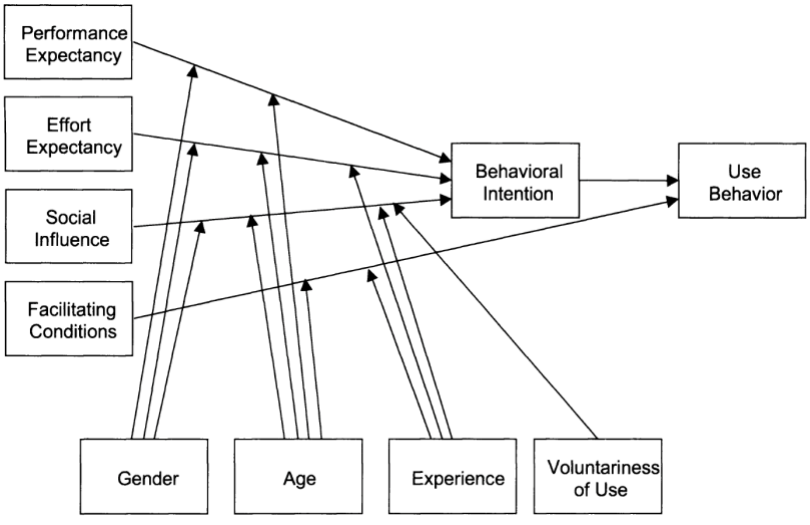

Figure 5: The UTAUT Conceptual Model.

The UTAUT has been widely applied across mHealth research. A systematic review conducted to identify theories that inform and explain digital health use revealed that 27% (32/119) of digital health studies have used the UTAUT as their basis (Heinsch et al., 2021). Comparative analyses of the primary technology acceptance models reveal that the UTAUT is the most comprehensive model for studying technology acceptance in health care (Khan & Woosley, 2011), and it has strong predictive power in explaining technology acceptance across different populations, including healthcare patients and providers (Asadollahi et al., 2025). The UTAUT is considered agency centered, as it primarily focuses on the individual and interpersonal elements of digital health acceptance, with individual attitudes, behaviors, and motivations being at the core of theoretical analysis and contextual influences such as cultural norms and infrastructural support being contributing factors. This makes the UTAUT suitable for use for this study, as it can help us understand individuals' decision-making processes regarding mHealth use and adoption, as well as contextual factors that support and detract from user engagement.

Study Rationale

While there is extensive literature investigating mHealth app use intention and use behavior through a UTAUT lens, very few studies also look at mHealth app selection in the context of user acceptance of new technology. This study examines individuals' considerations when searching for and selecting an mHealth app to try out before moving to identifying factors that affect the likelihood of adoption and ongoing use of that app. Previous research has demonstrated that the UTAUT has strong predictive power in explaining technology use intention, and this study seeks to understand whether, and to what extent, the UTAUT conceptual model maps onto technology selection as well – which, if any, of the UTAUT constructs are most relevant when users are deciding on a particular app to try out and what additional factors are at play? Additionally, this study contributes to the literature by exploring facilitators of and barriers to mHealth use and adoption from the perspective of diverse users intended to benefit from interventions for health behavior change. Through the inclusion of key moderators (gender, age, experience, and voluntariness of use), the UTAUT recognizes that individuals' experiences with technology acceptance differ based on their identities and backgrounds. However, there remains a lack of knowledge regarding mHealth access, familiarity, and use amongst underserved populations, especially immigrant populations and racial and ethnic minority groups (Liu et al., 2025). It is important to understand these groups' experiences with mHealth to design health behavior change interventions that can better address the needs of those who need them the most. To address these gaps in the literature, this study elicits perspectives from a diverse group of individuals regarding (1) how they search for and select an mHealth app to try out; (2) factors influencing their decision to adopt an mHealth app and use it over time; (3) helpful and desirable mHealth features for health behavior change; and (4) barriers to mHealth use and adoption.

Methods

Study Design

This exploratory study employs qualitative thematic analysis of interview responses from intended users of mHealth to provide recommendations for designing and refining mHealth

interventions to meet diverse user needs for health behavior change support. The interview and data analysis procedures are grounded in the UTAUT framework, with UTAUT constructs used to guide the initial development of the interview guide and codebook and the UTAUT conceptual model used to connect codes and identify key themes explaining how users come to select and adopt mHealth interventions.

The interview data was collected as part of a quality improvement project for an mHealth app designed to encourage healthy lifestyle behaviors (increasing physical activity and eating healthfully) and decrease the risk of chronic disease. Between February 2023 to March 2023, a total of 107 semi-structured interviews were conducted with 60 target users, 19 providers, and 28 organizational leaders for the purposes of exploring the potential of mHealth apps and improving the technology. This paper focuses on the 60 interviews conducted with target users.

Participants

Interview participants were intended users of mHealth interventions for health behavior change. Purposive sampling was employed with the intent of capturing a diverse sample with varying ages, nativity, primary languages, education levels, and health statuses. Participants were recruited through advertisement on various social media platforms, newsletters and listservs for health and wellness organizations (e.g., gyms, healthy meal delivery services, diabetes education groups), and snowball sampling. Eligibility criteria included: age $\geq$ 18 years, English-speaking, and self-report of at least one risk factor for chronic illness. Risk factors for chronic illness included physical inactivity, poor nutrition, tobacco use, excessive alcohol consumption, being overweight or obese, chronic stress, family history of chronic illness, hypertension, and prediabetes. Potential participants completed a screening survey to assess eligibility (i.e., age and self-report of risk factors).

Interview Procedures

Interviews were conducted virtually over Zoom, with each interview lasting between 30-60 minutes. Participants were provided with an overview of the study and verbally consented prior to starting the interview. Automated captioning was enabled for each meeting, and de-identified transcripts were saved and uploaded to Berkeley's secure Box. The interview guide was informed by the UTAUT model and prior qualitative studies on health behavior change, digital health applications, and mHealth adoption. It included questions about individuals' preferences for receiving health support, familiarity with digital health platforms, current and past experiences with mHealth, what they look for in mHealth apps, how they decide to use a particular mHealth app, perceived barriers to engaging with mHealth, and suggestions for improving mHealth interventions. Most questions on the interview guide were open-ended so as to elicit more detailed responses from participants. However, some closed-ended questions were used as gateways to more open-ended probing. As is common practice with semi-structured interviews (Adams, 2015), there was a general predetermined agenda with a tentative question order, but at times the order and specific topics covered varied to allow for discovery of novel ideas and elaboration on certain topics. The interview guide was pilot tested with five participants to determine a smooth sequence of questions. The interview guide was then refined and adjusted through an iterative process, resulting in questions being added, removed, or organized under a different theme to ensure clarity and alignment with study objectives. The final interview guide can be found in Appendix B.

Data Analysis Procedures

A qualitative thematic analysis of the interview responses was conducted using a hybrid approach incorporating both deductive and inductive coding. A hybrid approach to thematic analysis is advantageous as it relies on core tenets of dominant theories or frameworks, thus being grounded in well-established knowledge and research, while also allowing new themes to emerge directly from the dataset at hand, thus lending itself to novel and context-specific insights, exploratory research, and flexibility (Fereday & Muir-Cochrane, 2006). The deductive coding portion involved the a priori template of codes approach defined by Crabtree and Miller (1992), while the inductive coding portion utilized the data-driven approach defined by Boyatzis (1998).

All coding was conducted by author TCL. Analysis began with a preliminary reading of all interview transcripts. Then, an initial codebook was developed based on the interview guide, the participants' language and concepts, and constructs from the UTAUT. Analysis was guided by the predetermined codes, but these codes were modified and expanded upon, and new codes were inductively generated to capture unique insights into participants' digital health service-seeking and mHealth use, preferences, and needs. This was performed until thematic saturation was achieved.

Step 1: Developing the Codebook.

A codebook serves as an organizational tool for grouping similar or related text (Crabtree & Miller, 1992). Codes are based on theoretical concepts that address the research questions at hand. For this study, the codebook grouped text relating to participants' comfort level and familiarity with technology, decision-making processes for finding and using an app, views on in-person versus digital support for managing health, prior experiences using mHealth, desired design features and content in existing mHealth apps, and barriers to using or adopting mHealth apps. The codebook included separate columns for code label, definition, and example. An example of how the codebook was structured can be found in Table 7. Codes were based on the interview guide, the participants' language and concepts, and UTAUT constructs.

The four core UTAUT constructs include performance expectancy, effort expectancy, social influence, and facilitating conditions (Venkatesh et al., 2003), and these were used as the starting blocks of the codebook. In mapping these constructs onto the case of mHealth interventions for health behavior change, performance expectancy in the current study was defined as the degree to which users believe that mHealth apps are useful and can improve their health or health behavior in some way. Effort expectancy in this study was defined as the perceived ease of use of mHealth apps for health behavior change. Social influence for the study was defined as the extent to which mHealth users believe that their social circles support and encourage use of an mHealth app. Finally, the facilitating conditions construct was understood to be the degree to which mHealth users perceive that they have sufficient organizational and technical resources and support to use an mHealth app.

Table 7: Example of codes in the codebook.

Code	Definition	Example

Ease of locating	The degree of ease associated with locating the app	"I just found it first on the app store, like I probably looked up habit trackers or health in general."
Social influence	The extent to which mHealth users believe that their social circles support and encourage use of an mHealth intervention.	"Of course I'd love to see a professional, and if they recommended an app, then I'd try it."
Satisfaction with app performance	The degree to which users find it easy to get the app to do what they want it to do	"It fails a lot when you're using some third-party app, so I tend to use the built-in one unless the third party's has better functions."

Step 2: Testing the Reliability of the Code.

In order for the codebook to be considered reliable, the codes must be applicable to the data at hand (Boyatzis, 1998). Three interview transcripts were selected as test pieces. Codes were applied to these transcripts to assess compatibility of predetermined codes with the interview data, and the codebook was modified to better suit the data.

Step 3: Summarizing Data and Identifying Initial Themes.

Each interview transcript was summarized individually by outlining key points made by each participant in response to the questions on the semi-structured interview guide. These summaries provided an initial opportunity to formulate potential themes in the data.

Step 4: Applying the Codebook and Additional Codes.

Codes were then applied from the codebook to the text. Interview transcripts and the codebook were imported into Dedoose, a qualitative software program. From there, Crabtree & Miller's (1992) template analytic technique was used to identify important segments of text. Segments of text were highlighted and linked to codes in the codebook. This analysis was guided by the predetermined codes, but there was also opportunity to inductively generate codes that captured participant insights into digital health service-seeking and mHealth use, preferences, and needs. New codes were created for unique themes observed in the text based on the wording of participants' language. New codes were added until thematic saturation was achieved. During this process, predetermined codes were also expanded upon, condensed, or pulled apart into separate constructs.

The initial predetermined codes were centered around the UTAUT constructs of performance expectancy, effort expectancy, social influence, and facilitating conditions. As analysis proceeded, "performance expectancy" was reworded to "perceived usefulness and added value" to align with participants' language and more fully capture participant insights. A set of codes was generated inductively through a data-driven approach to address *how* the mHealth app improved health or health behavior through the presence of certain helpful and desirable features. These codes included "tracking and monitoring," "directive content," "personalization," "reminders," and "community interaction." Analyzing barriers to mHealth use as they relate to performance expectancy resulted in the code "lack of need or prioritization" being generated. The effort expectancy construct was pulled apart into two separate constructs – "ease of use" and

"satisfaction with app performance" – with an additional tangential code of "ease of locating." Analyzing barriers to mHealth use relevant to effort expectancy resulted in the code "time and effort." Finally, analysis of barriers as they relate to the facilitating conditions construct resulted in the following new codes being created: "cost," "cultural and contextual considerations," "attitudes toward technology," and "credibility and privacy concerns."

Step 5: Connecting the Codes and Identifying Themes.

This step involved discovering patterns in the data and identifying key themes that related to the research questions. The UTAUT framework for how users come to adopt technology was used to help connect codes and generate key themes. The UTAUT posits that actual technology use is determined by behavioral intention and facilitating conditions, with behavioral intention being influenced by performance expectancy, effort expectancy, and social influence. With this understanding, key themes were generated regarding how individuals select a mobile app that they intend to use to address their health needs and what factors influence the likelihood of ongoing use over time.

Stage 6: Corroborating and Legitimating Coded Themes.

In this final step of the analysis process, themes were clustered further and reviewed to ensure that the clusters were representative of the initial data analysis and assigned codes. After that, themes were labeled with a phrase or sentence that adequately described the meaning. From there, the interactions between the text, codes, and themes were interpreted to provide key insights, guidelines, and recommendations for the design and refinement of mHealth interventions.

Results

Participant Characteristics

A total of 60 target users were interviewed between February 2023 to March 2023. Of the 60, half were male (30) and half were female (30). Ages ranged from 18 to 65, with the mean age being 27 (SD=7.6). About three-fourths of participants (44/60) were born outside of the United States and identified as non-native English speakers, with Chinese being the most common native language (27), followed by Spanish (9). The highest level of education achieved was a high school diploma or equivalent for about one-third of participants (19/60) and a college or graduate degree for the remaining two-thirds (40/60). The majority (37/60) of participants reported having two or more risk factors for chronic disease, with the most common risk factors being a family history of chronic illness and physical inactivity. See Table 8 for participant characteristics.

Table 8: Participant demographics for 60 intended users.

	Percent (n)
Gender	
Male	50.0% (30)
Female	50.0% (30)
Age	
18-24	33.3% (20)
25-34	50.0% (30)
35-44	6.7% (4)
45-54	0% (0)
55-64	0% (0)
65+	1.7% (1)
Declined to state	8.3% (5)
Nativity	
US-born	26.7% (16)
Foreign-born	73.3% (44)
Native Language	
English	26.7% (16)
Chinese	45.0% (27)
Spanish	15.0% (9)
Persian	3.3% (2)
Other	10.0% (6)
Education Level	
Some high school or less	0.0% (0)
High school graduate	31.7% (19)
College graduate	51.7% (31)
Graduate degree	15.0% (9)
Declined to state	1.7% (1)
Health Status	
1 risk factor	38.3% (23)
2 risk factors	50.0% (30)
3 risk factors	10.0% (6)
4 or more risk factors	1.7% (1)

Research Question 1: What do individuals prioritize in their search for a suitable mobile app for their health needs?

When searching for and selecting a mobile health app to try out, determining factors for interview participants included ease of locating, social influence, and facilitating conditions.

Ease of Locating. Convenient access was widely recognized as an important factor in likelihood of engagement with apps. One participant stated, "I could definitely see myself turning to an app to manage a health condition. It's just the most convenient option." The most commonly mentioned factor in individuals' decision to engage with a particular app was ease of finding or locating the app. For example, 19 participants mentioned using only apps that were "built into" or "pre-downloaded onto" their phones like the Apple Health app or the Notes app. Many of these participants explained that they were able to find all the health features they needed on Apple Health, so they did not see the need to download another app. Another participant's rationale was that "it fails a lot when you're using some third-party app, so I tend to use the built-in one unless the third party's has better functions." Apart from apps that were already installed on phones, health apps that were most likely to be used were those that appeared at the top of lists on the App Store and Google Play Store, such as MyFitnessPal, Strava, and Headspace. For example, one participant stated, "I just found it first on the app store, like I probably looked up habit trackers or health in general." Another participant stated, "Honestly, there is no particular reason I chose this one other than it's a common one in a search and then I download it and see that it has the basic functionality I want."

Social Influence. Another major determining factor in individuals' decision to use an app was social influence. Over 1 in 4 participants mentioned their doctors as key influences on health app usage. Patient portal apps like MyHealth and MyChart were commonly cited. Some participants downloaded and used such apps to stay connected to their providers: "Like I do use [medical apps] but only if my doctor [uses] it because it feels like more official correspondence between us." Others used such apps to streamline their health management: "My doctor's with UCSF, so we do use MyHealth or MyChart, and then we also have One Medical, and One Medical has their own mobile app as well. They recommend that you use this because you schedule appointments and everything on there." Participants were also likely to try apps that their medical providers recommended for health management. For example, one participant stated: "Of course I'd love to see a professional, and if they recommended an app, then I'd try it." Another participant explained, "I used to use an app for physical therapy, recommended by my doctor. I used it only for recovery from surgery for a month." Two participants mentioned that the more they trusted their medical provider, the more likely they'd be to follow their recommendations. Primary care providers were most commonly mentioned, but participants also received and tried app recommendations from other health professionals including physical therapists, dietitians, and mental health therapists.

Other key influences were friends, with almost 1 in 4 participants mentioning trying out app recommendations provided by their friends. One participant explained, "One of my friends recommended me the app. She said it's easy to use, and you can also integrate the data to Apple Health." Many participants were drawn to an app due to a friend's positive endorsement, but others cited peer pressure or social competition as the primary motivation. For example, a participant stated, "I decided to use it because there was a group of people who were competing through Fitbit. And that was around the time when the Fitbit was like the new thing….I was

motivated socially by people competing." Another stated, "when you see your peers care more about their health, you're more likely to as well."

Additional sources of social influence included family members and individuals experiencing similar health conditions. Two participants stated that a family member had recommended and taught them how to use a health app to manage a chronic health condition. Another participant stated that they were convinced by their sibling to try a blood glucose tracking app after both were diagnosed with diabetes. Individuals with a chronic health condition were generally more likely to accept app recommendations from others navigating the same condition. For example, one participant explained: "[For support] I'll turn to people that I know who are well acquainted with the chronic illness, so people who have maybe had some experience navigating it already."

