# EVALUATING THE QUALITY OF MOBILE HEALTH APPS FOR MATERNAL AND CHILD HEALTH (MCH)

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## DEDICATION

There is a popular adage that I know to be true: It takes a village to raise a child. I dedicate this dissertation to all the wonderful people in my village (life) that have collectively helped me blossom both professionally and personally. I thank God for presenting me with the opportunity to pursue my Doctoral studies in one of the finest institutions in the world and for giving me the strength and capability to complete my dissertation. To my loving parents who, despite their countless sacrifices and struggles, have been a constant source of optimism. To my caring sister who is a friend and an associate and my wonderful husband who shows the importance of hard work and resilience. My grandparents, whose lives have been both an inspiration and a source of learning. My family & friends who made this journey an enjoyable and memorable one (some of whom I lost during this period). Last but not the least, my teachers and mentors as well as Indiana University for believing in me and honing my skills thoroughly.

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EVALUATING THE QUALITY OF MOBILE HEALTH APPS FOR MATERNAL AND CHILD HEALTH



**Introduction**

Mobile health (mHealth) applications (apps) are increasingly accessible and popular. In 2015, over 60% of smartphone users used their phones to look up health related information. mHealth apps related to maternal and child health (MCH) are particularly prevalent and frequently used. As high as 73% pregnant women and new mothers reported the use of MCH apps, with 27% using them daily.

**Methods**

A cross-sectional sample of MCH apps was extracted from the Apple App and Google Play stores using a JavaScript Scraper program. A multivariable linear regression, and series of ordinal logistic regression assessed the relationship between MCH app characteristics and two outcomes, end users' perceived satisfaction (star ratings), and intent to use (downloads). Next, theory-based content analysis reviewed the presence and use of behavior change techniques (BCTs) in popular MCH apps using the mHealth app taxonomy framework. Finally, a qualitative inductive analysis assessed user self-reported experiences, perceived benefits, and general feedback for MCH apps.

**Results**

Seven hundred and forty-two apps met the inclusion criteria. A large majority of MCH apps were developed by non-healthcare developers. Google Play store apps had higher user ratings; while, apps within health & fitness genre, with older updates, and no age-restrictions had fewer user ratings. Furthermore, lower priced apps, with high star ratings, in-app purchase options, and in-app advertisement presence had high downloads. And, apps belonging to medical and health & fitness genre had fewer user downloads. Content analysis revealed that popular MCH apps on an average include 7.4 behavior change techniques (BCTs) with a median of 6 BCTs. Apps developed by healthcare developers had higher BCTs present within app content. Qualitative analysis shows that consumers value apps that are low cost, with superior features, smooth technical aspects, high quality content, and easy to use.

**Conclusions**

Healthcare providers, app developers, and policymakers may benefit from a better understanding of MCH apps available in two popular app stores and may consider strategies to review and promote apps to consumers based on information accuracy and trustworthiness.

Christopher A. Harle, PhD, Chair

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| | |
|---|---|
| AA: | Apple App |
| Apps: | Applications |
| BCT: | Behavior Change Techniques |
| GP: | Google Play |
| IS: | Information System |
| mHealth: | Mobile Health |
| MCH: | Maternal and Child Health |

# CHAPTER 1

# INTRODUCTION

"There's an app for that" ~ Apple Inc.

## Information Seeking using Smartphones

Increasingly users are turning to digital technologies such as web-based and mobile platforms where information regarding any topic is obtained at the touch of a button. There have been significant changes in the types of digital technologies that are available for use, and smartphones are increasingly the most popular devices for "on the go" information access (Lupton, 2015; Smith, 2015). Globally, there were 7.9 billion mobile connected devices in 2015 and this number is estimated to grow to 11.6 billion by 2020 (Cisco, 2016). In U.S. alone, 92% adults owned a mobile phone in 2015, out of which 68% owned smartphones (Anderson, 2015). Today, smartphones are used for more than the basic features of calling, texting or even browsing the Internet. Increasingly, users are utilizing these devices to seek information on a wide range of life events, including their health (Smith, 2015). According to a recent study conducted by the Pew Research center, 62% of smartphone users in United States used their phones to look up health related information in the past year (Smith, 2015). This cultural shift has resulted in an increased access to health-related information to lay people and has offered them a platform to engage in behavior modification activities (Lupton, 2015). This trend is not limited to lay persons alone. Healthcare providers and other health professionals are also increasingly turning to hand-held devices to quickly and effectively perform tasks, such as storing patient information or reviewing lab results (Ventola, 2014; Yang & Silverman, 2014).

Smartphones are popular for their abilities to support third party programs, commonly known as mobile applications or mobile apps (Pandey, Hasan, Dubey, & Sarangi, 2013). Since their first appearance in 2008, millions of apps have been designed and published for smartphones, computer tablets, and other hand-held mobile devices (Lupton, 2014). Smartphone apps are marketed and distributed through five leading platforms namely: Apple iOS, Google's open source Android, Nokia's Symbian, Microsoft Windows Phone 7, and RIM Blackberry OS (Jain, 2011). From these, the Apple App Store and Android Market (Google Play Store) are the global market leaders in mobile applications or apps stores (BinDhim, Freeman, & Trevena, 2014). As of May 2016, 140 billion apps have been downloaded from the Apple's App Store. As of September 2016, 65 billion apps have been downloaded from the Google Play Store (Statista, "n.d"a; Statista, "n.d"b).

A wide range of mobile health (mHealth) apps are available in the market, targeting different audiences. Apps that are developed for healthcare workers, such as physicians and nurses, tend to be more sophisticated with the use of medical terminology and functions than those that are intended for lay persons (Boulos, Brewer, Karimkhani, Buller, & Dellavalle, 2014). A recent survey conducted on participants from the American Council for Graduate Medical Education (ACGME) training program, demonstrated that 85% of the respondents use smartphone medical apps in their clinical practice (Franko, & Tirrell, 2012). The most frequently used apps are drug guides, medical calculators, coding and billing apps, and pregnancy wheels, which are used to calculate the estimated date of delivery (Franko, & Tirrell, 2012; Chyjek, Farag, & Chen, 2015). Further, there are apps that target both patients and the general public (Boulos et al., 2014). These apps aim to assist patients in tasks such as disease diagnosis, chronic disease management, lifestyle modification, and smoking cessation (Boulos et al., 2014). A survey of 1,604 mobile phone users in the United States revealed that more than half (58.23%) of the mobile phone users had downloaded a health-related app to track their health, and over 41.6% respondents had downloaded more than five health-related apps (Krebs & Duncan, 2015). The most popular category of health apps used was fitness and nutrition, with majority of respondents using these apps daily (Krebs, & Duncan, 2015).

**Maternal and Child Health Interventions using Health Information Technology**

Increasingly pregnant women and their families are turning to health information technologies such as the Internet, patient portals, and mobile applications to manage their health information needs (Shenson et al., 2015). Developments in technology indicate that health programs can be delivered to people outside the traditional clinic setting, thereby improving access (as cited in Nwolise, Carey, & Shawe, 2016). Several social, economic, and cognitive factors contribute to the adoption of such technologies (Shenson et al., 2015). Therefore, adequate knowledge regarding information needs, information-seeking behaviors, and resource preferences are required to guide the development of interventions that lead to improved prenatal care and fetal outcomes (Shenson et al., 2015).

