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Leveraging Digital Technologies for Management of Peripartum Depression to Mitigate Health Disparities

Alexandra Zingg
University of Texas Health Science Center at Houston, Alexandra.Q.ZinggGuzman@uth.tmc.edu

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By

Alexandra Zingg, MPH, MS

APPROVED:

DocuSigned by:
Sakiti Myaeni
Advising Committee Member, Credentials

DocuSigned by:
Amy Franklin
Advising Committee Member, Credentials

DocuSigned by:
Angela Ross
Advising Committee Member, Credentials

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Leveraging Digital Technologies for Management of Peripartum Depression to Mitigate Health Disparities

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Alexandra Zingg, MPH, MS.

University of Texas Health Science Center at Houston

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Dissertation Committee:

Sahiti Myneni, PhD[1], Advisor
Amy Franklin, PhD[1]
Angela Ross, DNP[1], MPH, PMP, PHCNS-BC

[1]McWilliams School of Biomedical Informatics

Dedication

Dedicated to my parents, my grandparents, my siblings, and my nephews Oliver and Nico.

Acknowledgements

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Abstract

Health disparities are adverse, preventable differences in health outcomes that affect disadvantaged populations. Examples of health disparities can be seen in the condition of peripartum depression (PPD), a mood disorder affecting approximately 10-15% of peripartum women. For example, Hispanic and African-American women are less likely to start or continue PPD treatment. Digital health technologies have emerged as practical solutions for PPD care and self-management. However, existing digital solutions lack an incorporation of behavior theory and distinctive information needs based on women's personal, social, and clinical profiles. Bridging this gap, I adapt Digilego, an integrative digital health development framework consisting of: a) mixed-methods user needs analysis, (b) behavior and health literacy theory mapping, and (c) content and feature engineering specifications for future programmatic development, to address health disparities. This enhanced framework is then used to design and develop a digital platform (MomMind) for PPD prevention among women in their peripartum period. This platform contains a digital journal, social forum, a library repository of PPD patient education materials, and a repository of PPD self-monitoring surveys. In line with the existing Digilego digital health framework, throughout my iterative process of design and development, I gather design insights from my target population (n=19) and their health providers (n=9) using qualitative research methods (e.g., interviews) and secondary analysis of peer interactions in two PPD online forums (n=55,301 posts from 9,364 users

spanning years 2008-2022). These multimodal needs gathering efforts allowed me to a) compile women's information and technology needs, and b) utilize them as a guide for MomMind intervention development and evaluation. One key MomMind strength is its grounding in theory-driven behavior change techniques (e.g., shaping knowledge) and patient engagement features (e.g., electronic questionnaires) as facilitated by Digilego. Also, I extend Digilego by incorporating literacy domains (e.g., health literacy) and cognitive processes (e.g., understanding) from the eHealth literacy framework into my content engineering approach. After an in-house usability assessment, I conducted a pilot acceptability evaluation of MomMind using cross-sectional acceptability surveys and PPD health literacy surveys administered pre-and-post use of MomMind. Interviews were also conducted to assess participant's personal opinions and feedback. The study sample included n=30 peripartum women, of whom 16 (53.3%) were Hispanic and 17 (56.7%) were in low-income ranges. A total of 29/30 (96.6%) participants approved of MomMind, 28/30 (93.3%) deemed it a good fit, and 29/30 (96.67%) deemed it easy to use. Participants showed statistically significant improvement ($p<=0.05$) in their ability to recognize PPD symptoms, knowledge of how to seek information related to PPD, and knowledge and beliefs about self-care activities. Core interview themes included application's ease of use and benefits of communicating with peers and providers about PPD. Results reveal that the enhanced Digilego framework infused with health literacy models can enable development of digital health platforms widely acceptable to my target population. This work integrates siloed theories from multiple disciplines into a single approach towards addressing health disparities, and delivered a new digital health intervention for disease management among a disadvantaged population.

Vita

2018.....Masters of Science, Health Informatics, University of Texas Health Science Center, Houston, Texas.

2014.....Masters of Public Health, Community Health Practice, University of Texas Health Science Center, Houston, Texas.

2009.....Bachelors of Science, Biology, University of Texas Pan-American, Edinburg, Texas.

2022 to present.....Graduate Research Assistant, School of Biomedical Informatics, University of Texas Health Science Center, Houston, Texas.

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Field of Study

Health Informatics

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Chapter 1: Introduction to the Role of Digital Health in Mitigating Health Disparities: A Case Study of Peripartum Depression

Health disparities are associated with higher infant mortality rates, lower life expectancy, increased rates of mental illness, homicides, and teenage pregnancies, among other negative health outcomes (Schenkman & Bousquat, 2021). Health disparities are defined as *preventable differences in the burden of disease, injury, violence, or opportunities to achieve optimal health that are experienced by socially disadvantaged populations* (Centers for Disease Control and Prevention, 2020). Health disparities incur great economic strain on the U.S. healthcare system, causing annual healthcare costs of $93 billion in excess care and $42 billion in lost productivity (Kaiser Family Foundation, 2021). Minorities, women and children, rural communities, and low-socioeconomic status communities (SES) are populations that repeatedly experience health disparities and have been designated by the Agency for Healthcare Research and Quality as priority in efforts to improve healthcare outcomes (Agency for Healthcare Research and Quality, 2016).

One possible solution that has been frequently suggested to reduce existing health disparities is the leveraging of digital health technologies to improve access to healthcare resources. Digital health encompasses the use of communication and information technology tools to encourage wellbeing and manage disease (Ronquillo et al., 2022). Examples of digital health technologies are mobile health (mHealth) applications, wearable devices (fitness trackers, heart rate monitors), and patient portals. Such tools began emerging with the rise of disruptive technologies like the internet and smartphones (Della

Mea, 2001). They offer valuable functionalities, such as allowing patients to keep better track of their health and improve communication with their providers (Ronquillo et al., 2022). Digital health technologies have also reached significantly high presence levels in the consumer market, with more than 325,000 mobile health (mHealth) apps available to the public in 2017 (Paglialonga et al., 2018). This trend is expected to continue, with investments in digital health technologies reaching $14.1 billion in 2020 (Joseph, 2021).

Digital health technologies have the ability to improve health outcomes for populations affected by health disparities (Mayberry et al., 2019), and researchers have explored how these technologies can improve patient care in domains ranging from cancer care (Kemp et al., 2021) to rheumatology (Solomon & Rudin, 2020). For example, low-income individuals with diabetes who have used digital interventions to self-manage their diabetes have shown improved glycemic control and less hospitalizations and emergency room visits (Mayberry et al., 2019). However, caution must still be taken to ensure that the growing number of digital health solutions are beneficial to everyone. Heart rate monitors used in fitness trackers such as Fitbit and Apple Watch have reportedly misread heart rate values among people of color (Hailu, 2019). Additionally, while ethnic and racial minority groups such as Hispanics and Blacks make up the largest portion of adults who use smartphones to seek health information (Monica Anderson, 2015), researchers have pointed out that there is still a significant lack of engaging these groups during the digital health technology development process. This results in a subsequent "digital divide" and inequalities in use of digital health solutions by these groups (Emily Deruy, 2013; National Academies of Sciences, 2016), exacerbating existing difficulties for these groups in sustaining positive health behaviors (Jha et al., 2009).

These gaps in digital health utility can be addressed through careful assessment of information and technology needs for these specific groups of users. Such assessments can be made through, for example, having representatives of these populations participate in surveys, interviews, and focus groups where design preferences and digital feature preferences are identified. Furthermore, such user needs assessment can be strengthened through harvesting data from crowd-sourcing mediums such as online social forums, which are very commonly used by minority and low-income populations (Pew Research Center, 2021) and where common questions and trending topics can be identified as they emerge in real time. In turn, such user needs assessment can help inform the development of digital features and content that are directed towards improving health outcomes for disadvantaged populations.

While the work that is discussed in this dissertation is generalizable to several healthcare domains, including cancer care (Kemp et al., 2021) and chronic diseases like diabetes (Mayberry et al., 2019), I focus on peripartum depression due to this condition being an excellent representation of how some specific groups of women repeatedly experience significant health disparities across various health measures. As examples, for the year 2020 in the U.S., 20% of African-American and 22% of Hispanic women reported being in fair or poor health, and African-American women had a significantly higher number of deaths due to breast cancer (Kaiser Family Foundation, 2022). Additionally, the U.S. has much room for improvement in the areas of reproductive and maternal health, as it has a higher infant mortality rate than other comparable developed countries (Kaiser Family Foundation, 2019), and African-Americans are three times more likely to perish from pregnancy-related causes than their white counterparts (Office of Minority Health and

Health Equity, 2022). Furthermore, in the domain of mental health, women are twice as likely to suffer from depression than men, and mental health disorders are a significant cause of disease burden for women (Agency for Healthcare Research and Quality, 2012). PPD is at the intersection of these pivotal care domains that are heavily plagued with rooted disparities, which emerge and are strengthened due to structural racism, gender disparities, and mental health stigma. By integrating social determinants of health (i.e., health literacy, social networks) into the digital health development process, I will produce a novel digital health development framework that is cognizant of the psychosocial disadvantages experienced by specific groups of women in prevention of PPD.

1.1 Improving Health Outcomes through Reinvigorated Digital Health Solutions

Digital health could potentially revolutionize PPD care management, but there are currently many shortcomings in technologies dedicated to PPD management, as noted in previous literature reviews. Ashford, Olander, and Ayers (Ashford et al., 2016) reviewed eleven studies on computer and web-based interventions for perinatal mental health, and noted several limitations in these, beginning with a need for recruiting more patients who were representatives of low education and minority backgrounds. Another review by Dosani, Arora, and Mazumar found a minimal number of studies that focused on mHealth interventions for perinatal mental health in low-income countries, indicating a need for further collaboration between developers and clinical providers in these settings (Dosani et al., 2020). Additionally, research suggests that the information currently available in websites dedicated to PPD needs improvement in terms of providing treatment information, being accessible to readers with low reading levels, and incorporating user engagement design elements (Hardman et al., 2022). My previous review of market mobile

health applications for PPD prevention and management indicates that most of these do not incorporate theory-based behavior change techniques, nor do they leverage established patient engagement features (Zingg et al., 2022). The results of these reviews highlight the currently siloed nature of behavioral theories, health literacy, and user-centered design within the context of digital health development. I envision that this study will help bridge this gap by bringing together all of these disciplines into a single digital health development framework. This framework is unique in that it would provide a complete development pipeline, from the initial steps of analyzing user needs to offering a technology development approach that considers factors such as end user's preferred content formats. The main goal is to move from existing products that are targeted towards majority populations, and which offer siloed components for PPD management (i.e., patient education, PPD screening) (Figure 1), into a streamlined digital health solution that helps improve patient PPD knowledge and health literacy through a range of behavior change techniques and patient engagement optimizers in the digital era (i.e., self-monitoring, social support) (Figure 2).

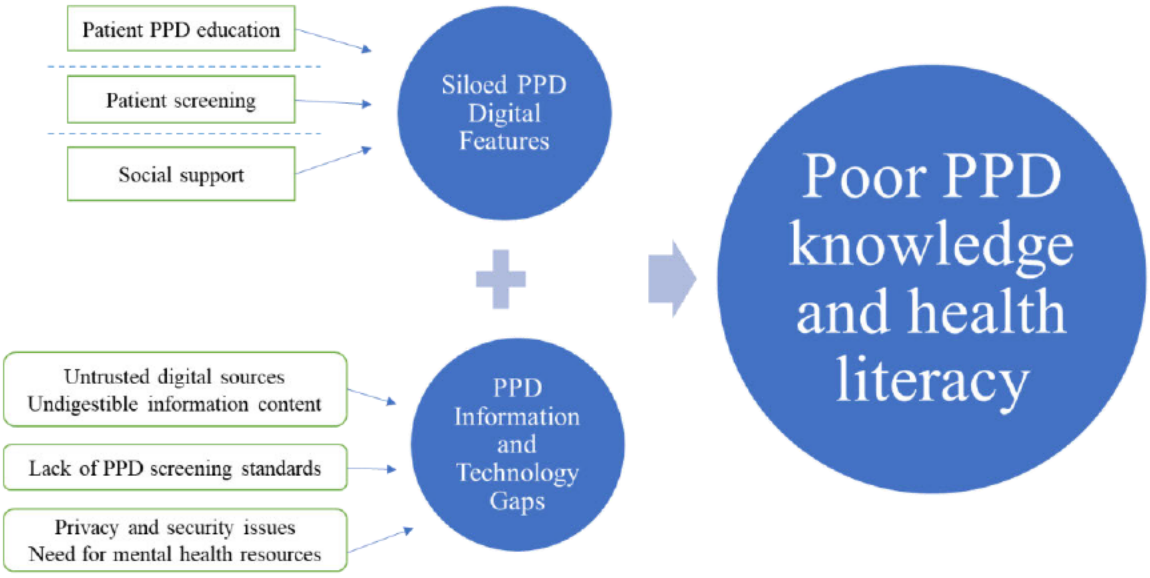


Figure 1. Current State of Digital Features for PPD Care

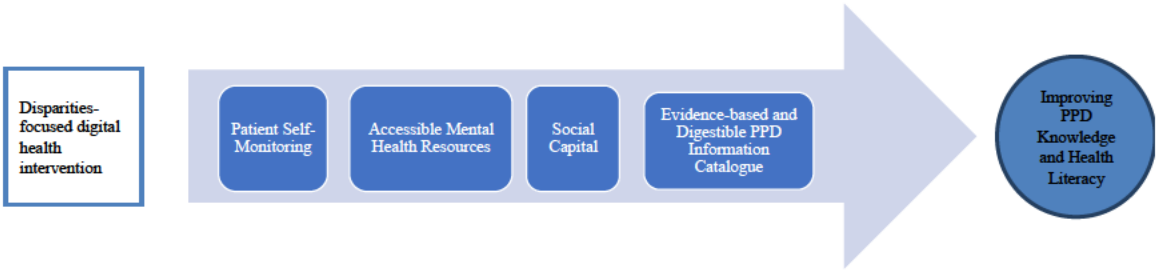


Figure 2. Potential State of Digital Features for PPD Care

1.2 MomMind: A Health-Disparities Focused Digital Health Solution for PPD Self-Management.

In this study, I design and develop a digital solution (MomMind) for the self-management of PPD among low-income perinatal women. This digital platform consists of four main modules that include a digital journal, a social forum, a library repository of PPD patient education materials, and a repository of PPD self-monitoring surveys. The main idea of

MomMind is to advance the current state of care of PPD, which is assessed in Chapter 2, by providing patients the necessary tools to become active and informed agents in their PPD prevention and management. The platform is theoretically guided by the existing digital health development framework Digilego and established behavior theories and patient engagement models that are described in Chapter 3. In line with the existing Digilego framework (Myneni et al., 2015), throughout my iterative process of design and development, I gather insights from my target population, their health providers, and user messages in PPD online forums to assess users' information and technology needs and guide content and feature specifications (Chapter 4). I also follow Digilego in incorporating theory-driven behavior change techniques and patient engagement features by mapping my user needs results to specific behavior change techniques (Abraham & Michie, 2008) and patient engagement digital features (Health Information and Management Systems Society, 2014). I extend Digilego by incorporating literacy domains and cognitive processes from the eHealth literacy framework (Chan & Kaufman, 2011) into our content engineering approach (Chapter 5). I expect that by extending Digilego in this manner, I will produce a digital health solution that is acceptable and appropriate to low-income perinatal women. I assess this by evaluating MomMind with a representative sample of our target population to assess changes in knowledge, attitudes, and beliefs about PPD, as well as gathering their initial impressions about the tool through interviews and surveys (Chapter 6).

Chapter 2: The Case of Peripartum Depression: Current State of Care

Peripartum depression (PPD) has received increased attention from researchers and healthcare providers, due in part to some individual cases being highly covered by mass communication channels (Wallace, 2015), and also to public figures encouraging open conversations about the topic and reducing the social stigma surrounding it (such as actress Brooke Shields, who published a book about her PPD experience titled "Then Came the Rain"(Shields, 2006)). Efforts to address the significant issue of PPD have also increased due to the coronavirus pandemic, which forced people to isolate, have restricted access to healthcare, and caused a significant increase in the number of PPD cases (Davenport et al., 2020). This new attention to PPD has highlighted the need for better patient education on the topic, streamlined screening and referral systems, and social support for peripartum women. Digital health solutions have emerged as a practical solution for PPD care and self-management, particularly for those populations with low access to mental health resources. In this chapter, I provide an overview of current practices in PPD screening and diagnosis, and available treatment and prevention options. Additionally, I describe existing digital health interventions for PPD management, and focus on interventions and resources meant for low-SES women.

2.1 Women's Health and Wellness

The top causes of death for women on a global scale are heart disease, stroke, and lower respiratory infections (World Economic Forum, 2017). In addition to these, there are

certain health issues that uniquely affect women. The World Health Organization has reported that Alzheimer's and other types of dementia in women have tripled in the past two decades, causing the greatest increase in women's mortality (World Health Organization, 2023). And, women may also develop cancers specific to their reproductive system (ovarian, cervical) (Centers for Disease Control and Prevention, 2022a). Differences in health outcomes between men and women are complex and dynamic; while women tend to live longer than men, they also spend a higher number of these years living with disabilities (Carmel, 2019). Additionally, women experience systemic disadvantages in the area of healthcare when compared to men, including: a) underrepresentation in clinical research trials, reducing the availability of data to develop medical treatments and care guidelines specifically for women (Sosinsky et al., 2022), and b) a current shortage of clinical specialists in women's healthcare and scarce representation of women in healthcare leadership positions (Odei et al., 2021; U.S. Department of Health and Human Services, 2021).

Reproductive and maternal health is a part of women's health that presents unique challenges and issues. As an example, in the U.S. in 2014 more than 50,000 women were affected by adverse labor and delivery outcomes including eclampsia, sepsis, and ventilation (Centers for Disease Control and Prevention, 2021). High-risk pregnancies, which are those with medical complications such as gestational diabetes and preeclampsia, occur in approximately 6-8% of all pregnancies (Francisco, 2021). Women with such pregnancies undergo additional pre-and-postnatal care procedures than those with normal pregnancies; for example, women with preeclampsia must see a Maternal and Fetal Medicine specialist in addition to their regular OB/GYN provider, and they must also

undergo additional blood pressure monitoring (Task Force on Hypertension in Pregnancy, 2013). Women who have high-risk pregnancies are also more likely to develop depression, with an early study reporting that 19.4% of a sample of women hospitalized for high-risk pregnancy complications had depression symptoms, and one recent study reporting incidence rates at 27% (Byatt et al., 2012).

Mental health is a crucial component underlying the overall wellbeing of women; for instance, depression in women is a risk factor for the top cause of death of heart disease (Mattina et al., 2019). And, the challenging time of pregnancy and the newborn stage may cause psychological distress (Hübner-Liebermann et al., 2012). Therefore, women with health conditions such as high-risk pregnancies are likely to require a team of interdisciplinary care providers (OB/GYNs, psychologists, psychiatrists, social workers) to manage their multiple health conditions and prevent adverse health outcomes, such as birth complications or preterm and low-weight births.

2.1.1 Peripartum Depression

The American Psychiatric Association defines Peripartum Depression (PPD) as a major depression episode that occurs during pregnancy or shortly after childbirth, choosing the term "peripartum" rather than "postpartum" to highlight the fact that most cases of PPD begin during pregnancy (American Psychiatric Association, 2020). PPD is not to be confused with the milder and more transient "baby blues", which are normal feelings of worry, anxiety, and sadness that about 80% of new mothers experience during their first days with their new baby. The baby blues do not affect the normal functioning of the new mother and resolve without need for medical intervention in a few days and no longer than a couple of weeks (American College of Obstetricians and Gynecologists, 2021). PPD

should neither be confused with bipolar mood disorder, a different type of mental health disorder that is characterized by cycles of “lows” (depression) and “highs” (manic or unusually productive periods), and that is frequently identified for the first time in women during the pregnancy and postpartum periods (Postpartum Support International (PSI), 2022). PPD is also different than postpartum psychosis, a very severe but rare peripartum mental health disorder that is characterized by sudden hallucinations and delusions, and that requires immediate medical attention (U.K. National Health Services, 2020).

PPD is the most common complication of pregnancy, and whether pregnant or not depression tends to be twice as common in women than men, especially during their reproductive years (Toohey, 2012). PPD is a serious public health problem that affects a significantly high number (approximately 10-15%) of peripartum women (Centers for Disease Control and Prevention, 2022b), and it is most likely to affect them during the 3-6 month postpartum window (Gavin et al., 2005). Recent studies have estimated that the costs to society for untreated perinatal mental health disorders reach approximately $ 14 billion per year and $31,800 per each mother-infant dyad (Luca et al., 2020). Risk factors for PPD include: having a prior personal or family history of depression, lack of support from others, financial and relationship issues, unplanned pregnancy, traumatic birth experience, sexual trauma, and having a child in the Neonatal Intensive Care Unit (Curry et al., 2019); also, it has been suggested that social determinants of health, such as having unstable housing and low education, can increase risk for PPD (Griffen et al., 2021; Office on Women's Health, 2021). However, any woman can experience PPD regardless of their socioeconomic background or medical history (Massachussetts General Hospital Center for Women's Mental Health, 2005). PPD can cause adverse health outcomes for both

mother and baby. For example, PPD is associated with pregnancy complications such as low birth weight and preterm births (Office on Women's Health, 2021; Vigod et al., 2016). Women with PPD may also forego recommended prenatal check-ups (Lusskin et al., 2007), immunization schedules for the baby, and well-baby check-ups (Rowan et al., 2012). If left untreated, PPD can result in longer and more intense episodes of depression for the mother, and later on with cognitive and behavioral issues for the baby (Bernard-Bonnin, 2004; Office on Women's Health, 2021). Sadly, untreated PPD can also result in the tragic outcome of suicide, which along with other self-harm behaviors like drug overdose is the leading cause of deaths within the first year of maternity (Oates, 2003).

While PPD can be managed through treatments including therapy and medications, most cases of PPD go undetected in primary care settings of OB/GYN and pediatric offices (Rowan et al., 2012). Factors that contribute to the low detection of PPD cases are a lack of systematic screening in most healthcare settings (Rowan et al., 2012), inadequate training of primary care providers to recognize and treat PPD (Brennan, 2018), and lack of data on patient's socioeconomic characteristics (education, income, employment status) (Goyal et al., 2010). Furthermore, many women are hesitant to seek adequate treatment for PPD due to barriers at multiple levels including social stigma, low access to care, and having limited knowledge on PPD (Dennis & Chung-Lee, 2006). These barriers significantly affect women of minority backgrounds and low-income when compared to their counterparts. Another factor that may contribute to inadequate treatment of PPD is lack of follow-up with patients. For example, Flynn and colleagues found that in a group of 46 pregnant women with a current diagnosis of depression, only 33% were receiving treatment (Flynn et al., 2006). The authors suggested that clinicians should adopt strategies

of linkage to care and consistent follow-up to improve treatment rates, and they also suggested that clinicians should carefully assess previous adherence to treatment in patients with recurrent depression.

*PPD Screening and Diagnosis***.** ACOG recommends that all peripartum women should be screened for depression and anxiety at least once by their OB/GYN providers. ACOG specifically recommends screening at the comprehensive postpartum visit, within the first 3 weeks after birth but not later than 12 weeks after birth, with a validated instrument (Committee on Obstetric Practice, 2018). The U.S. Preventive Services Task Force also recommended in 2016 that the general adult population should be routinely screened for depression, including pregnant and postpartum women (Siu et al., 2016). There are various validated instruments that providers can choose from to screen for PPD, including: The Edinburgh Postnatal Depression Scale (EPDS), the Postpartum Depression Screening Scale, the Patient Health Questionnaire 9 (PHQ9), and the Beck Depression Inventory I and II. Of these, the EPDS is the most widely used instrument by clinicians and researchers because it does not consider certain somatic symptoms that are common in pregnancy and can confound screening scores in other instruments (Milgrom & Gemmill, 2014; Miller et al., 2011). The EPDS contains ten Likert-scale question items asking patients about depression symptoms within the past week (Cox et al., 1987). It can be completed in approximately 5 minutes and the vocabulary used in the questions is appropriate for patients of low literacy levels. The ACOG screening recommendations are not enforced by federal or state policies, and it is left up to individual healthcare organizations, clinical practices, and providers to decide when, where, or whether to screen (Committee on Obstetric Practice, 2018). A diagnosis of PPD is made once a qualified

provider completes a clinical interview and notes severe depression symptoms, which may include: detachment from the baby, irritability, irregular appetite and sleep patterns, bouts of crying, feelings of sadness, guilt, hopelessness, and shame, loss of interest and joy in previously enjoyable things, and thoughts of harming self or the baby (Postpartum Support International (PSI), 2021). The provider makes the final diagnosis decision given the clinical context, regardless of PPD screening results (Committee on Obstetric Practice, 2018). When diagnosing, providers are able to use a peripartum-onset specifier for depression, present in the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2022). Once a diagnosis is made, the provider should refer the patient to appropriate mental health specialists or begin a course of treatment for PPD with the patient. Currently, many providers do not conduct this follow up of care due to not having adequate resources available, not having enough clinical training and feeling inadequate to manage PPD treatment, or not knowing where to refer patients to (Griffen et al., 2021). Figure 3 presents a workflow of PPD screening and treatment in primary care settings.