Facilitating Conditions. Facilitating conditions like sufficient external cues and organizational support were important in determining what health apps participants gravitated toward. A few participants stated that because they weren't familiar with the digital health landscape, they relied on marketing and other external cues for suggestions of health apps. For example, one participant stated, "I'm not that familiar with many health apps, so lack of motivation on my part, as well as maybe lack of promotion as well…not seeing ads for it…means I won't use it." If individuals were given access to an app by their workplace or school, they were more likely to try it. One participant described the benefits of having ready access: "Our school does have an app that provides online consultation. For example, if today I feel sick, then I can use the app and talk to a doctor, it's like 24/7 and when you talk to a doctor, and the doctor will listen to your description and give you, based on your scenario, she will give you the medicine, and you can go to the local pharmacy to pick it up." Another participant stated that they started using the Headspace app because "If you [attend] Berkeley, you can get Headspace Premium for free, so I think, like definitely having a free, low barrier app was really helpful…It will make me use an app more – having it be free."

Research Question 2: What factors influence whether individuals adopt an mHealth app and continue to use it over time?

When it came to adopting and using an app over time, participants' primary considerations were ease of use, perceived usefulness and added value, and satisfaction with app performance.

Ease of Use. One of the biggest determinants of app adoption and ongoing use was ease of use of the app: over 70% of participants mentioned the terms "easy to use" and "user friendly" when discussing why they chose to use a particular health app. Some participants prioritized ease of use because they wanted to be able to spend minimal time learning how to use the app and getting the desired outcomes. For example, one participant stated: "I remember thinking that it was pretty easy to use and connect and I liked that…it was very plug and play like as soon as you did it, it was like, I'm pretty sure this [Fitbit] is connected. That was all that you really needed to do. And then you had the information that you needed." Another stated, "It's easy to use and you can integrate the data to Apple Health, so it's easy for me to check."

Participants were likely to continue turning to an app over other forms of health support when they could get their needs met with minimal time and effort: "I think the pro [of apps] is saving time and if you need it, you can ask your question. If the team is available, they can give

feedback really quick. But if you do in person, you need to make an appointment, and it takes a long time, and you need to drive there and probably pay more money to get through the whole process. So, I think that big pro is convenience."

Overly complicated interfaces or requirements deterred participants from app usage. For example, one participant stated, "It's not that easy to use. I feel like it's a huge pain to correct all the data from other apps. For the Cycle app, it's more simple, it only has like 1 or 2 functions, and the screen, it's very simple, it doesn't have any edits, so it's quite easy for me." Other participants appreciated simplicity and basic functions because they had certain predefined needs and did not require or desire any additional functions. Quotes supporting this theme include:

- "I only use apps for self-support, with low tech things, like tracking time, tracking volume."
- "I think my requirement is pretty simple. I did not require any special functions."
- "For my purpose the app was very easy to use – it comes with very limited features, and because I only had limited information to track down, it was super useful."
- "That's what I really like about Hevy because it's like simple, but like it has a lot of features if you choose to also customize that. And it's just really simple and easy to use and look at."
- "I think both were pretty easy to navigate because I didn't really use them for complex functions. I just use very basic functions."
- "I think that the app has more powerful stuff. I just don't expect that much from the app. As long as one app is functioning, then that helps you."
- "If it's complicated, I'm not gonna be able to use it to a full extent."

Perceived Usefulness and Added Value. Another primary determinant of ongoing use was perceived usefulness and added value, with over 50% of participants mentioning this theme. Individuals had to believe that using an app would improve their health or enhance their lives in some way to adopt it. For example, one individual explained: "A lot of the apps on my phone, I'll download it but then not end up actually using it. But if I do find it's been a consistent part of my routine or helped me, then I keep using it." Perceived usefulness also determined whether and how much participants would be willing to pay money for an app, as many apps require an ongoing subscription fee or one-time purchase. Participants who were willing to pay for health apps spent anywhere from a total of $0.99 to $399 per month. The consensus was that if the app added value to their lives, they would be willing to pay for it:

- "I don't mind paying for an app as long as it helps, as long it is helpful."
- "I think that the specific price matters less, and it's more about usage, like how much value it brings to your life. Then you would be more willing to pay for something that's obviously being used a lot."
- "In terms of how much I would pay, I assume there would be like a trial period or something, and so I think it's how much it adds into your life. I think a lot of people wouldn't mind paying if it seemed helpful."

At the same time, there were individuals who did not see any advantage to mHealth apps as compared to other available supports and thus discontinued app use or subscription:

- "There are so many other ways to manage health or prevent a disease. I think that a health app wouldn't be my first choice. I would just do a quick Google search."
- "I think the issue is there's so much free content already, like on YouTube."

- "If there was some app that did have all of the features that I wanted, I think I would consider paying for it. Obviously, it would depend, like I think it would depend on a lot of what other apps I would be able to have as an alternative. But also, if it offers something that not a lot of other apps have, then I'll definitely consider paying for it."
- "It is quite a competitive space already with a lot of product offerings, so if you wanted to look for help, we can find quite a few solutions out there already."

Satisfaction with App Performance. A final determinant of whether apps continued to be used over time was satisfaction with app performance – whether the app "did what it's supposed to do." Some participants mentioned disappointment with an app "failing" or "crashing," while others mentioned apps not being accurate enough:

- "It fails a lot when you're using some third-party app, so I tend to use the built-in one unless the third party's has better functions."
- "Usually, it is not hard to start using an app if you do some research. But again, eventually you will find that they fail a lot."
- "Measurement accuracy is important. Once there is an error, I'm less willing to use it."

Research Question 3: What features of mHealth apps are most helpful and desirable for individuals?

Participants who had experience using mHealth apps to address their health needs expressed that the presence of the following features determined how helpful and desirable they perceived the app to be: tracking and monitoring, directive content, personalization, reminders, and community interaction.

Tracking and Monitoring. About two thirds of participants described health tracking and monitoring as highly desirable, making it the most commonly mentioned app feature. There were various reasons as to why participants found it helpful to have this capability. For many, health tracking and monitoring provided important information to guide their daily habits and lifestyle choices. For example, one participant explained, "So, it was right around the time that I was really beginning to get into the routine that I wanted to shoot for like, week by week, day by day. So, I really wanted to set a good foundation for myself, and I was researching all the macronutrients, how to hit the amount of calories I needed to take, and then I also wanted something to try and keep me accountable so that's why I downloaded MyFitnessPal." Similarly, another participant relied on a health app to eat more healthfully and increase physical activity: "It's something that you can record your diet…and then to see how many protein or glucose, so nutrients I need for today, and then also to record that the workout, the training, the amount of training." Tracking data also provided important indications to participants about the status of their health and which ways it was trending. As one participant stated, "[apps provide] very good monitoring. Make sure you and your disease are not getting worse. Good monitoring – you don't know what to monitor, and I think that requires some professional [help] to do that." Another explained, "When my dad tests his blood sugar level, he will have data out there through the app so he can track where he's at, for example, today he's like, I don't know, 100. 80 is like really high, so it's really bad, but he can see the number, and he would know okay, today, where am I? Blood level is? And I think it'll be good if the whole family can see this data together so we can help to track his health level or his blood sugar level." The desire to monitor family members' health was shared by other participants as well, with one explaining, "In our family, we have a

history of having diabetes. And it is something that I think our whole family wanted to figure out a way to track my father's diet and help him improve his health and make it get better…because as you know, that really can go really bad for a person."

Another reason participants appreciated tracking and monitoring was that it allowed them to measure their progress over time. Participants enjoyed being able to see improvements in their modifiable lifestyle behaviors like step count, activity level, nutrition, sleep, and medication adherence:

- "I could look at my long-term progress…and it gave me a sense of encouragement."
- "Starting to track my activity and recovery – that is very important to me, because it kind of recognizes my effort, and I really want to see that, and I sometimes even share my progress with my friends or family."
- "It's more like you track your own activity, and you know your progress more. It's maybe a little more for myself."
- "I really like [tracking] how many steps. It gave me a comparison. It showed your progress throughout the week and how many steps, so there is a curve."
- "It's also like, 'Oh you are on an 8-week streak,' or like, 'Oh, this is the heaviest you've lifted for this routine,' and stuff like that to motivate you to keep on doing it. It's like, if I stop, I'm letting down…I do think the streaks and like, 'Oh, this is your best score,' or like, 'Keep it up' – that kind of thing kind of helps me keep going."

Participants felt particularly motivated when there was some visual representation of their tracked health data:

- "I like data visualization, like the data visualization that I could see very clearly, like as a line, like whether my exercise goes up or exercise is decreasing."
- "Seeing everything logged afterwards, I feel like it's one project, it's like you do all these little entries and then you get to see all of your big layout of it, which is kind of satisfying."
- "I always like the graphs on the apps…like graphics showing things. So, it's something extremely minimalist."

Directive Content. About 1 in 3 users cited content when asked what was most helpful about the apps they used regularly, making it the second most frequently mentioned factor. Specifically, participants wanted content that was clear and directive, with specific instructions and guidance included. As one participant explained, "I want kind of like a checklist or some constant advice that they will give me." Another participant described how apps "really have to be organizing, helpful almost to the point where it would tell me what I should do." For example, participants trying to increase physical activity to reduce chronic illness risk found exercise and fitness apps most helpful when they provided a plan with specific exercises to do. One participant stated, "I'm always looking for some automatic suggestions of what to do today because I'm tired of thinking of what to do today.... I'm tired of making new schedules." Another described the value of such apps: "I wanted to have an app to check my exercise, and it's very professional, so when I go to the gym, I already know what I need to do today, and those exercises are good, like perfect for me, and the app plans everything out, so I'm willing to pay $10-20 per month." A few participants were pursuing physical therapy to manage chronic pain and appreciated the additional direction that visuals offered: "They had an app that would

tell you what exercises to do, they'd have pictures and videos of the types of exercises, so it was pretty helpful. I think it was called StriveHub."

When it came to modifying unhealthy diet to prevent chronic illness, a participant explained that a nutrition app was helpful because "I think it's not that intuitive, to be honest, of what I should be eating…so I think that's one thing that helped me, to have a baseline, have a basic understanding of what I should be eating and what I should not be eating." Another participant started using a diabetes prevention and management app to help her diabetic father manage his condition, with the purpose being to "get some valuable information about what is this particular product – is it good for my father, can we eat this or no? Because this has this much sugar content, so we cannot eat this." In addition to nutrition, participants relied on apps for up-to-date information regarding chronic illness management. One participant used health apps to "keep track of what is the latest research. Maybe there's already a new drug that can trick the disease." For another participant, an app helped them receive the care they needed: "Navigating the healthcare system to get to the right specialist to finally prescribe the right medicine that your insurance would cover…there's all of these kinds of hurdles…having either a checklist or a step-by-step guide that literally walks you through all of these different pieces because you know I would say that we're fairly, or at least averagely knowledgeable about navigating these things, and even we had a really hard time. So yeah, I think just something that is very concrete. First, you do this. Okay, then compile the information in here, then take that information and take it here and now to do something."

Personalization. About 1 in 4 participants mentioned a personalized experience as important for app adoption. They looked for personalization in app content, interface, and notifications. In terms of content, participants wanted tailored advice and plans. For example, for nutrition, "if [the app] offers like personalized suggestions towards diet and things like that, that would definitely make it a lot more desirable." A participant explained that they were much more likely to use fitness apps "if those exercises are really good for me, like perfect for me." Another participant stated that they would be willing to pay for any app "if the service itself pretty much guaranteed customized content. It depends on…the level of customizability…if I'm really getting one-on-one advice, if the option was a [exercise] position or a nutrient, or that direction." When it came to user interface, personalized touches as soon as users opened the app were appreciated: "I think it's a little bit more like personalized the way they guide you, the background, the music, and the purpose of every session." Participants also wanted to be able to customize their dashboard: "For Apple Health, one minor thing is that maybe I could choose the order or which categories appear when I first open up the app." Higher levels of personalization when it came to delivery timing of app notifications was widely desired:

- "I think it will be good if they can set up the time themselves because every person has different schedules, like some people wake up late, some people want reminders two times a day, so it's all different. More customized for each person."
- "I think the reminders are good, but I also think that, you know, if the reminders mostly come up in situations that you can't really do it, then that's not helpful. The time has to be right. I'll get the alerts, and I'll just swipe them away really quickly because I can't do anything about it right now. So maybe being able to have some kind of patterning, like it recognizing in these particular situations, you never pay attention, then you can't do it."
- "I think ideally, it would kind of be context aware, like they know when you're sitting on a plane or in the middle of class, etc."

- "Sometimes they will have a pointer, reminder, but they stay for 5 seconds, and they change to another one, so I would prefer that to be a notification or something because sometimes I'll miss that information. It would be nice to have a more clear interface with users, something that's easier to keep track of so you're not just swiping it away accidentally."

Reminders. Despite participants desiring more personalized timing of app notifications, reminders were still widely regarded as helpful, with 1 in 4 participants mentioning them. A couple participants even stated that reminders were their primary reason for adopting an app: "If I use a health app, its purpose is to remind me." Participants appreciated receiving reminders to engage in a particular health behavior: "I like notifications – notifications to ask me to drink more water, periodic reminders. I set up a daily reminder for me." There were specific contexts and circumstances in which participants felt it was particularly important to receive reminders. For example, one participant stated, "I think elders might need an app to assist because they are forgetful. The app can remind them to take medication, exercise, etc." Another participant described the type of reminder they wanted: "Support I would want is a reminder about when you should look for professional help. For example, maybe I have this problem, and if I have some symptoms, I should know when to seek professional help and when there's a sign that it is getting worse. You may have to develop symptoms to a stage, then I should be more careful about it." It was helpful when reminders related to participants' overall health goals: "I liked it when they had small things to remind me of the goal" and "being pushed a bit daily." Reminders that were delivered in a positive, encouraging tone were well received: "I think encouragement is very important. Encouraging a healthy behavior is really helpful. Encouragement and support, positive ways to encourage people." Participants especially appreciated motivating messages: "[The app says] 'Oh, this is the heaviest you've lifted for this routine,' and kinda like stuff like that to motivate you to keep on doing it. I do think the streaks and like, 'Oh, this is your best score,' or like, 'Keep it up' – that kind of thing kind of helps me keep going." Conversely, shaming participants about their health behaviors deterred users: "If the app just made me feel worse about myself, I would feel put off."

Community Interaction. Many participants stated that they were more likely to continue using an app for an extended period of time if it incorporated community interaction and support, such as through a social feed, chat feature, or live check-ins. These features were most commonly found in fitness and exercise apps, and participants who were working to increase their physical activity felt motivated by social feeds where their progress was visible and peers could provide them with positive reinforcement. For example, one participant stated, "I think the one thing is that because you can see other people's performance, and you can also see your own performance throughout the past few months, and if you see you're improving, that's very encouraging. And you see your friends are also improving, that makes you want to improve maybe a little more, so there's a little competitiveness in those apps, and that's fun. You can talk to your friend, you can laugh at them, they are slow, or they will lap me. I'm slow, and that kind of made me wanna run a little faster." Another participant was also motivated by competition and explained, "I decided to use [the app] because there was a group of people who were competing through Fitbit. And that was around the time when the Fitbit was the new thing…. I was motivated socially by people competing." Similarly, a participant expressed that they enjoyed using a workout tracker and gym planner app named Hevy because "it's kind of

equivalent to where you can see other people you follow, like how much they're lifting or what their routine is, so just like that aspect of a social element. It's always nice to get a comment like, 'Oh, nice workout!' or something like that."

Participants also enjoyed being able to connect with others with similar health goals and share support and guidance, discuss health concerns, and problem solve barriers. One participant explained, "I like when you can motivate each other, with people that have the same objectives. The social aspect, having the community – it keeps people on the app. So, you have to come in every day or every few days to check in." Another described the benefits of peer-to-peer interactions: "Someone who helps you each week – it's hard, you don't know where to start, someone who has experience with it; someone who continually checks in with you the week after; when you have a big issue, you don't know how to deal with it, you don't feel supported." In addition to peer support, some desired interaction with professionals: "I think also, it'll be good if, on the app, we can also contact some professional team, just like a consultant, or if some emergency happens, we can call one emergency number. But it also will be good to have somebody we can ask questions on the app and just get some valuable information about what particular product is good." Another participant stated they would only be willing to subscribe to an app "if there's professionals involved…a physical trainer, or like a nutritionist, that will actually help me.

Research Question 4: What barriers impede mHealth app use and adoption?

Primary barriers affecting the likelihood of mHealth app usage and adoption included cost, time and effort, lack of need or prioritization, cultural considerations, attitudes toward technology, and credibility and privacy concerns.

Cost. The most frequently mentioned deterrent to mHealth app use and adoption was cost, mentioned by almost 50% of participants. A significant portion of commonly used mHealth apps require either ongoing subscription fees or a one-time purchase fee, which many participants expressed displeasure about. Some participants were unwilling to spend any money on health apps because of the existence of other free health tools:

- "I think the issue is there's so much free content already, like on YouTube."
- "There are so many other ways to manage health or prevent a disease. I think that paying for a health app wouldn't be my first choice. I would just do a quick Google search."
- "I won't be paying if someone's going to sell me some health app…because I have a lot of free resources, and generally I know a lot of us have free resources."
- "I think a lot of people start from searching Google first."
- "I tend to not log in anymore once it passes the free trial period."

Other participants expressed willingness to spend money on health apps, but only if the cost was proportional to the perceived value added:

- "It will depend on the amount and what I will be getting. For example, if I decide to get some sort of professional help, the first thing I would do is go on Google and start searching. And if there is a website that can give me a pretty good overview of what I will do for free, I would probably hesitate to consider an [app] for this. On the other hand, if the [app] itself pretty much guaranteed customized content, then yes, I think a reasonable amount would be…for a normal mobile app, it depends on the level of customizability for this, like if I'm really getting one-on-one advice…30 bucks, 40 bucks,

but if it's more getting like a more generic content, like a more generic version, probably $10."

- "I feel like the most I pay is $0.99 a month or $1.99. I don't usually pay for apps though. I would pay for an app if…I like the free version first, and then if there's proof and results already and I feel like I can benefit even more if I was able to access their other features, then I would probably pay for the app."
- "They could be free. Unless there was a premium to the app, I'd probably just try to stick to the free version of it."