Today, text messaging is available on all mobile phones. Text messages can deliver information regarding health risks such as alcohol consumption during pregnancy, and prevention behaviors i.e. protecting infants from HIV. Further, it can also be used to provide referrals and motivational tips (Rotheram-Borus et al., 2012). Evans et al. (2012) conducted a randomized controlled trial (n=123) where underserved pregnant women and new mothers were randomized to an intervention group where they were enrolled to text4baby program along with receiving usual antenatal care, and the control group only received usual antenatal care. Text4baby is a mobile health program based on behavioral theory that sends text messages to traditionally underserved pregnant women and new mothers to promote healthy behaviors during pregnancy and improve clinical outcomes. Results of this study indicated a significant likelihood of women in the text4baby intervention group to agree with the statement “I am more prepared to be a new mother”, along with improved attitudes towards alcohol consumption from baseline to follow-up. Similarly, in a study conducted by Jareethum et al. (2008), 68 healthy pregnant women were randomized into two groups. The intervention group received two text messages per week from 28 weeks of gestation until birth, and the control group did not receive these text messages. The satisfaction, anxiety, and confidence scores for both groups were measured using questionnaires at the postpartum ward. Results of this study suggested that women in the intervention group had significantly higher satisfaction and confidence scores, along with lower anxiety levels in the antenatal period as compared to the control group.

Innovations in peripheral biosensors that can be linked with mobile phones, often wirelessly, have exhibited a huge potential in assessing and monitoring health status (Rotheram-Borus et al., 2012). A study conducted by Ganju, Krapf, Benham, & Marko (2016), aimed to test a mobile health platform that monitors weight through connected scale and offers feedback through “triggers” if the weight is over the Institute of Medicine (IOM) Gestational Weight Gain guidelines (GWG). The study enrolled 30 low-risk pregnant women who recorded their weight weekly during their pregnancy using the mobile platform. The authors concluded that around 66% of study participants remained within the target weight gain goal as compared to 38.5% of women in the general population. A company named Mobisante has developed an ultrasound probe that connects to a smartphone and helps in fetal monitoring from remote locations (Mertz, 2012). It enables nurse practitioners and community health workers in rural setting to conduct cursory screenings and in case of high-risk pregnancy the images can be transferred to a trained radiologist for expert guidance (Mertz, 2012). This helps in overcoming the barrier of inadequate access to prenatal and specialty care in certain geographic locations (Mertz, 2012). Similarly, in study conducted by Marko et al. (2016), 8 low-risk pregnant women were prospectively followed throughout their pregnancy. Participants received a mobile phone app connected with digital weighing scale and blood-pressure cuff for at-home data collection. Results of this study indicated that on an average the patient engagement with the mobile app averaged 5.5 times per week over a six-month study period. Weight and blood pressure data collection averaged 1.5 times and 1.1 times per week respectively. Further, these measurements were more accurate as compared to in-office measurements. Overall, the patients confirmed a high satisfaction level with the system, making it a feasible intervention for delivering prenatal care in a home setting.

Further, mobile and digital technologies hold promise to offer high quality care at low costs, making it a cost-effective intervention (Free, et al., 2013). Marko, Ganju, Brown, Benham, & Gaba (2016, May) conducted a study to measure the effect of reducing the frequency of prenatal visits with the use of mobile health technology on patient satisfaction, engagement, and clinical outcomes in low-risk pregnancies. This controlled study was conducted on 100 first-trimester obstetric patients where 50 patients were placed on an alternative prenatal care schedule (8 visits) along with an integrated technology platform of a mobile application and connected devices such as wireless weighing scale and blood pressure cuff. The control group consisting of 50 patients received usual care (14 visits). The researchers concluded that despite a 43% reduction in in-clinic visits, the treatment group demonstrated increased satisfaction and engagement throughout pregnancy as compared to control group, though no differences were observed in fetal outcomes. This indicates a shift of prenatal care delivery, which is cost-effective, safe, and risk-appropriate.

**Mobile Health Apps for Maternal and Child Health**

Pregnancy and new motherhood are times when women experience changes in their lives and often experience uncertainty, anxiety, and isolation while accepting their new role (Lupton & Pedersen, 2016). In the United States, there are around 6.5 million pregnancies each year resulting in over 4 million live births (as cited in Shenson, Ingram, Colon, & Jackson, 2015). Pregnant women tend to adopt new health behaviors that offer support to their developing fetus and help manage their existing medical conditions pertaining to pregnancy (Shenson et al., 2015). Maternal health behaviors during and after pregnancy such as smoking, drug use, infant sleep practices, breastfeeding rates, nutrition, and immunization, have shown to affect both maternal and fetal health outcomes (as cited in Lewkowitz, O'Donnell, Nakagawa, Vargas, & Zlatnik, 2016). Pregnancy is a period of increased health information seeking and increasingly pregnant women are engaging themselves with social media and technology, particularly through the use of mobile phone apps, to seek pertinent information (Shieh, Broome, & Stump, 2010; Robinson, & Jones, 2014). Lately, there is an increased use of mobile technologies for health promotion and disease prevention activities (Evans, Wallace, & Snider, 2012). There are three major domains that influence maternal and child health, i.e. reducing infant mortality, improving maternal health, and reducing infectious diseases such as HIV/AIDS, malaria, or tuberculosis. To that effect, mobile phones have exhibited a potential to improve access, quality, and utilization of care by providing health information, skills, support, and crisis services for a specific health condition, directly to the patient (Rotheram-Borus, Tomlinson, Swendeman, Lee, & Jones, 2012).

There are hundreds of apps directed towards pregnancy and new motherhood, and many of these apps are extremely popular among the to-be mothers (Thomas & Lupton, 2016). Download figures from Google's Play store reveal that apps such as the 'I'm Expecting-Pregnancy App' attract around 1 to 5 million downloads (Thomas & Lupton, 2016). User downloads is an indicative measure of an app's acceptability and popularity (Muessig, Pike, LeGrand, & Hightow-Weidman, 2013). A preliminary study using user comments suggests that users are in favor of apps that are easy to use, contain new information, and are motivational (Derbyshire, & Dancey, 2013). Areas that need improvement include quality of graphics, speed of download, compatibility with devices, ability to transfer data on to newer versions, and association with reputable organizations (Derbyshire, & Dancey, 2013).

As of June 2015, the most popular pregnancy-related apps in the Apple's App Store included 'Period Diary' (a fertility and ovulation tracker), 'My Pregnancy Today', and 'Pregnancy & Baby- What to Expect' (Thomas & Lupton, 2016). A survey conducted on 410 pregnant women in Australia revealed that 73% of the respondents had used at least one pregnancy app, mainly for information pertaining to fetal development (86%), changes in the body during pregnancy (71%), weight gain or diet (33%), online discussions with other pregnant women (27%) and keeping track of medical appointments (18%) (Lupton, & Pedersen, 2016). Another survey conducted on 193 pregnant women in South Korea suggested that over 55.4% respondents had used MCH apps during pregnancy, birth, and childcare, and the rates of usage were significantly higher among first time mothers (Lee & Moon, 2016). Forty three percent of respondents stated using the Saybebe app and 12% respondents noted using the pregnancy, and childcare encyclopedia app (Lee & Moon, 2016). Further, the study revealed that information most frequently obtained from these apps were risk signs and diseases during pregnancy, physical changes related to a normal pregnancy, and prenatal education (Lee & Moon, 2016). Likewise, from a sample of 2,400 women in USA, 56% first time mothers and 47% experienced mothers found maternal and child health (MCH) apps useful in providing valuable information (Declercq, Sakala, Corry, Applebaum, Herrlich, 2013). Similar findings were reported in a study conducted in Ireland, where 59% of the 399 women who owned smartphones reported the use of MCH apps (O'Higgins et al., 2014).