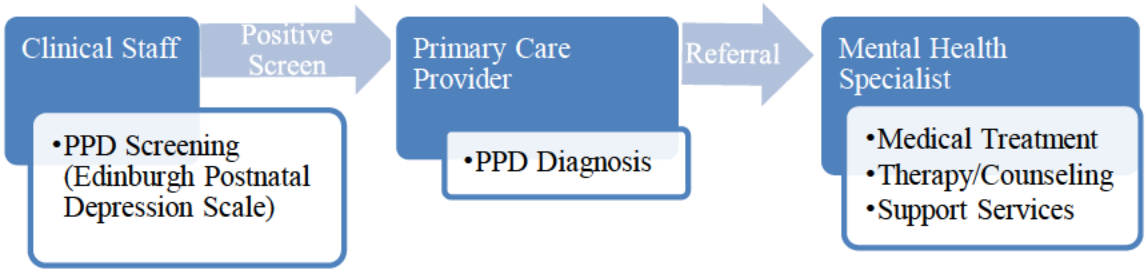


Figure 3. PPD Screening and Treatment Clinical Workflow

*PPD Prevention and Treatment***.** Once an individual is diagnosed with PPD, they decide on a plan of treatment along with their care provider. The treatment plan depends on factors including the severity of symptoms, the individual's personal preferences, and access to care. For example, mild cases of PPD may be managed with simple psychoeducational interventions. For more severe cases of PPD, psychotherapy and medication are the two main treatment options (Hübner-Liebermann et al., 2012). These can be received alone or in combination. Below are descriptions of these treatment options.

a) *Psychological Treatments***.** Two of the most commonly used forms of psychotherapy to treat PPD include Interpersonal Therapy (IPT) and Cognitive Behavioral Therapy (CBT). Interpersonal therapy is a time-limited and problem-focused form of therapy where the individual and the therapist focus on the connection between interpersonal problems and mood, and where the goal is to modify problematic relationships to construct an improved social support system (Leight et al., 2010). For example, the individual and therapist may choose to work on the individual's relationship with their partner. IPT can be administered individually or in groups. One study has shown that IPT can have high attrition rates, with 6 of 17 participants not completing the course of treatment (Klier et al., 2001). However, another study reported lower attrition rates (1 of 18 participants), and researchers attributed this to childcare being provided during treatment (Reay et al., 2006). Individuals may prefer IPT as treatment to manage PPD due to its time-limited nature (most treatment courses may be completed in 12-20 weeks) and its practical nature (Leight et al., 2010). CBT aims to modify the individual's negative thinking patterns and to reduce stress and improve coping through behavior change. In a randomized control trial that evaluated the effects of CBT along

with the medication Paroxetine, researchers found that attrition for the treatment was very low, with 32 of 35 participants completing the course of treatment (Misri et al., 2004). It is worth noting that this study found similar reductions in depression symptoms in both the treatment group that only included Paroxetine and the other group that combined Paroxetine and CBT. However, another study has found that psychotherapy treatment alone has been effective in managing moderate cases of PPD (Nonacs & Cohen, 1998).

b) *Pharmacological Treatments.* In some cases, the use of antidepressant medications is needed to manage PPD symptoms. Currently, the first line of medications used to treat PPD are selective serotonin reuptake inhibitors (SSRIs) such as Sertraline and Fluoxetine (Leight et al., 2010). Recently, the US Food and Drug Administration (FDA) also approved the first medication exclusively for treatment of PPD, named Zulresso (generic name Brexanolone) (U.S. Food and Drug Administration, 2019). SSRIS are safe to use during pregnancy and breastfeeding, as negligible levels have been found in breastmilk or infants exposed during pregnancy (Misri et al., 2000). A randomized controlled trial of the SSRI Paroxetine resulted in a high attrition rate, with 31 of 70 participants completing treatment (Yonkers et al., 2008). This result suggests that attrition may be an issue for the use of pharmacological treatment in the management of PPD. One possible reason why women may forego pharmacological treatment for PPD is fear of the effects on their infant (Leight et al., 2010).

c) *Psychoeducation.* Research suggests that psychoeducation and self-care can help prevent or mitigate PPD symptoms in mild cases (Griffen et al., 2021). This includes teaching new parents the essential information on PPD, providing simple techniques to

better manage stress (i.e., breathing, meditation), and social support. Programs such as Mothers and Babies, the Practical Resources for Effective Postpartum Parenting (PREPP), and the Reach Out, Stay Strong Essentials for New Mothers (ROSE) are programs that have effectively used psychoeducation and self-care for prevention of PPD among low-income women. These programs are mainly administered in-person through Federally Qualified Healthcare Centers or other safety-net healthcare providers (Griffen et al., 2021).

2.2 Overview of Digital Health Interventions for PPD Management

Pregnant women and their providers have indicated a wide optimism and interest in using digital tools like pregnancy apps, including for the mental health component of pregnancy (Osma et al., 2016). Digital health interventions refers to the use of electronic devices (e.g. apps, electronic health records, wearables) to deliver health services (Murray et al., 2016). There are many advantages that digital technologies can provide in the management of maternal mental health, including: 1) being accessible from almost any place and at any time, they provide patients with treatment flexibility, and 2) they are also discrete platforms and may provide patients a comfortable setting when expressing their personal feelings (Marzano et al., 2015). Digital health technologies have already been widely used by non-maternal mental health patients, and a systematic review by Rathbone and Prescott indicates that they are effective in helping manage mental health disorders like depression by increasing disclosure of depression symptoms, and decreasing anxiety and stress symptoms (Rathbone & Prescott, 2017). In the domain of PPD, digital health interventions have taken the form of websites that deliver psychological treatment (Baumel et al., 2018),

text messaging for administering screening (Bhat et al., 2018), and mobile health (mHealth) apps for patient mood tracking (Doherty et al., 2018).

2.2.1 Mobile Health (mHealth) Applications for PPD Management

Mobile health (mHealth) is defined as "*medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices*"(Kay et al., 2011). mHealth applications are a medium through which delivery of mental health interventions can be facilitated (Wills, 2013), and a recent study has shown that PPD treatment delivered via smartphones may improve care accessibility by overcoming barriers including lack of childcare and peer support (Baumel et al., 2018). Scientific evidence supporting mHealth app interventions for mental health is limited, but there is promising evidence regarding improvements in treatment efficacy (Donker et al., 2013). In a scoping review of mHealth interventions targeting PPD and/or peripartum anxiety, Hussain-Shamsy and colleagues selected 22 studies (Hussain-Shamsy et al., 2020). Of these studies, 12 implemented their interventions through apps, but text messaging was also a frequently used mode of delivery with 10 studies. Ten of the interventions targeted the postpartum period, seven targeted the pregnancy period. Two interventions were meant to be started during pregnancy and continued into the postpartum period, and one intervention could be used during either time. Sixteen of the twenty-two interventions aimed to prevent PPD through the strategy of psychoeducation.

To improve my understanding of how mHealth applications for PPD are able to engage patients and assist with implementation of behavior change (e.g., shaping knowledge), I

have also reviewed consumer market PPD mHealth apps (Zingg et al., 2022) and analyzed their content and features according to three important dimensions- (a) implementation of behavior change theory, (b) use of patient engagement features, and (c) the app's usability through user design elements. After searching in the Apple App store and Google Play store using search terms "Postpartum", "postnatal depression", "postnatal", and "Postpartum depression", my review included a total of 15 apps (Table 1) which targeted postpartum women. Three of the apps were research driven and included a theory behind their development, and the rest of the applications were purely for the for-profit consumer market (Zingg et al., 2022). My search was conducted during February 2019, March 2019, and updated in May 2021.

Table 1: Summary of Applications Included for Review

App Name	Content and Feature Summary
Mom Genes Fight PPD	Screening tool for PPD
Postpartum Health- Care and recommendations	Contains a variety of topics on postpartum health, divided into different modules. One of these modules is dedicated to PPD.
Postpartum Depression	Contains educational modules on PPD, including definition and signs.
Little Mother's Helper™	Provides suggestions for activities to prevent or lessen PPD.
MGHPDS	Screening tool for PPD
MomentHealth	Helps Postpartum women recognize symptoms of postpartum depression. Provides suggestions for local healthcare professionals and the opportunity to connect socially via their Facebook community. Paid features are also available, such as mood tracking.

Table 1 (continued)

App Name	Content and Feature Summary
Post Pregnancy Recovery/ Postpartum Recovery	Provides information on PPD symptoms, treatment options, risk factors, and causes. Suggestions for self-help and support and medical and pharmacological support are provided.
MamaMend: Postpartum Health	Contains information on different areas of postpartum health, including PPD. Provides links to information resources.
Canopie: Mental health, pregnancy and Postpartum	Offers postpartum mental health support in the format of audio files narrating women's personal experiences with conditions including PPD.
Edinburgh Postnatal Depression Scale (EPDS)	Screening tool for PPD
Postpartum Depression Test	Screening tool for PPD, also offers links to PPD resources.
Postpartum Screening for Moms	Screening tool for PPD
Postpartum Depression	Helps postpartum women understand and recognize the symptoms of postpartum depression. It provides suggestions for natural remedies and information about causes and treatment.
PPD ACT	Screening tool for PPD
Postpartum Depression Self-Evaluation	Screening tool for PPD

2.2.2 Online Forums for PPD Management

Social media is a source of information that is currently underexplored to reveal how different social factors (i.e., topics of importance, network size, level of user engagement) affect PPD management, yet perinatal women are highly active users of online social

media; as an example, about three-quarters of parents use Facebook groups to discuss various parenting topics (Duggan et al., n.d.). Along with Facebook, two of the most popular pregnancy social media applications are What to Expect (What to Expect, 2020) and BabyCenter (BabyCenter, 2023), which contain discussion forums for topics ranging from baby names to "Birth Clubs" (groups of moms who have the same delivery month). Previous research on how online forums can aid with PPD management has revealed how this specific digital format can greatly reduce social stigma against mental illness (Moore et al., 2017; Moore et al., 2020; Teaford et al., 2018). Moore, Ayers, and Drey (Moore et al., 2017) conducted a qualitative analysis of messages contained in PPD-specific forums for the website MumsNet, and found that the messages tended to reinforce women's seeking of professional help. Participants also provided abundant social support to one another, helping normalize the experience of PPD and eliminating derogative labels like "bad mother".

2.2.3 Digital Health Solutions for PPD Management Among Low-SES Women

PPD symptom rates remain high for certain subpopulations of women, such as those living in poverty or minorities including African-Americans and Hispanics (Postpartum Support International (PSI), 2021). Yet, Hispanic and African-American women are less likely to start or continue treatment for PPD (Lara-Cinisomo et al., 2018). In the state of Texas, access to care for low-income pregnant women may be provided through the Medicaid for Pregnant Women (MPW) program. This program facilitates PPD services including screening and medications. Once participants of MPW give birth, they may receive coverage for PPD care through the regular Medicaid program for a limited time of 60 days; another health insurance program that targets low-income women is Healthy Texas

Women, which also covers PPD care including diagnostic evaluation and counselling (Texas Health and Human Services, n.d.). Organizations like the Local Mental Health Authorities and Local Behavioral Health Authorities also have assistance programs to facilitate services to perinatal patients with limited access to care (Texas Health and Human Services, n.d.). Even though these programs exist to provide support to women of low resources, research suggests that they may be insufficient and women insured with Medicaid may still experience difficulties accessing care from specialists such as psychiatrists (Griffen et al., 2021; Grimbergen et al., n.d.).

Providers who treat low-income women covered by Medicaid may use tools such as Electronic Health Records (EHR) to ease clinical workflow for PPD management. As an example, in my target setting of the UT Physicians Maternal and Fetal Medicine Clinic, providers use the EPIC software for recording of PPD screening results and patient referral to mental health specialists (Figure 4). Providers also use the clinic's patient portal (e.g., MyChart in Epic electronic health record) for follow-up and communication with their patients. However, it should be noted that certain processes such as PPD screening are non-standardized (the Texas Health and Human Services Commission recommends that PPD screening be administered in paper while the patient is in the waiting room) (Texas Health and Human Services, n.d.).

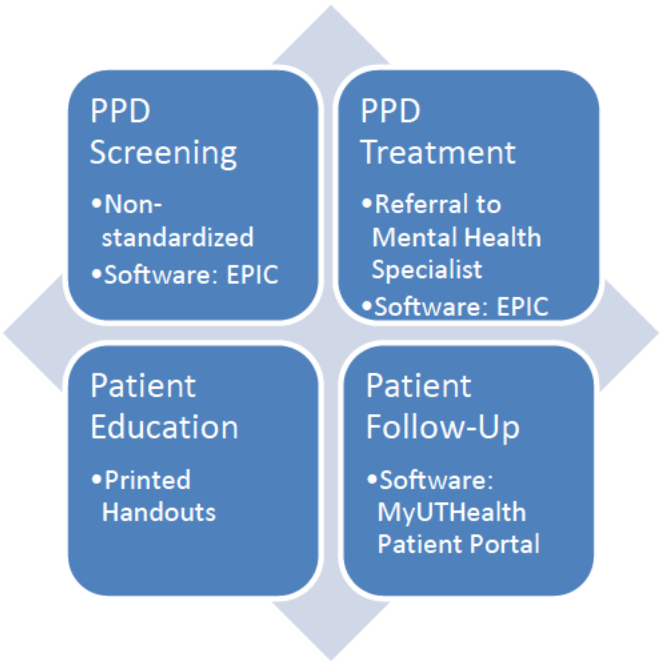


Figure 4- PPD Clinical Care Diagram (UT Physicians Maternal Fetal Medicine Clinic)

Given the high risk of PPD for minority and low-SES peripartum women, and the rapid rise of digital health interventions to address issues such as lack of patient education and access to specialist care, a thorough understanding of current digital health tools to support vulnerable women in their management of PPD is needed. Previous literature on the different types of mobile health interventions that have been used to address PPD health disparities among low-SES and minority perinatal women range from the design and development phase to randomized control trials (Table 2). The target populations of these studies have included low-income women (Hantsoo et al., 2017), minority women (Gordon et al., 2016), women living in low-income countries (Byanjankar et al., 2021), and teenage mothers (Gewali et al., 2021). Those studies that reported health outcomes as a result of their intervention found that strategies like information support through a two-way messaging system (Song et al., 2013), and supportive text messages as a supplement to

traditional counselling (Broom et al., 2015), were highly effective in reducing stress and depression symptoms.

One evidence-based intervention for PPD management that was specifically designed for low-SES women is the Mother and Babies course, originally designed for in-person prevention of PPD. Gewali and colleagues (Gewali et al., 2021) adapted the program to be delivered as a social media group intervention targeting perinatal women between 14-24 years old. The selection of social media as the mode of delivery is reflective of this format being highly used among young women (Pew Research Center, 2021). Results showed that participants desired the web-based version of Mothers and Babies to include additional components such as peer support channels and the ability to ask medical questions. Barrera and colleagues have also made efforts to adapt the MB course into an electronic format and adding text message reminders (Barrera et al., 2021; Barrera et al., 2015), with results suggesting benefits of the intervention to perinatal women of diverse backgrounds.

Table 2- Studies Addressing PPD Digital Health Interventions for Low-SES women

Study First Author (Year)	**Perinatal Population**	**Mental Health Disorder**	**Intervention Phase**	**Intervention Description**	**Intervention Strategy**	**Intervention Outcome**
Zuckerman (2022)	Low-income mothers	Depression and Stress	Pilot clinical trial	24 weekly parent education videos on early childhood, delivered via an app and website.	Psychoeducation	No significant difference; sub-analyses showed intervention group had improved stress outcomes.

Table 2 (continued)

Study First Author (Year)	Perinatal Population	Mental Health Disorder	Intervention Phase	Intervention Description	Intervention Strategy	Intervention Outcome
Byanjankar (2021)	Adolescent mothers with depression in Nepal	Depression	Design and development	Use of GPS app for mother's physical activity and proximity to child	Psychological counseling intervention	Not reported
Dalton (2018)	Pregnant women from a low socioeconomic community	Depression and anxiety	Feasibility trial	Mobile application delivering pregnancy information and community resources	Patient education (including information on relaxation)	No difference between app users and non-users
Gewali (2021)	Youth perinatal women	Depression	Feasibility	Online Mothers and Babies program	Patient education, social support	Not reported
Baker-Ericzen (2012)	Low-income perinatal Latinas (N=79)	Depression	Feasibility and Acceptability	Therapy delivered through telemedicine (telephone calls)	Access to therapy	Not reported
Barrera (2015)	Predominantly Spanish-speaking and Latina pregnant women	Depression	Randomized Controlled Trial	Electronic adaptation of the Mothers and Babies program	Psychoeducation	No difference

Table 2 (continued)

Study First Author (Year)	Perinatal Population	Mental Health Disorder	Intervention Phase	Intervention Description	Intervention Strategy	Intervention Outcome
Song (2013)	Low-income pregnant women (n=20)	Depression and stress	Evaluation of usability and effectiveness	Two-way text messaging system	Informational support	Significant reduction of symptoms

Most interventions focused on the viable approach of psychoeducation, and previous research suggests that most cases of PPD consist of mild symptoms that can likely be prevented or managed through this approach (Postpartum Depression: Action Towards Causes and Treatment (PACT) Consortium, 2015).

2.3 Discussion and Conclusion

Overall, my summary of the current standard of care for PPD reveals that advances need to be made in terms of screening policies and implementation, as the simple act of screening by itself can help lead women to help-seeking and effective management of PPD (Committee on Obstetric Practice, 2018). Providers also need better resources and training for when they encounter PPD cases, in order to better treat these cases or refer them to appropriate specialists. I have also found that most of the few digital health interventions targeting low-income perinatal women are currently in the stage of design/development or feasibility trials, indicating that the field needs further studies to better understand how digital health interventions can be made suitable to this specific population. Additionally, very few interventions consider user perspectives from sources such as providers of low-SES perinatal women or social media content in PPD-specific online forums. For example,

in 2021 social media sites were being used by 69% of all adults in U.S. households earning less than $30,000, and they were also used by 78% of women (Pew Research Center, 2021). Additionally, the ethnic groups that most used social media sites were Hispanic (80%) and Black (77%) (Pew Research Center, 2021). This represents a missed opportunity for enrichening current insights into the information and technology needs of this specific population. In the next chapter, I review theories and frameworks employed in the area of digital health technology design and development, with the goal of establishing a theoretical ground to help address current health disparities affecting the condition of PPD.

Chapter 3: A Review of Sociobehavioral, Health Education, and Technology Development Frameworks

The use of digital health technologies as mediums to empower consumers in their healthcare management continues to increase (Joseph, 2021). Many of the theoretical models and frameworks which have been successfully integrated in the design and development of digital health interventions come from a variety of disciplines including behavioral psychology (Mohr et al., 2014) and human factors engineering (Doherty et al., 2018). In this chapter, I describe how I leverage existing digital health frameworks in conjunction with theories and frameworks in the fields of health literacy and social determinants of health to produce a novel digital health framework that is cognizant of health disparities. Firstly, I provide an overview of existing theories and frameworks along the following domains: 1) behavior change, 2) health technology design and development, and 3) health literacy. Each of these domains plays a crucial role in individuals' management of their health and wellness. The domain of behavior change helps health researchers understand the internal motives and external environmental factors that prompt an individual to adopt a specific health behavior (Glanz et al., 2008a). Health technology design and development assists with the outlining of digital features that are ideal to activate and achieve the desired health behavior (Mohr et al., 2014). And, the domain of health literacy is dedicated to presenting health content in a manner that is optimal for individuals to understand and leverage when making healthcare decisions, including communication with their healthcare providers (U.S. Department of Health and Human Services, 2020). The intersection of these domains forms an environment where

an individual can leverage digital health technologies to facilitate the implementation of desired health behaviors (Figure 5). This allows the individual to become an active agent in making healthcare decisions and treatment plans, and it also allows their healthcare provider the opportunity to leverage available patient-generated data for clinical decision support.

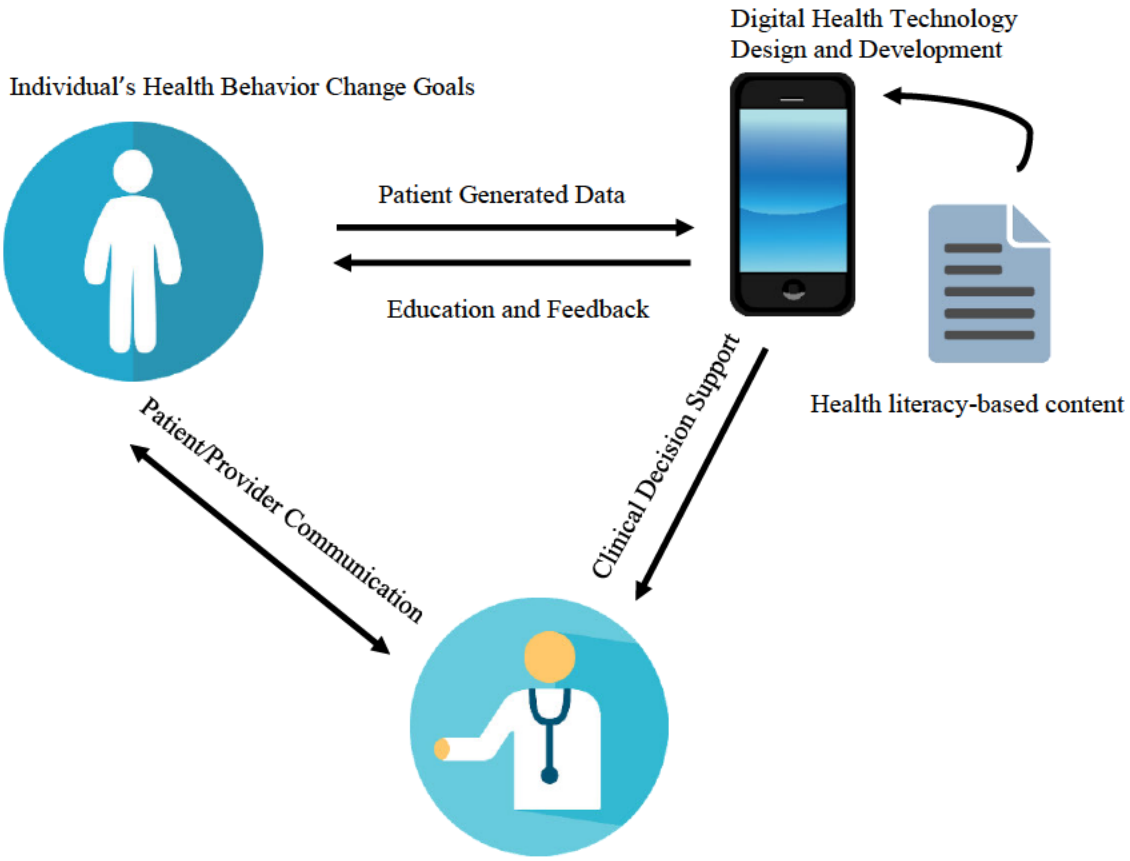


Figure 5- Relationship between digital health technologies, health literacy, and health behavior change.

3.1 Behavior Change Frameworks and Models

In seminal work on health behavior by Gochman, he defines health behavior as "*those personal attributes such as beliefs, expectations, motives, values, perceptions, and other cognitive elements; personality characteristics, including affective and emotional states and traits; and overt behavior patterns, actions, and habits that relate to health maintenance, to health restoration, and to health improvement"* (Gochman, 1997). Digital technologies have been adopted as tools to implement health behavior change beginning around the year 2001 with the rise of the internet and smartphones (Della Mea, 2001). A previous literature review by Taj, Klein, and van Halteren (Taj et al., 2019) has found that the three disciplines which have produced the most research in the field of digital behavior change are computer science, public and occupational health, and psychology. The authors also found that mobile phones were the most used technology in interventions, and the most frequently targeted behaviors were physical activity and healthy eating. And, among the few studies that reported the behavior change techniques employed, the top techniques were self-management and goal setting. Some of the most commonly used behavior change frameworks and models are the Integrated Behavior Model (Glanz et al., 2008a) and Abraham and Michie's Taxonomy of Behavior Change Techniques (Abraham & Michie, 2008), which I further describe below.

3.1.1 The Integrated Behavior Model

The Integrated Behavior Model (IBM) states that the most important determinant of individual behavior is the intention to perform the behavior. According to the model, there are four main factors that influence behavior: 1) knowledge and skills, 2) environmental constraints, 3) the behavior must be important to the individual, and 4) previous experience

of the individual with the behavior. The IBM unites and expands concepts from the Theory of Reasoned Action and Theory of Planned Behavior (Glanz et al., 2008b), both of which are heavily based on individual's perceptions of health behavior and are very popular theories in the domain of public health interventions. Specifically, the IBM employs the constructs of *experiential and instrumental attitude* (an individual's feelings about a health behavior), *normative influence* (beliefs about others' expectations and behaviors), *perceived control* (belief of the likelihood of an event occurring), and *self-efficacy* (one's own beliefs in abilities to perform a behavior) to help characterize an individual's intention to perform a health behavior.

Specific behaviors that have been linked to PPD are sleep, breastfeeding, and paternal involvement in healthcare. For example, the postpartum period is characterized by new sleeping schedules based on the baby's feeding needs. This frequently causes new mothers, as well as their partners, to experience disrupted sleep and possibly insomnia. Insomnia consists of significant and persistent difficulty with obtaining good quality sleep, even when there are no external disruptors (lack of time or a comfortable place to sleep) (Danielle Pacheco, 2022). If insomnia continues for a long period of time, it can have negative effects on the mother's mental wellbeing because it reduces energy levels (manifested as sleepiness) and exacerbates depressive symptoms (Okun, 2016); overall, poor sleep is associated with a three-fold increase of risk PPD (Danielle Pacheco, 2022). Insomnia is frequent during postpartum but may also occur during pregnancy, due to physical discomfort with the growing baby, and reduced bladder retention. Insomnia and depression have a converse relationship, where insomnia may be either a symptom or a contributor to depression (Danielle Pacheco, 2022).

Breastfeeding is the act through which a mother physically produces milk and directly feeds it to her infant. This process has the nutritional benefits of helping build the infant's immune system, and it also fosters healthy mother-infant bonding (Gandomi et al., 2021). Researchers suggest that mechanisms through which breastfeeding and PPD are related include the mother's intent to breastfeed, the process of initiating breastfeeding, breastfeeding duration, and dose (amount the infant feeds)(Pope & Mazmanian, 2016). For example, a mother who was intending to breastfeed her infant for the first six months after birth may become distressed if circumstances force her to stop breastfeeding at an earlier time than planned. Mothers with PPD are more likely to forego the initiation of breastfeeding or to stop early; however, similar to sleeping, the relationship between breastfeeding and PPD may be bidirectional, where PPD symptoms may be worsened through not breastfeeding (Pope & Mazmanian, 2016). Researchers have also found that fathers who are more involved in their own healthcare through doctor visits and who are married to their partners significantly reduce their partner's likelihood of developing PPD. A possible explanation behind these results is that fathers who are healthier and in a committed relationship may act as buffers for their partner's depression symptoms (Simon et al., 2022).

Previous research related to PPD-related behaviors and based on the IBM have included: 1) Gandomi, Sharifzadeh, and Norozi's study characterizing the intention of new mothers to exclusively breastfeed through a self-administered questionnaire (Gandomi et al., 2021), where results suggested that experiential attitudes, perceived self-efficacy, and injunctive norms could be used as predictors of breastfeeding, and 2) Allport and colleagues' use of the IBM to help explain and promote paternal involvement in infant's care (Allport et al.,

2018), thereby improving infant health outcomes including mental health. Neither of these studies have continued to be translated into the form of a digital health intervention. As we previously described in Ch. 2, such research efforts would greatly benefit by leveraging digital technologies, as this would significantly increase intervention access for a wider population, particularly low-income women. This, in turn, would allow for a wider capturing of data and a potentially more robust understanding of how factors such as mother's intention to exclusively breastfeed and paternal involvement can play a role in PPD management.

3.1.2 The Taxonomy of Behavior Change Techniques

Abraham and Michie's Behavior Change Taxonomy (BCT) was produced from a seminal review of behavioral interventions studies, were professionals from the discipline of psychology identified behavior change techniques implemented and grouped them into sixteen major categories that vary from "Social support" to "Self-belief" (Abraham & Michie, 2008). These groupings contain a total of 93 techniques that have been widely implemented in different types of behavior interventions. They are proven to be very effective in assisting patients achieve their health behavior goals and improve their health outcomes, such as losing weight and quitting smoking (Michie et al., 2018). Table 3 lists the BCTs contained in the grouping of "Goals and Planning", to help illustrate the nature of Abraham and Michie's Taxonomy.

Table 3- BCTs for the behavior change group of "Goals and Planning" (Abraham & Michie, 2008).