A few participants felt put off by apps' lack of transparency around pricing and discontinued use as a result:

- "I would prefer that they have a disclaimer beforehand. Just be honest and tell us what's being provided in a free option beforehand, rather than trying to trick you into downloading the app, and it's more disappointing that way."
- "Is it really free? Or are there a lot of paid options? Really being able to find an app that's truly free…a lot of the apps will say that they are free but the content that is free is probably only like less than 10% of what they provide, so you'll need to test out the process to see what's being offered in the free option, and I don't know, that's really, really complicated."

Time and Effort. The amount of time and effort required to learn how to use an app and fully engage with it felt overly burdensome to many participants:

- "It's not that easy to use. I feel like it's a huge pain to correct all the data from other apps."
- "I only kept it for one to two weeks…I think it was probably just because it required you to constantly go back to the app and add something for it to be accurate, which makes sense, but…I just at one point kind of forgot about it. And it just took too much time."
- "One of the big hindrances to the app was that for the two sections at least, you had to manually input things, which sort of could get a little bit tedious, and you'd have to do this every single time."
- "I think websites are the most accessible, and I think the thing about apps is like, 'Oh, I have to create an account in order to see like tips and stuff,' so I feel like websites are just low barrier things."
- "It was a little too time consuming."
- "You have to manually input everything right."
- "I would say I've probably tried for like 2 weeks. So, the effect is definitely not that visible for me, at least, like I would assume these would take quite a while to, or at least some time."
- "MyFitnessPal took too long; the problem with anything mobile-based is that you can't really rely on people to use it every day. They're going to slip up many days – only 1% of people will do it every single day; you have to find a solution that is easily accessible."

Lack of Need or Prioritization. Many participants did not have enough need for the features offered by health apps to use them on a daily basis. For example, one participant stated, "I feel like Apple Health just has too many features, and I don't really need all that…It's a fine line between having too much and too little…Keep it simple." Another participant realized they

didn't need a nutrition or diet app because "I just keep it in my head. And I feel like I have the same meals every day, so [the app] wasn't really necessary." Other participants felt that they didn't have any health needs specific or dire enough to warrant use of a health app: "Some…will then be using the app to monitor their diet or their health. I mean I would probably be hearing of those people [using apps], but those would probably just pass me as common process. One uses it for training, professional access, like professional sports…I think they're for professional use." For many participants, using an app was simply not a big enough priority for them to incorporate it into their daily routines:

- "I have other responsibilities I'm currently prioritizing. If I had the time, I would probably use an app."
- "I don't know if people really care enough about their health to use an app."
- "Actually, my smartwatch can detect physical activity, so it always tells me I've been walking for 10 min and starts to record my route. But do I actually refer back to them and extract information from my physical exercise? No, I don't. So not really. Guess I never really felt like I needed, I had a need to. I mean, it comes to priorities, right? Like the unfortunate reality is, I guess, at this current state – don't tell my mom – health is not super high in my list. It really should be higher."

Finally, some participants forgot to use apps or track information to input into apps:

- "I downloaded MyFitnessPal, but I never used it. I downloaded it, I wanna say 2 and a half weeks ago, 2 weeks ago."
- "I probably have tried once before, but then the time, like I think I just lacked the perseverance of keeping that happening."
- "I feel like even by downloading the app, it just wasn't enough, and I just keep it in my head."
- "It takes time, well not really time, but sometimes I would just forget. Oh, what did I do? How much? I can't really remember anymore."

Cultural and Contextual Considerations. A number of participants voiced that existing apps were not sufficiently tailored for individuals of particular backgrounds or identities. Participants described how existing health apps could be suitable for one demographic but not as accepted by others due to differing needs, contexts, and circumstances:

- "Depending on the population, it could look very different in terms of what they're looking for."
- "The lifestyle and environment in other countries is just different. So, this is another reason that it is not easy to develop a kind of app to adapt to other countries. The situational experiences are just different, like with comparing to Asian countries, like China to Japan or the UK, compared to the US, there are several different styles like the West Coast vs East Coast, compared to city life – it's just different."
- "Even different generations have different concepts or different mindsets of health care or health status."
- "Depending on where people are, like California or Massachusetts or New York, but I think demographically, it makes a difference."
- "I think a lot of people might say, go to the doctor, or ask family for advice, or Google search or YouTube videos for what to do. I think because I have friends that are doctors, so I would ask for my friends' opinion. But I'm not sure it is also dependent on culture."

- "Like my mom, she is not, or I guess like most immigrant parents aren't very tech savvy. I think that might be the general trend, especially for older people, but if the age range is 20 to 40, I feel like this should be good."

In addition to cultural differences and geographical considerations, some participants also mentioned language and literacy barriers when trying to access apps. While all participants spoke English, many were non-native speakers and struggled with technical language or terms used in mHealth apps. For example, one participant stated, "The difficulty for me is that since I'm an international student, I cannot really read the description accurately." Another participant explained that app use is hard for both them and "for my parents who are older and don't even speak English." Health literacy was an additional factor to consider. As one participant explained, "I don't know what else I should monitor I guess is my thing. If I knew what I need to monitor, then yes, but one needs help along the way to figure out what actually is important enough to be tracked."

Attitudes toward Technology. When it came to health management and illness prevention, many participants still preferred receiving support in person, rather than virtually. For example, one participant stated, "Normally I search for support from the people I know. I rarely use virtual support." Some participants were willing to turn to technology for health advice or minor issues but still preferred in-person support for serious health concerns: "For something like exercise advice, I would go on Google or online, but if there's something I feel is serious, I would go to the doctor. For minor things, I would look online and then for serious health issues, go to the doctor." Similarly, another participant explained that they would selectively turn to virtual support based on the severity of their health concern: "I feel like this is the case where if it becomes that big of an issue, I will turn to a medical professional. But if I know it's there, and it's not that big of an issue, I'll turn to the Internet instead or people that I know who are well acquainted with the chronic illness, so people who have maybe had some experience navigating it already." Several participants expressed dislike of mobile devices specifically, as compared to other forms of technology, and thus were unwilling to use mobile apps:

- "I feel like as I grow older, I try and stay less and less away from my phone. So, at this time, I'd say no. But, if there was a website where I can quickly look up something, I feel like I would use that more than an app."
- "I hate texting, so it would just feel like work."
- "When I have time for myself, I try to not be on my phone, but when I'm working and I need to take a mental break, my laptop's there, so I'd rather just search something up on my laptop."

Credibility and Privacy Concerns. A final category of deterrents to using mHealth and other technology-based supports related to credibility and privacy concerns. Some participants expressed uncertainty about the credibility of the information provided: "Using Google to find credible sources on the internet – you don't know how it's gonna be." Similarly, when another participant was asked whether they would turn to technology-based supports for health, they stated, "I don't think so, not a lot, just because I just don't trust it that much, and I feel like everything that I searched…like cancer, pregnancy, it doesn't make sense." Another participant described difficulties discerning between information from different sources: "One thing I've

noticed when searching, especially on the Internet, is that there's some information that's contradicting, so it's hard to know exactly what information is right and which innovation is misleading." Participants felt more comfortable using digital platforms if they were endorsed by a medical professional. For example, one participant stated, "If [a medical professional] recommended an app, then I'd try it." Another participant stated that they trusted an online source more because "the website shares an online website agreement from a doctor." Participants were more wary of health apps that tracked sensitive health information. One participant explained: "What just came to mind for me was like period tracking apps. And there was a whole thing about how they're sharing people's period tracking data with the government, like with the abortion stuff…that I wouldn't want." Participants also shared general concerns about data privacy and security such as: "I don't really know what they're doing with that data" and "I don't know exactly how their security works."

Discussion

In general, mHealth app selection was predicted by ease of locating an app, social influence, and facilitating conditions, while mHealth app adoption and ongoing use were determined by ease of use, perceived usefulness and value, and satisfaction with app performance. The most helpful and desirable features of mHealth apps were tracking and monitoring capabilities, directive content, personalization, reminders, and community interaction. Meanwhile, barriers to mHealth app use and adoption included cost, time and effort, lack of need or prioritization, cultural considerations, attitudes toward technology, and credibility and privacy concerns.

mHealth Apps are Selected Based on Convenience, Provider Recommendations, and Organizational Access

When searching for a mobile app to address their health needs, most individuals prioritized convenience and selected an app that was readily available or easy to locate. For many participants, this meant using only apps that were predownloaded onto their phones like the Apple Health app. Participants who chose to download additional apps generally selected such apps by going to the App Store or Google Play Store, typing in keywords such as "health," "fitness," "nutrition," "weight loss," and "diabetes management," and downloading the app that appeared first in their search or had the highest or most ratings. The most commonly mentioned apps across participants were MyFitnessPal for nutrition and diet tracking, Strava for activity tracking, and Headspace for mental health. There are hundreds of thousands of health apps, but many will never be used or even downloaded, as the majority of individuals use only apps that are predownloaded onto their phones or appear at the top of app stores. This finding aligns with those of other studies showing that a small percentage of mHealth apps (12%) account for over 90% of overall user downloads (IMS Institute for Healthcare Informatics, 2015). Over 50% of all mHealth apps are downloaded less than 500 times (Birnbaum et al., 2015) and 85% of apps less than 5,000 times (Organisation for the Review of Care and Health Apps, 2022). This suggests that mHealth developers should focus on improving existing apps and integrating other apps and features into highly used apps, rather than contributing to an already-saturated health app market.

Participants who expanded their search beyond app store rankings were often acting upon guidance from medical providers. Findings from these interviews indicate that healthcare providers have tremendous influence over the digital health landscape, as patients are much more likely to initiate use of a health app when it is recommended by their provider. As digital health

continues to evolve and play a larger role in individuals' lives, healthcare providers can guide and shape lifestyle behaviors, health choices, and self-management of health conditions by recommending apps that help patients track and manage their health concerns and conditions responsibly. Additionally, medical providers should work on building rapport with patients to maximize the likelihood of their recommendations being followed, as a few participants mentioned that the more they trusted their medical provider, the more likely they'd be to act upon their advice. Other key influences included friends, family members, and individuals experiencing similar health conditions. Individuals diagnosed with a health condition were more likely to act upon recommendations for mHealth apps from others who were navigating the same condition. Thus, an important avenue to reach these individuals is through support groups for individuals with chronic illness and increasing their awareness of the existence of apps that can help them manage their condition and track their symptoms.

Finally, individuals were significantly more likely to use an app if a subscription was provided or subsidized by their workplace or school and access to this app was widely advertised. Thus, business-to-business contracts between organizations and app developers can be an effective way to increase app use and adoption rates among intended users. App developers should explore the possibility of more corporate partnerships, and employers and organizational leaders should consider purchasing or subsidizing subscriptions to mHealth apps that can benefit members of their organization and ensure that individuals are aware of this benefit.

mHealth Apps that are Easy to Use and Add Value are Most Likely to be Adopted

Once users download an app, they are looking for a user-friendly interface and minimal time and effort required to set up the app and learn how to use it. The assumption is often that the more features, the better, but multiple participants expressed that they appreciated simplicity when it came to health apps. Overly complicated interfaces or too many functions often intimidated individuals and deterred them from using an app, which resulted in the app never being opened again and eventually being deleted. Many participants mentioned needing and desiring only basic functions because they had limited information to track or required only one or two specific features (e.g., activity tracking, blood sugar monitoring, diet planning). Thus, apps with simple features and straightforward user interfaces were well received.

The biggest determinants of whether individuals continued to use an app over time were how useful individuals perceived the app to be and how much value the app added to their lives. When individuals felt that an app offered something that other available resources and supports (e.g., in-person care, health websites, YouTube) did not, then they were very likely to continue using the app over time and were even willing to pay for it. The amount that participants were willing to spend on an app was often directly correlated with how useful they perceived the app to be. For example, if the app offered a "nice-to-have" feature like tracking a run or calculating weight lifted during a gym session, participants would pay $0.99 to $10 per month for it, but if an app offered a "must-have" feature like tracking blood sugar levels through integration with continuous glucose monitors, then participants were willing to pay up to $399 per month for it. This points to the need for users to be able to gauge added benefits of the app right from the start; app descriptions should clearly list features and functionalities and how they will enhance individuals' lives or help with health management. Additionally, it is important for apps that require purchases or subscription fees to first offer a free trial that includes all functionalities (and not just a subset of them) for individuals to determine the usefulness of the app as it pertains

to their individual health goals; otherwise, it is unlikely for potential customers to invest in the app.

Finally, when it comes to continued usage, consistent and high-quality app performance is important. Individuals often feel impatient and frustrated when apps do not perform as quickly or as well as expected. In general, users are unforgiving when it comes to technology and are quick to discontinue use when apps "fail" or become unresponsive. As such, it is important for developers to conduct sufficient user testing before launching an app and to promptly fix bugs and resolve issues as they arise; otherwise, they risk permanently losing users.

Users Desire Tracking and Monitoring, Directive Content, Personalized Reminders, and Community Interaction

The most highly desired feature for health apps was tracking and monitoring. Individuals wanted to be able to track their diet, caloric intake, nutrient intake, water intake, step count, cardiovascular exercise, and gym sessions to make healthier lifestyle choices. Similarly, for managing health conditions, individuals wanted to be able to monitor symptoms, blood glucose levels, and blood pressure readings and track medications and health appointments. A primary reason that tracking and monitoring was highly desired was that individuals felt motivated when they could see evidence of their progress over time towards their health goals. This instilled in them a sense of accomplishment and allowed them to celebrate milestones with their social circles. Participants particularly appreciated dashboards depicting their progress over time, especially data visualizations like graphs and charts. User interface designers should consider incorporating bright, colorful dashboards and graphs that are visible or easy to navigate to from the home screen to engage users each time they log in to the app. An additional capability that was desired but not widely available was data sharing, especially among individuals who were diabetic or prediabetic and also had family members with diabetes. These individuals voiced a desire to be able to check on their family members' blood glucose levels throughout the day and track each other's physical activity for motivation and accountability. Apps designed for chronic illness management should consider incorporating family plans or subscriptions and allowing individuals to consent to sharing and receiving health data with family members.

The second highest priority for participants after tracking and monitoring was directive content. Participants wanted specific guidance, step-by-step processes, and detailed instructions on what to do and when to manage or improve their health. Many participants expressed that they were able to get sufficient health advice and general suggestions from their providers (e.g., doctors, dietitians, physical therapists, mental health therapists, and fitness coaches) and online sources (e.g., Google, YouTube), so what they turned to apps for were detailed, step-by-step instructions and personalized plans and feedback that they could access around the clock. These participants wanted to minimize cognitive load when it came to managing their health, so a deciding factor for whether they chose to incorporate an app into their routine was whether the app content was specific and directive enough. If they were given only general instructions and recommendations that they then had to devise their own plans around, they were more likely to discontinue use. Based on participant feedback, physical activity apps should include weekly exercise plans with pictures and videos of how to safely perform the recommended exercises; nutrition apps should include daily meal plans, pictures of sample meals, and lists of foods that are beneficial (or not) for managing a health condition; mental health apps should include specific instructions for how to engage in an activity and for how long; and digital patient portal

apps should have a step-by-step guide that walks patients through how to establish care with a medical provider and a checklist for how to prepare for an appointment.

Along these lines, the more personalized an app was, the greater the likelihood of app adoption. Participants wanted to feel as though an app had curated individualized plans and targeted suggestions for them, rather than just providing general advice that could be applicable to most individuals. For example, participants wanted exercise plans that addressed their specific problem areas or avoided areas of pain or weakness, as well as meal plans that targeted their specific nutrient deficiencies. Participants also appreciated personalized touches like being addressed by name, hearing music upon opening the app, and being greeted with a goal and purpose for the day. Some wanted to be able to customize home screens of their apps so they could see the features that were most important to them first (e.g., a graph depicting their progress toward a goal). Most participants viewed reminders and notifications favorably – they appreciated messages encouraging them to take their medication, exercise, drink more water, keep up a streak, etc., especially when the reminder tied back to a goal they had set for themselves. Thus, apps should incorporate motivational interviewing techniques from the start to elicit participants' goals and deliver personalized content and reminders based on those goals. In general, participants disliked messages that made them feel shame about their current health habits or guilt about not engaging in a healthy behavior or following through with a plan of care. Thus, reminders should be delivered in a supportive, encouraging tone focused on individuals' strengths and potential for growth, rather than their weaknesses or failures. Overall, higher levels of personalization when it came to delivery timing of reminders was widely desired. Many participants expressed that they received app notifications at an inconvenient time or place or not at the desired frequency (i.e., too often or not often enough). This points to the need for apps to incorporate more just-in-time adaptive interventions (JITAIs), which provide dynamically tailored support in response to an individual's changing circumstances, with the goal of delivering support at the right moment and in a context where the individual needs it the most and is most likely to be receptive (Nahum-Shani et al., 2016). For example, a JITAI for a physical activity app should offer exercise suggestions based on time of day, weather conditions, location, physical surroundings, and a user's mood and energy levels (Luo et al., 2021).

A final desirable feature that was repeatedly mentioned in interviews was community interaction. This was particularly important for fitness and exercise apps, as participants were motivated by both positive reinforcement and feedback from their communities, as well as competition within their social circles. Community interaction was also helpful for individuals navigating health conditions. A couple participants explained that because they were the only ones within their in-person social circles with a particular health condition (e.g., diabetes), meeting people who were navigating similar health issues and being able to interact with them through an mHealth app was helpful and made them feel less alone in their struggles. Individuals with health conditions also appreciated when apps included a live chat option or an option to send and receive messages to and from a medical professional or care team. Thus, apps for chronic illness management should consider including a platform for individuals to interact with medical professionals to help them feel more connected and supported.