In addition to expectant mothers, obstetric care providers are increasingly using smartphone apps for various clinical purposes such as calculating gestational age of the fetus, and estimating the date of delivery (Chyjek et al., 2015). With the increased popularity of pregnancy apps and the concerns raised pertaining to the accuracy, security and privacy of data, it becomes imperative to address these issues especially since vulnerable populations such as pregnant women and children are involved (Robinson & Jones, 2014; Scott et al., 2015). Preliminary analysis of 20 pregnancy apps indicated that these apps are priced higher as compared to apps targeting other populations but tend to have lower user or star ratings (Derbyshire, & Dancey, 2013), which are a highly valuable and realistic evaluation of the popularity, acceptability, and benefits of apps (Arnhold, 2014; Muessig et al., 2013). Prior studies conducted to evaluate pregnancy-related mobile apps have cited trustworthiness of information as a major issue. Lee and Moon (2016) evaluated the 47 most used apps by their study population and concluded that these apps do not provide their source of information and fail to offer warnings pertaining to the use of this information. Scott et al. (2015) pointed out that of the 10 free MCH apps included in the study, only 4 apps were developed with the involvement of health professionals, and 4 apps provided information from evidence-based medical content. Three out of these 4 apps were developed by health professionals and provided evidence-based medical content. In addition, the study indicated that only 4 of the apps were fully functional (as described by what a system is supposed to do), 3 implemented security mechanisms to ensure privacy of user data, 2 were fully usable (as defined as the extent to which a user is able to use the system effectively), and 2 apps were inoperative. Further, they demonstrate the need for conducting a similar study with larger number of maternal and child health apps. Additionally, Robinson & Jones (2014) and Scott et al. (2015) urge for increased research that assesses the relationship between mHealth and maternal and fetal health outcomes.

**Value of Mobile Health Apps**

Mobile technologies have proliferated the healthcare market at an exponential rate in recent years; however, concerns have been raised regarding the accuracy, timeliness, and validity of information that these apps provide (Nilsen et al., 2012; Lupton, 2014). Other challenges include lack of evidence of clinical effectiveness, lack of integration with the healthcare system, a need for formal evaluation, and potential threats to safety and privacy (Eng & lee, 2013). The medical and public health professionals is extremely concerned regarding the risks of introducing ineffective or potentially harmful apps to the general public for use (Nilsen et al. 2012). For example, the pediatric societies advice against the use of mobile baby monitors to protect healthy children against sudden infant death syndrome (SIDS), yet the industry markets and sells these apps (Husain & Spence, 2015). Any developer can publish their app under the health and fitness or medical genre as long as they conform to the technical guidelines provided by the app stores (as cited in Lupton, 2014). The iOS app development and approval process is more stringent than other platforms (Kharrazi, Chisholm, VanNasdale, & Thompson, 2012). Apps that are submitted to the Apple's app store undergo a review process based on an app's technical compatibility and content verification review (as cited in BinDhim & Trevana, 2015a). At present, mHealth applications are unregulated by the federal government and there is no clinical validation process, which may pose risk to the health and well-being of the consumers, as they may rely on the apps for health-related decisions (Schulke, 2013; Scott, Richards & Adhikari, 2015). Consumers may also not realize that currently there is no effective evaluation process in place.

Recent academic literature focuses on evaluating the efficacy and trustworthiness of mHealth apps within the context of varying health conditions such as obstetrics and gynecology (Chyjek et al., 2015; Scott, Gome, Richards, & Caldwell, 2015; Farag, Fields, Pereira, Chyjek, & Chen, 2016; Lee & Moon, 2016; Mangone, Lebrun, & Muessig, 2016; Shaia, Farag, Chyjek, Knopman, & Chen, 2016), substance abuse (Abroms, Padmanabhan, Thaweethai, & Phillips, 2011; BinDhim et al., 2014; Choi, Noh, & Park, 2014; Jacobs, Cobb, Abroms, & Graham, 2014; Crane, Garnett, Brown, West, & Michie, 2015;

Heminger, Schindler-Ruwisch, & Abroms, 2016; Powell et al. 2016), chronic diseases (Demidowich, Lu, Tamler, & Bloomgarden 2012; Huckvale, Car, Morrison, & Car 2012; Bender, Yue, To, Deacken, & Jadad, 2013; Pandey et al. 2013; Schoffman, Turner-McGrievy, Jones, & Wilcox 2013; Arnhold, Quade, & Kirch, 2014; Kalz et al., 2014; Masterson Creber et al., 2016), mental health (Nicholas, Larsen, Proudfoot, & Christensen, 2013; Coulon, Monroe, & West, 2016), and so on. Around 65% of these studies indicate that a significant number of mHealth apps are inaccurate and not evidence-based, 8.7% studies state that mHealth apps lack expert recommendations, 21.7% studies specify that the apps are of poor quality in terms of content and functionality, and 8.7% studies point out that apps often lack source citations or privacy policies. Consumers may either not be aware of these gaps within mHealth app delivery, or they may value certain other factors while deciding on mHealth app uptake, which will be addressed later in this dissertation.

For example, in a study conducted on 63 unique colorectal themed apps (using search terms such as anal fissure, bowel incontinence, colorectal cancer, Crohn's disease, diverticulitis, hemorrhoids, irritable bowel syndrome, and ulcerative colitis), only 29% had customer satisfaction ratings, and only 32% apps had medical professional involvement in the development of the content, thereby urging for an increased regulation to improve the accountability of app content (O’Neill & Brady, 2012). Pandey et al. (2013) evaluated the content of 77 cancer-related smartphone apps and revealed that 55.8% apps provided scientifically valid data, and only 24.6% apps were uploaded by healthcare agencies. A small e-mail-based survey of 10 most popular ‘child health’ or ‘parenting’ apps available for purchase via Apple iTunes revealed that only one developer reported healthcare professional involvement in content development and product evaluation (Burke, Sargant,

& Marden, 2012). The involvement of healthcare agencies and professionals in app development ensures the validity and relevance of information that is received by the consumers (Dubey et al., 2014, Pandey et al., 2013). A study conducted to identify user perceptions of health behavior apps concluded that apps developed by experts are considered preferable over unknown or less reputable sources (Dennison, Morrison, Conway, & Yardley, 2013). Sunyaev, Dehling, Taylor, and Mandl (2015) cautioned users to be aware of the privacy policies of apps prior to their purchase or use. Of the 600 most commonly used apps, only 30.5% apps provided privacy policies. Further, they indicated that the privacy policies were not transparent to users, and often required college-level literacy to comprehend this information.