1. Goals and Planning
1.1 Goal setting (behavior)
1.2. Problem solving
1.3. Goal setting (outcome)
1.4. Action planning
1.5. Review behavior goal(s)
1.6. Discrepancy between current behavior and goal
1.7. Review outcome goal(s)
1.8. Behavioral contract
1.9 Commitment

There are currently no research studies that have assessed the effects of BCTs implementation in the management of PPD. However, there are two studies which have reported the impact of BCTs in interventions to prevent return to smoking (Brown et al., 2019) or support smoking cessation (Campbell et al., 2018) during pregnancy, and one study on use of BCTs and technology to promote weight loss in urban, low-income mothers (Herring et al., 2014). Although these studies do not specifically address the condition of PPD, their results can still provide guidance and information about techniques that have been effective for perinatal women in changing their health behaviors. Brown and colleagues conducted a systematic review to identify the BCTs that have been the most effective in preventing relapse to smoking among women in the postpartum period. In their

review, they included randomized controlled trials that had been published before 2015, aimed to maintain smoking cessation, included pregnant or postpartum women who had quit smoking, and reported the postpartum smoking status of the women. To identify the optimal BCTs to prevent postpartum relapse to smoking, the BCTs had to be reportedly used in at least two studies and maintained smoking cessation for at least six months. After searching and selecting 32 studies for review, the authors found that six of these resulted in long-term smoking cessation. Most of the studies consisted of counseling and cognitive-behavioral therapy interventions delivered in a face-to-face manner. The authors found six BCTs that were particularly effective for long-term smoking cessation in the postpartum period: 'problem solving', 'information about health consequences', 'information about social and environmental consequences', 'social support', 'reduce negative emotions' and 'instruction on how to perform a behaviour'(Brown et al., 2019). Campbell and colleagues used a Nominal Group Technique with twelve smoking cessation experts to identify significant barriers and facilitators for smoking cessation during pregnancy, and the corresponding BCTs that best addressed these. The experts identified "quitting not a priority" and "smoking a social norm" as important barriers to quit smoking during pregnancy, and "desire to protect baby" as the most important facilitator to quit. The authors identified 23 BCTs that could be potentially effective in addressing these barriers and facilitators, such as information about consequences (Campbell et al., 2018). In a randomized controlled trial, Herring and colleagues compared the effect of a weight loss intervention program delivered through use of text messaging and Facebook against usual care in low-incoming mothers residing in urban Philadelphia. Within the intervention the authors implemented BCTs including behavior cues, role modeling, and behavior rewards.

Participants lost significantly more weight (adjusted mean difference: -3.2 kg) than their control counterparts at 14 weeks of the intervention (Herring et al., 2014).

3.2 Technology Design and Development Frameworks

As the field of digital health continues to grow as its own separate discipline, several frameworks have emerged to address the process of outlining, designing, and developing the digital features to be used in digital health interventions. Some of these are Mohr's Behavior Intervention Technology (BIT) Model (Mohr et al., 2014), the Health Information and Management System Society's Patient Engagement Framework (PEF) (Health Information and Management Systems Society, 2014), and Myneni and colleagues' Digilego framework (Myneni et al., 2015). Some of these frameworks provide researchers with a high-overview lens through which they can outline the main purpose of their intervention (the BIT Model), while others classify commonly used digital features into their potential for patient engagement, with the purpose of assisting researchers and developers in selecting specific features to achieve specific levels of engagement (the Patient Engagement Framework (Health Information and Management Systems Society, 2014)) (Table 4).

Table 4- Digital Health Development Frameworks

Digital Health Framework	Behavioral Intervention Technology Model	Patient Engagement Framework (PEF)	Digilego
Target users	Researchers, healthcare providers, software developers	Healthcare organization leaders, providers, researchers	Researchers, developers, healthcare providers

Table 4 (continued)

Digital Health Framework	Behavioral Intervention Technology Model	Patient Engagement Framework (PEF)	Digilego
Functionality	Outlining of digital behavior change interventions (Why? What? When? How? (conceptual and technical))	Categorization of patient engagement digital features	Design and technical development of reusable, scalable, theory-informed and user-centered digital features; user testing
Digital Health domain	Behavior change	Telemedicine, consumer informatics	Social media analytics, consumer informatics, human factors engineering, extensibility with AI models and features

In this dissertation, I have designed and developed a digital health platform for PPD self-management integrating these traditionally siloed aforementioned models and frameworks. Digilego served as my overarching framework to guide user needs analysis, theory infusion, and content and feature development of the platform. I have selected to use the BIT model in conjunction with Digilego to refine the behavior change goals to be implemented within the platform, and PEF to outline the digital features that will engage patients in their behavior change journey. Below, I describe each of these frameworks in more detail.

3.2.1 Mohr's Behavioral Intervention Technology (BIT) Model

The BIT model is a well-established model for digital health development that has been used to design interventions in areas such as physical activity (Direito et al., 2018), as well

as anxiety and depression (Burns et al., 2013). This model helps researchers and developers create a strategy for user's behavior change through technology by asking five theoretical questions: Why? (the intervention aims), How? (How will users achieve the aims of the intervention; this includes both the theories supporting the intervention and the technical features), What? (What technological elements will be included in the intervention to facilitate the active ingredients of behavior change?), and When? (the workflow of the intervention). The model provides digital health developers with the benefit of outlining interventions with conceptual and technical support, therefore making such interventions more likely to be sustainable and engaging for users (Mohr et al., 2014).

3.2.2 Patient Engagement Framework (PEF)

This framework was developed by the Healthcare Information and Management Systems Society (HIMSS), and is originally meant to help healthcare organizations like hospitals in selecting engagement features for their patients (Health Information and Management Systems Society, 2014). The framework covers five cumulative patient engagement levels: "Inform Me", "Engage Me", "Empower Me", "Partner with Me", and "Support my e-Community". Within each of these levels, the framework contains engagement categories that are also cumulative. For example, the first level of "Inform Me" includes the categories of: "Information and Way Finding", "e-Tools", "Forms: Printable", and "Patient-Specific Education". There are a total of nine engagement categories. Importantly, the framework is also tied to the Meaningful Use criteria for Electronic Health Records established by the Centers for Medicare and Medicaid Services (now known as the Medicare Promoting Interoperability Program) (Centers for Medicare and Medicaid Services, 2022). Some minor limitations of the framework are possibly limited generalizability, as it is mainly

meant to be used in healthcare organizations that are planning to adhere to the Medicare Promoting Interoperability Program. Additionally, the framework does not address technology implementation factors such as how patient engagement can be maintained.

3.2.3 Digilego

The Digilego framework is defined as "*a digital health development framework for patient-facing health applications that are (a) built on theory-driven needs translation, (b) engaging for long-term sustained use, and (c) integrative of care coordination processes that are multilevel, inter- and intra-personal in nature*" (Myneni et al., 2015). Factors considered in the development process range from users' demographic characteristics, specific data from patient's electronic health records, and patient-generated data from surveys, consumer wearable health technology, and remote monitoring systems. The framework assists with guided packaging of the scattered nature of user needs and care procedures. Digilego's capacity to assist with care coordination and health promotion through a wide array of technology variants constitutes it as a groundbreaking, adaptable, modular, and fast-modeling framework. It provides researchers the skills to expand digital health interventions to specific populations, and to engage their intended users at optimal levels, while guaranteeing their digital health technologies are based on established theory. There are two main arms to Digilego: 1) theory-based and needs-responsive digital health development, and 2) an environment of reusable and customizable clinical and public health digital features (hence the name Digilego, from modular lego blocks). The framework has been used to produce health technologies in the areas of mental stress and cancer (Carter et al., 2019; Myneni et al., 2015). The framework employs three main steps towards digital health production: (a) assessment of user's information and technology

needs through traditional and data-driven methods (i.e., literature review, social media analysis, interviews, focus groups), (b) use of evidence-based behavior change theory to assist with user's behavior change goals and intentions; examples of such theories are the aforementioned IBM and the BIT model, and (c) establishing digital features for optimal and sustainable user engagement, using the previously described PEF. Previous studies suggest such employment of various approaches for user needs assessment and theory addition results in robust design models for digital health interventions, especially in the areas of patient behavior change and self-monitoring (Benlamri & Docksteader, 2010; Villarreal et al., 2014).

3.3 Health Literacy Frameworks

While there have been many definitions for the term "health literacy", a recent one by the U.S. Department of Health and Human Services' has expanded the term to reflect the significant role of organizations in this area (U.S. Department of Health and Human Services, 2020). They define personal health literacy as *the degree to which individuals have the ability to find, understand, and use information and services to inform health-related decisions and actions for themselves and others* (U.S. Department of Health and Human Services, 2020), and organizational health literacy as *the degree to which organizations equitably enable individuals to find, understand, and use information and services to inform health-related decisions and actions for themselves and others* (U.S. Department of Health and Human Services, 2020). There is now also a new term, electronic health literacy, that encompasses the relationship between digital health technologies and user's personal health literacy. Electronic health literacy (also known as eHealth literacy), is *the ability to search, locate, understand and use health information through electronic*

resources and use this knowledge to resolve health-related problems (Norman & Skinner, 2006).

Research suggests that eHealth literacy is a vital user engagement factor that needs to always be considered during digital health development. For example, Guendelman and colleagues (Guendelman et al., 2017) found that disadvantaged perinatal women with higher levels of eHealth literacy also had higher levels of web-based health seeking activities. Pineros-Leano and colleagues (Pineros-Leano et al., 2015) interviewed clinic staff regarding use of electronic tablets to complete PPD screening; interviewees identified literacy components such as users having multiple languages available and read-aloud capabilities as advantages. Choi and Bakken (Choi & Bakken, 2010) integrated literacy factors such as easy-to-read text and visual cues into a web-based education platform targeting parents with children in the NICU. This resulted in successful heuristic evaluations, with users reporting that they found the website to be easy to use, useful, and with content that improved their existing knowledge. While these studies sporadically provide examples of how digital health technologies can improve user's health literacy levels, current literature is in need of further studies that apply health-literacy driven content engineering methods in PPD digital health technologies.

Health literacy also has a crucial role in addressing PPD health disparities. For example, women with low health literacy are less likely to accurately recognize when they are experiencing significant depression symptoms (Fonseca et al., 2017), and therefore be proactive in seeking necessary information and professional help (Cheng et al., 2020; Shieh et al., 2010). Women with low health literacy are also less likely to know about or understand their available options for PPD treatment (i.e., therapy, medications) (Fonseca

et al., 2017). Additionally, low literacy is likely to lead to negative socioeconomic conditions like job insecurity (Zaslow et al., 2001), which in turn can lead to issues accessing resources for mental health care.

Some seminal theoretical frameworks that elaborate on the concept of eHealth literacy are described below.

3.3.1 The Lily Model

Norman and Skinner (Norman & Skinner, 2006), proposed that literacy can be of six types: *traditional literacy* (essential reading, writing, and arithmetic skills), *health literacy* (ability to understand health concepts and apply them through questions or seeking of health information), *scientific literacy* (ability to understand information in the domains of natural sciences, such as biology and chemistry, and also knowledge about the scientific method), *information literacy* (knowing how to organize knowledge and apply information), *media literacy* (being able to leverage different information formats such as video, audio, and text), and *computer literacy* (ability to control hardware and software, such as use of the internet). According to the model, all of these different types of literacy come together to influence an individual's levels of eHealth literacy, much like the petals of a lily flower surround the pistil.

3.3.2 The eHealth Literacy Framework

Chan and Kaufman extended the Lily model by incorporating cognitive tasks and learning categories that a user would need in order to successfully use a digital health technology, and named this new framework the "eHealth Literacy Framework" (Chan & Kaufman, 2011). The cognitive tasks and learning categories are based on Bloom's Taxonomy, a taxonomy widely used in the field of education to plan learning objectives (Armstrong,

2010). According to the eHealth Literacy Framework, developers of educational content to be presented in an electronic format should map their content to both the literacy domain being addressed (i.e., science literacy) and the cognitive task (i.e., remembering) that will be employed to improve the individual's literacy levels. Out of all the electronic health literacy frameworks we have reviewed, Chan and Kaufman offer the best process for systematically outlining cognitive tasks and literacy domains within digital health features.

3.4 Research Opportunities for disparities-focused digital health design and development

My overview of digital health theories and frameworks, along with my review of the current state of care for PPD (in Chapter 2), presents specific research opportunities to plan digital health solutions for improving the management of this condition, particularly among populations affected by health disparities. Identifying optimal mechanisms of behavior change in these populations, bridging the currently siloed digital health theories, and developing and evaluating a novel health-disparities focused digital health solution represent such research opportunities. What are the information and technology needs of women who are affected by disparities in their mental health management? Are these different from those of a more general population of women? The real-time and voluminous data contained in PPD-specific online forums provides the opportunity to supplement traditional user needs assessment methods (focus groups, interviews) to obtain a robust understanding of how digital health technologies can be made appropriate to this specific population. How can we adapt and extend existing digital health frameworks to be considerate of health disparities? And what are the optimal ways to operationalize sustainable behavior change, optimal engagement, and health literacy in a disadvantaged

population? Existing frameworks should be leveraged into a comprehensive and novel feature and content engineering methodology that addresses the unique needs of disadvantaged populations. This is crucial to incorporate psychosocial factors (social support, existing stigma against mental health), and health literacy attributes (readability, content formatting), into digital health design and development. As described earlier in Chapter 2, most studies dedicated to digital health and PPD use information from sources such as focus groups and interviews, but tend to overlook information present in other sources such as PPD online forums during the development process. Furthermore, there is still a scarcity of research that focuses on identifying optimal behavior change techniques to be integrated into digital solutions to be used by a population such as disadvantaged perinatal women. And, will a health-disparities focused digital health solution be acceptable among the intended population? The evaluation of the resulting product from my proposed methodology will provide insights into areas for improvement and future research focus. In Figure 6, I present my proposed integrative framework consisting of: 1) mixed-methods user needs analysis, (b) behavioral and health literacy theory mapping, and (c) content and feature engineering specifications.

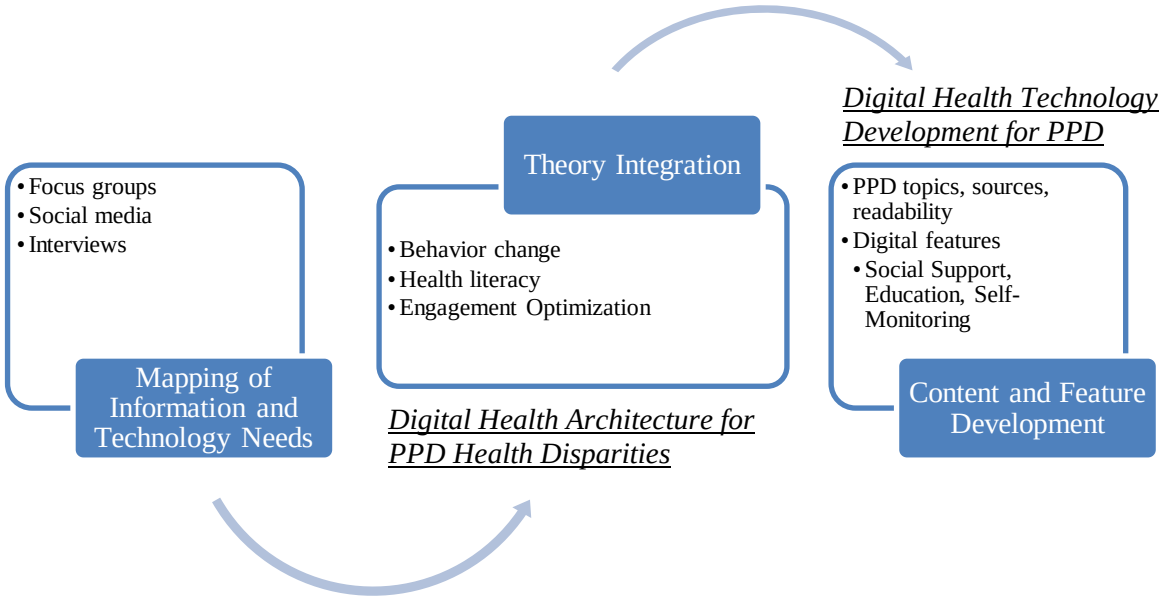


Figure 6- Integrative content and feature engineering approach for PPD.

This Digilego framework with an added focus on health disparities will allow researchers to consider technology and content specification from cognitive, task, and domain learning perspectives depending upon which health literacy theory we operationalize.

Chapter 4: Characterizing the Information and Technology Needs of Low-Socioeconomic Status Perinatal Women

In this chapter, I describe my qualitative analysis of PPD stakeholder perspectives regarding digital health information and technology. Stakeholders include low-income perinatal patients, healthcare providers, and participants in PPD online forums. The goal of the analysis is to identify and increase my understanding of the best digital health development strategies for a low-income population. By gathering perspectives through methods of individual interviews and content analysis of online forums, I can extract insights such as important PPD conversation topics, and personal preferences in technology design. These insights can then be integrated into feature and content design and development, to help our target population better navigate their pregnancy, newborn, and PPD self-management journey.

4.1 Methods

4.1.1. Capturing Patient Insights

Focus Groups and Interviews

The setting for my collecting of patient insights was the UT Physicians Maternal and Fetal Medicine (MFM) clinic in Houston, Texas. The clinic specializes in high-risk pregnancy conditions (such as gestational diabetes and preeclampsia). Two focus group sessions were held (n=9 patients), and 10 individual interviews were conducted (Zingg et al., 2020; Zingg, Singh, et al., 2021a). Eligibility criteria for participation were being a perinatal woman currently seeking care at the clinic, and being at least 18 years old. I focused on

recruiting English-speaking patients for this study, as English is the most common language spoken in Houston (*Data USA*, n.d.). A survey capturing demographics, pregnancy, and experiences with PPD was administered to participants before focus groups or interviews (Appendix A).

Focus groups and interviews were semi-structured, and question guides were used to carry out discussions with patients. Questions were meant to extract themes about participants' PPD knowledge and their use of technology (examples: "Do you like using health apps to get answers to questions, or would you rather sit down with your doctor when you have a question?", "What kind of information do you actually get from these apps?") (Appendix A). Both focus group and interviews used the same questions; however, interview questions also asked participants to elaborate on their preferred technology designs. Focus groups and interviews were audio recorded and transcribed verbatim.

Social Media

Focus group and interview participants stated that they are active users of online forums for pregnancy; based on this input I harvested and analysed data from PPD online social forums (Zingg, Singh, et al., 2021a, 2021b). I selected the websites What to Expect (What to Expect, 2020) and BabyCenter (BabyCenter, 2020) for data extraction based on user input, and also due to their being two very popular pregnancy applications used on a world-wide scale. Data extraction was conducted using the Python-based web crawling software Scrapy (Scrapy, 2021). A total of 55,301 posts exchanged by 9,364 users and 12,416 post threads were extracted. This data covered years 2008 to 2022. The selected forums and

user posts are publicly available, and potential identifiers (usernames, post title) were removed from the dataset.

4.1.2 Capturing Provider Insights

Nine healthcare providers specializing in perinatal health were interviewed. Inclusion criteria was that providers must practice in a clinic where women at risk for or diagnosed with PPD, or their children, receive any kind of healthcare treatment. Providers were recruited in the Texas Medical Center and the UT Physicians system. Interviews lasted approximately 30 minutes. To facilitate discussion, question guides were used (Appendix A). An example provider question is: "From your perspective, what are some difficulties that PPD health care team members face when trying to help perinatal women prevent or manage PPD?". Interviews were recorded and transcribed verbatim.

4.2 Data Analysis

4.2.1 Focus Group and Interview Analysis

Focus group and interview transcripts were coded using Dedoose analysis software. Qualitative content analysis was done using a grounded theory approach, which consists of three main steps: open coding, axial coding, and constant comparison (Glaser & Strauss, 2017; Strauss & Corbin, 1997). In open coding, a line-by-line reading of the content is done and essential ideas and concepts are recognized as they arise from the raw data. This process was done independently by two researchers. An example is illustrated below:

"I get on it every other day, um, and definitely as my week changes for the pregnancy just because it gives you all the different information, you know, as the baby's growing and things on the baby's health and things that my body goes through as well." (Participant I2)

In this comment, an individual describes how a mobile app helps her remain informed about her pregnancy. Open concepts from this comment were: “information”, “pregnancy”, “health”, and “baby”. Constant comparison was conducted to ensure reliability in code application. After no more open codes were identified, coders held discussion meetings to finalize a list of codes and confirm agreement. After open coding was finished came axial coding, whereby the fundamental discussion themes are identified by analyzing links among open codes. For example, the open codes of “information”, “pregnancy”, “health”, and “baby” were clustered into the fundamental theme of “Pregnancy Education”. This process was done by all coders in an iterative manner. After thematic saturation was reached, as indicated by no more axial codes being identified, a concluding list of fundamental themes was decided upon. Such a grounded theory approach helps instruct prototype design and integrate ideal PPD management content by means of human-centered design processes: (a) collecting and comprehending women’s mental health management needs, (b) outlining evidence-based PPD care perceptions, opinions, and barriers, and (c) conceiving of wanted digital features in the domain of perinatal mental health.

4.2.2 Social Media Analysis

Manual coding was done for 1424 randomly selected user posts; this coding was multi-label, where more than one code could be applied to a post. Grounded theory analysis was once again used to extract the main discussion themes in PPD online forums. A second coder was assigned a random subset of 150 posts to ensure reliability in code application,

as quantified by Cohen's Kappa (Table 5). Any disagreement among coders was resolved through iterative discussion meetings.

Table 5- Interrater Reliability Among PPD Social Media Themes

Theme	Cohen's Kappa
Medications	0.84
Family and Friends	1.00
Physical and Mental Health	0.85
Social Support	0.84
Mother and Infant Dyad	0.98
Doctor and Patient Dyad	0.92

4.3 Results

4.3.1 Patient and Provider Characteristics

All focus group and interview patient participants reported being pregnant. The most common age range was between 25-34 years old (n=10), and the most common ethnicity was Hispanic (n=7), followed by Black (n=6), White (n=4), and Other (n=1). Most had completed some college (n=5) or an associate's degree (n=5), and had a household income of less than $40,000 (n= 14). Thirteen of the 19 patients reported depression symptoms in their current pregnancy, and seven had mentioned this to their doctor. However, none had been diagnosed with depression. The internet was the most common source of pregnancy information for patients (n=17), followed by other non-digital sources such as books, friends, families, and their doctors (n=11) (Zingg, Carter, et al., 2021). Our provider sample consisted mostly of OB/GYNs (n=4), followed by nurses (n=2), and other specialists such as a neonatologist (n=1), psychologist (n=1), and social Worker (n=1). All providers in the study sample are female.

4.3.2 Interview Themes

Five core themes emerged from 134 open codes in patient interview transcripts and 185 open codes from provider interview transcripts. These core themes are: 1) Use of Technology/Features, 2) Access to Care, 3) Pregnancy Education, 4) Social and Community Support, and 5) Sources of information. Definitions of these themes can be found in Table 6.

Table 6- Top Interview Themes (Patients and Providers)

Theme	Definition
Use of Technology/Features	Comments where user describes the health technology applications and features she uses and for what purposes (pregnancy, family), as well as technology/feature characteristics that compelled or prevented them from using the application (price, perceived value of the features). Also includes instances when user mentions features that she is currently lacking or needing in their perinatal care.
Access to Care	Comments related to improving healthcare access, including the ability to communicate with providers, self-monitoring, education, and making appointments
Pregnancy Education	User describes the pregnancy information they receive or are wanting/lacking from pregnancy applications
Social and Community Support	User describes how a social forum app would assist them in creating social capital (friendships, community resources)
Sources of Information: Family	User prefers to receive information from ***FAMILY*** over doctor, electronic sources, or printed sources.
Sources of Information: Doctor	User prefers to receive information from ***DOCTOR*** over family, electronic sources, or printed sources.

Unique Patient Themes

A theme that was uniquely brought up by patients, in addition to the above common themes, was “Privacy and Security”, where patients discussed concerns about personal information safety when using technology. Patients emphasized a desire for technologies

offering the opportunity to connect with peers while maintaining privacy and confidentiality. For example, one patient was hesitant to use Facebook due to its being a public platform with a high volume of users:

"I know you could probably get that [community] from Facebook, but I would rather not do it on Facebook because it's a lot of people …". (Participant I5)

Patient interviews also revealed insights into technology design elements related to content creation, health literacy, patient engagement, and human factors engineering:

1) Specialized information systems to manage high-risk pregnancies: interviews showed that patients were seeking technology products specific to their unique pregnancies. This is illustrated in the following interview comment:

   "Since we're MFM, it's different than a typical pregnancy. Would be nice if in the app we could check his statistics, like femur length, tibia length, weight, week for week to see how he is developing. That would be reassuring [...]. I think that would be more meaningful, for not your typical pregnancy but in MFM, where we see a specialist. There isn't anything currently on the market.". (Participant I1).

2) Fast Digestible Education Materials: Most patients preferred dynamic educational content presented in amenable multimedia formats (e.g., slide shows, videos, audio). Such formats were also deemed a good fit for the busy schedules of expectant and new mothers:

   "Videos. I would include videos and wording on it. The topics I would include would be mental health, and just in general any information about pregnancy. I would look for research studies". (Participant I2)

   "If you could actually listen to them instead of reading, it's better because I'm a mother so I don't always have time to read." (Participant I2)

   Additionally, patients mentioned their preference for well-paced materials that separated topics into sub-topics.

"Well, when I was in school, I started off like the main topic and then I have bulletins that will help break down. You know, okay, like if it was for a symptom it brings it down to like, what I should do, or how I should treat it, any medication… broken down to the bullets or sections." (Participant I1)

3) Information Credibility: While patients valued information present in apps, they preferred to consult their doctor for more detailed or specific information. Some indicated skepticism of apps that did not provide their information sources.

   "Sometimes the apps have good information, but I mean, I would also like to sit down and talk with the doctor over here, for more feedback and things like that. If I have something to be answered, I would trust the doctor rather than the app". (Participant I3)

4) Minimalist design: Patients preferred simple and informative technology designs, and visual ways to indicate their mood and state of mind, such as pictures and colors. Many indicated they would be welcoming of PPD self-monitoring tools such as screening surveys; however, they strongly preferred those that could be completed fast (i.e., five minutes) and had a brief number of questions (i.e., five questions).

5) Affordable Tech: User reviews and functionality of the app are factors patients consider when deciding to purchase apps. Two interviewees stated they would only consider apps that are free of price, and the rest would consider low-price apps (i.e., $5).

Unique Provider Themes

Two themes that were unique to providers are:

1) "Managerial and Administrative Support for Providers", where providers expressed the need for better support from management and administrative level positions in terms of having adequate resources to carry out optimal care for PPD patients

(documentation, follow-up, interdisciplinary collaboration, workflow). An example comment is related to providing support to patients who experienced miscarriages:

"It [miscarriage] is an extremely common issue and I don't believe we have sufficient [mental health] support services to offer the between one in three and one in five women. I'm not saying that it wouldn't be beneficial, it certainly would, but I don't think that's something we've had the capacity for." (Participant P2).