Cost, Time, Lack of Cultural Tailoring, and Credibility and Privacy Concerns Pose Significant Barriers to mHealth Use

Cost was the most frequently mentioned barrier to mHealth app use. Almost half of the participants brought up concerns related to mHealth app pricing. Participants were not *un*willing

to spend money on mHeath apps – in fact, many expressed willingness to spend upwards of $10 per month on an app – but they wanted the cost to be proportional to the value the app added to their lives. In some cases, it wasn't clear to participants from the outset how paying for an app would be more beneficial than the free version of the app or other free apps and health tools, which resulted in them not considering the investment. In other cases, participants were asked to pay a fee after already initiating app use in order to continue receiving full access to app features, which caused frustration and deterred them from using health apps altogether. Given these findings, recommendations include:

1) Make apps free and widely available whenever possible to maximize reach.
2) Paid apps that charge a one-time fee or a subscription fee before download or upon login need to very clearly outline key features and explain how their product adds value over free tools in their description in app stores or on the home page to attract users.
3) Consider a "freemium" model, where a basic version of the app is offered for free, and more advanced features or functionality and additional content can be unlocked through in-app purchases or subscriptions. When a "freemium" model is used, provide a free trial where individuals gain access to all the app's features before being asked to pay so they can assess whether and how the app adds value to their lives.
4) Be transparent about pricing from the start and include a detailed breakdown of both free and paid features to allow users to make informed decisions about how they want to engage with an app.

Another barrier to mHealth app use was the amount of time and effort required to set up and fully engage with an app as intended by app developers. A few participants expressed annoyance that they were required to create an account, log in, and input personal details before being able to explore and understand app features and access basic health information. Apps should consider providing access to general health information and allowing users to explore and familiarize themselves with the interface from the start to minimize barriers to use. Afterwards, when devising a more personalized plan or tailored suggestions, apps can then ask users to create an account and input personal information. Another common complaint was that many mHealth apps require manual entry of information on a daily basis (or even multiple times a day) to work as advertised. For many users, the amount of time and effort needed to fully engage with an app outweighed any potential benefits of using the app. As such, app developers should explore ways to streamline or automate tracking and minimize the need for frequent manual input. Some individuals use multiple mHealth apps (e.g., one for diet, one for physical activity, one for blood glucose monitoring), and with user consent, app developers can consider arrangements to allow for responsible data sharing between apps to minimize the need for participants having to input the same information multiple times into different apps. Additionally, integrating wearable technology with mHealth apps is an important step to alleviate user burden by automating data entry. Some individuals wanted to minimize time spent on their phones or were unable to use their phones while at work, so they desired the option to input data through their desktops. As such, app developers should also consider utilizing hybrid apps that function on multiple platforms and operating systems, thus allowing for a single, unified experience across mobile devices and desktop browsers. Finally, numerous participants had an "all-or-nothing" mentality when it came to app usage where they felt that because they couldn't engage with the app as fully as the app recommended (e.g., twice a day), there was no point to using it at all. While apps

can encourage users to engage as much as possible, they should also specify benefits that can be gained from occasional use as well.

A third set of barriers related to cultural and contextual considerations. Almost three-fourths of participants (44/60) were foreign born, non-native English speakers, and many of them voiced concerns that existing mHealth apps were rarely tailored toward individuals of their backgrounds or identities. These individuals cited language barriers as a key issue. The majority of mHealth apps have been developed in the United States and European countries and are supported only in English (Organisation for the Review of Care and Health Apps, 2019). A small fraction of apps are supported in other languages spoken in European countries (e.g., German, Spanish, French, Italian), and an even smaller fraction in languages spoken in Asian countries (e.g., Chinese, Japanese, Russian). Despite increasing interest in and demand for mHealth apps supported by other languages, the current commercial marketplace is not meeting those needs (Muñoz et al., 2021). There are significant accessibility barriers for non-English speakers, and a key focus of mHealth app development should be on offering multilingual options to reach these population segments. Another issue mentioned was lack of familiarity with technology. Although smartphone ownership rates in the United States are very high, with 91% of Americans owning a smartphone (Pew Research Center, 2024), global smartphone ownership rates are much lower, with about 54% of the world's population owning a smartphone (Global System for Mobile Communications Association, 2025). Many immigrants come from countries with much lower smartphone ownership rates, and participants explained that even if they own a smartphone, they often still use basic mobile phone functions like SMS text messaging and voice calls more because those are the preferred methods of communication among their communities back home. They are less likely to download apps and use other features unique to smartphones, as those functions do not help them stay more connected to those in their social circles with lower technology use. Given some individuals' familiarity with and preference for voice calls, app developers who are attempting to reach this population should focus on developing less text-heavy interfaces and incorporate more ways to interact via voice or video. This is also important for reaching older adults who may have vision or motor skill challenges. Finally, participants brought up issues relating to geographic, regional, or cultural differences. For example, when it came to diet and nutrition apps, participants mentioned that many of the dietary recommendations provided did not align with their dietary needs or cultural preferences and desired a higher level of personalization in the suggestions provided. Along the same lines, a couple participants mentioned that exercise and activity suggestions provided by fitness apps often did not align with what they have access to in their areas: for example, individuals in suburban or rural areas often do not have reliable access to gyms and exercise equipment, while individuals in urban areas have less access to green spaces and outdoor spaces. Weather and safety considerations were also mentioned, as exercising outdoors or at certain times of the day is not a possibility for some. As previous research has shown, disparities in mHealth technology adoption are evident, particularly among lower-income minority populations in the United States due to a lack of tailored intervention (Liu et al., 2025). App developers should consider creating user personas based on ethnographic interviews and focus groups to better understand how to curate personalized content and tailored plans to meet diverse individuals' health needs.

The final category of barriers related to credibility, trust, and privacy concerns. Numerous participants voiced concerns about the credibility of information provided via digital platforms. In general, apps were viewed as more credible than websites, search engines, and YouTube videos. However, this trust can be misplaced, as health-related apps are often marketed

as standalone or adjunctive treatments despite the majority of them being largely unevaluated and never having undergone study in controlled trials (Carlo et al., 2019). Offering disclaimers and statements of whether an app had been reviewed or endorsed by health professionals went a long way in establishing credibility for interview participants. Medical professionals are increasingly taking on active roles as digital health leaders and developers, and when health apps deliver content developed by medical professionals, this should be made evident to users to increase user confidence. In general, apps should consider citing more medical professionals or healthcare organizations and directing users to scholarly articles or healthcare organization websites to instill more confidence in users regarding the credibility of information provided on digital platforms. Along the same lines, another trust-increasing factor was provider referral – participants were more likely to adopt an app that had been recommended by a provider or discussed as a way to maintain communication with their provider. As such, app developers should consider ways to increase provider awareness of health apps. To be a reliable health support and increase user confidence, apps must also be compliant with data security and privacy policies and practice transparent communication. Numerous participants voiced concerns relating to data handling, privacy, and security, particularly for apps targeting sensitive health areas like reproductive health or mental health, and there were many questions about how health data is handled and who has access to it. A lack of transparency, regulation, and standardization remains common in the digital health marketplace (Carlo et al., 2019). A significant portion of the digital health sector is unregulated, and the majority of health-related apps have unacceptable transparency regarding data practices, with over half lacking privacy policies altogether (O'Loughlin et al., 2019). Apps need to address these concerns by instating strong data protection measures, abiding by best practices for data handling, communicating policies to users, and partnering with medical providers and healthcare organizations to build trust.

Mapping onto the UTAUT through a Conceptual Model

The UTAUT model was able to account for much of participants' decision-making processes regarding app selection and adoption. The UTAUT constructs "social influence" and "facilitating conditions" were most relevant to predicting app selection, while "performance expectancy" (corresponding to the "perceived usefulness and added value" code) and "effort expectancy" (corresponding to the "ease of use" and "satisfaction with app performance" codes) were significant predictors of app adoption and ongoing use. An additional determinant of app selection that did not fall neatly under one of the four UTAUT constructs was ease of locating an app. The conceptual model in Figure 6 was developed to reflect interview participants' experiences with mHealth app selection and adoption.

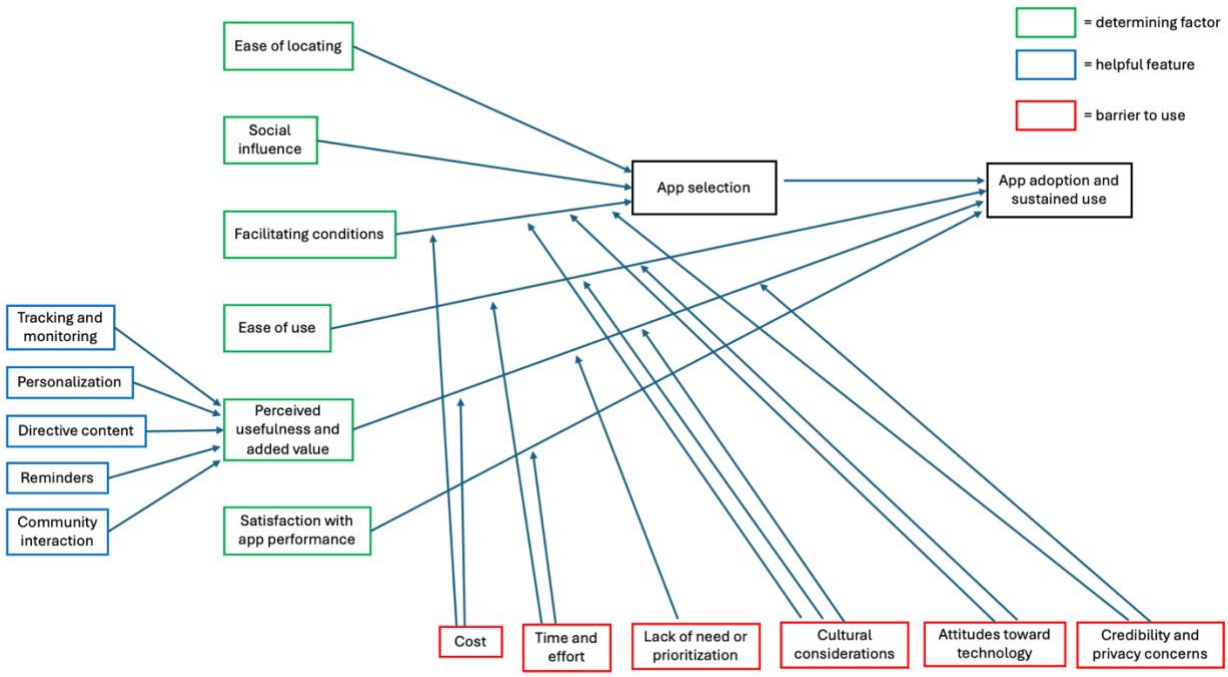

Figure 6: Conceptual Model Depicting Predictors of and Barriers to mHealth App Selection and Adoption.

This model depicts six main effects (outlined in green) as determinants of mHealth app selection and adoption, as well as six moderators (outlined in red) in the form of barriers to mHealth use. The conceptual model suggests that the influence of the six determinants (ease of locating, social influence, facilitating conditions, ease of use, perceived usefulness and added value, and satisfaction with app performance) on mHealth app selection and adoption is moderated by cost, time and effort required, level of need or prioritization, cultural considerations, attitudes toward technology, and app credibility and privacy. Additionally, perceived usefulness and added value is determined by the presence of helpful and desirable features (outlined in blue), which include tracking and monitoring, personalization, directive content, reminders, and community interaction. Figure 6 illustrates the relationships between determinants of and barriers to mHealth app selection and adoption.

Conclusion

This exploratory study based on interviews conducted with 60 target users of mHealth apps revealed important findings regarding how individuals find and select mHealth apps for their health needs. Individuals most commonly use apps that are predownloaded onto their phones or appear highest in app stores. However, another key influence that affects app selection is advice from medical providers, thus pointing to a need to better understand factors guiding medical providers' recommendations for mHealth apps, which will be explored in the third paper of this dissertation. In order for apps to be adopted into individuals' routines, they must have straightforward, user-friendly interfaces and add value to individuals' lives beyond what other available (free) resources and supports offer. App features that individuals prioritize most include tracking and monitoring, data visualization, directive content, personalization, well-timed reminders, and community interaction.

While a plethora of apps exist for various health issues, there are numerous barriers that continue to impede mHealth use and adoption, including the need to invest significant time, effort, and money to fully benefit from many mHealth apps. Certain social groups, especially older immigrants from non-English speaking countries, face more barriers to use due to lack of multilingual options, unfamiliarity with technology, and content and recommendations that do not sufficiently align with cultural preferences, social circumstances, or geographic location. Finally, lack of trust in digital platforms continues to hinder the growth of mHealth. Apps need to be transparent about data privacy practices, maintain robust privacy and security measures, and partner with medical providers and healthcare organizations to put forth evidence-based content and recommendations for users. Rather than continuing to expand the health app market, a key focus of the mHealth sector should be on improving existing apps to offer more content and features that address users' needs. The reach of mHealth can be furthered by developing more culturally relevant content, incorporating multilingual support, and partnering with medical providers to increase awareness of apps, which will be explored in the third paper of this dissertation.

Paper 3: Exploring Medical Providers' Perspectives on the Utility and Value of Mobile Apps for Health Behavior Change: Qualitative Analysis of Interviews

Background

Technology adoption is influenced by the processes of diffusion and dissemination, both of which are methods of spreading an innovation across individuals and communities. Diffusion is defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1995). In diffusion, the spread of an innovation is unplanned, informal, decentralized, and primarily horizontal or mediated by peers (Greenhalgh et al., 2004). Interpersonal influence through social networks – advice and support being communicated among members of a social system – is the dominant mechanism for diffusion. In contrast, dissemination is an active and planned process in which the spread of an innovation is formal, centralized, and propagated through vertical hierarchies with the goal of persuading target groups to adopt an innovation.

As discussed in the second paper of this dissertation, individuals' mHealth adoption decisions are heavily influenced by both diffusion and dissemination. Social influence was a key determining factor in interview participants' decision to use a particular mHealth app, with participants being significantly more likely to select a particular app to try out if their medical providers had recommended it. mHealth apps can directly benefit both patients and providers, as they are a convenient way for patients to access information, resources, and self-management tools, while also allowing providers to work more efficiently with patient information, deliver patient care instructions and support, and streamline workflow. mHealth apps have tremendous potential to improve patient care management, delivery, and outcomes, and providers' perceptions of such apps are critical to whether they are adopted and integrated into practice (Miller et al., 2019).

Providers hold significant influence over the digital health market, but there is a lack of research regarding their decision-making processes for recommending or disseminating an mHealth app. Understanding how providers view mHealth apps and assess whether they are suitable for addressing their needs can help guide the design of apps so they have a higher likelihood of diffusion, dissemination, implementation, and ultimately, adoption by intended users. Whereas the first two studies of my dissertation place users' perspectives at the forefront, this third study focuses on providers' perspectives regarding mHealth interventions' utility, value, and appropriateness, with appropriateness being defined as the perceived fit, relevance, or compatibility of the intervention for a given setting, provider, or consumer and for addressing a particular issue (Proctor et al., 2011).

Theoretical Framework

This study is informed by the Diffusion of Innovation (DOI) Theory, which is commonly used to guide digital health implementation. DOI theory, coined by Rogers (1995), is one of the most popular theories for studying adoption of technology and understanding how technology spreads within and between communities (Venkatesh et al., 2003; Rogers et al., 2014). According to Rogers (2003), there are five key elements that influence the diffusion of an innovation: 1) attributes of the innovation; 2) attitudes of the adopters; 3) communication channels; 4) time; and 5) the social system. Attributes of the innovation can be understood as five user-perceived qualities: relative advantage, compatibility, complexity, trialability, and observability. Relative advantage is defined as the extent to which the user perceives benefits or

improvements to the existing or superseding technology. Compatibility is the degree to which an innovation is perceived to be consistent with the existing technical and social environment, as well as the existing values, past experiences, and needs of potential adopters. Complexity measures how difficult an innovation is to understand, implement, and use. Trialability is the extent to which a new innovation can be experimented with for a limited time period with minimal investment and without total commitment. Generally, innovations with higher trialability are more likely to be adopted by individuals (Zhang et al., 2015). Finally, observability is the degree to which the benefits and results of an innovation are clearly visible to potential adopters.

The second element influencing diffusion is the attitudes of the adopters, which can be classified into five groups: innovators, early adopters, early majority, late majority, and laggards. The third key element, communication channels, are mediums and processes by which individuals create and share information with one another about the innovation and its perceived usefulness to reach a mutual understanding. The two primary communication channels are mass media (e.g., digital and print media, social media, advertising) and interpersonal communication. Mass media tends to be more effective at creating awareness about innovations, while interpersonal communication is more effective at forming or changing strong attitudes held by an individual toward an innovation, thus influencing the individual's decision to adopt or reject the innovation. The fourth key element is time, as innovations are rarely adopted immediately. The passage of time is necessary in the innovation decision process as an individual moves from gaining initial knowledge of an innovation to forming an opinion of the innovation to deciding whether to adopt or reject the innovation and finally, to implementing the innovation. The final key element is the social system, defined as "a set of interrelated units engaged in joint problem solving to accomplish a common goal" (Rogers, 2003, p. 23). These units may be individuals, groups, organizations, or subsystems. Because the diffusion of innovations always takes place within social systems, it is strongly influenced by the structure and nature of the social system it operates within. Social systems affect adopters' attitudes toward the innovation and consequently, the rate of adoption of the innovation.

Study Rationale

The second paper of this dissertation, which was based on interviews with intended users of mHealth, emphasized the importance of the attributes of the innovation as well as the attitudes of the adopters in mHealth app selection and adoption. Various attributes of the intervention were discussed that affected app use and adoption, including relative advantage and observability (termed "perceived usefulness and added value" in the second paper), compatibility (termed "facilitating conditions"), and complexity (termed "ease of use"). At the same time, one of the key findings that emerged was that individuals' mHealth selection and adoption decisions are heavily influenced by interpersonal communication and the social system, with participants being significantly more likely to select a particular app to try out if their medical providers had recommended it. Thus, this third paper now turns our attention to communication channels and the social system, two other key elements that influence the diffusion of an mHealth app. Social systems and interpersonal communication between providers and intended users have tremendous potential to influence users' attitudes toward an mHealth app and consequently the rate of adoption of an app. However, there is a lack of research explaining how members within social systems come to support or endorse use of a particular app. This study seeks to address that gap in literature by eliciting the perspectives of medical providers within users' social

systems and exploring how interpersonal communication regarding mHealth apps occurs between providers and users. Specifically, this study looks at (1) providers' views of existing mHealth apps and their utility and value to patients and providers; (2) key factors influencing providers' decision to recommend an mHealth app to patients; and (3) features and content that providers would like to see further developed in mHealth apps to improve their appropriateness for patient care and patient use.