**Regulation of Mobile Health Apps**

In United States, as per the American Health Information Management Association, agencies such as the Food and Drug Administration (FDA), the Federal Trade Commission (FTC), the Federal Communications Commission, the National Institute of Standards and Technology, and the Office for Civil Rights of the Department of Health and Human Services (HHS), are possible key players in the regulation of health apps in the future (Yang & Silverman, 2014). Increasingly, there are efforts taken in the direction of ensuring that the content of medical and health apps is evidence-based, and peer-reviewed, with most updated clinical information (Visser & Buijink, 2012). On September 25, 2013, the FDA issued guidelines for mobile medical apps (Food and Drug Administration (FDA), 2015). A mobile medical app is a medical app that meets the definition of a medical device as per section 201(h) of the Federal Food, Drug, and Cosmetic Act (FD&C Act) (FDA, 2015). As per the guidelines, a mobile medical app is defined as an app that can either be used as an accessory to a regulated medical device, or one that transforms a mobile device into a regulated medical device (FDA, 2015). Such medical apps could pose a real risk to consumers if they do not accurately serve the purpose as claimed by the developer (Boulos et al., 2014). Hence, apps which are intended for prevention, diagnosis or treatment of diseases, or are known to affect the structure or function of the human body, are considered medical devices, and must be regulated by the FDA (FDA, 2015). Furthermore, since the new healthcare reform facilitated by the Affordable Care Act (ACA) places huge emphasis on quality and cost-effectiveness in the context of healthcare delivery, it is anticipated that mobile medical apps may increasingly gain popularity in this new patient-centered environment; thereby calling for increased regulations (DeMuro, 2013; Mendiola, Kalnicki, & Lindenauer, 2015). At present however, the FDA seeks to regulate only those apps that fall under the category of a mobile medical device and does not include a vast majority of other health and medical apps (Cortez, Cohen, & Kesselheim, 2014; Lupton, 2014; Yang & Silverman, 2014). This puts the onus onto the consumers to make prudent judgments regarding the accuracy and validity of the information provided (Lupton, 2014). Few studies have suggested a closer regulation or implementing guidelines for the quality of apps (BinDhim & Trevena, 2015b).

**Theoretical Framework**

The purpose of this dissertation was to evaluate the quality of mobile health apps for maternal and child health. The conceptual framework for this study was adapted from "DeLone and McLean IS Success Model". The framework was used to study user behavior, i.e. intent to use, and user satisfaction; app information quality; and net benefit derived by users upon app use. The following sections describe the DeLone and McLean IS Success

Model and present a conceptual model that will detail the overview of this dissertation.

*Information Systems (IS) Success Model*

One of the most widely known and cited frameworks in contemporary information systems research, is the "Information Systems (IS) Model" by Delone and McLean (1992) also called D & M IS Success Model. The original works consisted of six major dimensions of measurement, i.e. system quality, information quality, use, user satisfaction, individual impact, and organizational impact (DeLone, & McLean, 1992). These six variables are not independent, but are interdependent variables, used to measure the success of an information system (Petter, DeLone, & McLean, 2013). The model can be described from two standpoints: (1) a temporal pattern which follows a sequence of system creation, utilization, and impacts; (2) a causal perspective, where the system quality and information quality affects individuals' use of a system, which further impacts user satisfaction, individual task performance, and organizational effectiveness (DeLone & McLean, 2003). These six variables are discussed as follows (DeLone, & McLean, 2003; Petter, DeLone, & McLean, 2013).

1. System quality: the desirable characteristics of an IS, such as ease of use, system reliability, flexibility, sophistication, and response time.
2. Information quality: the desirable characteristics of the systems output such as accuracy, conciseness, completeness, currency, reliability, relevance, usability, and understandability. According to the model, the content should be complete, easy to understand, personalized, relevant, and secure.
3. System use: degree and manner in which users utilize the capability of an IS, i.e., amount of use, nature of use, appropriateness of use, number of site visits and extent

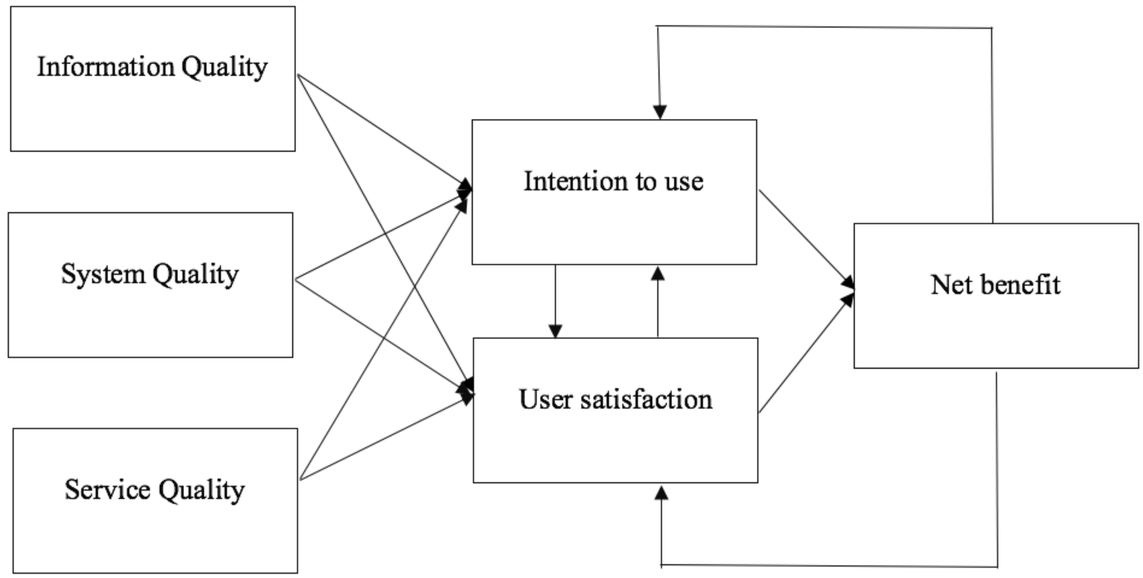
of use.

4. User satisfaction: users' level of satisfaction with the IS. It includes repeat purchases, repeat visits, and user surveys.
5. Individual impact: measures the impact of a system on users' behavior
6. Organizational impact: impact on organizational measures such as cost reduction and return of investment (ROI).