And a second example comment is related to having insufficient time and resources to offer patients services such as social work visits:

"…so if someone had, uh, post-partum depression that they thought needed treatment we would actually refer them immediately so we, we immediately refer them for social work consult so that they can find out if there's any home stressors and any additional things, and then we refer them immediately to, um, to our multi-disciplinary team. So we don't have the time or resources to sort of, um, to sort of start that process. So it is a team process. So we're, we're kind of in the identification business and once we identify then we refer." (Participant P5)

2) "Peripartum Depression Clinical Decision Support", where providers expressed the need for better clinical decision support systems, specifically definitions and clinical practice guidelines for PPD (includes screening process and leveraging patient history and patient-generated data). Example comments:

"There's not a formal screening process that I'm aware of; that doesn't mean it's not happening because I do know every parent or mother who has a baby in the NICU does get visited by a social worker, and so it may actually be part of their intake. I just, honestly, don't know too well." (Participant P6)

"So what would be ideal would be to have, uh, a sort of a patient interactive app that, you know, there are some of those that are already available where people put their due date in and then it gives them messages about different gestational ages and education about different gestational ages and they go through the pregnancy. And if that could be linked with an app that, um, screened for depression and then messaged the physician if the patient had an elevated score, that would be helpful because right now we only screen for depression at very set times during pregnancy: at intake and, you know, in the third

trimester. But we don't screen, you know, continuously and obviously, that's, um, a limitation." (Participant P5)

4.3.3 Focus Group Themes

A total of 106 open codes emerged from focus group transcripts, representing idea concepts ranging from "app use" to "family support". User participation in focus groups is illustrated in Figures 7 and 8, where we have assigned each participant an alphanumerical ID (i.e., A1) and show the number of speaking turns each participant had. For focus group session 1, the most active participant was participant A2 with 70 speaking turns, and the least active participant was participant A4 with 12 speaking turns. For focus group session 2, the most active participant was participant A2 with 72 speaking turns, and the least active participant was participant A3 with 42 speaking turns. Top open codes included: "Use of Mobile Applications", "Sharing of Stories and Narratives", "Information on Mental Health", "Means of Information Seeking", and "Managing Lab Results" (described in Table 7). Of these codes, "Use of Mobile Applications" was the one most mentioned in Focus Group 1 and "Means of Information Seeking" was the most mentioned in Focus Group 2. The distribution of these codes is illustrated in Figure 9. We have assigned these codes the core themes of "Use of Technology", "Education/Information", and "Digital Data" (Table 7).

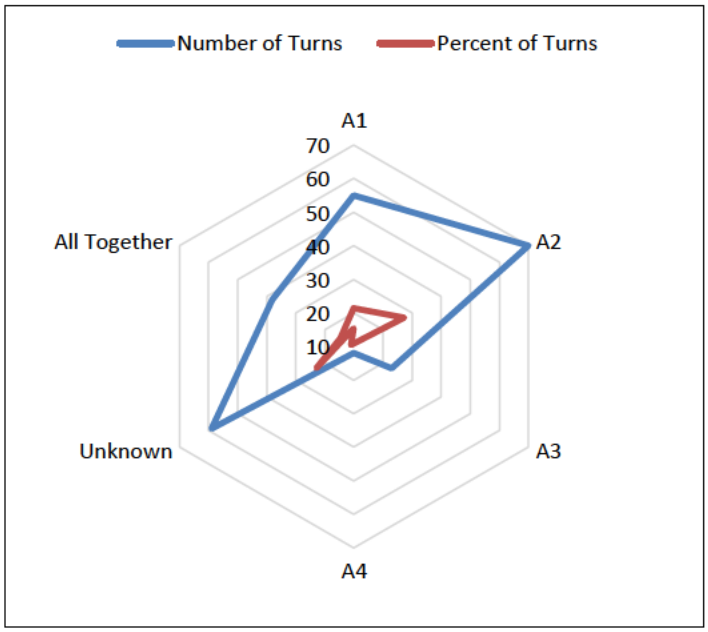


Figure 7- Speaking Turns per Participant (Focus Group 1)

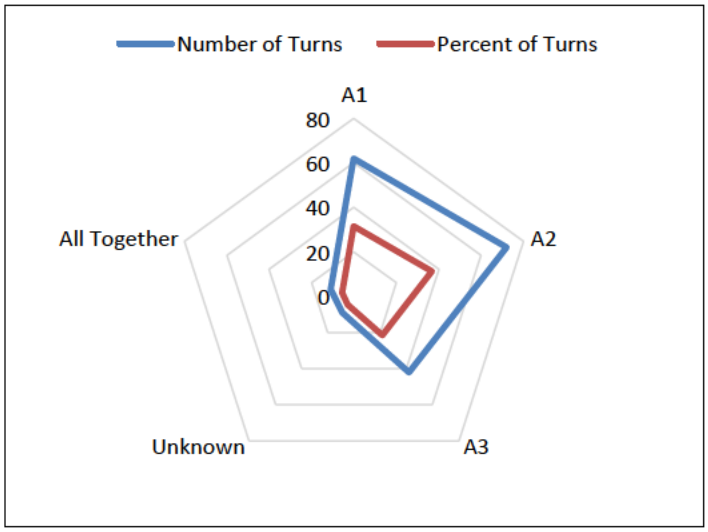


Figure 8- Speaking Turns per Participant (Focus Group 2)

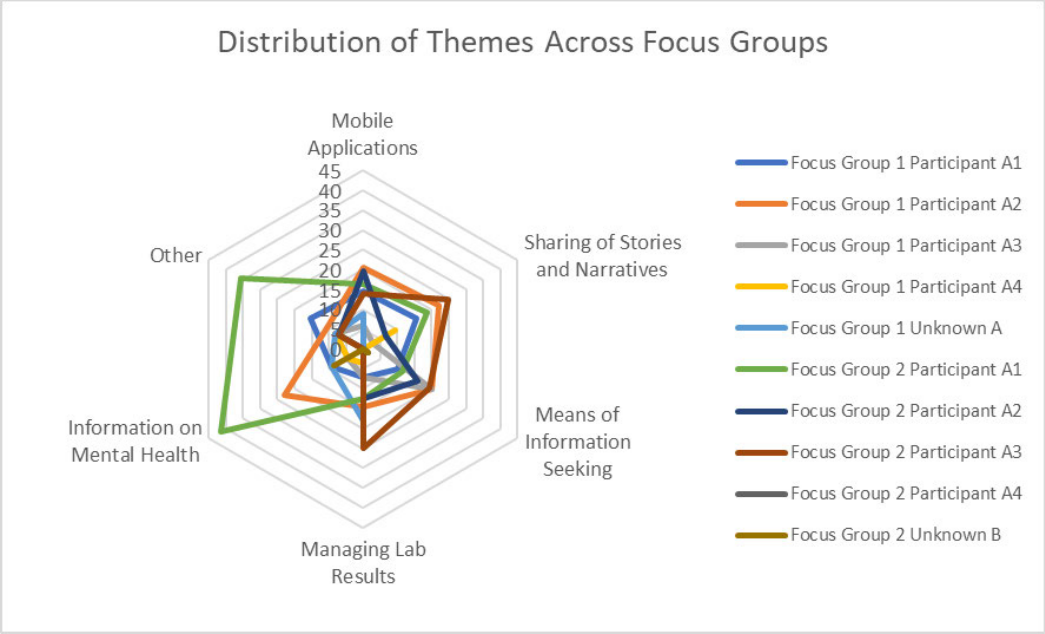


Figure 9- Distribution of PPD Information and Technology Themes across Focus Groups

Table 7- Top Focus Group Themes

Theme	**Open Code**	**Definition**	**Sample comment**
Use of Technology	Use of Mobile Applications	Comments that describe how users navigate their pregnancy journey with help of smartphone applications	*"Well, for pregnancy, I use the What to Expect app. I use that one a lot. So, it gives you different stories of what you will go through, what symptoms you might have. It will also tell you what you need energy—or to eat. Things like that." (Participant F2A2)*
Education/ Information	Means of Information Seeking	Users describe how they use technologies such as social forums to gather information of interest about their pregnancy	*"It was almost like, well, you don't have a heartbeat so I asked other mothers, and they were, like, oh, that happened to me, just give it a couple of weeks and the heartbeat should be there then. Then a couple more weeks and the heartbeat is there." (Participant F2A3)*

Table 7 (continued)

Theme	Open Code	Definition	Sample comment
Education/ Information	Information on Mental Health	Comments where participants describe instances when they were wanting or needing information on mental health but could not find it	*"Of the seven apps that I have to track everything, nothing says, if you have a history of miscarriages—like I do—like both of us, I guess—or if you have a history of depression, anxiety, or PTSD, or all of these different things, how do you now cope with, is this a normal feeling?" (Participant F2A1)*
Education/ Information	Information on Mental Health	Comments where participants describe instances when they were wanting or needing information on mental health but could not find it	*"Of the seven apps that I have to track everything, nothing says, if you have a history of miscarriages—like I do—like both of us, I guess—or if you have a history of depression, anxiety, or PTSD, or all of these different things, how do you now cope with, is this a normal feeling?" (Participant F2A1)*
Digital Data	Managing lab results	Participants express confusion and sometimes frustration with the various channels available to share lab results as well as the want of lab results even if normal.	*"Sometimes they call—only if it's abnormal, but some of us, we just want to know, hey, like I have a bleeding disorder—well, what's my level? What's my level? Should I be doing . ." (Participant F1A3)*

Participants also expressed the at times frustrating experience of following up with their doctors after having read information from digital sources (e.g., social media). It was difficult for them to discern when to trust these sources, and when to contact their doctors if such sources indicated a possibly abnormal event in their pregnancy. This indicates a

barrier for participants in using the information they receive from non-traditional sources, as Comment 4 shows.

Comment 4: *"Sometimes I'll come to my doctor (with the app) and show 'Look, this says this is not normal' and they'll say 'Oh no, don't trust those things'. Well, then I don't want to bug you every five minutes for the nine months we get to go through this. I was told this would not happen to me."*

4.3.4 Social Media Analysis

There were six major themes that emerged from our qualitative analysis of 1424 social media posts, with the most common theme being "Physical and Mental Health" (n=725 posts, 50.9%), followed by "Social Support" (n=674, 47.3%), "Medications" (n=612, 42.9%), "Mother and Infant Dyad" (n=461, 32.3%), "Family and Friends" (n=428, 30.1%), and "Doctor and Patient Dyad" (n=423, 29.7%) (Figure 10).

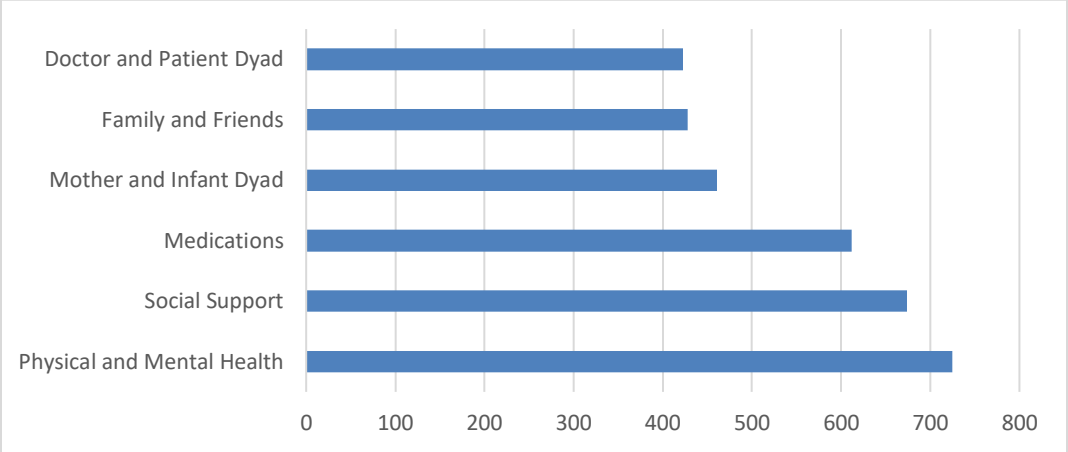


Figure 10- Distribution of PPD Social Media Themes (manual labeling)

A minor number of user posts (n=17, 1.2%) were omitted from our analysis due to content of a miscellaneous nature. Most user posts exchanged in our selected PPD-specific online communities were focused on sharing of personal experiences with PPD, including struggles, success stories, and advise for day-to-day management of symptoms. The providing of sympathy and friendliness were also prominent characteristics of user posts,

and are crucial to encouraging positive health behaviors such as communicating PPD symptoms to providers. Definitions and examples of major themes are provided below.

a) Family and Friends: These are posts where the user specifically mentions relationships with family and/or close friends as an important factor in their mental health state. Role of family and friends can be direct or undirect, and positive or negative. In the following example, a user describes how she projects her worries about her ill child onto her significant other, which has negatively affected their relationship:

   "My boyfriend is amazing, but lately I've been so against him. I've been taking everything I feel out on him without even realizing it?? I'm afraid due to my son being ill it's bringing on PPD. I'm scared about it and I would get so much comfort in knowing I'm not the only mum going through this." (Post # 65)

b) Medications: User statements or queries about pharmacological treatments for peripartum depression. Characteristics of these posts include questions about optimal dosing and medication options. Other characteristics include queries about medication effects on breastfeeding and medication effects on baby. As an example, in the next post a user is wondering about the safety of a newly prescribed medication and what her peer's experiences have been:

   "I'm 34 weeks and my Psych doctor recently prescribed Buspar 5 mg for myself. I still have to get an okay from my OB just wondering if anyone else has taken this Med during pregnancy and what their experience with it was ??". (Post # 197)

c) Physical and Mental Health: User describes changes in their body or state of mind during the peripartum period. These can include symptoms of anxiety, insomnia, negative thoughts or feelings, happiness, and exhaustion. In this next example, a user describes in detail the physical symptoms she has experienced as a consequence of

PPD, her frustration at the fluctuation of the symptoms, and her difficulty accepting them.

"*Hey ladies- I'm 6 weeks postpartum as of today. Having a hard time. I have anxious spells- with severe symptoms where I feel like I'm in a dream, panicky, heart racing, thoughts that I know I don't actually think. This can go on all day. For whatever reason I do feel some relief at night. Then I have times where in goes into depression. And then- suddenly a veil lifts and I feel like myself again. Sometimes I'll go all or most day and feel asymptomatic of PPD and I'll want so badly to believe it's gone. But the symptoms return and I'm left heartbroken. […] I've never had depression in my life. In fact, I love my life. Or did. I feel robbed. This is so unfair*." *(Post # 12)*

d) Mother and Infant Dyad: Posts where user describes their interactions and relationship with their infant, of both positive and negative nature. These may focus on breastfeeding and the bonding process. In the illustrating post, we find a user who feels resentment toward the difficult task of caring for her infant.

"Same boat! my baby is 3 weeks old in 2 days and I don't feel like I love him at all. I'm already depressed from not sleeping and with breast feeding and feeling like I can't do anything because as soon as I start he's hungry and feeling resentment towards your new baby doesn't help. Makes me feel like I'm already failing as a mom. You're not alone! I've been told it'll pass so hopefully it does for the both of us". (Post # 673)

e) Social Support: Content where a user provides support to their peers, and can be of four types: emotional (words of encouragement and kindness), an appraisal (feedback on a situation), instrumental (a practical tool), and informational (personal experiences or educational resources). For example, in the next post a user is trying to reshape her peer's self-perception by normalizing feelings of inadequacy as a new mom.

"You're not lazy or incompetent. You miss that time, which is totally normal since your life just changed. But having a kid is a TON of work. It's not being lazy if you're not always up to the task." (Post # 8)

f) Doctor and Patient Dyad: User describes interactions with their care providers as part of their mental health management. Such posts may include instances of disclosing

PPD symptoms to providers, providers managing PPD treatment, and managing appointments. In this next post, a user finds relief in her doctor's reaction to her delayed seeking of PPD care.

"I just went to the dr for ppd yesterday and my girl will be 7 months this week. The dr took it very seriously and said it can take a good year for the chemicals in our brain and our hormones to find their normal again. It's never too late to be brave enough to ask for help??" (Post # 865).

4.4 Discussion

Our patient focus groups and interview themes are similar to ones reported in previous qualitative studies assessing information and technology needs for PPD management. In a UK study consisting of interviews with perinatal women and midwives, Doherty and colleagues found themes of "The pregnancy journey" (describing positive and negative experiences during the nine months of pregnancy, contrary to intuition that pregnancy is a purely positive experience), "Experience of Perinatal Care" (complex relationship with midwive professionals, lack of mental health screening in the clinical care setting), and "Technology Use in Pregnancy" (technology as provider of health information and communication with providers). These are analogous to our themes of "Use of Technology/Features", "Pregnancy Education" and "Sources of Information: Doctor". The providers interviewed in the Doherty study were mostly midwives, reflecting the organizational structure of the UK national healthcare system. However, UK providers had very similar views on technology and PPD management as the interviewed providers for the present study. Specifically, a common theme was how providers saw technology as a potential assistant to PPD management in clinical environments that allocate scarce resources to processes like PPD detection and treatment. For example, midwives

commented that many times they assessed the mental wellbeing of their patients based on the patient's appearance (rather than performing a PPD screening through digital health tools) due to insufficient support services available. Therefore, technology could aid in improving this informal approach to mental health in the perinatal care setting.

4.4.1 Differences and Similarities Between Perspectives in Different Data Sources

This data analysis considered stakeholder perspectives ranging from individual-level interviews to thousands of user posts from PPD social media. Significant similarities and differences in discussion themes were found among these data sources. For example, social media analysis revealed that a wide-ranging population of perinatal women tend to leverage these channels for sharing of personal experiences with PPD, to receive feedback on practical matters like pharmacological treatment, to release tensions regarding personal relationships, and mostly to exchange social support. Small focus groups and individual interviews, in contrast, provided in-depth insights into the need of improved access to mental health care (i.e., referrals to specialists) that is specific to the population of low-income women. A common thread that was observed across all datasets was a need for facilitated peer-to-peer and patient-provider interpersonal communication, as well as facilitated access to health information on the mental health aspect of pregnancy and how to manage it. Topics that were repeatedly discussed within PPD social media channels, and that are excellent candidates for PPD educational content, are: mental and physical symptoms of PPD, and effects of medications on breastfeeding and infants.

4.4.2 Designing for Young Perinatal Women

Most of the study samples for focus groups and interviews consisted of young women, suggesting that digital health solutions for PPD management should be targeted to this demographic. This population regularly uses digital tools in many aspects of their daily lives, and a novel tool for managing mental health during the transition to motherhood is a welcome addition, according to previous acceptability studies (Drake et al., 2014; Hantsoo et al., 2017). As mentioned during interviews and focus groups, participants desired products containing evidence-based materials and design. Another existing gap in PPD health technologies for this population is that most available products do not implement research-based behavioral change techniques, as found in my previous review of market PPD apps (Zingg et al., 2022). It is likely that behavior change techniques such as rewards (i.e., a congratulatory message after completing PPD screening) would be effective for optimal engagement among our young population and therefore should be integrated in future digital health solutions for PPD management.

4.4.3 Designing for Interprofessional Care Delivery

Digital health technologies can improve the streamlining of mental health care, as suggested by insights from provider interviews. This is crucial in the area of perinatal mental health, where providers from various disciplines cooperate to coordinate patient care. Clinical decision support for PPD management can be better empowered through digital platforms if these deliver patient-generated data to providers. For example, if PPD screenings for a patient constantly indicate the presence of depression symptoms, a system alert could be sent to the provider. However, according to insights from provider interviews

in this study, for such digital solutions to be fully effective there needs to be a systemic-level improvement in allocation of health care resources for perinatal mental health. For instance, two of the providers interviewed in this study mentioned not having sufficient resources to refer or treat patients who exhibited depression symptoms.

Such insights were also echoed by patients, who mentioned experiencing confusion when managing their lab results due to information silos in the clinical setting (lab results could be accessed variably via phone calls or regular mail; text messaging was used to share ultrasound links). Additionally, patients are seen by many different care providers during their perinatal appointments, making it difficult for them to interact with their caregiver team and seek health information. Most patients stated that their mental health was a specific topic not discussed enough by providers, and desired increased patient education on the topic. As indicated by these gaps, digital features such as a bi-directional communication channel between providers and patients could improve interprofessional care delivery.

4.4.4 Designing for Personalized Support

Our participants mentioned a lack of digital health tools that provide personalized support throughout their unique pregnancy experiences and the postpartum period. They desired social support according to their emotional needs and health history. For instance, participants wanted reassurance about their high-risk pregnancies through clinical information. Additionally, anxiety from prior miscarriages was a theme that all participants could identify with, and they specifically wanted digital solutions to help normalize the feeling of being happy again if a miscarriage was followed by a pregnancy. They

mentioned such type of support was missing from digital health technologies available to them. Therefore, future digital solutions for PPD management should consider individuals' medical history and psychosocial characteristics (i.e., previous pregnancies, PPD experiences, insurance, income) during the design and development process.

4.4.5 Limitations

A limitation of this analysis of perspectives from PPD stakeholders is that only one clinical site was used for focus group and interviews, and more interviews in different types of sites should be done to improve the capturing of these perspectives. For example, public health clinics would be a viable setting to capture additional data and compare views of women attending an academic vs. a public health practice. An additional limitation of our study is a low sample size in our social media dataset, and possible representation bias as the content in our data may not be attributed to my target population of low-SES women. Also, Spanish-speaking women were excluded from this study. In future work, we aim to remediate these limitations by taking measures such as including Hispanic women in our samples to ensure appropriate representation, and to address factors such as language barriers by producing bilingual digital health platforms. The next steps in our research program will be to leverage our findings for optimal design paradigms in the self-management and care coordination for PPD.

4.4.6 Conclusion

In this chapter, I document and analyze the opinions of various PPD stakeholders, including low-SES perinatal women and their providers, regarding digital technology use for their mental health management. Results indicate that while participants have access to

numerous pregnancy apps, not many of these apps focus on the topic of mental health. My target population is very young and in need of technology platforms that provide tailored support based on their individual peripartum experiences. Providers also need technology to improve the integration of care across different disciplines. This analysis highlights the different settings (small in-person groups, social media) that perinatal women use and need to obtain and share information on their mental health and pregnancy. Given these different settings, perinatal women and healthcare providers need to carefully discuss and consider how to best make use of each.

Chapter 5: Designing A Health Disparities-Focused Digital Health Solution: MomMind

Interventions for PPD prevention and self-management directed towards populations affected by health disparities (i.e., low health literacy levels, limited access to care) include programs such as the "Mothers and Babies" course (Muñoz et al., 2007), which are usually administered through federally qualified healthcare centers in formats including in-person group therapy. However, such programs may not be widely accessible, and few studies have leveraged the advantages that digital technologies offer to develop scalable PPD digital solutions which are sensitive to health disparities affecting vulnerable groups of women. In this chapter, I describe my methodology for designing MomMind, a digital solution for PPD management that offers individuals social support, self-monitoring tools, and literacy-appropriate PPD education. MomMind features and content have been developed by addressing the following research questions: 1) How can I adapt and extend a generic digital development framework, such as Digilego, to integrate factors of health disparities (i.e., health literacy) in a specific population?, and 2) What are the best practices to integrate known behavior change techniques, established engagement optimizers, and tested literacy skills to elicit and sustain positive self-health management practices related to PPD in this population?

5.1 Methods

5.1.1 Feature Engineering

Theory Mapping for PPD Digital Features

My theoretical basis to make PPD self-management an easier process for a vulnerable PPD population is Mohr's BIT model (Mohr et al., 2014). This model prompts intervention

developers to answer the questions of "Why?", "How?" (Conceptual and Technical), "What?", and "When?" at the time of technology development. The main idea of the model is to define a relationship between digital features and their aims and characteristics. I have used this model for initial outlining of digital features to meet PPD user needs and put previously mapped BCTs into practice. For example, the user need for improved PPD clinical decision support (the *Why*) can be met through the BCT of self-monitoring (the *How*), and this can be operationalized through a digital feature of PPD surveys (the *What*).

Engagement Optimization

The HIMSS PEF framework (Health Information and Management Systems Society, 2014) is designed to assist healthcare organizations, such as hospitals, in creating digital platforms for their patient population. However, it can also be applied to a more specific population of patients, such as PPD patients. It consists of five categories that are cumulative in their level of engagement and complexity: "Inform Me," "Engage me," "Empower Me," "Partner with Me," and "Support my e-Community". The framework illustrates how digital features can be used to reach different patient engagement levels. For instance, if a mobile health application provides a patient with information on the days left until her pregnancy due date, this would be the PEF "Engage Me" level because it keeps the patient informed but requires no other action. However, if the application advances to provide a secure messaging function where the patient can actively make specific queries related to her pregnancy symptoms (nausea, insomnia), this would be considered the PEF "Empower Me" level. I have used the framework to outline the technical functions that can facilitate patient self-management of their health (in my case, PPD self-management). I have conducted a direct mapping from my identified PPD

information and technology user needs to the PEF framework in order to pinpoint patient engagement features that could optimally address user needs.

Digital Feature (Digilego) Components

To develop digital feature prototypes specific to PPD, I have leveraged existing Digilego core architecture. This includes the Digilego blocks "DigiMe", "DigiSocial", "DigiEHR", and "DigiConnect" (Myneni et al., 2018). "DigiMe" is dedicated to the management of individuals' personal and administrative information as related to their healthcare, "DigiSocial" enables social connections with providers and peers, "DigiEHR" provides information on the individuals' health from their recent Electronic Health Record, and "DigiConnect" collects and presents sensor data generated through health technologies (for example, personal fitness trackers). I have selected, from these available blocks, the ones that best fit individuals' information and technology needs for PPD self-management (as established from my user needs analysis, described in Chapter 4).

Digital Feature Development

I chose the application development kit Django (Django Software Foundation, 2019) for technical development of MomMind. Django is a Python-based software that allows for production of replicable and module-based web applications, fitting ideally with the Digilego digital health development framework. Originally created for fast production of news websites, Django is based on a Model-View-Controller architecture, where the first step in development is to create models for data formatting and saving (the Model object), and once the user makes a data request from a web browser (the Controller object), the selected data is presented in the user interface through HTML pages (the View object) (Savić et al., 2008). Django offers the advantage of having ready-to-use view functions,

making the development process more streamlined. The end result of my feature development is a patient-facing digital health solution to assist low-SES perinatal women in obtaining the necessary tools of symptom monitoring, social support, and education for PPD self-management. This solution has a solid foundation on established behavior change and patient engagement theories. It also has the advantage of being directly informed by perinatal women's own views and opinions, as well as PPD clinical experts' opinions. The major deliverables of my development process include content specification models, content delivery features, and implementation of behavior intervention techniques.

5.1.2 Content Engineering

Theory mapping to model the relationships among user, content, and digital environment

In my outlining of a health-disparities sensitive digital health architecture, I first conducted a direct mapping of resulting knowledge gaps, literacy needs, and topics of interest from my user needs (previously described in Chapter 4) to literacy skills and learning categories that are part of the e-Health literacy framework (Chan & Kaufman, 2011). This mapping further extends Digilego theory integration by incorporating health literacy principles into the process of content development; it specifically helps refine answers pertaining to the active ingredients that will help individuals learn basic PPD concepts. My mapping of the eHealth literacy framework to PPD management helped me model the relationship between my users and the content presented in a digital environment. An example that illustrates this mapping process is: if an identified knowledge gap among my population of interest is a general lack of knowledge on mental health, I can map this need to the related literacy task of *understanding* information about mental health. This task can be accomplished, for

example, through reading a text passage about perinatal mental health in a digital repository of health information. The eHealth literacy domains that would be applied in this task would be *computer literacy* (having the essential skills to use a computer, such as internet browsing), *information literacy (*being able to communicate information needs, and to find, assess, and apply information), *media literacy* (ability to gather knowledge from information presented in multimedia formats such as audio and video), and *health literacy* (being able to make health decisions and communicate about health matters from acquiring relevant health information). This mapping process allowed me to produce content and literacy features that are motivated by existing electronic health literacy models.