Methods

Study Design

This exploratory study employs qualitative thematic analysis of interview responses from medical providers regarding the mHealth landscape to identify key factors that affect the diffusion of mHealth interventions for health behavior change. The study is informed by Diffusion of Innovation Theory (Rogers, 1995) and utilizes a constructivist grounded theory approach (Charmaz, 2006) to develop a conceptual model that reflects providers' attitudes toward mHealth interventions for use by patients and providers. The interview data was collected as part of a quality improvement project for an mHealth app designed to encourage health behavior change (increasing physical activity and eating healthfully) and decrease the risk of chronic disease. Between February 2023 to March 2023, a total of 107 semi-structured interviews were conducted with 60 target users, 19 providers, and 28 organizational leaders for the purposes of exploring the potential of mHealth apps and improving the technology. This paper analyzes the 19 interviews conducted with providers.

Participants

Interview participants were selected through convenience sampling. Providers were recruited through targeted recruitment on LinkedIn, hospital and university networks across California, newsletters and listservs for health and wellness organizations, and snowball sampling. Eligibility criteria for providers included: age $\geq$ 18 years, English-speaking, licensed professional, and actively practicing in some area of health behavior change (e.g., diet, physical activity, medication management, mental health, chronic illness management/ prevention). Examples of providers included medical doctors, nurses, dietitians, physical therapists, mental health therapists, pharmacists, and patient navigators. Potential participants completed a screening survey to assess eligibility.

Interview Procedures

Interviews were conducted virtually over Zoom and lasted 30-60 minutes. Participants were provided with an overview of the study and verbally consented prior to starting the interview. Automated captioning was enabled for each meeting, and de-identified transcripts were saved and uploaded to Berkeley's secure Box. The interview guide for providers included questions about the provider's profession and day-to-day responsibilities, standard workflow, personal and professional use of mHealth apps, perceived benefits of mHealth apps as they relate to their responsibilities and patient care, what they look for in mHealth apps, how they decide to use a particular mHealth app, barriers to patient and provider engagement with mHealth, and suggestions for improving mHealth. Participants were provided with a definition of mHealth apps and examples of apps for clinical support and for health worker support, but during the interview, mHealth apps were referred to generically, and providers were encouraged to answer

questions in the context of any mHealth apps they were familiar with. Most questions on the interview guide were open-ended to elicit more detailed responses from participants. However, some closed-ended questions were used as gateways to more open-ended probing. There was a general predetermined agenda with a tentative question order, but at times, the order and specific topics covered varied to allow for discovery of novel ideas and elaboration on certain topics. The interview guide was refined and adjusted through an iterative process, resulting in questions being added, removed, or organized under a different theme.

Data Analysis Procedures

A qualitative thematic analysis of the interview responses was conducted through a constructivist grounded theory approach, which consists of a flexible set of guidelines and procedures for analyzing data with the goal of developing a conceptual model that reflects participants' experiences (Charmaz, 2006). Constructivist philosophy is appropriate for interpersonal health settings and research that aims to openly explore participant perspectives without preconception while acknowledging the expertise of the researcher in analyzing and interpreting the data (King et al., 2025). The constructivist grounded theory approach is grounded in the tenet that knowledge is co-constructed and gained between the researcher and participant. The constructivist grounded theory process includes several stages including open (initial) coding, focused (advanced) coding, analytical memo-writing, theoretical sampling and sorting, and theory generation. These stages build upon each other but are not followed in a linear sequence; rather, researchers move cyclically between stages and continuously refine and expand upon their analysis.

Inductive coding of data for this study utilized the constructivist grounded theory approach defined by Charmaz (2006). Analysis began with a preliminary reading of all interview transcripts. Initial, line-by-line coding of the interview transcripts was conducted, and extensive lists of preliminary codes were generated. In the focused coding process, codes were then reviewed, merged, and organized into broad categories based on similarities or relationships. Analytical memo-writing was done concurrently throughout to capture ideas, insights, and initial interpretive ideas. Multiple rounds of coding and memo-writing were performed until thematic saturation was achieved. Finally, codes, categories, and memos were combined to inform theory generation and integration.

Results

Participant Characteristics

A total of 19 interviews were conducted with providers between February 2023 to March 2023. Of the 19 interview participants, 5 were male (26%) and 14 female (74%). Ages ranged from 23 to 54, with the mean age being 36 (SD=11.1). About two-thirds of the participants (12/19) were born outside of the United States and identified as non-native English speakers, with Chinese being the most common native language (42%). See Table 9 for participant characteristics. The 19 providers included 7 medical doctors (37%), 5 dietitians (26%), 2 patient navigators (11%), 1 mental health therapist (5%), 1 physical therapist (5%), 1 preventive medicine expert (5%), 1 registered nurse (5%), and 1 pharmacist (5%).

Table 9: Participant demographics for 19 providers.

	Percent (N)
Gender	
Male	26.3% (5)
Female	73.7% (14)
Age	
18-24	15.8% (3)
25-34	26.3% (5)
35-44	10.5% (2)
45-54	21.1% (4)
55-64	0.0% (0)
65+	0.0% (0)
Declined to state	26.3% (5)
Nativity	
US-born	36.8% (7)
Foreign-born	63.2% (12)
Native Language	
English	36.8% (7)
Chinese	42.1% (8)
Japanese	10.5% (2)
Spanish	5.3% (1)
Persian	5.3% (1)

Key Findings

Overall, providers held complimentary views of mHealth and appreciated their functionality in both supporting patient health behavior change and streamlining provider workflow and care provision. Certain key factors determined how likely providers were to recommend an app for patient use, including positive personal use experiences and app credibility. Providers acknowledged that despite mHealth apps' utility and diverse offerings, there are still many areas that require further development to better address patient health needs, particularly in racial and ethnic minority groups and immigrant populations. A summary of factors influencing the likelihood of provider recommendations of mHealth apps, as well as desired improvements and additions to mHealth apps can be found in Table 10 below.

Table 10: Factors influencing provider recommendations of mHealth apps.

Factors influencing provider recommendations	**Desired improvements and additions**
Personal use experience	Inclusive and culturally appropriate content
Credibility of app content	Personalized reminders and well-timed notifications

Cost and accessibility	Integration of wearable devices
Patient technology familiarity	Visuals
Ease and likelihood of use	Social support

Research Question 1: What are providers' views of existing mHealth apps and their utility and value to patients and providers?

In general, providers viewed mHealth positively and saw mHealth apps as useful tools for implementing and sustaining patient health behavior change, tracking patient health progress, expediting provider workflow, and exploring less invasive treatment options to prevent the need for unnecessary medical services.

Patient Health Behavior Change. Multiple providers spoke to the potential of mHealth apps in prompting and sustaining various health behavior changes in patients. A doctor explained that she recommends mHealth apps to patients because they can record step count, water consumption, food intake, and period and cycle tracking, which are all important metrics that she asks patients about. Additionally, she appreciates that mHealth apps can send notifications reminding patients to drink water and engage in physical activity, thus increasing the likelihood of behavior change. Similarly, a dietitian described her thought process behind referring patients to mHealth apps for long-term blood glucose management during office visits or hospital discharge: "Most of the patients are coming back after, even though they finish treatment…What I can do, to [prevent] people getting into this situation is recommend an app…to people to support their health." Another dietitian working with patients preparing for organ transplants described mHealth's potential to help these patients improve their health status over time:

> They are donating a liver or kidney to a family member, and a lot of them are not in a healthy state – that is, they're ready to give, they're ready to donate, they're ready for the surgery, so for a lot of them, it's reducing BMI, reducing cholesterol, there's a ton of markers…and so getting certain kinds of blood measures to certain levels. From the algorithmic perspective, if [mHealth apps] have a set of constraints that [they're] designing around, if it's a diabetic patient we have, we could have different constraints in there that we're working around with algorithms, so all of that should be possible. We don't want to limit it to that one population, but we don't have enough capacity to work with a bunch of different populations…but with [mHealth apps], we have a staged process, and we have kind of a first stage of our algorithm where we just make meal recommendations that fit in individuals' dietary preferences and then there's a second stage that puts constraints on that.

A pharmacist also spoke to the potential of mHealth for helping with medication management and compliance over time:

> As a pharmacist, I will say medication compliance is very important. Most chronic illness patients – they have multiple medications to take during the day, and different schedules, sometimes prior to meals, sometimes twice a day, three times a day, or once a day. And then usually the chronic illness comes with multiple diseases, not usually only one, so helping them to take the right medication on time or at the right time is important…I think [digital health] would be helpful as a reminder cause right now, it's only a

> medication box that they use Monday to Sunday, morning, noon, and night, three times a day. So, you put all the pills in the box so you can easily tell which one you took, which one still remains in the box, so that is helpful, but it's not easy to carry all the big boxes around. So, I think maybe the digital health platform will help them say, "Hey, it's time for you to take this," and then you can check and say, "Yeah, done that." Or if they missed those and they don't know what to do, [the digital health platform] probably will be helpful and the technology will help them to remind them and then record.

Patient Health Tracking. Another way in which mHealth apps held utility to providers was through their ability to track patient's health and behavior change progress. A nurse stated that she recommends an app to her patients that can monitor blood pressure, heart rate, and oxygen levels with the integration of a wearable device: "It can be modified to check [patients'] EKG and remind [them] to check it and see if [they] have any heart issue. Using this application and device – it's not really difficult, it's very easy." A doctor also recommended wearable integration for exercise tracking: "It's really convenient – it's a watch, like a smartwatch, so if you're about to do the exercise, you just find the app and then open it, [enter] what exercise you are about to do, and then they'll start tracking. So I think that's really convenient, and because [if you're] using an iPhone, it just directly transfers the data. Also, it's easier to see your record." Another doctor asked patients to monitor health behaviors and appreciated being able to see patients' daily habit records: "And we have homework – I need you to put down how many grams of nutrients you intake…and monitor sleep and how many steps you did in a day." He found it helpful to be able to view statistics generated by patients' apps and appreciated that "the history ideally can be kept forever sometimes." Similarly, a doctor expressed that apps can provide "data visualization I can see very clearly, like as a line that shows whether [my patient's] exercise goes up or exercise is decreasing." A dietitian stated that she recommends Apple Health because she likes the progress dashboards: "I just really like the user experience with it. And the amount of steps compared to the day before your average, what you did last year, or something, and having that as a metric has been really helpful, and I think motivating…all the progress dashboards, basically." Finally, a dietitian working in hospital settings explained that because she doesn't see her patients regularly, she recommends nutrition tracking apps to them and "check[s] it and then tr[ies] to give them feedback."

Expediting Provider Workflow and Responsibilities. Many providers also brought up ways in which mHealth apps can expedite and streamline their workflow and support them in clinical diagnosis and decision making. For example, one dietitian explained that she will "do some testing and see how [an app] works with patients and then go from there to see if it's something we can feel confident recommending and if it will save us time developing [diet plans and recommendations] ourselves." She stated that she often recommends diet apps to her clients because these apps can set a generic plan, track food intake, and provide nutrition information: "It really is convenient…for information purposes, it's a really convenient way to look up information, to guide the client to what to look for…I truly think that's going to be the future." Similarly, a doctor stated that in addition to nutrition tracking, apps help her provide health education to patients to "make a lasting change – it's about teaching, but also getting people to continue with those habits, so that it's not like 'I'm tracking my food, therefore I'm good, and as soon as I'm not tracking, I'm gonna go buy the Doritos,' or whatever that is." Another reason why many providers appreciated apps was that it helped them maintain patient records and

streamline documentation. A pharmacist stated, “I think the phones make that easier, so I don't need to keep the papers.” She also spoke about paper records being less secure and harder to keep up to date. Similarly, a nurse explained that digital patient portals make it much easier for providers to schedule appointments with patients, share visit notes and lab results, and provide follow-up instructions regarding diet, medication, etc. Additionally, she described how being able to upload and sync data from different providers to a patient’s medical file within a short time was attractive to doctors and nurses.

Preventing Unnecessary Services and Treatments. Finally, a few providers viewed mHealth apps as an important way to explore less invasive treatment options that rely primarily on behavioral change, prior to considering more serious medical interventions or procedures. For example, a patient navigator spoke about his own journey managing cartilage loss through using mHealth apps to learn how to do exercises that increase strength and mobility and decrease pain, thus preventing the need for aggressive medical procedures. This has influenced how he advises patients, where he recommends conservative, minimalist treatment – behavioral interventions related to exercise, diet management, and therapy – over surgical procedures whenever possible:

> One thing to understand about my professional background is that I am a patient advocate, and so I help people figure out how to consume health care wisely. In the US economy, we do have to be careful when seeking professional advice. You're almost equally at risk of being overtreated as under treated. There's enormous professional and financial incentives for people to push drugs, devices, surgeries, procedures, because that's how an entire medical and industrial complex makes money, and many of these things have very limited evidence for effectiveness, and yet they keep happening. So, I do consult professionals, but I tend to be fairly minimalist about actually the interventions that I'll take. So, for example, most people with my condition would have had a hip replacement or two hip replacements by now. But you know, my experience has led me to believe that you can actually live without cartilage, that you just have to learn how to extend your range of motion and pain tolerance… you can stabilize your joints and…keep things lubricated and achieve a real range of motion and reasonable lack of pain, absence of pain. So I would say generally, I'm trying to avoid interventions. There's usually behavioral [interventions] in the area. Say, diabetes, there's a tremendous amount of evidence around the power of diet and exercise. Same thing in mental health. I think I just saw some headlines about studies where exercise is as effective as therapy, or more effective than therapy and drugs.

Similarly, a neurosurgeon shared that she introduces patients to mHealth apps for muscle training for the lower back, core, and neck. She explained that using these apps regularly, such as multiple times during the workday, can help to strengthen muscles, decrease pain, and ultimately prevent surgery. Additionally, when surgery is necessary, using these apps can help expedite the recovery process, maintain gains, and prevent the need for another surgery later due to improper healing.

Research Question 2: What are the primary deciding factors for whether providers would recommend an mHealth app to patients for health behavior change?

In deciding whether an mHealth app was appropriate for patient use, providers’ priorities and determining factors included personal positive experiences using the app, credibility of app

content, cost and accessibility of the app, patients' technology familiarity, and perceived likelihood of regular app usage.

Positive Experience Using an App. Most providers interviewed expressed familiarity with the digital health sector and had previously tried out mHealth apps. If they had a personal positive experience using an app, they were significantly more likely to recommend that app to their patients. For example, one doctor had tried numerous apps: "I still keep track of my daily water amounts in my app. And I also…use Cycle to record menstruation. So basically in the Health app, I will record how many steps I walk per day, and how much water I consume per day…Cycle is easy to use, and also, you could integrate the data to Apple Health, so I feel like, okay, it's easy for me to check…But I feel like the Health app within the iPhone is not that easy to use. I feel like it's more like a huge pain to correct all the data from other apps. For the Cycle app, it's more simple…quite easy for me." She explained that although she continues to use these apps, she recommends only Cycle to patients because she finds it easiest to use. Similarly, a doctor talked about trying many different apps to help manage her own back pain, and once she found an app that relieved lower back pain through muscle training, she started introducing her patients to that app as well. She noted that another app didn't work well for her because of her irregular hospital shifts, but she thought it had potential and would introduce them to patients with more regular work schedules. A patient navigator discussed two apps that he experienced great success with for managing his own health and thus recommended to patients he worked with:

> Right now, I'm using a diet and exercise tracking app, and it's just a free app…What I find it useful for is, well, I guess weight management is my motivation…I lost, probably, using this app, I lost 15-20 pounds and now, I'm keeping it off because I'm in a good place of balance with being able to support my weight and not make my joint injuries worse. It's very handy…It's not just the weight management, but I tend to have just anecdotally hyper- and hypo-glycemia, and all my work requires concentration, so I find that if I get too low blood sugar or too high blood sugar, I'm either jittery or I can't concentrate. Either extreme is not good. For me, [the app has] really been a wonderful way of managing my blood sugar. My blood sugar is good, I can concentrate, I'm not hungry for 4 hours and 'til the next meal, and then I track exercise – same thing, you just put in which exercise you're doing, and that just gives me an idea of just maintaining a slight caloric deficit…For my exercise, mobility, range of motion, I'm relying heavily on Mark Lauren, who is a kind of a body weight expert, so I have his app, and 3-4 mornings a week, I'll do his – he calls it 9-minute body weight exercises."

Some providers didn't have personal need for mHealth apps but felt it was important to try them to provide guidance to patients on app selection. For example, one doctor explained that she tried out multiple apps herself so she could have a better understanding of each one before recommending them to patients: "I've tried pretty much all the [popular] apps…MyFitnessPal, Headspace, Apple Health, Strava… gosh, there's so many that I've used! Apple Watch, I use that all the time. I've also used 'Lose it!' I really like trying different applications…another one that focuses on mental health. I have tried a lot of different apps, so that I could understand the concept before diving into one." Along the same lines, a dietitian explained that although she didn't personally have much use for diet and nutrition apps, she recognized that they held value for others: "This is the major trend – utilizing a lot of cell phone apps now. So I, personally, have

not looked for myself, but I definitely help friends and family use MyFitnessPal, you know, calorie counters…I have a couple apps for tracking intake…tracking personal consumption, and the second thing is looking for nutrition information." Given the large number of available diet apps, she saw it as her responsibility to test apps and provide guidance to patients on which one to use: "I'll probably do some testing myself to see [if it'll] suit me as a patient…see how it works with patients, and then go from there to see if it's something we can feel confident recommending…there's going to be good and bad apps, and you need to be the one screening before we actually introduce it to clients."