The authors DeLone and McLean, later revised this model and presented a new model in their works that was published in the year 2003 (DeLone & McLean, 2003) (see figure 1.1). The author redefined their original framework in three distinct ways (DeLone & McLean, 2003):

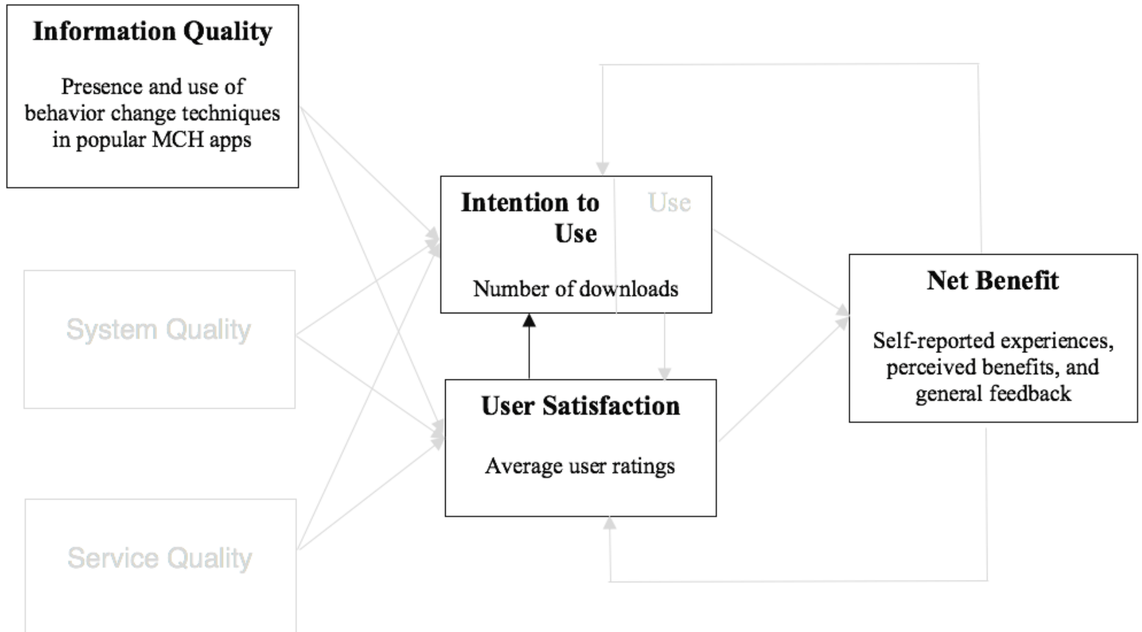
1. Adding a third dimension "service quality": Along with information quality and system quality, information systems are also commonly evaluated according to the quality of the service that they are able to deliver.
2. Substituting "intention to use" for system usage by users.
3. Combining the individual and organization impact into one variable namely "net benefit". Net benefit may positively or negatively impact on intention to use and user satisfaction. It includes cost savings, time savings, expanded markets, and reduced search costs.

Figure 1.1. Information Systems (IS) Success Model (DeLone & McLean 2002, 2003)




The Information Systems (IS) System Success Model was adapted as follows for the purpose of this dissertation (see figure 1.2). The information quality dimension was measured as the presence and use of behavior change techniques in popular MCH apps in chapter 3. Intention to use was measured as number of downloads, and user satisfaction is measured as average user ratings in chapter 2. Further, net benefits were qualitatively measured as user self-reported experiences, perceived benefits, and general feedback of MCH app use in chapter 4. Of note here is that the dissertation does not measure the interrelationship between any of these dimensions but uses four out of the six dimensions as unit of analysis for each of the three papers.

Figure 1.2. Dissertation Conceptual Model using IS Success Model




## Overview of the Dissertation

This dissertation consists of three papers that: (1) examine the relationship between MCH app characteristics, and two outcomes, i.e. end users' perceived satisfaction (user ratings), and intent to use (downloads); (2) review the use of behavior change techniques in maternal and child health apps; (3) assess user self-reported experiences with MCH apps, their perceived benefits, and general feedback.

**References**

Abroms, L. C., Padmanabhan, N., Thaweethai, L., & Phillips, T. (2011). iPhone apps for smoking cessation: a content analysis. *American Journal of Preventive Medicine*, *40*(3), 279-285. doi:10.1016/j.amepre.2010.10.032

Anderson, M. (2015). *Technology device ownership: 2015*. Retrieved from Pew Research Center website: http://www.pewinternet.org/files/2015/10/PI_2015-10-29_device-ownership_FINAL.pdf

Arnhold, M., Quade, M., & Kirch, W. (2014). Mobile applications for diabetics: a systematic review and expert-based usability evaluation considering the special requirements of diabetes patients age 50 years or older. *Journal of Medical Internet Research*, *16*(4), e104. doi:10.2196/jmir.2968

Bender, J. L., Yue, R. Y., To, M. J., Deacken, L., & Jadad, A. R. (2013). A lot of action, but not in the right direction: systematic review and content analysis of smartphone applications for the prevention, detection, and management of cancer. *Journal of Medical Internet Research*, *15*(12), e287. doi:10.2196/jmir.2661

BinDhim, N. F., Freeman, B., & Trevena, L. (2014). Pro-smoking apps for smartphones: the latest vehicle for the tobacco industry? *Tobacco Control*, *23*(1), e4. doi:10.1136/tobaccocontrol-2012-050598

BinDhim, N.F., Naicker, S., Freeman, B., McGeechan, K., & Trevana, L. (2014). Apps promoting illicit drugs- A need for tighter regulation? *Journal of Consumer Health on the Internet, 18*(1), 31-43. doi: 10.1080/15398285.2014.869166

BinDhim, N.F, & Trevena, L. (2015a). There's an App for That: A Guide for Healthcare Practitioners and Researchers on Smartphone Technology. *Online Journal of Public Health Informatics, 7*(2), e218. doi:10.5210/ojphi.v7i2.5522

BinDhim, N.F., & Trevena, L. (2015b). Health related smartphone apps: regulations, safety, privacy, and quality. *BMJ Innovations*, 1-3. doi:10.1136/bmjinnov-2014-000019

Boulos, M. N., Brewer, A. C., Karimkhani, C., Buller, D. B., & Dellavalle, R. P. (2014). Mobile medical and health apps: state of the art, concerns, regulatory control and certification. *Online journal of public health informatics, 5*(3), 229. doi:10.5210/ojphi.v5i3.4814

Burke, K.B., Sargant, N., Marden, B. (2012, November). Smartphone technology in paediatric setting. *Archives of disease in childhood, 97*(11), 1007-1008. doi: 10.1136/archdischild-2012-302790

Cisco Systems Inc. (2016). *Cisco visual networking index: Global mobile data traffic forecast update, 2015-2020 White Paper*. Retrieved from http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html

Choi, J., Noh, G. Y., & Park, D. J. (2014). Smoking cessation apps for smartphones: content analysis with the self-determination theory. *Journal of Medical Internet Research, 16*(2), e44. doi:10.2196/jmir.3061

Chyjek, K., Farag, S., & Chen, K. T. (2015). Rating Pregnancy Wheel Applications Using the APPLICATIONS Scoring System. *Obstetrics and Gynecology, 125*(6), 1478-1483. doi:10.1097/AOG.0000000000000842

Cortez, N. G., Cohen, I. G., & Kesselheim, A. S. (2014). FDA regulation of mobile health technologies. *New England Journal of Medicine, 371*(4), 372-379. doi:10.1056/NEJMhle1403384

Coulon, S. M., Monroe, C. M., & West, D. S. (2016). A Systematic, Multi-domain Review of Mobile Smartphone Apps for Evidence-Based Stress Management. *American Journal of Preventive Medicine, 51*(1), 95-105. doi:10.1016/j.amepre.2016.01.026

Crane, D., Garnett, C., Brown, J., West, R., & Michie, S. (2015). Behavior change techniques in popular alcohol reduction apps: content analysis. *Journal of Medical Internet Research, 17*(5), e118. doi:10.2196/jmir.4060

Declercq ER, Sakala C, Corry MP, Applebaum S, Herrlich A. (2013, May). *Listening to Mothers III: Pregnancy and Birth.* New York: Childbirth Connection.