Content engineering specifications optimized for electronic health literacy

My content engineering approach consisted of translating findings from my theory mapping into the development of digital content which implements the literacy skills and tasks needed by my target population. This step was accomplished through methods including text and script writing for educational content, and multimedia content development. Text and script writing were informed by results from my previous user needs analysis and theory mapping; all scripts and text were written based on information from evidence-based resources, including research publications and professional organizations (American College of Obstetricians and Gynecologists, 2022). During content development, I employed the National Institute on Minority Health and Health Disparities Research Framework (National Institute on Minority Health and Health Disparities, 2017) as a guide to consider social determinants of health (SDoHs) to be addressed through the produced content and digital features. I particularly focused on the SDoH of health literacy, and I aimed to improve my target population's PPD health literacy

by presenting desired PPD educational topics in acceptable formats, as gathered from active input through focus groups, interviews, and social media analysis.

I incorporated active behavior change techniques from Michie's Taxonomy of Behavior Change Techniques (BCTs) (Abraham & Michie, 2008) into my content, as resulting from my mapping of BCTs to my PPD user needs. My mapping was done by selecting, from all 93 available BCTs, the ones that best addressed specific user needs for PPD self-management. For example, to address the specific user need of lack of information on mental health, my content incorporated the BCT of "Credible Source" by presenting evidence-based information to my users.

Multimedia content was developed using the software Doodlemaker (DoodleMaker, n.d.) in collaboration with scientific programmers and creative services professionals (i.e., videographers). Content selection and curation were verified in an iterative manner by seeking expert input through interviews with one PPD clinical expert and one SDoH expert. These experts were presented an overview of user needs analysis results, including major PPD themes brought up by participants in focus groups, interviews, and social media. Interviews were semi-structured, where I demonstrated a preliminary MomMind prototype and asked questions in relation to the design and content being shown (Examples: "Do you recommend any changes to the education content presented? If so, what changes?", "Are there any particular educational resources you recommend?", "Based on your experience, what feedback and recommendations do you have for the features presented in MomMind?"). The purpose of these questions was to obtain expert feedback regarding behavior change techniques and engagement optimizers that should be included in MomMind.

5.2 Results

5.2.1 Feature Engineering

Theory mapping to model the relationships among user, content, and digital environment

The specific digital components from core Digilego architecture that I have reused for PPD management include: the patient's demographic profile (*DigiMe*, which includes components of condition-specific surveys), and social engagement (*DigiSocial*, which incorporates online forums and patient education). These building blocks were used to build the four PPD Digilegos of "My Surveys", "My Library", "My Diary", and "Mom Talk". Table 8 further describes the leveraging of these components to new PPD Digilego blocks.

Table 8- Leveraging Digilego Core Architecture to Peripartum Depression

Existing Digilego and Features	Related New PPD Digilego
DigiMe: A digital representation of the patient's profile (i.e., name, age, location). Features: insurance information, transition assistance, related surveys according to target condition, and personal profile.	The "My Surveys" Digilego block is a repository of screening survey tools that can be accessed by the patient on a daily or weekly basis.
*DigiSocia*l: Encompasses digital social engagement. May include components such as online discussion forums and education sources. Features: Social hub, education, question corner, and journaling.	"My Diary": an open notebook-style tool for patients to record recent experiences and feelings. "My Library": information center where patients can search and access the latest evidence-based information about PPD, and related topics. "Mom Talk": a social media feature where patients can share their experiences and provide each other support and a sense of community.

Theory Mapping for Feature Development

Table 9 shows results of my initial mapping of the BIT model to the overall aims, technical characteristics, and workflow of the MomMind application**.** MomMind is meant to address the PPD health disparity of literacy by providing users easy access to essential knowledge, tools to track their mental wellbeing, and channels that facilitate social support.

Table 9- Mapping of BIT Model to Identify Digital Features for PPD Health Disparities.

BIT Component	Mapping to PPD (Examples)
Why	Increasing PPD health and science literacy by improving awareness of and access to PPD education materials, self-monitoring of symptoms, and social support.
How (conceptual)	Taxonomy of Behavior Change Techniques (i.e., Self-Monitoring, Social Support); eHealth Literacy Framework: Cognitive Tasks (i.e., evaluating) and Literacy Domains (i.e., health, science)
What	Digital features: (a) Catalogue of evidence-based information and research findings. (b) Bidirectional messaging with peers (c) Self-monitoring of symptoms (surveys, journaling)
How (Technical)	Web-based digital platform with modular, user-centered design. Patient Engagement Features (i.e., electronic questionnaires, self-management diaries)
When	Participant will be able to access the digital patient engagement features at any time during the perinatal period

Table 10 provides my results of mapping of BCTs to PPD Digilegos, and how these Digilego components address user needs. I have gathered user needs results from my different data sources (patients, providers, social media) and state what BCT most appropriately addresses it out of all 93 BCTs. I then show through which PPD Digilego I help the user exercise the BCT. In total, the PPD Digilego blocks activate 7 specific BCTs (Table 10).

Table 10- Digilego Results Mapping to address Health Disparities in Peripartum Depression Management

PPD Digilego	BCT Identifier	User Need
"My Diary" "My Surveys"	2.3- Self-monitoring of behavior 5.4- Monitoring of emotional consequences 15.4- Self talk	Peripartum Depression Clinical Decision Support Doctor and Patient Dyad Physical and Mental Health
"Mom Talk"	3.1- Social support (unspecified) 6.2 - Social comparison 6.3- Information about other's approval	Social and Community Support
"My Library"	9.1- Credible source	Pregnancy Education Sources of information Information on Mental Health

Engagement Features

Based on results from user needs analysis and theory mapping, I have found that the following PEF features would be particularly useful for my target population: Patient-Specific Education, Patient Access and Use, and e-Tools. These features will be used at different engagement levels ranging from "Engage Me" to "Support my e-community" (Table 11). In total, the PPD Digilego blocks present to the user three patient engagement categories (E-tools, Patient Generated Data, and Community Support) and trigger four levels of patient engagement, including the highest level of Support my e-Community (Table 11).

Table 11- Mapping of Patient Engagement Framework to Peripartum Depression Health Disparities Management

PEF Engagement Level	PEF Engagement Category and Related Features	Related PPD Digilego
Inform Me	E-tools - Health Encyclopedia	"My Library"
Engage Me	E-tools - Option to share progress and health milestones on social media.	"Mom Talk"
Empower Me	Patient Generated Data -Self-management diaries -Symptoms Assessment	"My Diary" "My Surveys"
Support my e-Community	Community Support - Online Community Support Forums	"Mom Talk"

Technical Development of Digital Features

Illustrations for the initial prototype of "MomMind" are included in Appendix B. The illustrations show: a) the main landing page for the user, where my PPD Digilego blocks are highlighted, b) the index page for "MomTalk", where the user will see recent posts from other users, c) the "My Diary" homepage, which contains a list of the user's previous diary entries, d) the "My Library" feature (contains educational whiteboard videos and links to PPD resources), and c) implementation of the Pick-a-Mood mood survey as an example of a self-monitoring assessment. Figures 11 and 12 below provide illustrations of the MomMind homepage and the Pick-a-Mood survey, and Figure 13 gives an example of the "PPD 101: What is PPD?" education module.

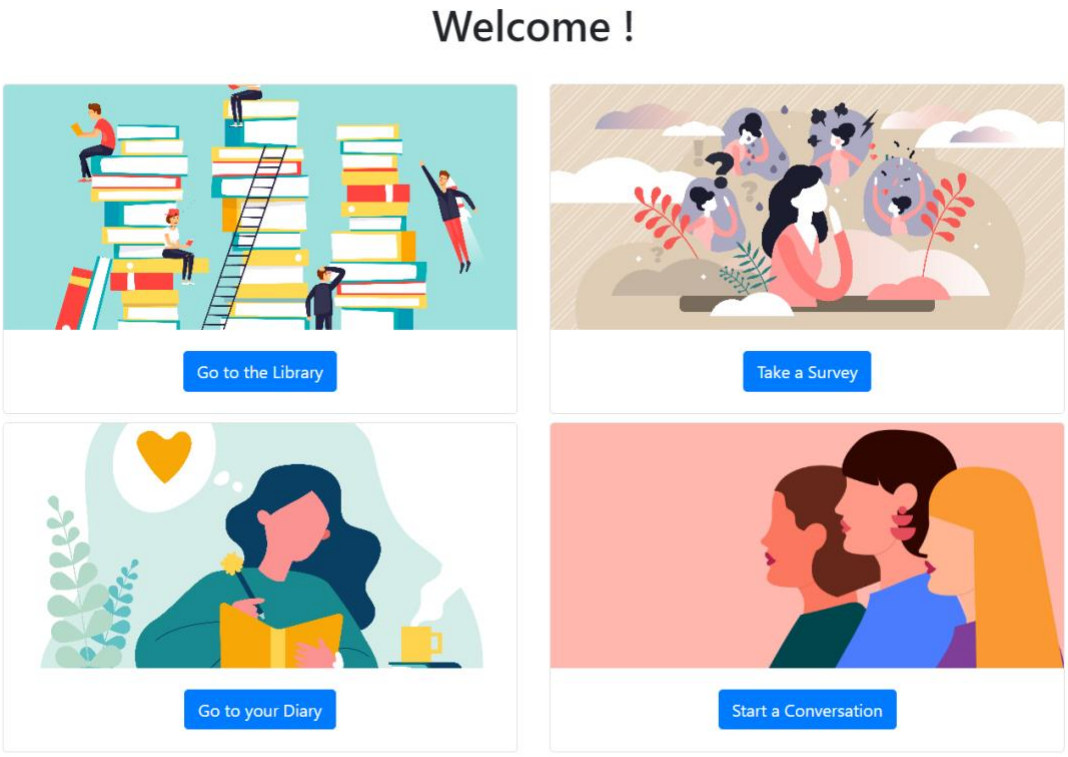


Figure 11- MomMind Homepage

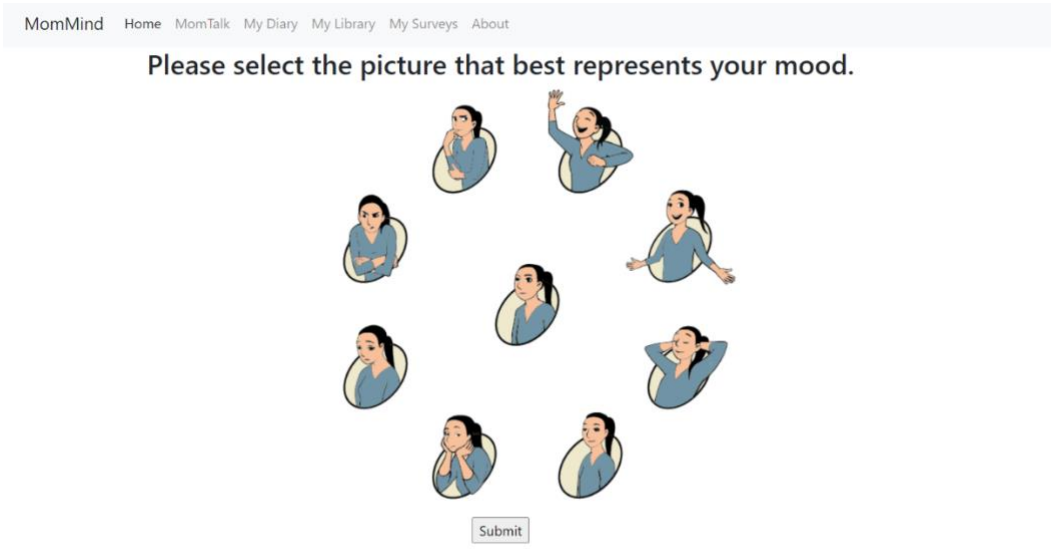


Figure 12- Pick-a-Mood survey.

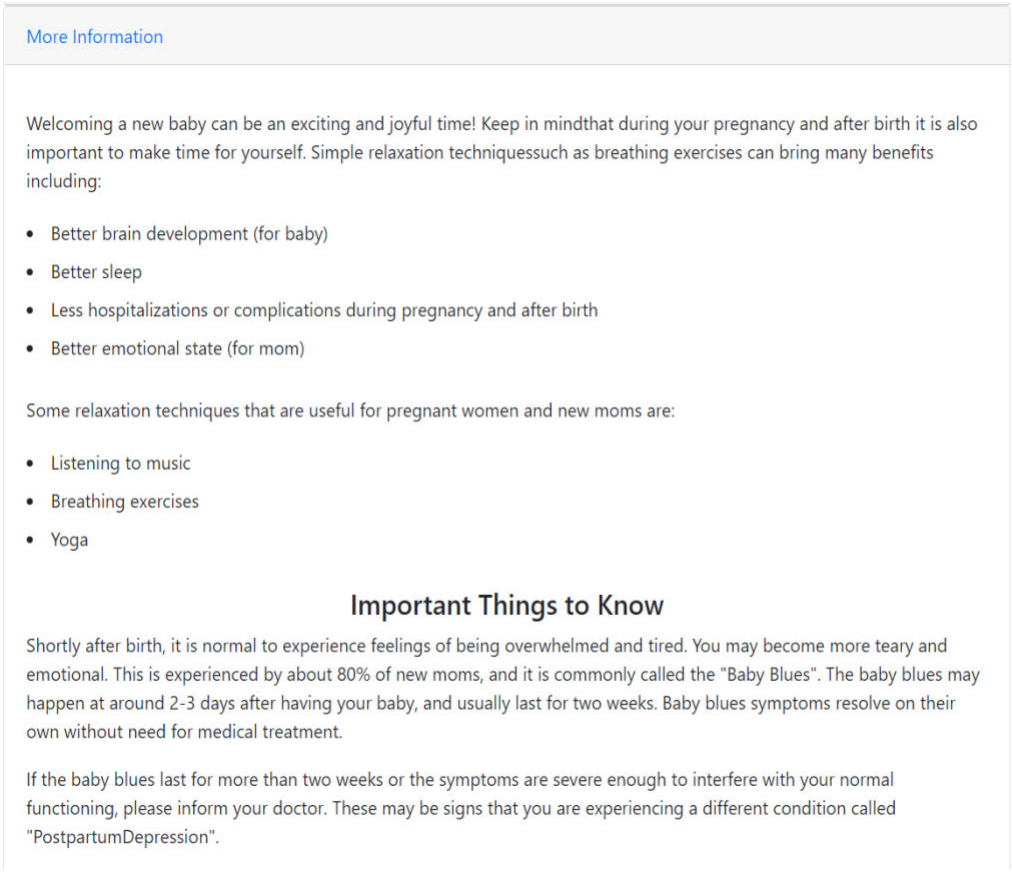


Figure 13- “PPD 101: What is PPD?” educational content example.

5.2.1 Content Engineering

Table 12 shows my mapping of user needs to literacy skills and learning categories of the e-Health literacy framework. In this table, I showcase specific cognitive tasks that my users would be completing through my digital features, and the example interactions through which they would exercise literacy techniques such as reading and writing.

Table 12- Mapping of the eHealth Literacy Framework to PPD Digital Features

Digital Features (MomMind Modules)	Applicable Literacy Domain (s)	Literacy Techniques	Cognitive Task(s)	Media Options and Example User Interactions
"My Diary": journaling feature where user can freely document their thoughts and emotions.	Science, Health	*Writing* diary entry	*Remembering* events of personal significance; *Analyzing* these events	Text Example: User writes diary entry about activity they did with their baby
"Mom Talk": Social forum component where participants can discuss PPD topics	Science, Health	*Reading* other users' posts; *Writing* by creating posts or replying to posts	*Analyzing* other's posts; *Evaluating* information in other's post	Text Example: User discusses an article about healthy sleeping habits with forum peers
"My Library": repository of evidence-based educational PPD information	Science, Health	*Viewing* educational content	*Understanding* PPD concepts presented in multimedia educational videos	Text, Video, Audio Example: User can learn about hormonal changes in the peripartum period through viewing a whiteboard video.
"My Surveys": PPD survey repository	Health	*Reading survey questions; Selecting best answer*	*Understanding survey questions; Evaluating survey results*	Text Example: User completes PPD screening presented in written format

There is an average of two behavior change techniques and one health literacy technique per each MomMind Digilego block. The behavior change techniques of social support,

social comparison, and information about others' approval are related to the social determinants of health social networks and community environment. The BCT of credible source is related to the SDoH of health literacy and medical decision making. And, the BCTs of self-talk, monitoring of emotional consequences, and self-monitoring of behavior are related to the SDoH of personal environment. Table 13 further shows my results of mapping my PPD Digilegos to the SDoH that each Digilego addresses. The content that I have developed and present through the library module particularly focuses on the SDoH of health literacy, as my participants have expressed a need for more information on mental health during the perinatal period. Each education module also incorporates links to important SDoH resources, such as scale-based community health centres, and other specialized tools including links to social workers and lactation resources.

Table 13- Mapping of PPD Digilegos to Health Disparities Research Framework.

PPD Digilego	**Social Determinant of Health**	**Domain of Influence**	**Level of Influence**
Mom Talk	Community Environment Social Networks	Physical/Built Environment Sociocultural Environment	Community Interpersonal
My Library	Health Literacy Safety Net Services	Health Care System	Individual Community
My Diary	Personal Environment	Physical/Built Environment	Individual
My Surveys	Medical Decision Making	Health Care System	Interpersonal

Expert Input Summary

Consultation with an expert on social determinants of health produced suggestions on instrumental resources that could reduce stressors from participant's daily routines and

therefore prevent or reduce their risk for peripartum depression (Table 14). Emphasis was placed on providing participants with tools to create simple and attainable goals that would improve their psychosocial environment, in a step-by-step manner. For example, the resource TrustPlus was mentioned as a way to provide participants access to financial coaching and ease their financial worries. An OB/GYN clinical expert proposed releasing all PPD education modules at once rather than weekly, with the reasoning that some patients may benefit more and earlier if they can see all modules and obtain just-in-time education on PPD to help prevent or alleviate symptoms. All PPD education modules and content have been approved by an OB/GYN clinical expert.

Table 14- Design specifications for MomMind based on expert input

Design Specification	Design specification details	Example expert quote
Links to instrumental resources	Participants will have access to tools dedicated to improving social determinants of health including income, food insecurity, and access to healthcare.	"What are the tools for me, as a human, that I need to see in my environment, that I need to create awareness around?"

Content engineering specifications optimized for electronic health literacy

As determined from my patient focus groups and interviews, my population of interest desired more information on general mental health wellness during the perinatal period. They also prefer to receive content in a format of short videos or educational text that is broken down into small sections, and that does not include technically heavy jargon. At the same time, providers recommended that information should be presented to the patient in a centralized manner, where all information can be found in one place. Therefore, I have created a repository of PPD information ("My Library") that is focused on pregnancy

education, particularly the mental health component. I present this education to the user across six modules, named the "PPD 101" video series. Each module contains a short video (around 1-3 minutes) that introduces the user to specific topics of PPD interest as determined through my user needs analysis: general knowledge on PPD (definition, symptoms), feeding the baby, sleep, family and friends, nutrition, and general tips for mental health wellness (Table 15). I selected the format of animation videos due to previous research suggesting that formats such as whiteboard videos help with information retention and understanding (Türkay, 2016). Each module also contains a brief text passage broken down into small sections and bullet points.

Table 15- MomMind Education Modules (PPD 101 Series)

Module	Module Description
PPD 101: What is PPD?	Introduction to PPD symptoms, risk factors, and available treatments.
PPD 101: Sleep and PPD	Illustrates relationships between lack of sleep and PPD, defines postpartum insomnia and provides tips on how to achieve and maintain good sleeping habits while pregnant or after birth.
PPD 101: Feeding your Baby	Provides resources and tips on breastfeeding, and provides reassurance for mothers who choose to formula feed.
PPD 101: Family and Friends	Information and tips on how family and close friends can help with providing social support during the perinatal period.
PPD 101: Eating Well	Information on necessary nutrients during the perinatal period, including cooking tips and recipes. Emphasis on preventing morning sickness and not being able to eat when experiencing depression symptoms.
PPD 101: Everyday Tips for Feeling Good!	General tips for physical and mental wellness, with emphasis on physical activity and relaxation techniques.

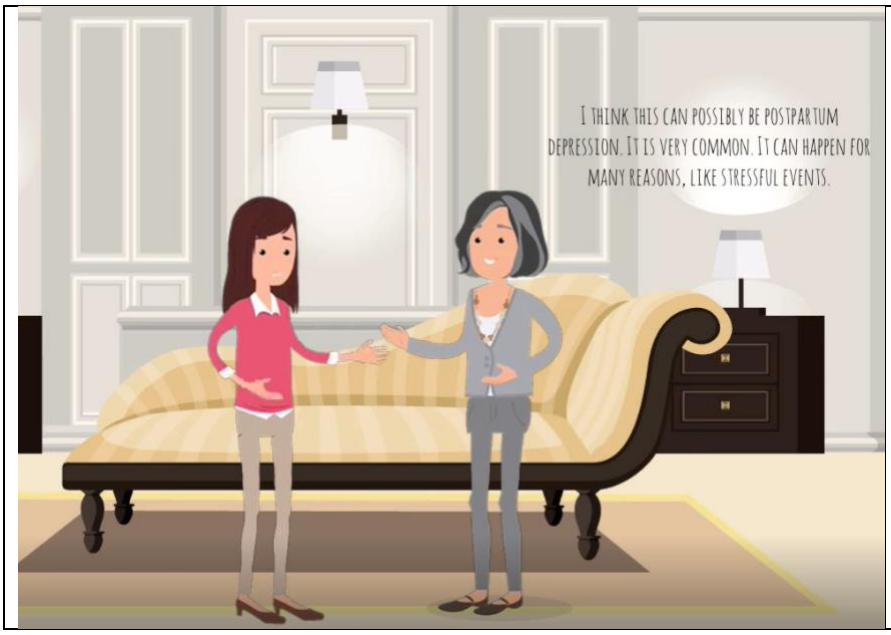
In the videos, I present the information to the user through stories told from the perspective of minority and/or low-income perinatal women characters that the user can feel identified

with. Each video addresses at least one of the behavior change techniques (BCTs) that were mapped to user needs. For example, the scripts of the videos can include positive messages that address the BCT of social support. Please see Appendix C for full documentation of scripts and related BCTs. In Table 16, I include snapshots of the introductory PPD 101 video ("PPD 101: What Is PPD?"), where a fictional low-income perinatal patient, named Jenny, is seeking advice from her mental health provider, named Dr. Peters. Throughout her conversation with Dr. Peters, she learns about the difference between PPD and the Baby Blues, which represents the BCTs of "Information about antecedents" and "Credible Source". The "PPD 101" series activates a total of 6 behavior change techniques and the two literacy domains of health and science.

Table 16- "PPD 101: What is PPD?" video snapshots

	BCT: Information about antecedents

	BCT: Information about antecedents
	BCT: Credible source

	BCT: Credible source

Videos accessed from: https://youtube.com/playlist?list=PLUlN-0kA-J1uu7spHqDIQReZUrSzAC39-

5.3 Discussion

My design and development of MomMind leverages well-established theories in the disciplines of behavior change, patient engagement, and health literacy to produce a digital health solution which, to the best of my knowledge, is one of the first to integrate all of these disciplines into a platform for disease management. Such a platform has been designed and developed while considering the unique psychosocial challenges (i.e., social stigma, low health literacy, low access to care, financial hardships) that my target population faces in their pregnancy journey. This is in contrast to other studies targeting low-income populations which have adapted existing in-person PPD interventions for electronic delivery (example: adaptation of the Mothers and Babies course into a Facebook-delivered program (Gewali et al., 2021)), or those that have digitally implemented a single PPD management task in low-resource settings (e.g., question-and-

answer text messaging system delivering pregnancy information (Song et al., 2013)). My methodology advances existing market products for PPD self-management, which are normally generic, by incorporating a comprehensive approach to SDoH (i.e., social support, education materials that are health-literacy appropriate) into the design and development process. For example, my development of the "PPD 101" series is aligned with target individuals' comments on preferring content that is of short length. The "PPD 101" series differs from existing general PPD patient education materials (i.e., content in Postpartum Support International) in that the content is brought to life through the adoption of animated video formats. Additionally, the PPD 101 video series is different from other multimedia sources like the Mothers and Babies course by covering a comprehensive range of PPD topics of interest including physical symptoms and inter/intrapersonal relationships. Limitations of my design and development include that my process of theory mapping presented in this study only employed a few select theories and frameworks. However, as shown through the results, the theories and frameworks selected have adequately addressed the research questions and purpose of this study. There is also the possibility of subjective bias in qualitative coding and analysis, however in this work the substantial interrater reliability and constant comparison helped address this limitation.

5.4 Conclusions

In this chapter, I have adapted and extended the Digilego digital health framework to integrate the following specific factors of health disparities: a) a content development strategy that incorporates electronic health literacy components (i.e., multimedia materials, brief and easily digestible information) and which is presented through storytelling with characters that my target population can feel identified with, and b) a feature development

strategy that incorporates functions of social support (a social media forum) and access to community resources that my target community may benefit from (links to social work services, financial coaching). According to my user needs analysis and the mapping of these user needs to established behavioral and patient engagement theories, the best practices to elicit and sustain positive self-health management practices related to PPD in this population include operationalizing behavior change techniques of credible information sources for PPD, social support, and self-monitoring of behavior. I have operationalized these mechanisms through further development of MomMind's technical features, which include PPD-specific screening surveys for self-monitoring, a library module that contains credible sources for PPD information, and an online forum where users can receive and provide social support. The methods presented in this chapter can be easily replicated to address health disparities present in various health conditions and domains such as diabetes, nutrition, Alzheimer's, and cancer.

Chapter 6: A patient acceptability evaluation of MomMind

The prototype version of MomMind was created with input from stakeholder interviews, focus groups, social media analysis, and clinical and public health experts. The next step was to conduct a heuristic evaluation of the prototype, as well as evaluate the acceptability of MomMind amongst my target population of low-socioeconomic peripartum women. My goals with this study were: 1) to qualitatively and quantitatively assess the initial reactions from patients to the prototype, and 2) to assess the impact of my extended Digilego framework, in which I incorporated health disparities factors, on outcomes including PPD health literacy (i.e., knowledge on essential PPD concepts) and psychosocial variables (i.e., attitudes and self-efficacy regarding PPD). The hypothesis being tested was that my proposed framework will result in positive acceptability and improved literacy and psychosocial variables. In this chapter, I describe the mixed methodology used in this study and present the results.

6.1 Methods

6.1.1 Heuristic Evaluation

A heuristic evaluation of the first prototype version of MomMind was done by two human factors experts from the Center for Digital Health and Analytics at the UTHealth School of Biomedical Informatics. Evaluators marked any design principles violations according to their severity (minor, moderate, major, catastrophic). The design principles used in the evaluation are based on the National Center for Cognitive Informatics & Decision Making in Healthcare's General Design Principles for EHRs (National Center for Cognitive Informatics and Decision Making in Healthcare, 2018) (Appendix D).

6.1.2 Acceptability Evaluation

My acceptability evaluation of MomMind consisted of cross-sectional and pre-post surveys, as well as one-on-one interviews with a sample of 30 peripartum women. The main purpose of the evaluation was to document participant's initial impressions and feedback regarding the prototype.

Inclusion Criteria

To be eligible for the study, participants had to be over 18 years old, English-speaking, and seeking pre/post-natal care at the UT Physicians Fetal Center, located within the Texas Medical Center. The clinic treats women with high-risk pregnancy conditions including preeclampsia and gestational diabetes. No individuals were excluded based upon income. Based on previous work conducting focus groups and interviews within this setting (Zingg, Carter, et al., 2021), it was expected that most participants would have an income below 185% of the federal poverty guidelines.