Credibility of App Content. When evaluating an app for patient use, it was important to providers that app content was based on clinical guidelines and that the app had been evaluated in clinical trials or reviewed by healthcare providers or organizations. A few doctors spoke about the importance of apps putting forth content that was based on scientific evidence and healthcare provider expertise. For example, one doctor talked about how he wanted to see exercise apps explicitly discuss the scientific rationale behind certain exercises – how an exercise increases mobility and builds muscle strength, which body parts are used in a compound movement, how physical activity can reduce joint pain. While providers in multiple fields mentioned credibility, dietitians expressed the most concerns regarding the credibility of information provided in diet and nutrition counseling apps. One dietitian discussed how it can be hard for patients to find information in diet apps and determine its credibility:

> A lot of times, more if you are doing calorie counting, you have nutrition information, and the database is coming from, say USDA, versus if [your food preferences] are more Asian driven, because I encounter a lot of [patients who] have this Chinese vegetable they want to eat, and we start looking into its nutrition analysis everywhere and not able to find a very reliable resource…You see, people are comparing a lot, but [we] need to make sure they are not coming from a random place that has a lack of valid nutrition data.

She provided a detailed explanation of what she needs to see in an app to consider recommending it to patients:

> From a practitioner perspective, we'd like to have a little bit more understanding about how, credibility wise, the information the app is actually providing is, and it is sometimes not very easy to trace where this information is coming from. So I think the app developer probably can do more, like maybe there's a page or a tab that really provides the practitioner to know where their information is from. And so we can feel a little bit more comfortable, confident to recommend certain apps. There's gonna be good and bad apps, and you need to be the one screening that before we actually introduce it to clients and family members. So mak[ing] it easier to find the references would be good…You are really trying to provide education, then the information needs to be like saying you're citing or recommending. Where does it come from? Reliable studies or references or recommendations.

Another dietitian also spoke about the sources she wants to see referenced by mHealth apps: "I rate Mayo Clinic highly…I'd probably look for a lot of hospital health resources like those kinds of research agencies. I know Harvard has it – Harvard has a nutrition forum. I'd probably look towards those, to be honest with you…also academia or literature." Yet another dietitian expressed frustration around the lack of credible diet apps available to patients, which prompted her to start developing her own app based on USDA dietary guidelines to help organ transplant patients improve their health:

> The data sources that we're working with, recipe data sources, that are informing the meal recommendations, and those could be modified by a dietitian. What we're working around are specific nutritional guidelines, and we're also looking to maximize micro-nutrient availability in the right levels…We have a staged process, and we have a first stage of our algorithm where we just make meal recommendations that fit individuals' dietary preferences and then there's a second stage that puts constraints on that and says, "Okay, this fits what they need and where this doesn't fit…" and then what we plan to do in the future is be able to actually do individual-level ingredient substitutions…My vision for the next stage of this is I'm going to use this one-year project to get some preliminary results and I can then go to the NIH and get a bigger pot of funding to do clinical trials where we're actually seeing if patients use this and improve and there's some measurable health improvements from using it.

Finally, a provider expressed a desire for more standardization and review of apps so she and other providers in her organization can put forth recommendations:

> I'm not allowed or given permission to just advertise any kinds of apps or digital things unless it has been approved, so what I do is when I get a client who says, "Oh, you know what, I'm tech savvy, I need to use an app." Well, I can't recommend what they do if they're using an [app] already, and they have their own thing, so obviously, they get to use their own [app]...then I tell them, look at these things and think about what works for you, then we can review it, and if they have any questions, if there's any conflict between what I have said and what the app says, then we can work it out…I feel that, down the road, it'd be really good to have an app that is approved by the public health [department] where there's no hidden agenda, where it's standard, it is something that's authorized and approved, where it is for the best interest of the client without any other messages coming in.

Cost and Accessibility of the App. Another factor influencing providers' decision to recommend an app to patients was whether the app was free or easily accessible to patients, whether through patients' health insurance or workplace (e.g., employer, school) benefits. A nurse explained that her patients do not want to pay any more than they absolutely have to for health care. She explained that while there are a lot of apps that could help people, she would only recommend them if they're free because "I don't know if people really care about their health enough [to pay for an app]." She stated that she thinks insurance companies should pay for apps, so the burden isn't on patients. A physical therapist shared this view, based on her personal experience using health apps: "What I do to this day actually is I use the app that is called Headspace, and the reason why it piqued my interest is because the health insurance gives you those [subscriptions]. You know you can sign up to those apps and try them. I didn't even know they were out there until I kind of ventured into exploring a little bit. So, to this day, I still use it…When I got health insurance, it said that [the app subscription] was part of it, and so I was like, 'Oh, perfect!'" She explained that she would recommend this app to patients whose insurance also covered a subscription, and she also encouraged patients to review their insurance benefits to see what other apps might be covered and to use those. A dietitian mentioned, "sometimes Kaiser has offered certain apps that you could use for free, and I wonder if they integrate things on their end too. I never paid for [apps]. I feel like that's been a disincentive. I feel like if it's a paid app, I almost will never buy it unless it's like 99 cents." She explained that if she is unwilling to spend money on an app as someone who cares deeply about health, she

does not think patients will be willing to either, so she recommends only the apps covered by Kaiser. A doctor similarly expressed frustration about app costs and discontinued app use as a result: "I think the most annoying stuff for this was like it kept coming up, ads to tell me to buy the subscription of their app. Sorry guys. Probably not." Another doctor acknowledged that certain population segments are more willing than others to consider using and paying for an app, so she selectively recommends apps to patients: "Younger age groups [believe they're] less likely to have things like prediabetes. It's not actually true. [They] actually are just as likely. But [they're] not going to a primary care physician to be diagnosed…We started with younger, like focusing on twenties to thirties, active, working people and self-pay, and we were not as successful…Right now, millennials, Gen X, Y, just generally don't really go to primary care providers so even if [they're] at risk, [they] don't know, and therefore, are less likely to use [an app] that's preventing a disease process versus [apps] that are more focused on health." She explained that, in her experience, the population segment that has been the most open to paying for an mHealth app is middle-aged women who are prediabetic. Additionally, she has had success with older adults acting upon her app recommendations as long as the app is paid for by insurance.

Multiple providers expressed that the United States is "not prevention oriented enough," and as such, insurance companies rarely cover mHealth apps for health behavior change, viewing them as "not medically necessary." As one dietitian stated:

> We [in the United States] are not really focused on preventing type 2 diabetes…In Canada, we have pre-diabetes programs, so if you go into a doctor and he does your yearly checkup and he finds that your A1C is getting close to high numbers, he or she will say, 'Listen, you're getting close, and there's a free diabetes app to help you figure out how to manage this…you can be in the green zone if you exercise, lose weight, watch what you eat, or you can ignore this, and then you're going to end up being in the red zone, which is going to end up in diabetes.'...Prevention could be so critical, because I think, moving forward to the Sustainable Development Goals of 2030, diabetes is going to be huge, but prevention is something that we hardly do…Generally we're not prevention focused because we are always dealing with what's happening now, so you wait until it's too late. But there are [app] programs.

Similarly, a pharmacist spoke about the limits of health insurance coverage:

> They are not prevention oriented yet, but for our patient, … the doctor might prescribe, for example, a weight loss program – they probably will refer them to do physical activities or [see a] nutritionist, or if they have some health education need, they will refer to that team. We have a health education team that covers smoking (to quit smoking or alcohol), substance abuse, and that also includes weight, nutrition [counseling]. But that's only for patients that got referrals. But as a patient, if I'm not in that chronic disease state that I need the program…typical medical plans will not cover [prevention programs].

Patient Technology Familiarity and Digital Literacy. In deciding whether to recommend an mHealth app to a patient for health behavior change, many providers relied on their subjective view of a patient's familiarity with technology and digital literacy. For example, a dietitian explained that she feels that digital health is "the new trend," and if she perceives a patient to be "tech savvy," then she will introduce them to apps to help them track their intake or blood sugar levels. About half of the providers interviewed held the assumption that older adults

were either disinterested in using technology or would struggle to use health apps properly. For example, a dietitian stated, “There are a lot of older generation [patients]. They're not the type of generation that's going to use the computer, or they don't want to deal with it, they're old school.” Another provider shared similar views, explaining:

> The challenging [patients] will be the older generation. They're probably going to have a hard time catching up on, utilizing [apps]. When telehealth started, we spent like 30 minutes just trying to make sure that Zoom – they got it up. That’s where the gap is, how do you make sure anyone above 50 or 60, again, not because of the age only, but also the technology savviness, they may have a harder time to access those apps on mobile devices to get to what they really need to get the care…It is challenging…if the app has technical support, like, I know, we need to work on it a lot [with patients] in the first session. This may be what the expectation is, spending 15-20 min to make sure things are set up, and then not a lot is going to be accomplished…Of course, if there's family members that can assist them, would be great, but not always because there's a lot of people who are actually relatively independent in terms of their medical care.

At the same time, providers recognized that older adults were often the ones who stood to benefit the most from health apps. A nurse explained, “I think elders need reminders more than young people. For us [younger people], if we really care about our health, and we know how to watch out, then we don't need – we might not need – an app to assist, but elders might need it, because they are kind of forgetful, so the app needs to remind them to take medication or to exercise or something. [The app can give] them at least a reminder or alert to tell them what to do.” Similarly, a pharmacist discussed the importance of app use for older adults:

> It's hard for older adults to adopt technology. And then, for example, it's most important, I would say, for the elderly – they tend to have more chronic illnesses, and then they don't remember things, and then their medications could be more than 10, and it's confusing. They probably forget what they took or the day they took it, or they have different schedules like twice a day, once a day, 3 times a day, or maybe another one before bed, so compliance – they try, sometimes they pick and choose what they want to…but they always say, ‘I took everything…We just assume everyone wants to [follow our instructions], but they just forgot, or they don't remember.

Some providers recognized that older adults might be interested in using an app, but existing technology is often not configured to serve their needs. For example, one doctor stated:

> Then the other thing would just be to have the technology in a way that works for the client, and I think that's a hard thing to solve, because not everyone is the same, and you definitely do have to tailor your product to the market…A 20 year old is going to have very different interests and ease of use of applications compared to a 50 year old, so I think that's one of the things is making sure that you're considering the technology that's going to work for the group that you're working for…There are people who love paper and pencil right? So if they could actually record their things right, writing it down, for some people, it feels more permanent than you know, just tapping buttons on the phone. So that would be another thing to kind of consider is, think outside the box – even if you're creating a digital company, how else can you gather more ways for people to meet their goals?

> The thing we never think about is that because of the age difference, I mean, you know – people who are older tend not to use apps – that is a really great misconception. I thought so too when I was in my twenties, and I thought, "Oh, for sure it's just young people." But I was wrong, and I see that because my parents are in their sixties, and they and their friends all use [apps]. And so it's interesting that there's conceptions that you don't necessarily know unless you're actively scanning that population. And what we found actually in diabetes prevention programs is that the majority of top users were actually women in their fifties, which I did not expect at all, so we have to adjust our technology to meet that age group more than we are expecting.

Another provider discussed ways that apps might pose challenges to older adults: "Not everyone is up to date on technology. So voice sample. You probably need to teach your grandma how to use a cell phone, and then they are not easily adopted by the elderly. So that will be a con, and also some apps are not supported by their cell phone…They probably say, 'Oh, my cell phone – I only use that for talking and answering calls.'...I need to buy the most recent iPhone 14. Can I stay with iPhone 10? But Apple is not supporting that anymore. And remembering all the passwords."

Perceived Ease and Likelihood of App Use. Providers also factored in time and effort required of patients to use a particular app when deciding whether to recommend that app. For example, a patient navigator spoke about how she bases her recommendations on her own personal experience trying to sustain use of an app over time: "When I see an app…I go, 'How long term can I follow it?' I would love to adopt it. I just feel like, in terms of how long term can I adopt something, and I don't want to, you know, we always have a bunch of apps on our phones that don't end up ever being used ever again. And…then I just uninstall it because I haven't touched it in two months." Similarly, a provider spoke about how app use has to become a regular habit for health behavior change to occur:

> I really think at the end of the day, it's up to the person to put in the effort, because it's almost like humans are such interesting creatures, it's really up to you – you can pick up your phone and have the app there. Like I have an app on my phone that tells me how many steps I've walked, but it doesn't motivate me to do more or do less unless I make a point of looking at it. And I think every individual is different where the core thing that comes to that decision is how much effort you put into it. So I have a friend who uses Noom for example. She's very educated. She's in the health profession. But she finds that Noom is helpful for her because she's so all over the place that it grounds her, so like it sort of prompts her to drink her water and to eat her meals…Everybody's different on how they're going to get motivated and what commitment they have…You're stacking up all these habits into something that's going to work for you as an individual.

Another dietitian expressed the difficulty of getting patients to adhere to regular mHealth app use: "I think those are some of the difficulties to overcome, just the actual usability and correctness of the input. I think in general habits, I think a lot of these things people will do. But when they do, they treat them almost like a diet. So it's like they're all in, or they don't do it at all, which I think is difficult in terms of, you know, how do you make a lasting change? Hmm! It's about teaching but also getting people to continue with those habits."

Some providers discussed how app usability affects the amount of time and effort required of patients and thus the likelihood of continued use:

> I think [the app] should be easily customized, because unless you have unlimited time, those categories should be easy to access, don't need to press through so many buttons, and then that would be ideal. And also, another thing is [the app should] be easy to update and the history ideally can be kept forever. Sometimes we just couldn't find – we got a good app, but either it started to charge [money], or we couldn't find history for some reason. The interface – it's so, so important. Sometimes it just takes too much time to get what you want. And that's kind of a waste of time. I can just write down myself instead of having to click through everything.

A dietitian shared these sentiments about the importance of good usability:

> It's too complicated to upload that data, or it's not responding. As you can imagine, any difficulty during the process for you using those apps [will lead to discontinued use]. One of the things that we tried to change is like for Lose it! and MyFitnessPal…when you're going ingredient by ingredient, it's difficult [to input dietary intake], which makes the complexity higher. And unless you eat the same thing over and over, which is great, but if you have it entered in incorrectly…nutritionally and calorically, it's different…so I think those are some of the difficulties to overcome as just the actual usability and correctness of the input.

A couple doctors also explained that they did not recommend some apps to patients because they required frequent logins and consistent use over a long period of time, which they did not think most patients would be able to follow through with. When discussing why she chose to recommend one app over another, a doctor stated that the recommended app "is easy to use, and also, you could integrate the data to Apple Health…it's more simple, it only has like a few functions, and the screen is very simple, quite easy" but the [other] app is "not that easy to use. I feel like it's more like a huge pain to correct all the data from other apps. I have to key in every data I get, like when I drink water, I have to recall how much I drink in the past two hours, and to type the amount inside, but sometimes I would just forget. 'Oh, what did I do? What, how much?' You can't really remember anymore."

Research Question 3: What features and content would providers like to see further developed in mHealth apps to improve their appropriateness for patient care and patient use and increase the likelihood of providers recommending mHealth apps to patients?

Providers desired more inclusive and culturally appropriate content, particularly within diet and nutrition apps. Additionally, they believed that mHealth apps would benefit from more well-timed notifications and reminders, integration between apps and wearable devices, visuals, and social support.

Inclusive and Culturally Appropriate Content. One of the primary criticisms that providers had about existing mHealth apps is that they are often designed for only one demographic and as such, the content is not as effective or helpful for other population segments. This was particularly true for diet and nutrition apps, with many providers expressing difficulty finding apps that offered culturally appropriate dietary advice for their patients. One dietitian discussed her hesitancy to recommend diet apps to her patients because they are "super Westernized in focus." She explained that "people are using these apps but only a certain population, and [we need] a digital health intervention or just a tool for broader populations to use." She discussed the need for apps to work with "databases of recipes that are culturally diverse…and fit individuals' preferences." While she primarily works with Latinx populations

and has found a lack of "diverse recipes, meal plans that are culturally appropriate" for that population, she also noted that there are "data sources that have recipes from…across the world, so we don't have to be limited to that population…You can put in a region and country and there are tens, or hundreds of thousands of recipes by these different regions and countries, and I had a friend who knows Hispanic foods, and a friend who knows Korean foods go through and say, Okay, these are legit." She expressed a desire for "machine learning algorithms to create meal plans that fit people's cultural needs" and for diet apps "to be able to make individual-level substitutions of ingredients in meal plans and find recipes that are culturally diverse." These preferences were shared by another dietitian who primarily works with Asian populations and stated:

> A lot of times, more if you are doing calorie counting, you have nutrition information, and the database is coming from, say USDA, versus if you are more Asian driven, because I encounter a lot of like, you know, they have this Chinese vegetable they want to eat, and we start looking into this nutrition analysis everywhere and not able to find a very reliable resource…What they have is, you see, people are comparing a lot, but just need to make sure they are not coming from like a random place that have a lack of validating the nutrition data. I think if the app developers try to reach into cultural differences also at the same time, then the reference is quite important. We need to make sure those are being validated properly."

Similarly, a doctor shared that he initially was a proponent of MyFitnessPal, but it was hard to track cultural foods and restaurant meals, so he stopped using the app and recommending it to patients: "I tried that, but the thing is sometimes, it's just hard to find how much you ate in a specific meal, or it's hard to – cause like when you go to like a chain like McDonald's or something…you could find the meal in the app, right? And it's actually easier. But when you cook yourself, or like you go to a local restaurant, and it's not even there in the app, it's hard to record, especially, I think, with a lot of Asian restaurants, there's no additional information."