DeLone, W. H., & McLean, E. R. (1992). Information systems success: The quest for the dependent variable. *Information Systems Research, 3*(1), 60–95. Retrieved from https://pdfs.semanticscholar.org/a041/45f1ca06c61f5985ab22a2346b788f343392.pdf

DeLone, W. H., & McLean, E. R. (2003). The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. *Journal of Management Information Systems, 19*(4), 9–30. doi: 10.1080/07421222.2003.11045748

Demidowich, A. P., Lu, K., Tamler, R., & Bloomgarden, Z. (2012). An evaluation of diabetes self-management applications for Android smartphones. *Journal of telemedicine telecare, 18*(4), 235-238. doi:10.1258/jtt.2012.111002

DeMuro, P. (2013). *Mobile medical applications and the affordable care act*. Retrieved from The Lund Report website: https://www.thelundreport.org/content/mobile-medical-applications-and-affordable-care-act

Dennison, L., Morrison, L., Conway, G., & Yardley, L. (2013). Opportunities and challenges for smartphone applications in supporting health behavior change: qualitative study. *Journal of Medical Internet Research, 15*(4), e86. doi:10.2196/jmir.2583

Derbyshire, E., & Dancey, D. (2013). Smartphone Medical Applications for Women's Health: What Is the Evidence-Base and Feedback? *International Journal of Telemedicine and Applications, 2013,* 782074. doi:10.1155/2013/782074

Dubey, D., Amritphale, A., Sawhney, A., Amritphale, N., Dubey, P., & Pandey, A. (2014). Smart phone applications as a source of information on stroke. *Journal of Stroke, 16*(2), 86-90. doi:10.5853/jos.2014.16.2.86

Eng, D. S., & Lee, J. M. (2013). The promise and peril of mobile health applications for diabetes and endocrinology. *Pediatric Diabetes, 14*(4), 231-238. doi:10.1111/pedi.12034

Evans, W. D., Wallace, J. L., & Snider, J. (2012). Pilot evaluation of the text4baby mobile health program. *BMC Public Health, 12*, 1031. doi:10.1186/1471-2458-12-1031

Farag, S., Chyjek, K., & Chen, K. T. (2014). Identification of iPhone and iPad applications for obstetrics and gynecology providers. *Obstetrics and Gynecology, 124*(5), 941-945. doi:10.1097/AOG.0000000000000510

Farag, S., Fields, J., Pereira, E., Chyjek, K., & Chen, K. T. (2016). Identification and Rating of Gynecologic Oncology Applications Using the APPLICATIONS Scoring System. *Telemedicine journal and e-health*. doi:10.1089/tmj.2016.0040

Food and Drug Administration (FDA). (2015, February). *Mobile medical applications: Guidance for industry and Food and Drug Administration staff*. Retrieved from http://www.fda.gov/downloads/MedicalDevices/.../UCM263366.pdf

Franko, O. I., & Tirrell, T. F. (2012). Smartphone app use among medical providers in ACGME training programs. *Journal of Medical Systems, 36*(5), 3135-3139. doi:10.1007/s10916-011-9798-7

Free, C., Phillips, G., Watson, L., Galli, L., Felix, L., Edwards, P., . . . Haines, A. (2013). The effectiveness of mobile-health technologies to improve health care service delivery processes: a systematic review and meta-analysis. *PLoS Medicines, 10*(1), e1001363. doi:10.1371/journal.pmed.1001363

Ganju, N., Krapf, J., Benham, J., & Marko, K.I. (2016, May). Preventing excessive gestational weight gain by using connected weight scales paired with mobile apps [22L]. *Obstetrics & Gynecology*, *127*(5), 103S-104S. doi: 10.1097/01.AOG.0000483431.23644.71

Heminger, C. L., Schindler-Ruwisch, J. M., & Abroms, L. C. (2016). Smoking cessation support for pregnant women: role of mobile technology. *Substance abuse and rehabilitation*, *7*, 15-26. doi:10.2147/SAR.S84239

Huckvale, K., Car, M., Morrison, C., & Car, J. (2012). Apps for asthma self-management: a systematic assessment of content and tools. *BMC Medicine, 10*, 144. doi:10.1186/1741-7015-10-144

Husain, I., & Spence, D. (2015). Can healthy people benefit from health apps? *BMJ (Clinical Research ed.), 350*, h1887. doi:10.1136/bmj.h1887

Jareethum, R., Titapant, V., Chantra, T., Sommai, V., Chuenwattana, P., & Jirawan, C. (2008). Satisfaction of healthy pregnant women receiving short message service via mobile phone for prenatal support: A randomized controlled trial. *Journal of the Medical Association of Thailand, 91*(4), 458-463.

Jacobs, M. A., Cobb, C. O., Abroms, L., & Graham, A. L. (2014). Facebook apps for smoking cessation: a review of content and adherence to evidence-based guidelines. *Journal of Medical Internet Research, 16*(9), e205. doi:10.2196/jmir.3491

Jain, A. (2011). Apps Marketplaces and the Telecom Value Chain. *IEEE Wireless Communications, 18*(4), 4-5. doi: 10.1109/MWC.2011.5999758

Kalz, M., Lenssen, N., Felzen, M., Rossaint, R., Tabuenca, B., Specht, M., & Skorning, M. (2014). Smartphone apps for cardiopulmonary resuscitation training and real incident support: a mixed-methods evaluation study. *Journal of Medical Internet Research, 16*(3), e89. doi:10.2196/jmir.2951

Kharrazi, H., Chisholm, R., VanNasdale, D., & Thompson, B. (2012). Mobile personal health records: an evaluation of features and functionality. *International Journal of Medical Informatics, 81*(9), 579-593. doi:10.1016/j.ijmedinf.2012.04.007

Krebs, P., & Duncan, D. T. (2015). Health App Use Among US Mobile Phone Owners: A National Survey. *JMIR Mhealth and Uhealth, 3*(4), e101. doi:10.2196/mhealth.4924

Lee, Y., & Moon, M. (2016). Utilization and Content Evaluation of Mobile Applications for Pregnancy, Birth, and Child Care. *Healthcare Informatics Research, 22*(2), 73-80. doi:10.4258/hir.2016.22.2.73

Lewkowitz, A. K., O'Donnell, B. E., Nakagawa, S., Vargas, J. E., & Zlatnik, M. G. (2016). Social media messaging in pregnancy: comparing content of Text4baby to content of free smart phone applications of pregnancy. *Journal of Maternal-Fetal & Neonatal Medicine, 29*(5), 745-751. doi:10.3109/14767058.2015.1017460

Lupton, D. (2014). Apps as artefacts: Towards a critical perspective on mobile health and medical apps. *Societies,* 4(4), 606-622, doi:10.3390/soc4040606

Lupton, D. (2015). Health promotion in the digital era: a critical commentary. *Health Promotion International, 30*(1), 174-183. doi:10.1093/heapro/dau091

Lupton, D., & Pedersen, S. (2016). An Australian survey of women's use of pregnancy and parenting apps. *Women and Birth, 29*(4), 368-375. doi:10.1016/j.wombi.2016.01.008