Participant Recruitment

Patients were invited to participate through referrals from clinical collaborators.

Patients who expressed an interest in participating were explained the study by their OB/GYN provider, and provided their informed consent. Participants were offered an incentive of a $25 gift card for their time spent completing the evaluation. This study was approved by UT Health IRB HSC-SBMI-22-0750.

Study Procedures

After participants completed informed consent, a brief electronic survey was administered to collect sociodemographic characteristics (Appendix A). Participants were then given a

brief tour and description of MomMind, and asked to complete a series of activities as follows-

1) writing a test post in MomTalk, 2) writing a test diary entry in My Diary, 3) choosing their current mood through the Pick a Mood scale, 4) completing the Edinburgh Postnatal Depression Scale (EPDS, Appendix A) (Cox et al., 1987) given through a paper copy, and 5) viewing the PPD 101 video series. Both before and after these tasks, participants completed the Postpartum Depression Literacy Scale (PoDLiS) (Mirsalimi et al., 2020). The PoDLiS instrument uses a 5-point likert scale system (1 = strongly disagree or not likely at all and 5 = strongly agree or very likely) to assess user's PPD literacy levels for the following seven attributes: ability to recognize PPD, attitudes which facilitate recognition of PPD and appropriate help seeking, knowledge and beliefs of self-care activities, knowledge of how to seek information related to PPD, beliefs about professional help available, knowledge about professional help available, and knowledge of PPD risk factors and causes (Appendix A). In the PoDLiS scale, a high score corresponds to high PPD literacy levels, while a low score indicates low levels of PPD literacy. The exceptions to this are for attitudes which facilitate recognition of PPD and appropriate help seeking and beliefs about professional help available, where a lower score corresponds to higher literacy levels for these attributes. The scale has substantial internal consistency as measured by Cronbach's alpha coefficient ($\alpha = 0.78$).

Once participants finished all tasks, they completed Weiner's battery of Acceptability of Intervention Measure, Feasibility of Intervention Measure, and Intervention Appropriateness Measure (Weiner et al., 2017). These are three separate 4-item Likert scales. The purpose of using these measures was to quantify participant's acceptance and

perceived feasibility and appropriateness of the prototype. The Cronbach's alpha for the Acceptability of Intervention scale is α= 0.85, while the Feasibility scale has α= 0.89, and the Appropriateness scale has α= 0.91. Finally, a one-on-one exit interview was conducted where participants verbally shared their satisfaction with the prototype. Interview questions were based on the Integrated Behavioral Model (previously described in Chapter 3), a model that merges constructs from the Theory of Reasoned Action and Theory of Planned Behavior (Glanz et al., 2008a) (Table 17).

Table 17- MomMind Exit Interview Questions

Construct	Interview Question
Experiential Attitude	How do you feel about the idea of using MomMind? What did you like the most about MomMind? What did you like the least?
Instrumental Attitude	What are the benefits that might result from using MomMind? What are the negative effects that might result from using MomMind?
Normative Influence	Who would support your using MomMind? Who would be against your using MomMind?
Perceived Control	What things make it easy for you to use MomMind? What things make it hard for you to use MomMind?
Self-Efficacy	If you want to use MomMind, how certain are you that you can?

As part of the exit interview, participants also completed a brief feedback survey focused on the educational content of MomMind. The survey is adapted from existing literature pertaining to digital interventions addressing health literacy (Valera et al., 2021) and contains five Likert-scale items (1= Strongly Disagree, 5=Strongly Agree): 1) The PPD 101 videos helped improve my basic understanding of peripartum depression, 2)Would you recommend the PPD 101 videos to friends and family?, 3)The PPD 101

videos were easy to understand, 4) I enjoyed the graphics and audio of the PPD 101 videos, and 5) I would want to watch other PPD 101 videos to learn more.

Data Analysis

As part of the acceptability evaluation, I conducted descriptive statistical analysis for all acceptability survey results. Participant demographics were also analyzed in this manner. For analysis of PPD health literacy scores, pre-and-post intervention mean scores were calculated, and statistically significant differences were assessed using the Wilcoxon-Signed Rank Test (Rosner, 2011). For interviews, transcript data was entered into the qualitative analysis software Dedoose and analyzed using grounded theory analysis (Strauss & Corbin, 1997) (previously described in Chapter.5). One researcher independently coded all interview transcripts, and a second researcher coded five interview transcripts to ensure objectivity. An iterative process of code comparison was used to ensure code consistency and agreement, and from this a resulting final list of major MomMind acceptability themes in participant interviews was produced.

6.2 Results

6.2.1 Participant Characteristics

The study sample consisted of 30 perinatal women, of whom 29 completed the demographic survey. The majority were Hispanic (n=16, 55%), followed by non-Hispanic White (n=9, 31%). Fewer identified as Black (n=3, 10%), or Asian (n=1, 4%) (Figure 14).

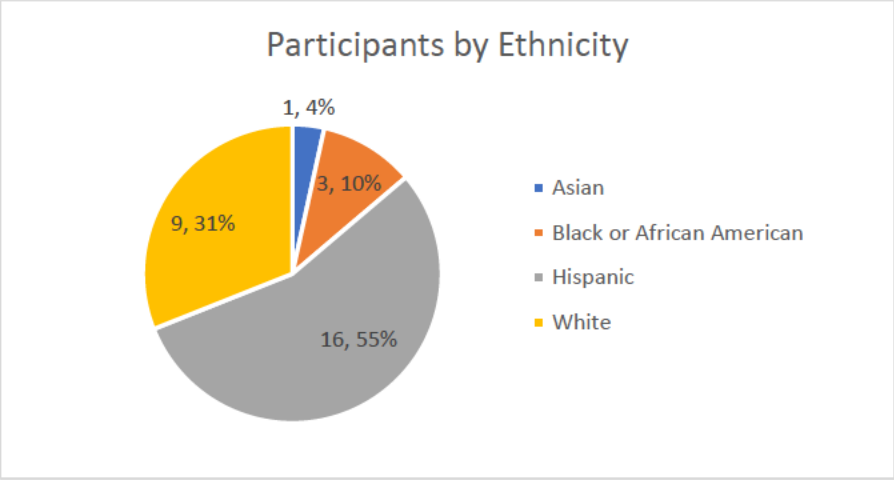


Figure 14- Participant Characteristics

Twenty-one percent of participants (n=6) had household earnings between $25,000-$39,999, and another six had earnings between $40,000-$69,999. Seventeen percent lived in households earning less than $25,000 (n=5), and an equal number lived in households earning $150,000-$199,999 (Figure 15). In total, 17 out of 30 participants resided in households of low-income ranges.

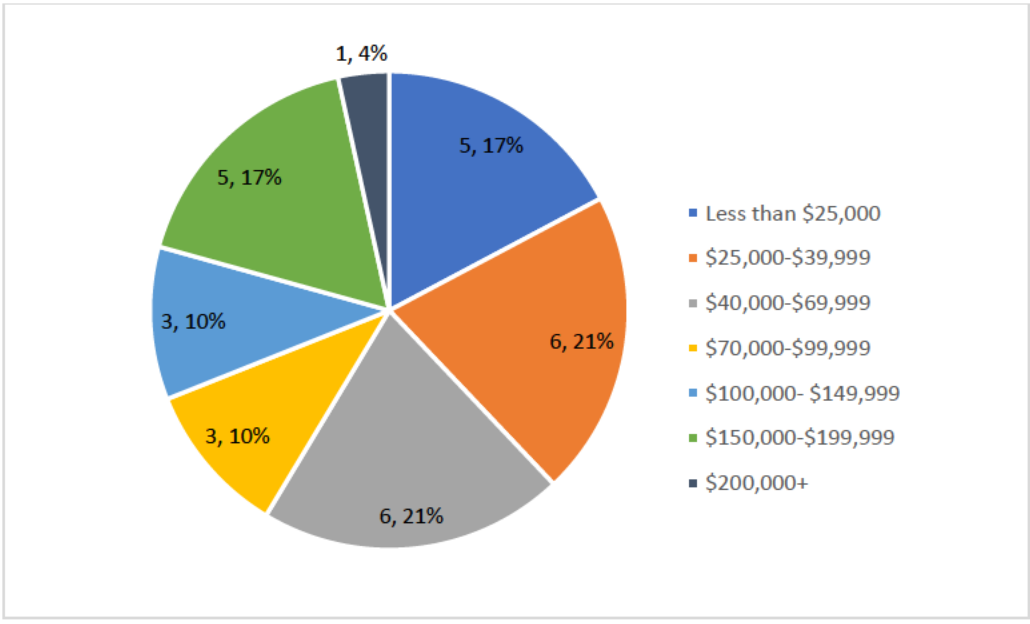


Figure 15- Participants by Income

A total of 8 individuals (28%) had completed a Bachelor's Degree, while six (21%) obtained a High School Diploma and another six had some college credit (Figure 16).

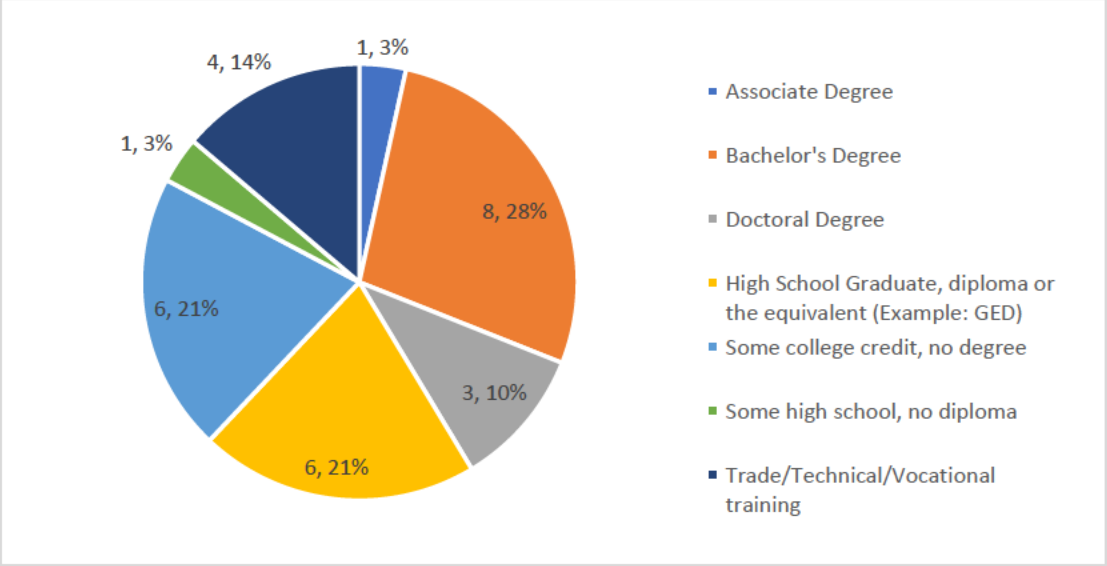


Figure 16- Participants by Education

The average EPDS score for individuals was 6.6 (out of a possible 30), with a minimum of 0, maximum of 19, and standard deviation of 4.45. An EPDS score of 10 or higher indicates possible depression, and in this study a total of 8 participants had EPDS scores falling within that range.

6.2.2 MomMind Acceptance, Appropriateness, and Feasibility

Acceptability

Ninety-six percent (29/30) of our sample agreed or completely agreed with approval of MomMind, while 23 participants highly welcomed it, 21 completely liked it, and 19 found it very appealing (Figure 17).

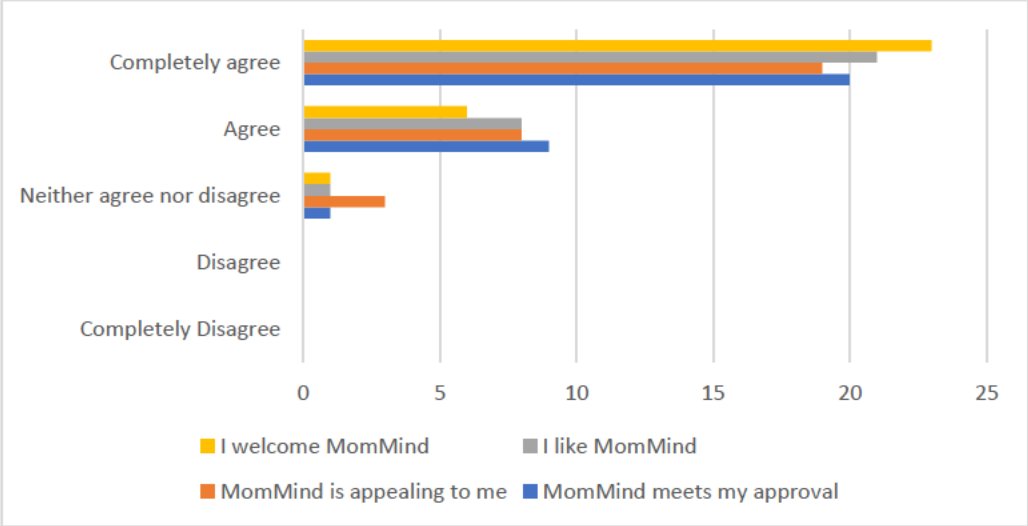


Figure 17- MomMind Acceptability

Appropriateness

For appropriateness measures, 28/30 (93.3%) participants deemed MomMind a good fit. Results revealed that the majority of participants (73.33%, n=22) responded "Completely Agree" to the statements "MomMind seems like a good match" and "MomMind seems applicable". Seventy percent (n=21) of participants completely agreed with "MomMind seems fitting" and 63.3% (n=19) with the statement "MomMind seems suitable" (illustrated in Figure 18).

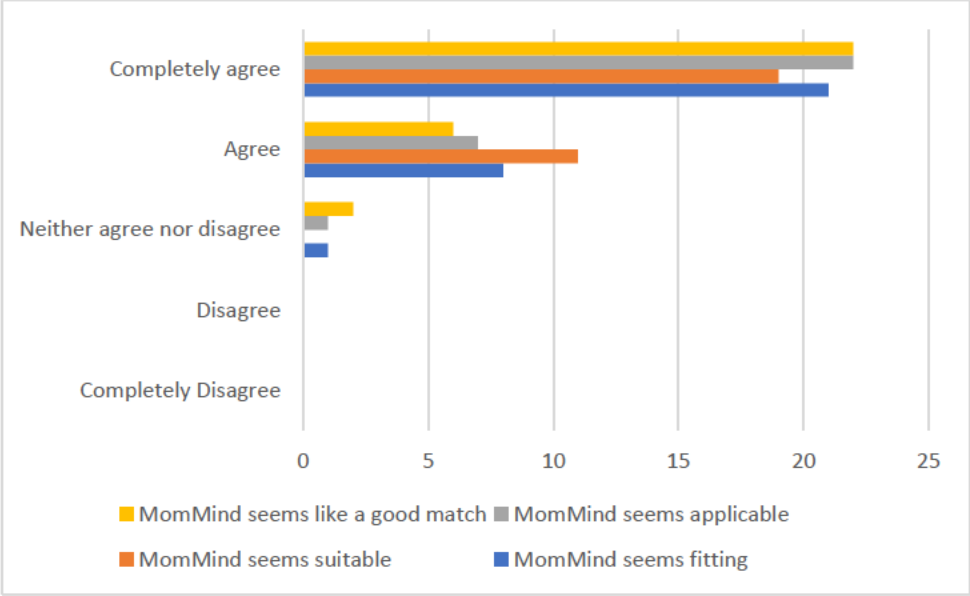


Figure 18- MomMind Appropriateness

Feasibility

The majority of participants completely agreed with statements regarding the feasibility of MomMind. Specifically, 80% (n=24) completely agreed with "MomMind seems easy to use", 70% (n=21) with the statement "MomMind seems doable", 66.67% (n=20) with the statement "MomMind seems possible", and 63.33% (n=19) with the statement "MomMind seems implementable" (Figure 19).

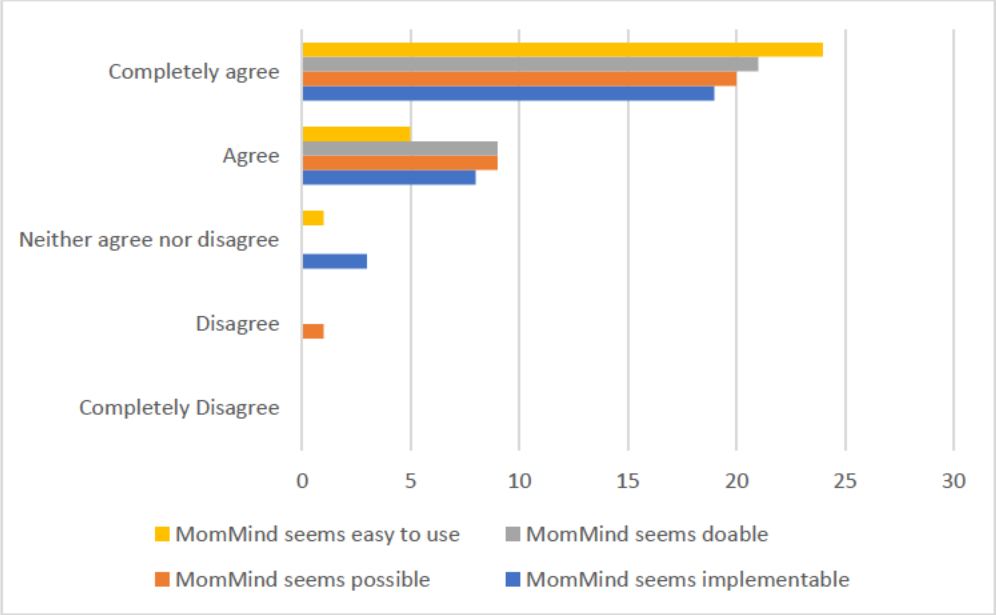


Figure 19- MomMind Feasibility

6.2.3 MomMind Content Evaluation

Twenty-four out of thirty individuals (79%) were above neutral (agreed) to the statement that they would recommend the PPD 101 videos to friends and family. Ninety percent (27/30) agreed that the PPD 101 videos were easy to understand. Twenty-five (83.34%) agreed that they enjoyed the graphics and audio of the videos, and an equal number wanted to watch other PPD 101 videos to learn more (Figure 20).

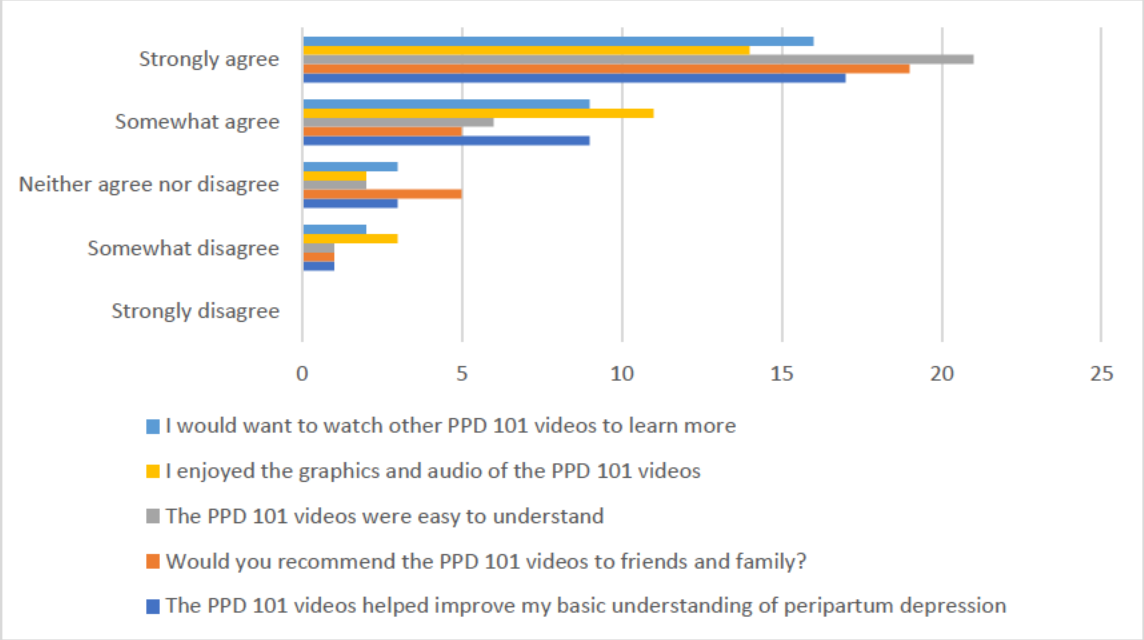


Figure 20- MomMind Content Evaluation

6.2.4 Participant Postpartum Depression Health Literacy

a) Ability to recognize postpartum depression: Most participants selected "Somewhat Agree" to the statements "Feeling unusually sad and teary may be a sign of postpartum depression" (n=21), "Loss of interest or pleasure in most things may be a symptom of postpartum depression" (n=14), "Eating too much or losing interest in food may be a sign of postpartum depression" (n=13), and "Sleeping too much or too little may be a sign of postpartum depression" (n=11). Most participants strongly agreed with the statement "Postpartum depression affects a person's memory and concentration" (n=13). A majority of nine participants neither agreed nor disagreed with the statement "Symptoms and signs of postpartum depression last for a period of at least 2 weeks" (Figure 21). On a Likert scale of 1-5, participants' average score on ability to recognize PPD at pre-intervention was 3.89, and post-intervention the

average score was 4.25, a statistically significant improvement. For participants of low-income ranges (n=17), average score at pre-intervention was 3.69, and at post-intervention it was 4.03. This change is not statistically significant.

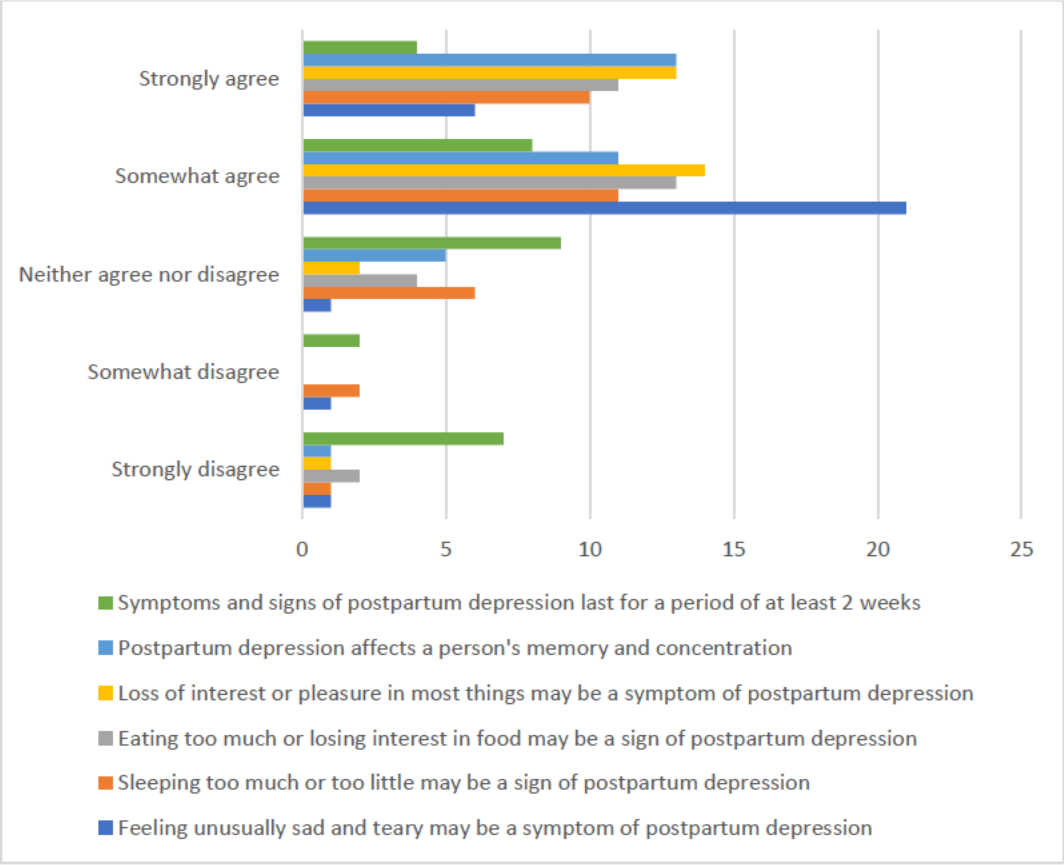


Figure 21- Ability to recognize postpartum depression

b) Knowledge of PPD risk factors and causes: Most participants strongly believed that postpartum depression could be caused by stressful life circumstances (n=19), lack of social support (n=17), a previous history of depression (n=16), or a hormonal imbalance (n=16). Fourteen somewhat believed that postpartum depression could be caused by a genetic disorder (Figure 22). Participants' average score on knowledge of PPD risk factors and causes was 4.23/5 pre-intervention, and 4.27/5 post-intervention, showing no statistically significant change. For participants of low-income ranges,

changes were also not statistically significant with average score at pre-intervention being 4.12, and at post-intervention 4.17.

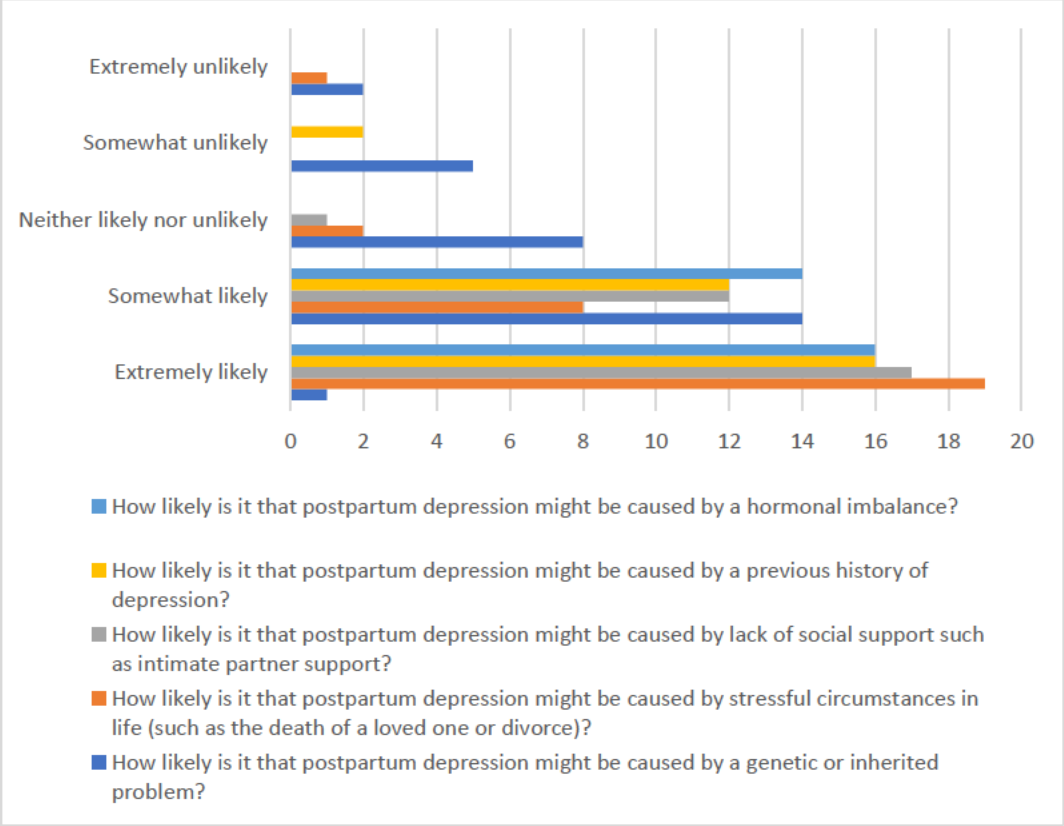


Figure 22- Knowledge of PPD risk factors and causes

c) Knowledge and beliefs of self-care activities: most participants (n=18) strongly agreed with the statement "Seeking help with tasks like infant care and household chores from intimate partners and family members is helpful for the prevention or management of postpartum depression", and a majority (n=17) somewhat agreed with the statement "Physical activity is effective for the prevention or management of postpartum depression". Fourteen of 30 participants strongly agreed that good sleep is helpful for prevention or management of postpartum depression (Figure 23). Participants' average score on knowledge and beliefs of self-care activities was 4.05 at pre-intervention, and

4.28 post-intervention. This was a statistically significant improvement. For participants in low-income ranges, average score at pre-intervention was 3.98, and at post-intervention it was 4.23, a change that is not statistically significant.