In general, providers expressed that higher levels of personalization were needed for mHealth apps to serve patients well. One dietitian stated, "There still will be one type of client who always wants the [diet] plan….If the app has the feature of individual [tailoring], just like your shopping list, you can put your preferences, and then they can create a some type of new plan based on that and I don't think I encounter a lot of that yet. It's still a lot of them like just [giving] a set example. But in terms of smartly combining patients' preferences and then generating some kind of [personalized plan], that will be actually a good welcome feature." She explained that she would love to use an app in her work if it could generate personalized plans based on patients' preferences. Another dietitian also expressed the need for apps to factor in individuals' medical conditions and dietary needs:

> This is going along the lines of medically tailored meals since I know that's becoming a thing. Okay, say I go to a doctor and they're like, "Hey, your blood pressure is super high, here's a nutritionist who will tell you what type of meals to take," and then that would be cool to see that happen in one dashboard to say, "Hey, you should work out this much, and then this is your meal plan with foods that will help reduce your blood pressure."

Similarly, a nurse stated: "I think for diabetes patients, if they have an app to tell them what kind of food they can eat or they cannot…this person has diabetes, and every day she can check her blood sugar, and she enters it, and it can keep monitoring her blood sugar daily. And okay, for example, I want to eat steak now, I enter it, and [the app] tells me how much steak I can eat for today…If the app can tell them how much they can eat, then it will be more helpful."

Personalized Reminders and Well-Timed Notifications. In addition to more tailored content, providers also noted the need for more personalized reminders and well-timed notifications. Multiple providers pointed out that what works for one patient may not work for another patient. As one doctor stated, "Tech needs to work for clients. Not everyone's the same. Consider the group you are working for." A dietitian brought up how patients' motivations and mindsets differ and as such, apps need to send reminders that align with individuals' needs and preferred methods of communication: "[Reminders] definitely need to be tailored to [each individual's] situation so [they] are willing to trust the app and move forward. I think it's personalized, because I think the question needs to be there to say, 'Are you the kind of person that an authority needs to push you or are you the kind of person that you do it yourself?'" She explained that if apps don't provide the right type of motivation, "it's going to be very short term, rather than the long-term, sustainable impact that you wanted to have…those key words, key things do impact the person." She described how she has found some apps to be more successful than others at sustaining change because they "actually talk about the behavioral change principles" and deliver reminders that are based on "your goals or your mission…you work with it and you get it, you have that goal. It's always reminding you. It drives you." Another provider also thought it'd be helpful for apps to have challenges: "So every month, or like every day, you could set your goal, and then, if you achieve it, the [app] will give you a medal or something… Motivating things is good."

The majority of providers agreed that reminders are helpful and important. However, they expressed that apps should allow for customization of timing, frequency, and type of notification delivery. As one doctor explained:

> Allowing people to customize notifications would be really helpful. So like reminders of, you know, if they are someone who eats 5 meals a day or 3 meals and 2 snacks a day, then they can put in reminders to help remind them to utilize the app because it's easy to ignore notifications. But if they chose to have those notifications on, and they could choose which ones to turn on, then I think that would be helpful as a reminder to themselves…they want to be reminded to log meals, for example, or exercise, or whatever it is, like this is something that you decided you want to do.

Similarly, a nurse discussed how individuals need different types of notifications: "Reminders - oh, it's time for you to check your password, or it's time for you to check the blood pressure, or it's time for you to eat a snack or drink water because for diabetes it's kind of dangerous if they don't eat for too long, they need to maintain their blood sugar in the same level, so, sometimes if it's too low or too high, either way, it's not good." A pharmacist also explained how individuals will need different frequencies of notification delivery: "I think it will be good if they can set up the time themselves because every day, every person has different schedules, like some people wake up late…And all the medications that they take – some people take two times a day, or once a day, so it's all different…If you can set up, it's more customized for each person, so yeah, if they can just set up for themselves, then that's good."

Integration. Providers desired more integration between mHealth apps and between mHealth apps, wearable devices, and other forms of technology. One provider spoke about how a plethora of mHealth apps exist for different purposes, such as managing weight and BMI, reducing blood pressure, reducing cholesterol, and monitoring blood glucose levels, but it is overwhelming for patients with multiple health goals to use multiple apps to manage their health.

She discussed the need for more integration between these apps so patients do not have to input data into multiple apps on a daily basis. A dietitian also envisioned integration between apps and with meal plan services:

> More integration – it would be cool to see what different apps can do with each other…like MyFitnessPal integrated with the Apple Health app. It'd be cool to see that happen, because, I mean, a lot of us have smart watches, so it's very real-time data. And these assessments of figuring out when you're walking, if somehow integrated with my calendar, my Apple Watch, and maybe even a meal plan service, like people have Every Table or Hello Fresh or something, that would be kinda cool too. And this is going along the lines of medically tailored meals since I know that's becoming a thing of like, okay, say, I go to a doctor and they're like, 'Hey, your blood pressure is super high, here's a nutritionist who will tell you what type of meals to take,' and then that would be cool to see that happen in one dashboard to say, 'Hey, you should work out this much, and then this is your meal plan with foods that will help reduce your blood pressure.'...I know sometimes Kaiser has offered certain apps, that you could use for free and I wonder if they integrate things on their end too, but I know that's kind of a future thing.

A surgeon also discussed how apps should integrate smartphone features to maximize their potential. For example, she observed that neck muscle training apps tend to be used the most by her patients because these apps use the built-in smartphone camera to allow patients to see and track their movements. In contrast, when she recommended a core muscle training app that did not embed a camera feature, patients did not use the app because they were unsure if they were doing the movements correctly. Similarly, a patient advocate wanted more apps to allow for connectivity to larger screens and devices so it was easier for patients to follow app instructions, routines, and workouts:

> What I really like about the app, and this may be me and my generation, but the app works on my smart TV, and it's not that expensive. I bought a giant Roku…a smart TV with the Roku operating system, probably 55–60-inch screen. And Mark Lauren's app – I can put it on there, and that's great, because then I see the demonstrations he does of these compound movements. His whole thing about mobility is compound movements, and so they're quite complicated, so seeing them on a giant screen is super helpful. I would not have stuck with the program or thrived on it as much without having this big screen option. If your audience has large screens, they can be really transformative for things like exercise…on the big screen is definitely much more helpful than just your 5-inch stream.

Visuals. A few providers thought it would be beneficial for mHealth apps to include more visual content to help patients apply app content to their daily lives. For example, a dietitian explained that it can be difficult for patients to accurately track their caloric intake and input it into diet and nutrition apps: "You have to do the ingredient portion yourself. People have no idea what a portion is. What does that actually look like? The complexity is higher, and you have to enter it accurately. Such as different sizes of banana – it's not accurate. Rice, sides, homemade [foods], and restaurant [foods] are different and difficult to calculate calories." Another doctor stated that even as a medical professional, "it was hard to find the exact amount of what [he] ate in a specific meal and it was hard to track cultural foods and restaurant meals, which is why [he] stopped using the app." Both dietitians and doctors voiced the need for more

illustrations of different serving sizes and portions within diet and nutrition apps. Furthermore, when it came to physical activity and fitness apps, providers expressed that having video content that guided patients through exercises would be helpful: "I think if they have suggestions, like more detailed suggestions…for example, if it's an exercise app, you could provide some video content about how you should do your exercise, maybe teach you how to do a specific workout or something. I think that would be great."

Social Support. A final desired feature that providers wanted to see further developed was social support from family and communities. One doctor explained, "Sometimes it's hard to do all these things by yourself, so if, actually, [app developers] could incorporate some features that encourage your friends or your family, encourage them to do all this stuff with you, I think that will actually help a lot." Additionally, providers found that patients were often motivated by seeing not only their own progress but that of those around them: "I think that's kind of the thing, you know, in this era, because people not only want to get themselves help here, but at the same time, they love to share, and it's kind of mutual, right? If you see people and they're doing these things, and you find out, and you also want to do it, you will start right away."

Discussion

This qualitative study based on thematic analysis of interview responses from medical providers revealed key factors that influence providers' attitudes toward mHealth and their likelihood of recommending mHealth interventions for patient use. Interviews with providers revealed that at present, diffusion is a more common process than dissemination within healthcare systems when it comes to spreading mHealth apps for health behavior change. There did not appear to be many planned, targeted efforts where providers' healthcare organizations had asked them to promote use of a particular app and persuade target groups to adopt it. A few providers mentioned that organizational access or insurance coverage influenced their recommendations, and they were more likely to recommend an app to patients if it was free or easily accessible through health insurance or workplace benefits. However, for the most part, when medical providers recommended a particular mHealth app to patients, they were doing so by choice, in an informal, decentralized way, simply because they thought the app could be a helpful tool in furthering patients' progress towards their health behavior change goals. This finding makes sense within the context of Rogers' DOI theory (2003), where the social system is defined as "a set of interrelated units engaged in joint problem solving to accomplish a common goal" (p. 23). In the case of mHealth interventions, providers and patients were engaged in joint problem solving to accomplish the mutual goal of implementing and sustaining health behavior change within patients.

mHealth Apps Hold Much Potential for Patient Health Behavior Change and Provider Workflow and Responsibilities

Overall, providers had positive impressions of mHealth and saw much potential for mHealth apps to help patients with sustained health behavior change and to assist providers in tracking patient health progress, providing guidance to patients, and preventing the need for more serious medical procedures and interventions. Providers appreciated that there are numerous apps available to the public for various health purposes, such as tracking food and water intake, blood glucose levels, heart rate, medications, physical activity, and menstrual cycles. Providers expressed that the availability of such apps makes it easier for patients to start

implementing health behavior changes and for providers to monitor patient progress and give feedback accordingly. Additionally, providers recognized that mHealth apps often held utility for their own workflow, saving them time in providing patient health education and discussing health plans and recommendations with patients. Finally, a few providers noted that use of mHealth apps can help patients make small, sustained health behavior changes over time that then prevent the need for more complex and invasive medical procedures down the road.

Providers Recommend mHealth Apps that are Credible, Accessible, and Ease to Use

A key finding that emerged from the interviews was that providers often recommend an mHealth app to patients simply based on their own opinions of or personal experiences with the app. Providers were significantly more likely to recommend an app if they had positive experiences using them. The majority of providers interviewed had previously tried out an mHealth app: some providers did so because they were trying to manage some aspect of their own health, while others did so because they felt that it was their responsibility to test out an app and make sure it was credible and beneficial before recommending it for patient use. This suggests that app developers should make an effort to include providers in user testing and consider giving providers free trial periods to test out an app. While this requires financial investment from app developers, it will likely be a worthwhile tradeoff, as providers can significantly increase the likelihood of patient adoption of an app through their recommendations. Similarly, this will require investment from providers, as they will need to take time to review and test apps themselves. While it may be burdensome at the outset, it can save providers time down the road by expediting patient care and streamlining provider workflow.

A primary consideration providers had when deciding whether to recommend an mHealth app to patients was credibility of app content. It was important to providers that content was based on scientific evidence, provider expertise, and clinical guidelines. Providers wanted to see credible sources referenced in apps and know whether the app had been evaluated in clinical trials or reviewed by healthcare organizations. At present, the majority of mHealth apps are unevaluated, with very few having undergone rigorous evaluation in controlled trials (Carlo et al., 2019). Despite this, many apps are marketed as standalone or adjunctive treatments for health issues. Additionally, there remains a lack of transparency around data use, privacy, and security practices for mHealth apps. There needs to be greater oversight and regulation of mHealth apps, as well as standardized quality and effectiveness measures that mHealth apps are held to. Furthermore, it is important for app developers to continually include providers in developing app content to reflect the most up-to-date health guidance for patients and providers. App developers should also include easily accessible information in apps about how the content was developed, including references and links to databases, empirical evidence, journal articles, and healthcare organization websites.

Providers were more likely to recommend apps that were free to use or accessible through patients' health insurance coverage or workplace benefits, as they understood that cost was often a deterrent for patients. Many providers expressed that the United States is not "prevention focused" enough. They believe that insurance companies should pay for more prevention-focused interventions, including mHealth apps, as these apps are often crucial tools for health behavior change and maintenance and prevent the occurrence of chronic illnesses and mental health conditions, which account for 90% of the United States' annual health care expenditures (U.S. Centers for Disease Control and Prevention, 2025). Subsidizing interventions

to prevent and manage chronic diseases can result in significant health benefits for patients and economic benefits for insurance companies.

Another factor that providers considered when recommending apps to patients was technology familiarity. Many providers relied on their subjective view of patients' technology familiarity and recommended apps only to those they perceived to be "tech savvy." Providers often assumed that older adults were either disinterested in or unfamiliar with using technology. While this is the case for some older adults, studies show that many older adults are interested in, or already using, an app to improve their health, especially to receive health information, ask questions of providers, manage health conditions, and track medications (Parker et al., 2013; Sproul et al., 2023). Thus, providers should consider assessing technology familiarity, digital literacy, and mHealth interest in all patients, regardless of age, by asking questions from validated technology attitudes and use scales before gauging whether recommending an app would be appropriate and desired. At the same time, providers who did recognize that some older adults are open to technology use brought up concerns that existing technology is often not configured to these users' needs. Many apps have complex interfaces and features, and patients may need help navigating apps and determining which features can benefit them. Patient navigators, care coordinators, and medical assistants often play crucial roles in reducing patient barriers to receiving health care, providing health education, and connecting patients to community resources. Healthcare organizations should consider training these providers to introduce patients to mHealth apps and give them a short tutorial on key features. A related consideration is ease of use of the app: providers often factored in time and effort required of patients to learn to use, and continue to use, a particular app when deciding whether to recommend that app. Apps that require frequent scheduled logins (e.g., multiple times a day), consistent use over a long period of time, and manual data entry were unlikely to be recommended, as providers felt that patients would not be able to sustainably adhere to these practices long term. Apps should consider additional ways to reduce user burden, such as through automating data entry, integrating wearable devices, or partnering with other commonly used mHealth apps.

Providers Desire More Culturally Appropriate Content and Personalized Reminders in mHealth Apps

Multiple providers brought up the need for more inclusive and culturally appropriate content, as existing mHealth apps are rarely designed for individuals of diverse cultural backgrounds. Providers felt that diet and nutrition apps in particular needed improvement, as they experienced difficulty finding apps that offered culturally relevant dietary advice to individuals of racial and ethnic minority backgrounds. As one dietitian stated, many apps tend to be "super Westernized in focus," drawing upon only American or European nutritional databases. Providers explained how many of the food recommendations, meal plans, and recipes put forth by nutrition apps are not applicable to diverse populations and result in patient "nonadherence." Additionally, it is difficult for individuals of racial and ethnic minority groups to input home cooked meals and find nutritional information for ethnic foods and cuisines. There is a well-established literature base documenting the importance of diet and healthy eating in chronic illness prevention (Neuhouser, 2019; Willett et al., 2006). At the same time, chronic diseases disproportionately impact racial and ethnic minority groups, resulting in higher prevalence rates and worse outcomes (Price et al., 2013). Thus, it is crucial for health behavior change interventions targeting diet and healthy eating to consider the needs and preferences of

racial and ethnic minority groups. Diet apps should supplement nutritional information from the U.S. Department of Agriculture (USDA) database with that of databases from other countries as well. Additionally, apps should include recipes from diverse cultures or recommend culturally appropriate substitutions of ingredients. Individuals should be able to input dietary preferences and receive personalized meal recommendations that fit those preferences. In general, higher levels of personalization are needed across mHealth apps, as many providers noted that few apps give personalized health plans, with most just providing generic sample plans.

Similarly, providers noted that more personalized app reminders and notifications were needed to benefit patients more fully. Providers explained that reminders needed to be aligned with patients' health needs, goals, and motivations behind behavior change. Apps should consider including introductory questions based on motivational interviewing principles to elicit patients' goals and reasons for health behavior change. Additionally, notifications need to be better timed to reach patients. As providers noted, some patients may require or desire more notifications than others. For example, some individuals have more medications to manage and thus could benefit from more frequent notifications throughout the day reminding them to take a specific medication before or after a meal. Apps should allow users to customize the timing, frequency, and type of notification delivery. Additional mHealth features that providers felt could use further development include integration of wearable devices, visuals, and social support.

Conclusion

Medical providers are an integral part of patients' social system within the mHealth landscape, and interpersonal communication between providers and patients contribute greatly to the process of app selection and adoption. Provider recommendations are a key way for patients to learn about mHealth interventions that can benefit their health and help them achieve health behavior change goals, thus highlighting the tremendous influence that providers have over the digital health landscape. App developers should consider including providers in user design and testing processes and giving providers a chance to try out apps first, as positive personal experiences with an app were often a driving force behind providers' decision to recommend an app for patient use. In order for mHealth apps to receive providers' approval, they should focus on improving credibility, reducing cost, exploring health insurance and employer-sponsored program options for coverage, increasing user-friendliness of app interfaces, and decreasing user burden when it comes to manual data entry. Additionally, as mHealth apps become more integrated into mainstream clinical care, it is crucial to develop culturally appropriate content for diverse racial and ethnic minority groups, design app platforms to be compatible with the needs and preferences of older adults, and allow for personalization of health behavior change plans and health reminders.

Concluding Chapter

This three-paper dissertation examined the use of mobile-phone based technology, specifically SMS text messaging and mobile apps, to provide clinical support for health behavior change. Mixed methods were employed to gather broad data and rich insights into diverse individuals' experiences of mHealth. Findings from this dissertation can be used to guide more equitable design and implementation of mHealth interventions.

Current Role of Digital Health Interventions

Results of this dissertation contribute to our understanding of how mHealth programs can both supplement standard healthcare provision and act as standalone behavioral change interventions. In the first paper, patients found a text messaging adjunct designed to improve adherence to psychotherapy for depression to be satisfactory and useful, and they felt more supported and connected to their providers due to this adjunct. Patient responses illustrated that text messages uplifted mood, increased patients' self-efficacy, and enhanced treatment salience and applicability, thus effecting positive changes on individuals' capability and motivation to attend treatment. This highlights the important supplemental role that technology-based interventions can play in improving adherence to a primary treatment protocol.