Mangone, E. R., Lebrun, V., & Muessig, K. E. (2016). Mobile Phone Apps for the Prevention of Unintended Pregnancy: A Systematic Review and Content Analysis. *JMIR Mhealth Uhealth, 4*(1), e6. doi:10.2196/mhealth.4846

Masterson Creber, R. M., Maurer, M. S., Reading, M., Hiraldo, G., Hickey, K. T., & Iribarren, S. (2016). Review and Analysis of Existing Mobile Phone Apps to Support Heart Failure Symptom Monitoring and Self-Care Management Using the Mobile Application Rating Scale (MARS). *JMIR Mhealth Uhealth, 4*(2), e74. doi:10.2196/mhealth.5882

Marko, K.I., Ganju, N., Brown, J., Benham, J., & Gaba, N.D. (2016, May). Remote prenatal care monitoring with digital health tools can reduce visit frequency while improving satisfaction [3]. *Obstetrics & Gynecology, 127*(5), 1S. doi: 10.1097/01.AOG.0000483620.40988.df

Marko, K. I., Krapf, J. M., Meltzer, A. C., Oh, J., Ganju, N., Martinez, A. G., . . . Gaba, N. D. (2016). Testing the Feasibility of Remote Patient Monitoring in Prenatal Care Using a Mobile App and Connected Devices: A Prospective Observational Trial. *JMIR Research Protocols, 5*(4), e200. doi:10.2196/resprot.6167

Mendiola, M.F., Kalnicki, M., & Lindenauer, S. (2015). Valuable features in mobile health apps for patients and consumers: Content analysis of apps and user ratings. *JMIR Mhealth and Uhealth*, 3(2), e40. doi: 10.2196/mhealth.4283

Mertz, L. (2012). Ultrasound? Fetal Monitoring? Spectrometer? There's an app for that!: Biomedical smart phone apps are taking healthcare by storm. *IEEE Pulse, 3*(2), 16-21. doi: 10.1109/MPUL.2011.2181019

Muessig, K. E., Pike, E. C., Legrand, S., & Hightow-Weidman, L. B. (2013). Mobile phone applications for the care and prevention of HIV and other sexually transmitted diseases: a review. *Journal Medical Internet Research, 15*(1), e1. doi:10.2196/jmir.2301

Nicholas, J., Larsen, M. E., Proudfoot, J., & Christensen, H. (2015). Mobile Apps for Bipolar Disorder: A Systematic Review of Features and Content Quality. *Journal of Medical Internet Research, 17*(8), e198. doi:10.2196/jmir.4581

Nilsen, W., Kumar, S., Shar, A., Varoquiers, C., Wiley, T., Riley, W. T., . . . Atienza, A. A. (2012). Advancing the science of mHealth. *Journal of Health Communication, 17 Suppl 1*, 5-10. doi:10.1080/10810730.2012.677394

Nwolise, C. H., Carey, N., & Shawe, J. (2016). Preconception care education for women with diabetes: A systematic review of conventional and digital health interventions. *Journal of Medical Internet Research*, *18*(11), e291. doi:10.2196/jmir.5615

O'Higgins, A., Murphy, O. C., Egan, A., Mullaney, L., Sheehan, S., & Turner, M. J. (2014). The use of digital media by women using the maternity services in a developed country. *Irish Medical Journal, 107*(10), 313-315.

O'Neill, S., & Brady, R. R. (2012). Colorectal smartphone apps: opportunities and risks. *Colorectal Disease, 14*(9), e530-534. doi:10.1111/j.1463-1318.2012.03088.x

Pandey, A., Hasan, S., Dubey, D., & Sarangi, S. (2013). Smartphone apps as a source of cancer information: changing trends in health information-seeking behavior. *Journal of Cancer Education, 28*(1), 138-142. doi:10.1007/s13187-012-0446-9

Powell, A. C., Torous, J., Chan, S., Raynor, G. S., Shwarts, E., Shanahan, M., & Landman, A. B. (2016). Interrater reliability of mHealth app rating measures: Analysis of top depression and smoking cessation apps. *JMIR Mhealth Uhealth, 4*(1), e15. doi:10.2196/mhealth.5176

Robinson, F., & Jones, C. (2014). Women's engagement with mobile device applications in pregnancy and childbirth. *The Practising Midwife*, *17*(1), 23-25.

Rotheram-Borus, M. J., Tomlinson, M., Swendeman, D., Lee, A., & Jones, E. (2012). Standardized functions for smartphone applications: examples from maternal and child health. *International Journal of Telemedicine and Application, 2012*, 973237. doi:10.1155/2012/973237

Schulke, D. F. (2013). The regulatory arms race: mobile-health applications and agency posturing. *Boston University Law Review, 93*(1699), 1700-1750. Retrieved from http://www.bu.edu/bulawreview/files/2013/10/SCHULKE_Arms-Race.pdf

Schoffman, D. E., Turner-McGrievy, G., Jones, S. J., & Wilcox, S. (2013). Mobile apps for pediatric obesity prevention and treatment, healthy eating, and physical activity promotion: just fun and games? *Translational Behavioral Medicine, 3*(3), 320-325. doi:10.1007/s13142-013-0206-3

Scott, K.M., Richards, D. & Adhikari, R. (2015). A review and comparative analysis of security risks and safety measures of mobile health apps. *Australian Journal of Information Systems, 19*, 1-18. doi: 10.3127/ajis.v19i0.1210

Scott, K.M., Gome, G.A., Richards, D., & Caldwell, P.H. (2015). How trustworthy are apps for maternal and child health? *Health and Technology, 4*(4), 329-336. doi:10.1007/s12553-015-0099-x

Shaia, K. L., Farag, S., Chyjek, K., Knopman, J., & Chen, K. T. (2016). An evaluation of mobile applications for reproductive endocrinology and infertility providers. *Telemedicine journal and e-health*. doi:10.1089/tmj.2016.0079

Shenson, J.A., Ingram, E., Colon, N., & Jackson, G.P. (2015). Applications of a consumer health information needs taxonomy to questions in maternal-fetal care. *AMIA Annual Symposium Proceedings Archive, 2015*, 1148-1156. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4765568/

Shieh, C., Broome, M. E., & Stump, T. E. (2010). Factors associated with health information-seeking in low-income pregnant women. *Women & Health, 50*(5), 426-442. doi:10.1080/03630242.2010.506152

Smith A. (2015). *U.S. smartphone use in 2015*. Retrieved from Pew Research Center website: http://www.pewinternet.org/2015/04/01/us-smartphone-use-in-2015/

Statista ("n.d"a). *Cumulative number of apps downloaded from the Google Play as of May 2016 (in billions).* Retrieved from https://www.statista.com/statistics/281106/number-of-android-app-downloads-from-google-play/

Statista ("n.d"b). *Cumulative number of apps downloaded from the Apple App Store from July 2008 to September 2016 (in billions)*. Retrieved from https://www.statista.com/statistics/263794/number-of-downloads-from-the-apple-app-store/

Sunyaev, A., Dehling, T., Taylor, P. L., & Mandl, K. D. (2015). Availability and quality of mobile health app privacy policies. *Journal of American Medical Informatics Association, 22*(e1), e28-33. doi:10.1136/amiajnl-2013-002605