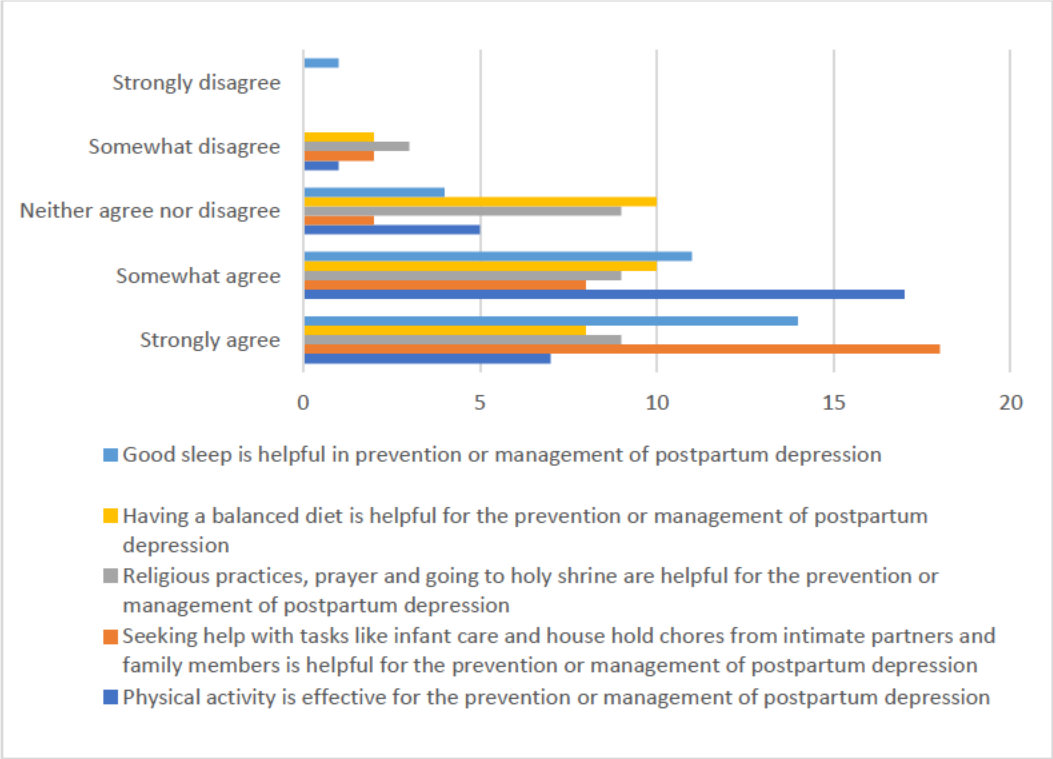


Figure 23- Knowledge and beliefs of self-care activities

d) Attitudes that facilitate PPD recognition and help-seeking: The majority of participants (n=22 out of 30) strongly disagreed with the statement "It is best to avoid women with postpartum depression so that you don't develop this problem", and n=18 strongly disagreed with "I am afraid of what my family and/or friends might think of me for attending psychology and/or psychiatry appointments". Most were neutral on the statement "Although there are clinics for postpartum depression, I would not have much faith in them" (n=18). Half of participants (n=15) strongly disagreed with the statement "If I had postpartum depression, I would not tell anyone". Twelve somewhat

disagreed with the statement "I would rather live with postpartum depression than go through the ordeal of getting psychiatric treatment". An equal number of ten partcipants were neutral or somewhat disagreed with "Most women who have postpartum depression are violent" (Figure 24). Please note that for this PPD literacy attribute, a lower score represents a higher level of literacy. Pre-intervention average score in attitudes that facilitate PPD recognition and help-seeking was 1.98, and post-intervention average score was 1.86. This was not a statistically significant change. Participants in low-income ranges had an average pre-intervention score of 2.01, and at post-intervention it was 1.79, a change that is also not statistically significant.

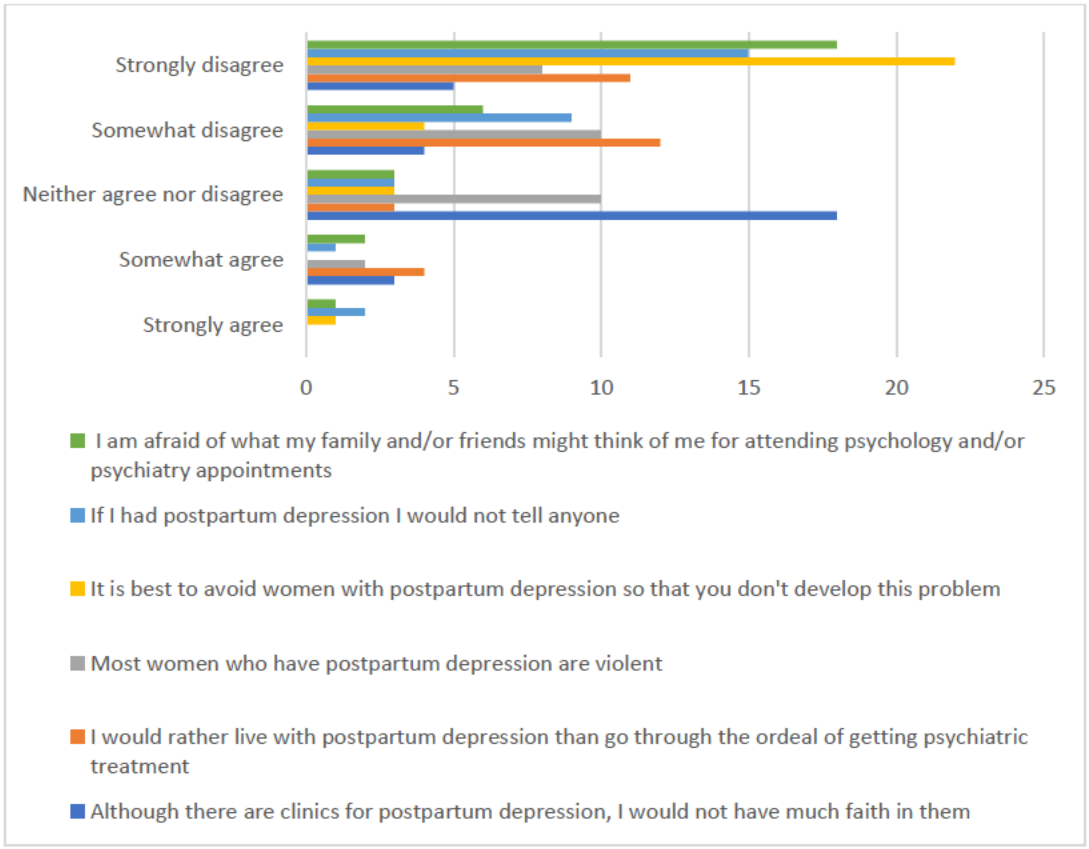


Figure 24- Attitudes that facilitate PPD recognition and help-seeking

e) Knowledge and beliefs about professional help available for PPD: Seventeen out of thirty participants somewhat agreed with the statement “Psychotherapy (for example, talking therapy or counselling) can be effective in treating postpartum”, and sixteen somewhat agreed that “Treatment for postpartum depression, provided by a mental health professional, can be effective”. Regarding beliefs about professional help for PPD, most participants were neutral on the statements “Antidepressants cause brain damage” (n=18 being neutral) and “Antidepressants are addictive” (n=16 being neutral) (Figure 25). Please note that lower scores for items on beliefs about professional help for PPD indicate a higher level of literacy for this attribute.

   Average score for items on knowledge about professional help available for PPD was 4.28 at pre-intervention, and 4.32 at post-intervention, showing no statistically significant change. Participants in low-income ranges had average pre-intervention score of 4.27 and post-intervention average of 4.29, showing no statistically significant change. For items on beliefs about pharmacological interventions for PPD, pre-intervention average score was 3.05, and post-intervention average score was 2.93. This change was not statistically significant. For low-income participants, changes in score were also not statistically significant (pre-intervention average= 3.32, post-intervention average=3.00).

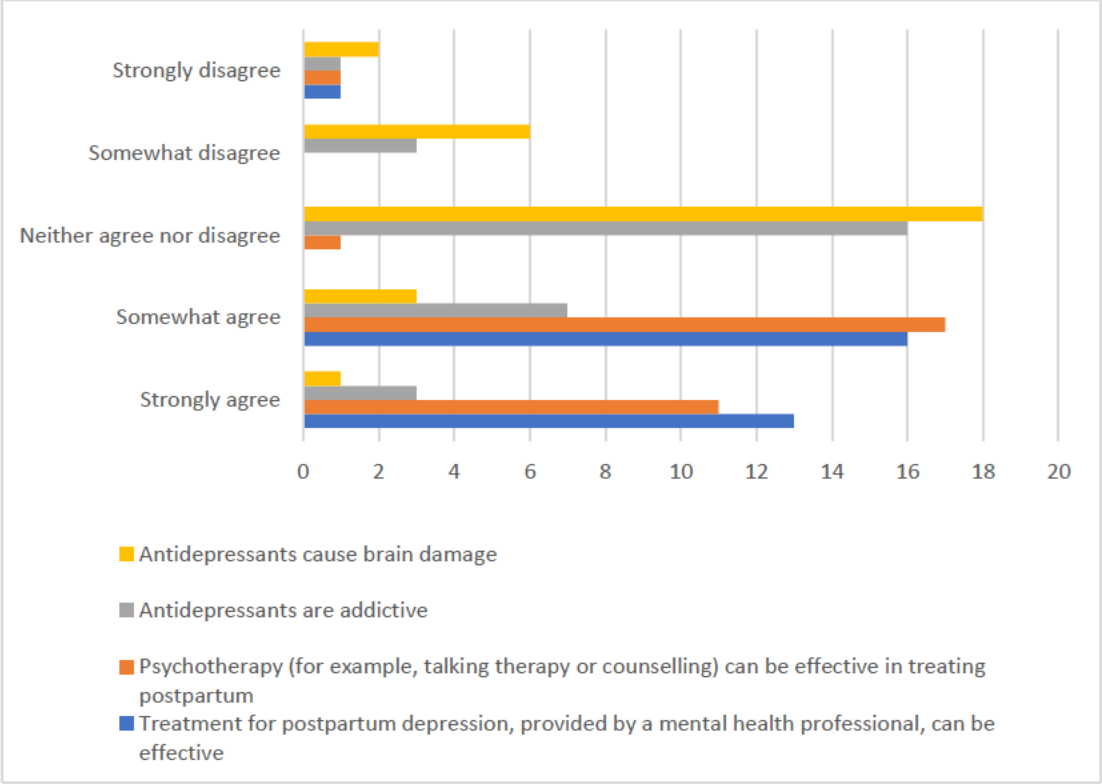


Figure 25- Knowledge and beliefs about professional help available for PPD

f) Knowledge of how to seek information related to PPD: Sixteen of thirty participants somewhat agreed with the statements "I know where to seek information about postpartum depression" and "I know how to use various sources to seek information about postpartum depression". Fourteen were neutral on the statement "I can appraise the accuracy of information about postpartum depression on the Internet" and thirteen were neutral on the statement "I can appraise the accuracy of information about postpartum depression on the radio and television". Eleven out of thirty participants somewhat agreed with the statement "I can appraise the accuracy of advice about postpartum depression given by friends and family" (Figure 26). Average pre-intervention scores for knowledge of how to seek information related to PPD was 3.49, and at post-intervention it was 3.79, a statistically significant improvement.

Participants in low-income ranges also showed statistically significant improvement, with an average pre-intervention score of 3.31 and an average post-intervention score of 3.64.

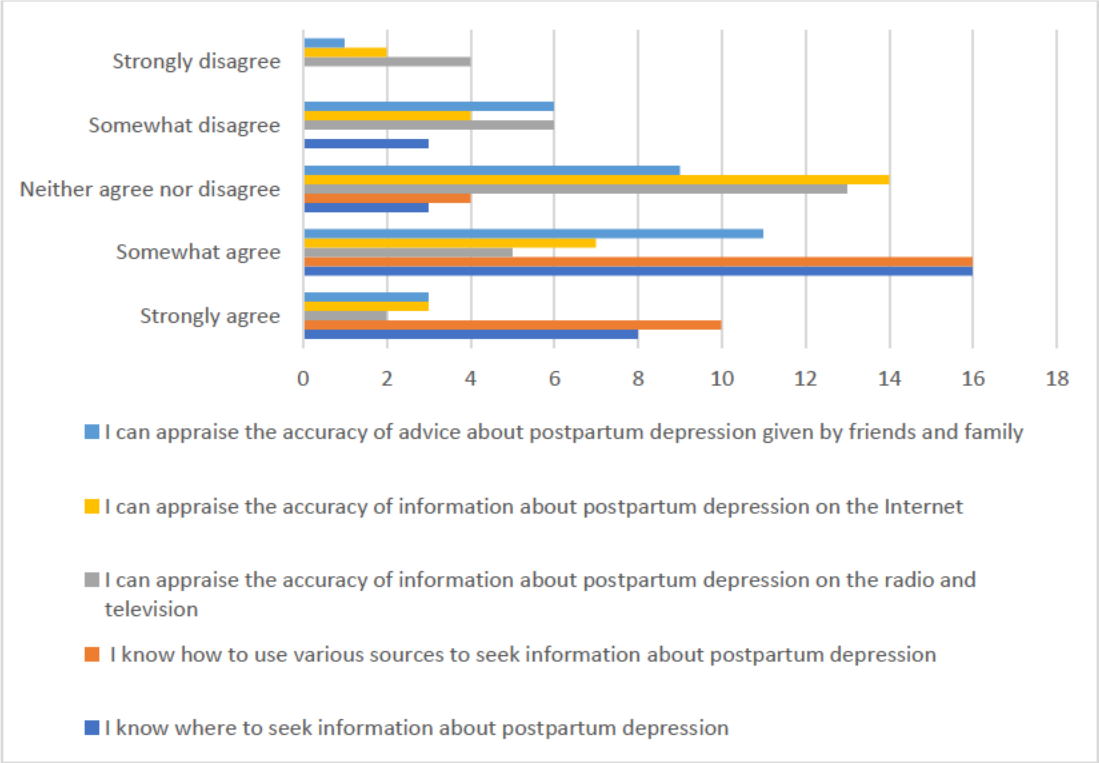


Figure 26- Knowledge of how to seek information related to PPD

6.2.5 Interview Themes

Analyses of individual interviews revealed the following core themes:

a) Positive Characteristics of Feature Design: Individuals commented on the application's clear structure and their ability to navigate it.

P2*: "It's really good because it wasn't difficult to navigate. It's pretty precise in what it is, so if you go to the library, you know what it is, if you want your diary, you know what it is…"*
P21*: "It's pretty user friendly. There's nothing about it that was confusing or suspicious to me"*

P28*: "I think the layout is really nice. It's easy to kind of walk through it and you can see definitely, what each of the tabs are in each section there. I think it'd be pretty easy to move through and access"*

b) Influencers: Comments where individuals expressed the encouragement they would receive from their family members, medical team, and others in using MomMind.

P9: *"[My sister] I kind of complained to her a lot. Her knowing that there's something like this application, she'd probably tell me to turn to it…"*
P21: *"I'd say my fiancé would be pretty supportive. He's very much into mindfulness"*
P18: *"I would say probably the younger generation. So people my age that are really intimately familiar with apps"*

c) Benefits of app for PPD prevention: Individuals mentioned the benefits that each individual feature provided for PPD prevention. For example, benefits of the MomTalk forum included social connections and a sense of support.

P1: *"We'll learn reading from other mothers that may have experienced the same thing you're experiencing at the moment. You'll have it right there. And you'll be able to talk to the women upfront".*
P28*: "I like the diary portion because I can kind of 'Oh, this happened on this day'. Having a digital copy would be really helpful, and just having the resources to look things up and videos as well".*
P21*: "I liked it. For most people who don't want to talk about something, but like having a resource"*

d) Recommendations for Improvement: During interviews, participants had recommendations for improving MomMind content. Participants mentioned the addition of voice-over features and changing of text font in the videos to better fit their need for on-the-go multi-format content (audio, text, video). Other features like application calendars and reminder notifications were also recommended by participants. Example comments:

P21: *"I think it'd be cool if the video had a voice-over or something because I listen to things a lot while I'm at work".*

P30*: "If I had to suggest anything it would be like a calendar, I guess to send alerts"*
P2*: "If I had any personal barriers [to using the app],it would be needing little pep talks, like, you want to get something off your chest, or you know, your doctor's appointment is coming up, just logging in"*

e) Modern Aspects of App: Participants appreciated the dedication of the app to the topic of PPD and recognized that the topic had a broach reach and could help many women; they also commented on how having PPD prevention features (i.e. diary, surveys, library) in a single centralized system was something they had not previously seen in other apps. Example comments:

P11: *"I've never seen an app where you could be connected to others like that. I mean, obviously Facebook, but not for something specific like pregnancy."*
P1: *"I feel like this would help anybody who doesn't want to ask questions outright. Instead, they can look and see what they learn on here first, before they ask their doctors questions."*
P14: *"I think it's nice because you have one place to go for everything. You have resources, you can also talk to other people, which can be helpful sometimes, or you can just write to yourself. So, I think it's good."*

6.3 Discussion

Our survey results indicate that MomMind is positively accepted by our sample of peripartum women, who are majority low income or minority populations. These results are consistent with previous works regarding the benefits of using digital technologies among low-income peripartum women; an example of such a study is that by Bhat and colleagues (2018), where 94% of a sample of low-income rural peripartum women in Washington state found the format of two-way text messaging to be helpful as a supplement to patient education and care management for depression. Additionally, after interacting with MomMind and seeing the features and content which were produced through a health disparities-focused focused framework, our participants showed significant improvements in some PPD literacy attributes. It is very likely that a longer

interaction time with the tool would result in even more PPD literacy improvement. The PPD 101 content presented to participants was positively accepted, in particular its reliable information resources and its multimedia design. Participants indicated that the content sparked their interest in learning more about PPD and showing to others.

During our evaluation interviews, individuals identified many benefits of the application, including creditable mental health information and the ability to socialize with others. Individuals also deemed the application to have a simple design and ease of navigation, both seen as positive characteristics. However, MomMind also had room for improvement in areas such as providing informational feedback after completion of surveys. Individuals also recommended inclusion of additional features such as notifications, calendars, and stratifying participants in forums by due date. Such recommendations are to be considered for future iterations of MomMind.

This evaluation is not without limitations. The goal of the heuristic evaluation was to identify problems of usability within the MomMind system in a fast manner. Human factors experts marked seven design violations of minor severity in MomMind, in the areas of match, memory, visibility, and language. Five violations of moderate severity were marked for the areas of control, visibility, match, and memory. There were also five violations of major severity in the areas of match, visibility, feedback, error messages, and closure. One catastrophic violation was marked in the area of undo due to the application not providing features for users to edit or delete social posts or diary entries. All usability problems identified during the evaluation will be addressed through revising the MomMind user interface according to the evaluators' observations. As an example, new form templates for editing and deleting posts (MomTalk posts, diary entries) may be introduced

in th future versions. Another limitation of our study is that participants had a limited time of interaction with the application, and a longitudinal study may provide a more thorough assessment of participant's experiences with MomMind. However, one advantage of a cross-sectional study design is the reduction of attrition rates that is common in longitudinal studies of digital health technologies (Dalton et al., 2018). This study also has limitations in the representation and generalization of the study sample. For example, Spanish-speaking women were not included in the study. Future works should consider bilingual materials that allow recruitment and participation of women who donot speak English.

6.4 Conclusion

In this Chapter, I describe the procedures used for evaluating MomMind and the evaluation results. An integrative digital health development framework that is considerate of health disparities factors (such as potential users' health literacy) has produced a digital platform that has been widely accepted by our participant sample consisting of mostly low-income or minority peripartum women. These results support my hypothesis that a platform built using enhanced Digilego frameworks with specialized focus on health disparities (in my case health literacy) would be acceptable and result in improved health literacy for its intended end users.

Chapter 7: Innovation and Contributions

7.1 Innovation

Health disparities affect an increasing number of people in the U.S. and around the world. At the same time, digital health technologies are becoming ever more present in all areas of healthcare, from pharmaceutical management to individual lifestyle choices like diet and exercise. Therefore, it is imperative to find and implement digital health development strategies that are responsive to and integrative of the unique profiles and needs of populations that are prone to experiencing health disparities. The main innovative aspect of this dissertation is that it presents a digital health framework which integrates SDoH factors (i.e., health literacy) into the design and development process. This is an important addition to the field, as few studies have produced digital health technologies in such a manner to help prevent or reduce health disparities. Innovative components of this study are: a) it integrates siloed theories from behavior science, health literacy, and human factors engineering into a single approach towards addressing health disparities, b) it adapts the existing digital health framework Digilego for health disparities, making this one of the first research studies that addresses multi-level factors (e.g., self-monitoring, peer interactions, clinician interactions) underlying disease management in a disadvantaged population and contributing to research on health disparities by linking social determinants of health to the technology development process, and c) this dissertation resulted in a new digital health intervention that is capable of capturing various patient-generated data points (e.g., ecological momentary assessments for measuring depression symptoms and mood) in disease management, with a unique emphasis on collecting and analyzing these variables

from a disadvantaged population of peripartum women seeking care in a clinic specializing in high-risk pregnancies.

7.2 Contributions

7.2.1 Theoretical Contributions

While there are established behavior change theories that have been integrated within digital health design and development processes, most efforts have been directed towards the general population and there are limited number of studies which have tested their effectiveness among vulnerable populations. This dissertation presents a methodological framework that creates a bridge between health disparities and digital health technology development. It expands the design and development process to consider the unique information and technology needs of vulnerable populations, and also addresses health literacy factors of readability and comprehension through multimedia storytelling. Through the infusion of theories and models such as the BCT and PEF, I arrived at the implementation of digital features and content that are meant to assist my target population in becoming more articulate and knowledgeable when discussing their healthcare plans and making healthcare decisions as pertaining to their pregnancy and mental health journey.

7.2.2 Informatics Contributions

This dissertation offers various informatics contributions: a) it gathers user needs data from a vulnerable population of patients and providers through traditional methods (focus groups, interviews) and then transforms this data into information to be integrated within a health-disparities focused digital health solution from a human factors perspective. As an

example, our identified user needs for increased mental health knowledge was operationalized into a digital library of evidenced-based educational resources, and b) it leverages social media analytics methods to gather large-scale user data and supplement our user needs analysis by providing us with content topics of interest as well as the nature of user communications.

7.2.3 Public Health Contributions

Populations that are prone to health disparities, such as immigrants and minorities, will make up the majority of the U.S. population by the year 2050 (Pew Research Center, 2008). Additionally, mental health disorders such as peripartum depression are a significant public health issue that generate emotional, physical, and financial hardships for individuals, their families, and society as a whole. This dissertation provides public health professionals with specific operational pathways (e.g., gathering of user needs, theory infusion) to engage these populations and design and develop public health interventions targeted towards groups of people who may need it the most. It shows a novel mixed-methods approach to gathering user needs data from the granular level of interviews to the population-level overview of social media channels, allowing interventionists to address population health issues through a comprehensive and robust methodology. Furthermore, this dissertation shows that such mixed methods for design and development can indeed improve outcomes of health literacy for individuals of low-income and minority backgrounds. This is a significant achievement indicating that tools like MomMind can be leveraged to improve population health outcomes.

7.3 Summary of Results

This study identified unique information and technology needs among disadvantaged peripartum women. These needs included more patient education in the area of mental health (presented through materials that are easy to understand, and covering particular topics of PPD importance as indicated through our social media analysis), a sense of community, and digital features and content that are engaging and to which the user can feel identified with. Based on these needs, a digital health solution for PPD prevention named "MomMind" was designed and developed. This solution offers the user the opportunity to obtain social support, self-monitoring tools, and patient education (PPD 101) through a single digital system. This tool also activates specific cognitive and literacy domains based on theory integration through frameworks such as the Behavior Intervention Technology Model, the Taxonomy of Behavior Change Techniques, and the Patient Engagement Framework. As a result of this careful user needs analysis and theory mapping, MomMind had tremendous acceptance and approval rates. Additionally, the intervention significantly improved knowledge on how to seek PPD information among my target population of low-SES peripartum women. The generalizability and the power of this study to find significant pre-post intervention differences may be affected by a small sample size and a lack of a control group. However, the purpose of this study was to examine the initial feasibility and effectiveness of MomMind. The aim of this study was not to produce conclusive and decisive findings that are characteristic of more advanced study designs (e.g., randomized control trials), but instead to collect preliminary pilot data.

7.4 Future Directions

Future work should further evaluate the enhanced digital health framework presented in this study by implementing it among different populations and examining whether it produces similar results regarding outcomes such as health literacy or other health disparities factors such as access to care. Digital health tools such as MomMind can be expanded to cover a wide range of health topics, not just in the domain of peripartum depression but in many other domains. For example, the tool can be expanded to cover pediatric wellness by including more education modules about infant health and infant health trackers. In the long-term future, the tool can also be scaled up and be implemented in multiple clinical settings (e.g., Psychiatry, OB/GYN, Neonatal Intensive Care Units) through integration with electronic health records, which would facilitate patient care and interdisciplinary collaboration. In the more immediate future, the work to be done for MomMind will include: a) inclusion of Spanish-speaking women in user needs analysis, b) surveying additional PPD experts for further refinement of optimal behavior change techniques and strategies to meet the information and technology needs of low-SES women in preventing and managing PPD, c) exploring the application of other theoretical frameworks for areas such as intervention implementation (i.e. the RE-AIM Framework) (Holtrop et al., 2021), d) production of PPD 101 content in multiple languages and dissemination in clinics and community centers, and d) conducting longitudinal evaluation studies.

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Appendix A

Surveys and Questionnaires

Participant Survey

Q1 What is your age?

- ○ 18-24 years old (1)
- ○ 25-34 years old (2)
- ○ 35-44 years old (3)
- ○ 45+ years old (4)

Q3 What is your gender?

- ○ Male (1)
- ○ Female (2)
- ○ Other (3) _____
- ○ Prefer not to answer (4)

Q4 Which best describes your race?