In the second and third papers, patients and providers alike affirmed the potential of mobile apps to add value to standard healthcare provision and to serve as standalone behavioral change interventions. Interviews with target users of mHealth revealed that mHealth apps are used for a variety of health purposes including tracking diet, water intake, physical activity, sleep, blood glucose levels, heart rate, and medications, as well as preventing and managing chronic health conditions. mHealth app selection was predicted by ease of locating an app, social influence, and facilitating conditions, while mHealth app adoption and sustained use were determined by ease of use, perceived usefulness and value, and satisfaction with app performance. The most helpful and desirable features of mHealth apps for patients were tracking and monitoring capabilities, directive content, data visualization, personalization, reminders, and community interaction. From the provider perspective, mHealth serves important roles in helping patients initiate and sustain health behavior change over time and assisting providers in tracking patient health progress, providing guidance to patients, and preventing the need for more serious medical procedures and interventions. Providers expressed that the availability of a wide range of apps makes it easier for patients to start to implement health behavior changes and for providers to monitor patient progress and give feedback accordingly. Additionally, providers recognized that mHealth apps often hold utility for their own workflow, saving them time in providing patient health education and discussing health plans and recommendations with patients.

Future Directions for Digital Health Design and Implementation

Digital health interventions already play important roles in health care as adjunctive and standalone interventions, and they have the potential to reduce health disparities by expanding access to care for underserved populations. However, in order to further their reach and effectiveness, there are a few important priorities that should take precedence in digital health design and implementation. Across the three papers, key themes that emerged included the need to bolster digital health credibility and data security practices, design more inclusive features and culturally responsive content, further personalize intervention delivery, and expand diffusion and

dissemination efforts by establishing partnerships with providers, healthcare organizations, and health insurance companies.

Improving Credibility and Data Security Practices

In general, the credibility of digital health interventions must be bolstered, as the second and third papers of this dissertation revealed that patients and providers hold concerns about app credibility and desire more rigorous review of apps. At present, the majority of mHealth apps are unevaluated, with very few having undergone study in controlled trials (Carlo et al., 2019). There needs to be greater oversight and regulation of mHealth apps, as well as standardized quality and effectiveness measures that mHealth apps are held to. Content delivered via digital interventions should be based on scientific evidence, clinical guidelines, and provider expertise. Apps should cite and include easily accessible links to credible sources such as scholarly articles, databases, and healthcare organization websites to instill more confidence in users regarding the credibility of information provided via digital platforms. They should also disclose how content was developed and whether the app has been evaluated in clinical trials or reviewed by healthcare organizations. Finally, app developers should continually include healthcare experts in developing app content to reflect the most up-to-date health guidance for patients and providers.

In order to be a reliable health support and increase user confidence, apps must also be compliant with data security and privacy policies and practice transparent communication. Across the three studies, individuals voiced concerns relating to data handling, privacy, and security, particularly for apps targeting sensitive health areas like reproductive health or mental health, and there were many questions raised about how health data is handled and who has access to it. A lack of transparency, regulation, and standardization remains common in the digital health marketplace (Carlo et al., 2019). A significant portion of the digital health sector is unregulated, and most health-related apps have unacceptable transparency regarding data practices, with over half lacking privacy policies altogether (O'Loughlin et al., 2019). Apps need to address these concerns by instating strong data protection measures, abiding by best practices for data handling, communicating policies to users, and partnering with medical providers and healthcare organizations to build trust.

Designing Culturally Responsive Content and Inclusive Platforms

As mHealth apps become more integrated into mainstream clinical care, it is crucial for app content and features to reflect and address the needs of diverse groups, especially underserved populations, as they often stand to benefit the most from these interventions. Interviews with both patients and providers revealed that at present, there is a lack of culturally responsive content and multilingual options for racial and ethnic minority groups, as existing mHealth apps are rarely designed for individuals of diverse cultural backgrounds. A key focus of mHealth app development should be on offering multilingual options to reach these population segments. Additionally, app content needs to be improved, especially within certain categories of mHealth apps. Patients and providers experienced difficulty finding nutrition and diet apps that offer culturally relevant guidance to individuals of racial and ethnic minority groups. Diet apps should integrate nutritional information from U.S. databases with that of other countries' databases. Additionally, apps should include recipes from diverse cultures or recommend culturally appropriate substitutions of ingredients. Individuals should be able to input dietary preferences and receive personalized meal recommendations that fit those preferences. In general, higher levels of personalization are needed across mHealth apps, as many providers

noted that few apps give personalized health plans, with most just providing generic sample plans. App developers should consider creating user personas based on ethnographic interviews and focus groups to better understand how to curate personalized content and tailored plans to meet diverse individuals' health needs.

Besides content, app features and platforms need to be inclusive and compatible with the skillsets and capabilities of those with lower technology familiarity and digital literacy. App developers should conduct extensive user testing, during which they assess technology familiarity and digital literacy within their target user populations by asking questions from validated technology attitudes and use scales. Many apps have overly complex interfaces and features that can be simplified, as interviews revealed that users often require only basic functions and one or two specific features. An additional finding was that apps that require frequent scheduled logins (e.g., multiple times a day), consistent use over a long period of time, and manual data entry were unlikely to be used long term. As such, apps should consider ways to reduce user burden, such as through automating data entry, integrating wearable devices, or partnering with other commonly used mHealth apps. Finally, app developers should consider developing less text-heavy interfaces and incorporating more ways to interact via voice or video to accommodate older adults who may have vision or motor skill challenges.

Personalizing Intervention Delivery through JITAIs and Reinforcement Learning

Overall, higher levels of personalization when it came to timing and frequency of text messages and app notifications were widely desired. Many participants expressed that they received text messages or app notifications at an inconvenient time or place or not at the desired frequency (i.e., too often or not often enough). Frequency and timing of text messages have been established as important determinants of success for technology-based interventions (Berrouiguet et al., 2016), with sufficient message tailoring and personalization being significantly associated with greater intervention efficacy (Head et al., 2013). In particular, interventions that use an individualized frequency of messages over the course of the intervention are more successful than interventions that use a fixed message frequency. Additionally, the receipt of an optimal dose of an intervention (e.g., the optimal number of text messages) may explain the relationship between engagement with an intervention and intervention effectiveness, but the optimal dose for particular interventions varies depending on user characteristics (Perski et al., 2017). For example, in past research studies, weekly reminder messages have been more likely to be well received, while daily messages have, for some users, been perceived as intrusive and caused user fatigue, especially if received at an inconvenient time.

This points to the need for apps to incorporate more just-in-time adaptive interventions (JITAIs), which provide dynamically tailored support in response to an individual's changing circumstances, with the goal of delivering support at the right moment and in a context where the individual needs it the most and is most likely to be receptive (Nahum-Shani et al., 2016). For example, a JITAI for a physical activity app can offer exercise suggestions based on time of day, weather conditions, location, physical surroundings, and a user's mood and energy levels (Luo et al., 2021). This would help to address some of the concerns raised by participants about how exercise and activity suggestions provided by fitness apps often did not align with what they have access to in their areas: for example, individuals in suburban or rural areas often do not have reliable access to gyms and exercise equipment while individuals in urban areas have less access to green spaces and outdoor spaces.

Another promising avenue is machine learning algorithms, which can be used to tailor and personalize content, timing, and delivery of text messages to fit individuals' needs, preferences, and capabilities, thus helping to increase intervention efficacy. Machine learning is a subfield of artificial intelligence focused on building systems that use previously collected data to recognize patterns, make predictions, and improve performance (Yom-Tov et al., 2017). One particular type of machine learning, reinforcement learning, trains software to make decisions that achieve the most optimal results by observing the results of particular actions. Reinforcement learning can be used to adjust an intervention's delivery based on an individual's behavior and response to the intervention, thus adaptively optimizing intervention strategies for an individual's context (Wang et al., 2021). There have been promising results thus far with using reinforcement learning to increase healthy lifestyle behaviors and manage chronic illnesses (Wang et al., 2021; Yom-Tov et al., 2017), but reinforcement learning algorithms are rarely trained on data from individuals of marginalized backgrounds (e.g., racial/ethnic minority groups of lower socioeconomic status) and rarely applied to these populations as well. Instead, they're typically trained on and tested with white, healthy, middle- to upper-class individuals, who are already disproportionately represented in research, thus leading to datasets that underrepresent key population segments and data-driven interventions like machine learning algorithms that are effective for a segment of the population but often ineffective for the rest (Ibrahim et al., 2021). To counter this, researchers need to evaluate interventions with study samples that are representative of the intended user population and design interventions in such a way where they can perform across diverse population groups and settings. Additionally, machine learning algorithms must be built with and trained on diverse populations to ensure that they are suitable for many contexts and able to meet the needs of underserved groups. In general, when developing digital health interventions that incorporate artificial intelligence, additional safeguards are required to ensure they are safe, ethical, and socially responsible. Strong data governance is essential and must include measures around data quality and integrity, privacy and security, compliance with regulations, transparency, and bias mitigation. Systems should also have strict boundaries on what content and recommendations can be generated, especially in sensitive areas like mental health, crisis intervention, and reproductive health. Furthermore, there should be regular monitoring to prevent any unintended or undesirable outputs of machine learning algorithms, and human support from medical providers and healthcare experts should be readily available.

Partnering with Medical Providers, Healthcare Organizations, and Insurance Companies

At present, the spread of interventions is often occurring through diffusion, with one of the primary ways for individuals to learn about digital interventions that can improve their health being through informal recommendations from their medical providers. As digital health continues to evolve and play a larger role in individuals' lives, healthcare providers can guide and shape lifestyle behaviors, health choices, and self-management of health conditions by recommending apps that help patients track and manage their health concerns and conditions responsibly. Given that providers hold much influence over the digital health landscape, app developers should consider including providers in user design and testing processes and giving providers a chance to try out and familiarize themselves with mHealth apps.

Another key method of spreading an innovation is through dissemination, which can be done through establishing partnerships with healthcare systems and insurance companies. Partnering with public healthcare systems and Medicaid programs specifically will increase the

accessibility of these interventions to low-income populations. While this may increase expenses up front, mHealth apps can be crucial tools in preventing the occurrence of chronic illnesses and mental health conditions, which account for a significant majority of the United States' annual health care expenditures. Subsidizing digital health interventions to prevent and manage chronic diseases can result in significant health benefits for patients and economic benefits for healthcare systems and insurance companies.

Policy Implications

Payers and policymakers can play an important role in enabling broader use of mHealth tools among safety-net populations like Medicaid beneficiaries (e.g., low-income populations), Medicare beneficiaries (e.g., older adults), racial and ethnic minority groups, and immigrants by promoting policy changes regarding payment structures, technology access, and community support. Specific initiatives should include expanding coverage and reimbursement pathways for mHealth services, improving digital literacy, providing technical support, and shifting away from fee-for-service payment models in favor of value-based and outcomes-based payment models.

At present, many digital health services are not covered or reimbursed by payers, including Medicaid and Medicare, thus limiting patient and provider uptake. Payers should expand coverage and reimbursement for services such as patient monitoring and health tracking, patient-provider communication, evidence-based apps for chronic illness prevention and management, and wearable devices. Additionally, there should be payment parity between virtual and in-person health services when appropriate. Financial barriers at the patient level should also be addressed, as low-income patients may be deterred from digital health services that require purchase or subscription fees or co-payments. As such, cost-sharing for digital health services should be eliminated or reduced to support preventive care and patient self-management of chronic health conditions.

Despite high phone ownership rates across a range of demographic groups and geographic locations, many older adults, low-income groups, and immigrant populations lack the confidence and skills needed to make use of mHealth programs. These population segments may need support to download and navigate apps effectively. Payers and policymakers should consider funding patient navigators, care coordinators, and medical assistants within healthcare organizations to introduce patients to mHealth apps, give them a short tutorial on key features, and assist with troubleshooting. They should also consider providing technical support hotlines and community-based training via community health workers, libraries, senior centers, and other public spaces. Multilingual support options should be made available whenever possible to reach immigrant populations.

Finally, shifting away from fee-for-service payment models and toward value-based care models or outcomes-based payment models may be beneficial. Under value-based care models, providers and healthcare organizations can be rewarded for using mHealth to advance health equity and improve patient health outcomes, particularly in underserved communities. Providers are incentivized to address social determinants of health, reduce disparities, and address issues relating to need and access. By shifting from volume-driven to patient-centered care, this also has the potential to reduce unnecessary services and improve patient experience and satisfaction. Similarly, under outcomes-based payment models, providers are rewarded based on patient health improvements and other performance metrics, rather than on volume of services delivered, which can reduce costs and improve care. Payments are linked to specific, measurable results, such as reduced emergency department utilization and improved chronic disease management.

mHealth programs have been shown to be effective at preventing and managing chronic illness, as they can improve patient self-management of health, adherence to treatment protocols, and care coordination between patients and providers. Under outcomes-based payment models, incorporating digital health tools can be rewarded for improving patient health outcomes while reducing workforce burden and producing economic benefits for healthcare systems and insurance companies.

The findings reported in this dissertation provide important lessons into how to design and implement mHealth interventions to better serve their intended users and address the needs of underserved populations. As the digital health landscape continues to develop, it is critical to maintain a key focus on equitable design and implementation to ensure that digital health does not further leave behind those who need it the most. Rather than continuing to expand the digital health market, key directions for mHealth development should include improving digital health credibility and privacy and security measures, designing inclusive and culturally responsive content, innovating intervention delivery, and partnering with providers, healthcare organizations, and insurance companies to further increase mHealth reach. Additionally, target users and medical providers should be included in mHealth design, implementation, and evaluation processes in order to put forth equitable interventions that expand access to health care and address the needs and preferences of diverse groups. Finally, payers and policy makers should work to create an environment that supports equitable and widespread use of mHealth solutions that improve health outcomes, particularly among underserved populations.

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Appendix A: Ethics and Human Subjects Protection Statement

Paper 1: All procedures and materials related to the MoodText study were reviewed and approved by the University of California, San Francisco Institutional Review Board Committee (IRB: 10-04985).

Papers 2 and 3: All procedures related to the interviews with participants were initially reviewed and approved by the National Science Foundation (NSF) Innovation Corps Program Director in February 2023. The project was considered exempt from Institutional Review Board review at the time due to not meeting the definition of research with human subjects set forth in the Code of Federal Regulations (45 CFR part 46). Following the conclusion of the NSF Innovation Corps program, all participant data were de-identified and stored on a secure, password protected cloud server through Berkeley Box. In August 2024, an application was submitted to the University of California, Berkeley Committee for Protection of Human Subjects (CPHS) to request use of data from this project for research purposes, and it was once again determined to be exempt from Institutional Review Board review: “It has been determined that the protocol referenced below does not meet the definition of research with human subjects set forth in Federal Regulations at 45 CFR 46.102. For this reason, the protocol does not fall within the scope of CPHS/OPHS responsibilities, and the project may proceed without further review from this office. Protocol ID: 2024-08-17710.”

Appendix B: Interview Guide

Theme 1: Defining Health

1. Please tell me what it means to you to be healthy. What does health look like to you?
2. What are some of the things that you have tried to do to be healthy?
    a. How would you describe this experience? Has it been effective? Why or why not?
3. How important is it to you to be healthy? Where does it fall in your priorities?

Theme 2: Diet and Physical Activity

4. How would you describe your diet?
    a. What does a typical day of eating look like for you?
5. How do you decide what foods to eat?
    a. For example, do you prioritize taste, nutritional value, prep time, cost, convenience?
6. How would you describe your physical activity on a weekly basis?
    a. How often do you exercise per week and for how long?
7. What are some barriers to your health goals? What prevents you from being healthier?
8. Have you worked with a doctor, nutritionist, personal trainer, therapist, etc. to try to be healthier?
    a. If so, tell me about your experience? What did you like and not like?
    b. If not, why not? Why have you chosen not to pursue existing health supports?

Theme 3: Service Seeking and Utilization in Digital Health

9. Have you ever used mobile apps for health support such as MyHealth Online, the Apple Health app, MyFitnessPal, Strava, or Headspace?
    a. If yes, what apps have you used?
        i. How did you hear about this app?
        ii. How did you decide to use this particular app?
        iii. What was the process of finding and obtaining the app like for you?
        iv. What was easy about the process?
        v. What was difficult about the process?
        vi. What are some changes you would recommend making to this process?
    b. If not, have you heard about mobile health apps before? What were some factors that stopped you from obtaining or using a mobile health app?
        i. Would you ever consider using an app to improve your health, particularly if you found out you were at risk for a health condition? Why or why not?
10. Tell me about your experience and feelings using these apps.
    a. In what ways was the app helpful?
    b. In what ways was the app frustrating?
    c. What content and features of the app were most helpful?
    d. What would you change about the app?
    e. In what ways could the app experience be improved?
11. Would you be willing to pay for individual mobile health apps targeting diet or exercise?
    a. If so, how much would you pay per month?
    b. If not, why not?

Theme 4: Managing Health Conditions

12. Are you aware of any family history of illness or are you yourself navigating a chronic illness? Please share only as much as you feel comfortable sharing.
    a. If so, where have/would you turn to for support managing this illness?
    b. How likely would you be to seek out in-person support (e.g., doctor's appointment, nutrition counseling, therapy, advice from people you know) compared to seeking virtual support (e.g., Google search, health app)?
13. What kind of support do you think would be helpful to have when managing a chronic illness?
    a. Do you think any of the supports you mentioned could be delivered via a digital platform (e.g., online, videoconferencing, app)?
    b. How might digital support differ from face-to-face support?
    c. What do you think are the pros and cons of digital support?

Wrap-up

14. Thank you so much for your time today. Before we wrap up, is there anything you would like to share that I didn't ask about?
15. Are there 2-3 people you can think of who might be open to also participating in an interview? Would you be able to introduce me to them?