- ○ White (1)
- ○ Black or African American (2)
- ○ American Indian or Alaska Native (3)
- ○ Asian (4)
- ○ Native Hawaiian or Pacific Islander (5)
- ○ Other (6) _____
- ○ Prefer not to answer (7)

Q5 Are you Hispanic or Latino?

- ○ Yes (1)
- ○ No (2)

Q22 Education level (please select the highest you have completed)

- ○ No schooling completed (1)
- ○ Nursery school to 8th grade (2)
- ○ Some high school, no diploma (3)
- ○ High School Graduate, diploma or the equivalent (Example: GED) (4)
- ○ Some college credit, no degree (5)
- ○ Trade/Technical/Vocational training (6)
- ○ Associate Degree (7)
- ○ Bachelor's Degree (8)
- ○ Master's Degree (9)
- ○ Professional Degree (10)
- ○ Doctoral Degree (11)

Q23 Employment Status

- ○ Employed for wages (1)
- ○ Self-employed (2)
- ○ Out of work and looking for work (3)
- ○ Out of work but not currently looking for work (4)
- ○ Homemaker (5)
- ○ Student (6)
- ○ Military (7)
- ○ Retired (8)
- ○ Unable to work (9)
- ○ Prefer not to answer (10)

Q6 What is your marital status?

- ○ Single (Never Married) (1)
- ○ Married (2)
- ○ Widowed (3)
- ○ Divorced (4)
- ○ Separated (5)

Q24 Number of people currently living in your home:

_____

Q2 What is your annual household income?

- ○ Under $20,000 (1)
- ○ $20,001-$40,000 (2)
- ○ $40,001-$60,000 (3)
- ○ $60,001-$80,000 (4)
- ○ Over $80,000 (5)

Q25 What languages do you speak in your home?

_____

Q26 What is your current Zip code?

_____

Q7 How many children do you have?

_____

Q8 How many pregnancies have you had?

_____

Q9 Are you currently pregnant?

- ○ Yes (1)
- ○ No (2)

Q10 How long ago did you have your most recent child?

_____

Q11 With your most recent/current pregnancy, have you experienced episodes of depression, feeling down, or what is sometimes called the baby blues?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If With your most recent/current pregnancy, have you experienced episodes of depression, feeling dow... = Yes

Q13 When did you experience these episodes?

- ○ During pregnancy (1)
- ○ After delivery (2)
- ○ Both (3)

Display This Question:

If With your most recent/current pregnancy, have you experienced episodes of depression, feeling dow... = Yes

Q16 Did you speak with a doctor about these feelings?

- ○ Yes (1)
- ○ No (2)

Q17 Did you have episodes of depression or feeling down with your previous pregnancies or following the birth of other children?

- ○ Yes (1)
- ○ No (2)

Q18 When you are interested in learning more about something like your pregnancy or how you are feeling do you:

- ☐ Look for information on the Internet (1)
- ☐ Speak with your Doctor (2)
- ☐ Look in books or other written source of information (3)
- ☐ Speak with friends or family (4)
- ☐ Look for information from social media (5)

Q19 Do you currently own a cell phone?

- ○ Yes (1)
- ○ No (2)

Q20 Do you use apps like:

- ☐ Games (1)
- ☐ Kindle (2)
- ☐ Spotify (3)
- ☐ Pregnancy related apps (4)
- ☐ Healthcare apps (tracking activity) (5)
- ☐ Banking apps (6)
- ☐ Uber/Lyft (7)
- ☐ Shopping apps (Amazon, Target, Walmart) (8)
- ☐ Netflix (9)
- ☐ Google Maps (10)
- ☐ Snapchat (11)
- ☐ Instagram (12)
- ☐ Facebook (13)
- ☐ Twitter (14)
- ☐ WhatsApp (15)

Q21 What is your favorite app?

_____

Edinburgh Postnatal Depression Scale

As you are pregnant or have recently had a baby, we would like to know how you are feeling. In the past 7 days:

I have been able to laugh and see the funny side of things
•As much as I always could

•Not quite so much now

•Definitely not so much now

•Not at all

I have looked forward with enjoyment to things
•As much as I ever did

•Rather less than I used to

•Definitely less than I used to

•Hardly at all

I have blamed myself unnecessarily when things went wrong
•Yes, most of the time

•Yes, some of the time

•Not very often

•No, never

I have been anxious or worried for no good reason
•No, not at all

•Hardly ever

•Yes, sometimes

•Yes, very often

I have felt scared or panicky for no very good reason
•Yes, quite a lot

•Yes, sometimes

•No, not much

•No, not at all

Things have been getting on top of me
•Yes, most of the time I haven't been able to cope at all

•Yes, sometimes I haven't been coping as well as usual

•No, most of the time I have coped quite well

•No, I have been coping as well as ever

I have been so unhappy that I have had difficulty sleeping
•Yes, most of the time

•Yes, sometimes

•Not very often

•No, not at all

I have felt sad or miserable
•Yes, most of the time

•Yes, quite often

•Not very often

•No, not at all

I have been so unhappy that I have been crying

•Yes, most of the time

•Yes, quite often

•Only ocassionally

•No, never

The thought of harming myself has occurred to me
•Yes, quite often

•Sometimes

•Hardly ever

•Never

Postpartum Depression Literacy Scale

Please rate your level of agreement with the following statements (1 = strongly disagree or not likely at all and 5 = strongly agree or very likely)

1) Feeling unusually sad and teary may be a symptom of postpartum depression

2) Sleeping too much or too little may be a sign of postpartum depression

3) Eating too much or losing interest in food may be a sign of postpartum depression

4) Loss of interest or pleasure in most things may be a symptom of postpartum depression

5) Postpartum depression affects person's memory and concentration

6) Symptoms and signs of postpartum depression last for a period of at least 2 weeks

7) How likely is it that postpartum depression might be caused by a genetic or inherited problem

8) How likely is it that postpartum depression might be caused by stressful circumstances in the life (such as the death of a loved one or divorce)?

9) How likely is it that postpartum depression might be caused by lock of social support such as intimate partner support?

10) How likely is it that postpartum depression might be caused by a previous history of depression?

11) How likely is it that postpartum depression might be caused by a hormonal imbalance?

12) Physical activity is effective for the prevention or management of postpartum depression

13) Seeking help with tasks like infant care and house hold chores from intimate partners and family members is helpful for the prevention or management of postpartum depression

14) Religious practices, prayer and going to holy shrine are helpful for the prevention or management of postpartum depression

15) Having a balanced diet is helpful for the prevention or management of postpartum depression

16) Good sleep is helpful in prevention or management of postpartum depression

17) Although there are clinics for with postpartum depression, I would not have much faith in them

18) Treatment for postpartum depression, provided by a mental health professional, can be effective

19) Psychotherapy (for example, talking therapy or counselling) can be effective in treating postpartum depression

20) Antidepressants are addictive

21) Antidepressants cause brain damage

22) I would rather live with postpartum depression than go through the ordeal of getting psychiatric treatment

23) Most women who have postpartum depression are violent

24) It is best to avoid women with postpartum depression so that you don't develop this problem

25) If I had postpartum depression I would not tell anyone

26) I am afraid of what my family and/or friends might think of me for attending psychology and/or psychiatry appointments

27) I know where to seek information about postpartum depression

28) I know how to use various sources to seek information about postpartum depression

29) I can appraise the accuracy of information about postpartum depression on the radio and television

30) I can appraise the accuracy of information about postpartum depression on the Internet

31) I can appraise the accuracy of advices about postpartum depression which given me by friends and family members

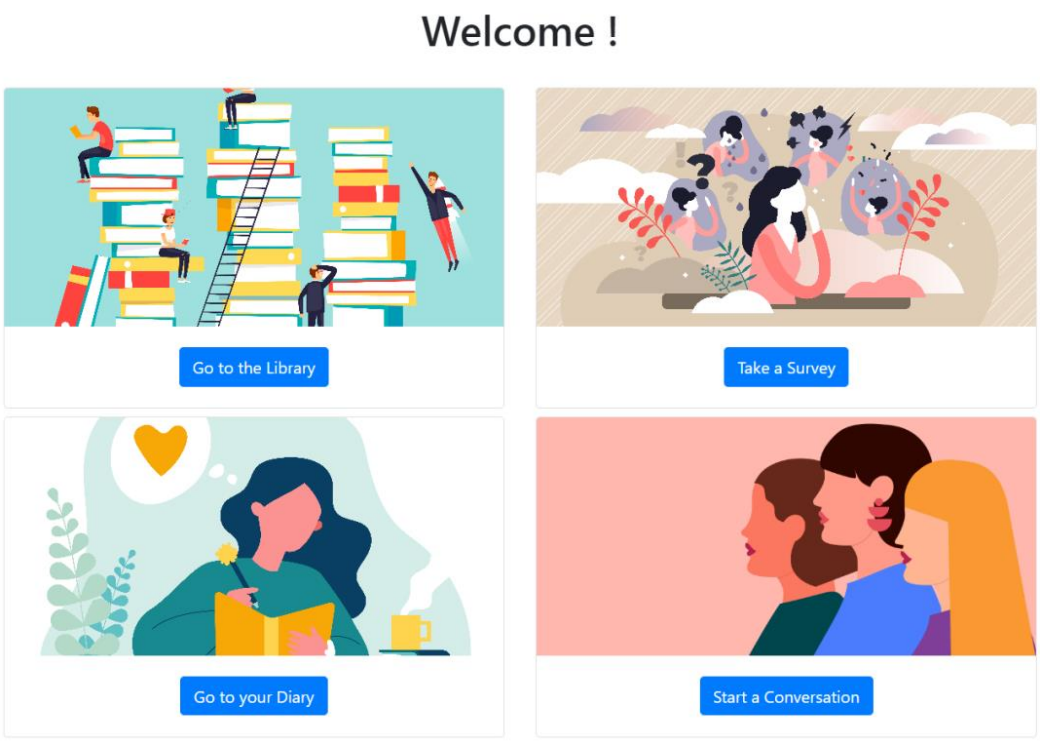
Patient Interview Questions

patient_interview_guide.pptx

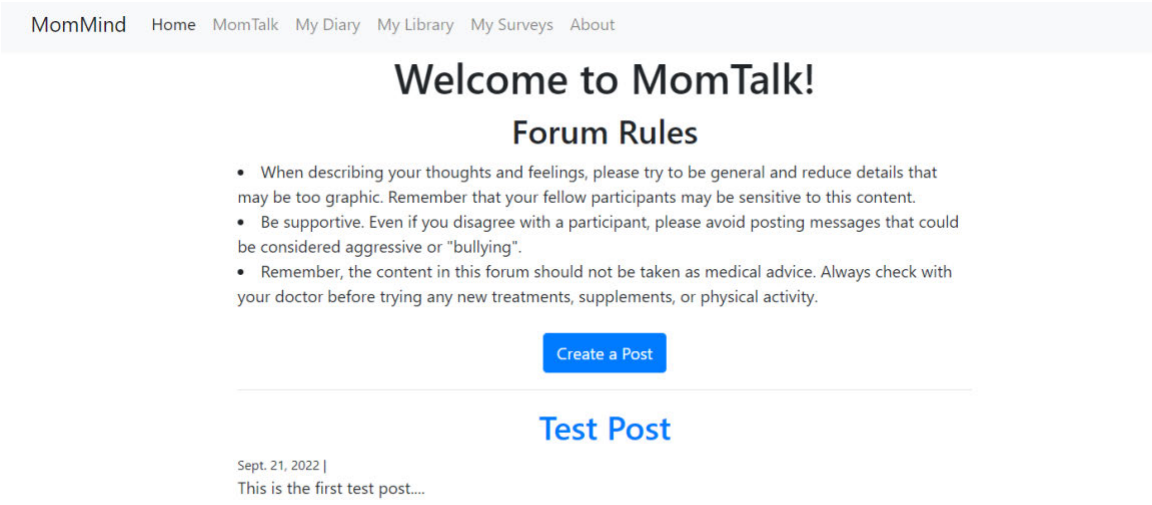
Provider Interview Questions

provider_interview_guide.pptx

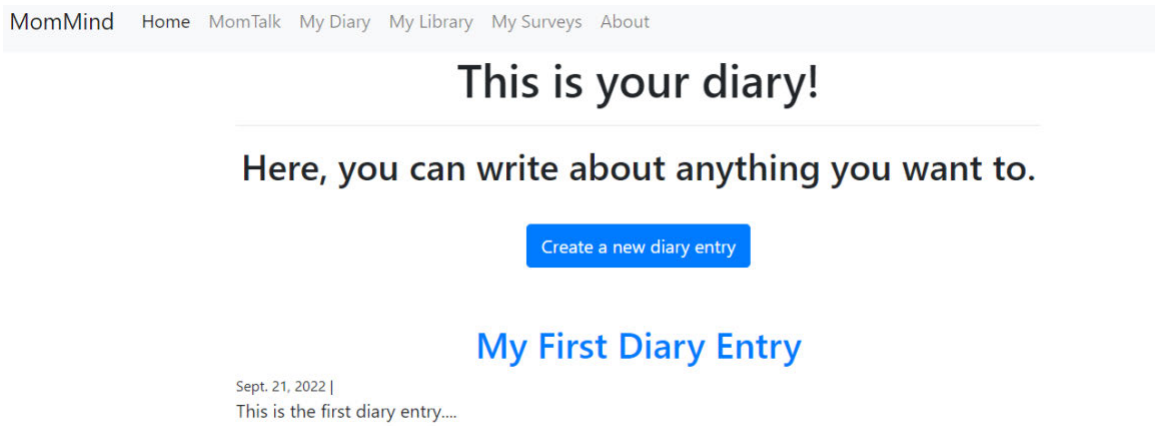
Appendix B: MomMind Screenshots



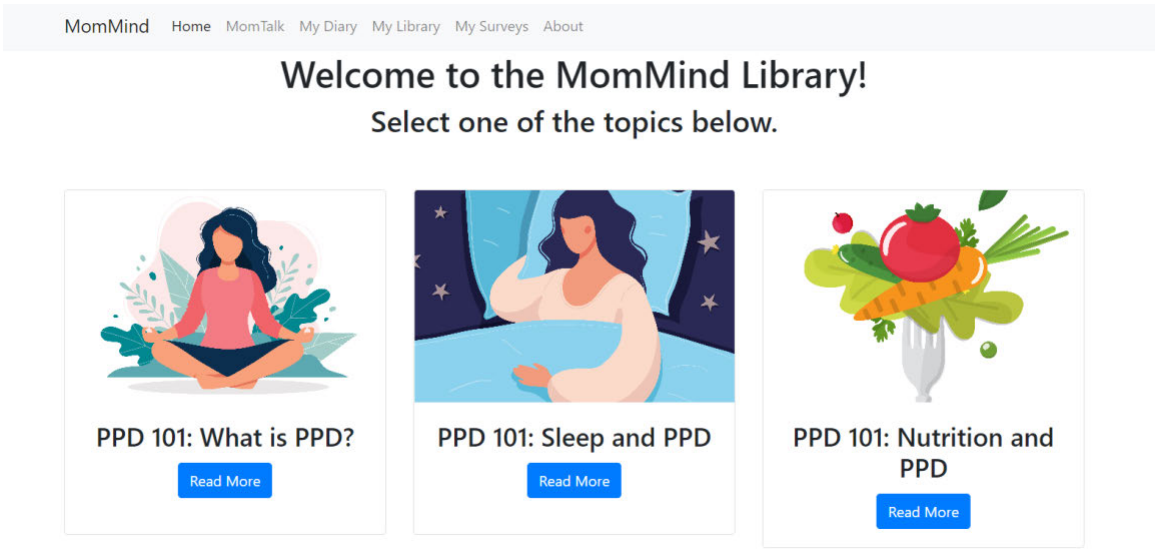
MomMind Homepage



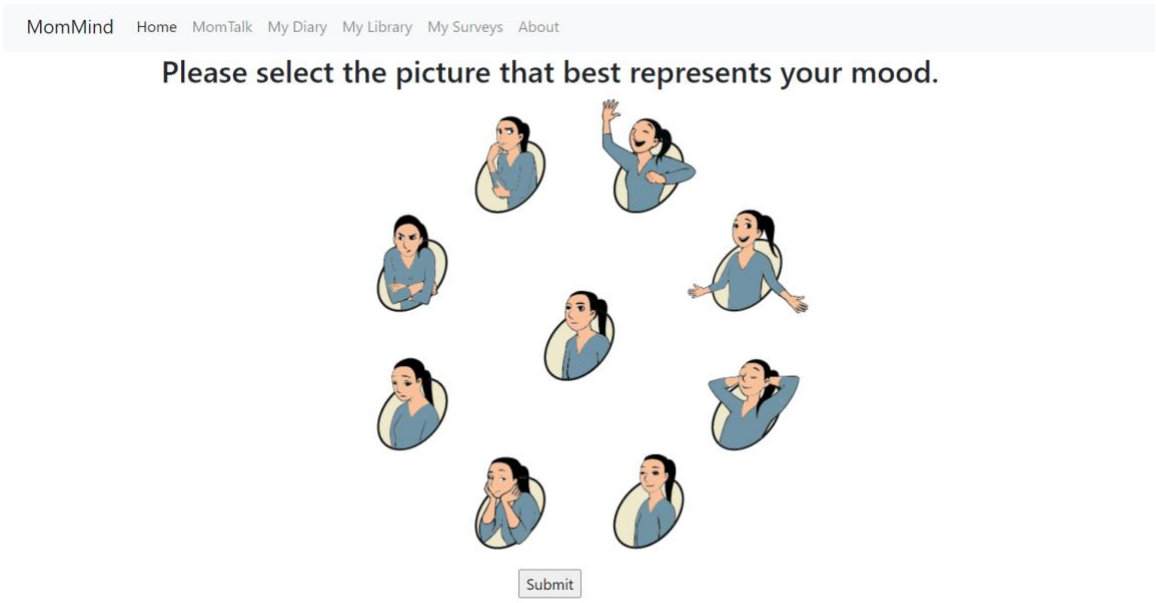
MomTalk Module



My Diary Module



My Library Module



Pick-a-Mood Survey

Appendix C: "PPD 101" Scripts

PPD 101: What is Perinatal Depression (PPD)?

Cindy: This last month, I have been feeling very overwhelmed with the baby, and even sad sometimes.	4.2 Information about antecedents
Doctor: It looks like you need help coping with being a new mom.	
Cindy: Is this what people call the baby blues?	
Doctor: The baby blues usually go away on their own in about two weeks. I think this can possibly be postpartum depression. It is more serious, but very common. It can happen for many reasons, like stressful events or hormonal changes. The good news is that there is a lot of help we can give you to cope better, through therapy or medication or both.	BCT 5.1 Information about health consequences
Cindy: But what if I can't afford therapy?	
Doctor: Don't worry about that! We have an excellent social worker who can point you to any resources you may need. The important thing is that you have asked for help and are on your way to feeling better!	BCT 3.2 Social Support (practical and emotional)

References and Evidence-based resources:

National Institute of Mental Health. (n.d.). Perinatal Depression. Accessed from: https://www.nimh.nih.gov/health/publications/perinatal-depression.

Centers for Disease Control and Prevention. (2022). Depression During and After Pregnancy. Accessed from: https://www.cdc.gov/reproductivehealth/features/maternal-depression/index.html

Postpartum Support International. (2022). Accessed from: https://www.postpartum.net/

PPD 101: Sleep and PPD

Nurse: “Thank you for calling us! How can I help?” Cindy: “Hi! I am having a lot of trouble sleeping with my newborn, and I feel exhausted” Nurse: “Are you able to sleep when your baby sleeps?” Cindy: “No, I always end up checking on him. Then the next day I feel in a very bad mood and sometimes even sad”.	6.1 Demonstration of behavior 4.2 Information about antecedents
Nurse: “It *is* normal for a new mom to get a bit less sleep than normal. But if this becomes constant, then you made the right decision to call. It is important that you get at least a couple of hours of deep sleep every night.”	9.1. Credible source
Cindy: “Is there anything I can do to sleep better?”	
Nurse: “Yes: - Take some time to unwind before bed. - Avoid screens. - Ask family for help with nighttime feedings. - Keep a sleep diary.	3.2. Social support (practical) 4.1. Instruction on how to perform the behavior
Cindy: “Thank you!”	

References:

Sleep Foundation. (2022). “Postpartum Insomnia”. Accessed from: https://www.sleepfoundation.org/insomnia/postpartum-insomnia

Other Evidence-based resources.

Kimberly E. Monday, MD.
UT Health Neurosciences
(832) 325-7080
6410 Fannin Street, Suite 1014

Houston, TX 77030

Sarah Aguilar, FNP.
Houston Sleep and Headache Solutions.
13114 FM 1960 West, Ste 105B Houston, TX 77065
832-688-8886

PPD 101: Nutrition and PPD

Doctor: How are you feeling with the morning sickness, Helen?	
Helen: Well, I have been very sensitive to some smells. And, not being able to eat comfortably makes me a bit moody.	4.2 Information about antecedents
Doctor: It looks like you have a very mild case of morning sickness. Here is what I recommend you can do: ● Make sure you stay hydrated. ● Foods like ginger can help you fight off the morning sickness. ● Eat snacks when you get hungry. This will help you stay in a better mood.	6.1 Demonstration of behavior 9.1. Credible source
Helen: Sometimes I worry that this might affect the baby's growth.	
Doctor: As long as you are taking your prenatal vitamins and eating plenty of vegetables, fruits, protein, and dairy, both you and the baby should be excellent!	BCT 3.2 Social Support (practical and emotional)
Helen: Thank you!	

References and Evidence-based resources:

National Health Services. (2021). Vomiting and morning sickness. Accessed from: https://www.nhs.uk/pregnancy/related-conditions/common-symptoms/vomiting-and-morning-sickness/

U.S. Department of Agriculture. (n.d.). Healthy Eating for Women who are Pregnant or Breastfeeding. Accessed from: https://www.myplate.gov/tip-sheet/healthy-eating-women-who-are-pregnant-or-breastfeeding

PPD 101: Feeding Your Baby

Cindy: I am having a difficult time feeding my baby. He is having trouble latching. Elaine: The same thing happened to me!	4.2 Information about antecedents
Elaine: I talked to my pediatrician and her lactation consultant.	6.1 Demonstration of behavior
They gave me some excellent tips: • Make myself comfortable when breastfeeding so that I could enjoy it more. • She taught me to recognize when Lucy was hungry. For example, if I saw that she was making sucking noises, I knew it was time for her to eat. • She told me to not use any bottles or pacifiers during the first few weeks of breastfeeding to avoid nipple confusion.	4.1. Instruction on how to perform the behavior
Elaine: They also assured me that it would be ok if I decided to formula feed. Cindy: I thought breastfeeding was better than formula! Elaine: Breastfeeding does have some great benefits, but it is also important to consider how you feel about it. Formula can be a healthy alternative.	5.1. Information about health consequences
Cindy: Thank you for your advice!	

References:
Icahn School of Medicine at Mount Sinai. (2022). Breastfeeding vs. Formula Feeding. Accessed from: https://www.mountsinai.org/health-library/special-topic/breastfeeding-vs-formula-feeding
Nest Collaborative. (2021). Accessed from: https://nestcollaborative.com
Section on Breastfeeding (2012). Breastfeeding and the use of human milk. Pediatrics, 129(3), e827–e841. https://doi.org/10.1542/peds.2011-3552
Other evidence-based resources:
UT Physicians OB/GYN Offices (can request appointment with a lactation consultant)
https://www.utphysicians.com/specialty/obstetrics-and-gynecology/
832-325-7131

PPD 101: Family and Friends

Jenny: My husband doesn't understand the struggles that I'm going through as a new mom! I would just like for him to support me more with taking care of the baby.	4.2 Information about antecedents
Therapist: New routines and responsibilities can be stressful. It is normal for couples to go through an adjustment phase as new parents. Keep in mind that fathers may also struggle.	4.2 Information about antecedents 9.1. Credible source
Therapist: Some activities that might help you both reduce stress are: ● Schedule some time for just the two of you. It can be a simple activity like a 15-minute walk outside. ● Doing fun activities as a family, like both of you playing with the baby. ● Communicate how you are feeling, but without being aggressive. ● Try to find ways to collaborate with taking care of the baby and around the house. For example, you can ask him what chores he would prefer to do.	6.1 Demonstration of behavior 9.1. Credible source 3.2 Social Support (practical and emotional)
Jenny: Thank you!	

Evidenced-based resources:
Postpartum Support International. (2022). Help for partners and families. Accessed from: https://www.postpartum.net/get-help/family/

PPD 101: Everyday Tips for Mental Wellness

Jenny: Hi Mary, can you tell me about things you do daily that make you feel good?	
Mary: Hi Jenny! Yes, of course. - I try to take at least 10-15 mins. of "me" time every day. I prefer mornings. Sometimes I write down, or just think about, three things that I am grateful for, or just enjoy the quiet. - I listen to my favorite music while doing chores like cooking or cleaning. - Connecting with other parents really helps! It makes me feel less lonely. - Doing an outdoor activity is so refreshing to me! My doctor recommended that I go for 30-minute walks, at least 3-5 times a week.	6.1 Demonstration of behavior
Jenny: This is very helpful!	
Mary: And remember, it is important that you also keep up with your medications and doctor appointments. Any time you don't feel well, don't hesitate to speak up and ask for help if you need it!	BCT 3.2 Social Support (practical and emotional)

References and Evidence-based resources:
Mothers and Babies. (n.d.). Self-Care Tips. Accessed from: https://www.mothersandbabiesprogram.org/parents/self-care-tips/
The American College of Obstetrics and Gynecology. (2020). Physical Activity and Exercise During Pregnancy and the Postpartum Period. Accessed from: https://www.acog.org/clinical/clinical-guidance/committee-opinion/articles/2020/04/physical-activity-and-exercise-during-pregnancy-and-the-postpartum-period

Appendix D

Design Principles for Heuristic Evaluation. Adapted from National Center for Cognitive Informatics and Decision Making in Healthcare, General Design Principles for EHRs, 2018.

Violations	**Definition**
Consistency	*Users should not have to wonder whether different words, situations, or actions mean the same thing.*
Control	*Do not give users that impression that they are controlled by the systems. Users are initiators of actors, not responders to actions. Avoid surprising actions, unexpected outcomes, or tedious sequences of actions.*
Flexibility	*Users always learn and users are always different. Give users the flexibility of creating customization and shortcuts to accelerate their performance.*
Help	*Always provide help when needed. Such as task-oriented; alphabetically ordered; semantically organized; and search.*
Language	*The language should be always presented in a form understandable by the intended users.*
Match	*The image of the system perceived by users should match the model the users have about the system.*
Memory	*Users should not be required to memorize a lot of information to carry out tasks. Memory load reduces users capacity to carry out the main tasks.*
Minimalism	*Any extraneous information is a distraction and a slow-down. Less is more.*
Visibility	*Users should be informed about what is going on with the system through appropriate feedback and display of information.*
Feedback	*Users should be given prompt and informative feedback about their actions.*
Error Messages	*The messages should be informative enough such that users can under- stand the nature of errors, learn from errors, and re- cover from errors.*
Prevent Errors	*It is always better to design interfaces that prevent errors from happening in the first place.*
Closure	*Every task has a beginning and an end. Users should be clearly notified about the completion of a task.*
Undo	*Users should be allowed to recover from errors. Reversible actions also encourage exploratory learning.*