Thomas, G. M., & Lupton, D. (2016). Threats and thrills: pregnancy apps, risk and consumption. *Health, Risk & Society, 17*(7-8), 495-509. doi:10.1080/13698575.2015.1127333

Ventola, C. L. (2014). Mobile devices and apps for health care professionals: uses and benefits. *Pharmacy & Therapeutics, 39*(5), 356-364. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4029126/

Visser, B. J., & Buijink, A. W. (2012). Need to peer-review medical applications for smart phones. *Journal of telemedicine and telecare, 18*(2), 124. doi:10.1258/jtt.2011.110205

Yang, Y. T., & Silverman, R. D. (2014). Mobile health applications: the patchwork of legal and liability issues suggests strategies to improve oversight. *Health Affairs (Millwood), 33*(2), 222-227. doi:10.1377/hlthaff.2013.0958

# CHAPTER 2

# FACTORS RELATED TO USER RATINGS AND USER DOWNLOADS OF MOBILE APPS FOR MATERNAL AND CHILD HEALTH

## Introduction

Increasingly, women are turning to digital technologies for their information needs, and mobile health (mHealth) apps are among this new range of technologies that are available to women during pregnancy (Thomas & Lupton, 2016). The ubiquity and penetration of mobile phones offer a unique opportunity to utilize mHealth for maternal and child healthcare services (Tamrat & Kachnowski, 2012). Recently, mobile health apps are gaining popularity in providing maternity information with easy access at little or no cost (Lee & Moon, 2016; Tripp et al., 2014; Robinson & Jones, 2014). A significant 56% first time mothers and 47% experienced mothers found maternal and child health (MCH) apps useful in providing valuable information (Declercq, Sakala, Corry, Applebaum, Herrlich, 2013). As high as 73% pregnant women and new mothers reported the use of MCH apps, with 27% using these apps almost daily (Lupton & Pedersen, 2016). In addition, MCH apps were deemed more useful by socially disadvantaged women who may otherwise lack access to alternate educational resources (O'Higgins et al., 2014; Thomas & Lupton, 2016).

Compared to other health topics, mobile apps for MCH subjects, such as pregnancy, childbirth, and childcare are some of the most prevalent and commonly used (Lee & moon, 2016; Tripp et al., 2014). There are hundreds of apps directed towards pregnancy and new motherhood, and some of these apps are extremely popular among pregnant women (Thomas & Lupton, 2016). Maternal and Child Health (MCH) apps frequently appear on the iTunes and Google Play Store's list of most downloaded apps and some have been downloaded over five million times (Lupton & Thomas, 2015). Some of these apps have an average user rating (i.e. "stars") of 4.5. Both user downloads, and user ratings offer an arbitrary indicator of the popularity, acceptability, and satisfaction with apps (Arnhold, Quade, & Kirch, 2014; Muessig, Pike, LeGrand, & Hightow-Weidman, 2013). An analysis of user commentaries from women's health apps indicate that overall women are in favor of apps that are easy to use, contain new information, and are motivational (Derbyshire & Dancy, 2013). Therefore, as consumers increasingly use mobile apps, healthcare providers, app developers, policymakers, and patients, may benefit from a better understanding of the underlying factors that drive user demand, and popularity of MCH apps.

The rapid proliferation of mobile health apps has not been accompanied by equal attention to determine the factors that consumers require or prefer when selecting from a multitude of available apps (Rahman et al., 2017). Consumers have little reliable information to refer to when seeking the best apps for their health needs (Rahman et al., 2017).

Moreover, research within the realm of understanding user behavior and user adoption of mobile health apps that quantify consumer preferences for different app features and categories is limited. Ghose & Han (2014) built a structural econometric model to quantify consumer preferences towards different mobile app characteristics using data from 400 non-health specific, top-ranked apps from the Apple iOS and Google Android platform. They report that low priced apps, offering in-app purchase options, and those with updates (i.e. whether an app has been updated since launch), tended to have high user downloads. Similarly, Pereira-Azevado et al. (2016) studied the factors that are related to high user downloads of urology apps from the Google Play store. They showed that apps developed with expert urologist involvement, optional in-app purchases, and high user ratings were more likely to be downloaded, while app cost was negatively related with number of downloads.

Considering the popularity of MCH apps along with the rapidly evolving mHealth market (Tripp et al., 2014), necessitates a better understanding of user behavior within the context of intention to use and user satisfaction of these apps. Using app data from both Apple App and Google Play stores, this study quantifies apps features and characteristics that effect end users' perceived satisfaction and intent to use. Given the specificity of MCH apps, this study also examines the influence of app developer type (i.e. healthcare vs. non-healthcare) on user behavior, i.e. do users frequently download and rate apps developed by healthcare developers? Therefore, the objective of this study was to examine the relationship between MCH app characteristics (e.g., price, age, and developer organization), and two outcomes, i.e. end users' perceived satisfaction (user ratings), and intent to use (downloads).

**Methods**

*Source of Data*

The association between app characteristics, ratings, and downloads was explored in a cross-sectional sample of MCH apps available in the Apple App and Google Play stores. The dataset of MCH apps was built by scraping data from the Apple App Store (Apple Inc. iTunes) and Google Play Store (Google Inc., Google Play) platforms using a java-based scraper program called Node.js (Node.js Foundation).

The scraping program functioned by submitting a keyword search to the respective app stores, which automatically retrieved textual information about each app provided by the stores' search algorithms. Each store returned apps in the same order as if the search was conducted by an end user. Only the first 200 app results for Apple App and the first 250 app results (later reduced to 50 starting January 2017) for Google Play stores were returned by the scraper program (Larsen, Nicholas, & Christensen, 2016; Mangone, Lebrun, & Muessig, 2016). It is understood that the app stores list more popular apps first as ranked by a non-disclosed proprietary search algorithm (Pereira-Azevado et al., 2016; Boudreaux et al., 2014). Therefore, the results of the scraping searches for this study contain those apps that were higher-ranked when searched and therefore most likely to be accessed by store visitors.

*Sample*

A three-step process was followed to create a dataset of MCH apps. Step 1 was identifying a list of relevant keywords that users might search when locating apps related to MCH (see appendix A for list of keywords). Step 2 was the scraping of the two app stores for candidate apps, merging results, and de-duplicating the resultant apps. Step 3 applied inclusion and exclusion criteria to identify those apps that were eligible for the study. The data reflect app store content as of March 2017.

*<u>Step 1: Identify keywords for app searches</u>*

To include a comprehensive set of MCH apps in the dataset, I first identified a list of relevant keywords to use for scraping. Search terms 'pregnancy' and 'prenatal' were identified as the starting point. The app stores were scraped in September 2016, and the process resulted in a total of 699 apps. Next, I examined only English language apps belonging to education, health & fitness, and medical categories, which eliminated about 34% apps. Subsequently, the app results from each store were merged and duplicates were removed, further eliminating around 3% apps. The resultant sample consisted of 448 unique apps from the two stores (see figure 2.1). From the resulting apps a simple random sample of 45 apps was selected, and additional keywords related to MCH were identified from the app descriptions (n=34) (see appendix A for a complete list of keywords used for this study). The aim of this process was to identify a comprehensive list of keywords that users might enter when searching for apps related to MCH.

*Step 2: Identify comprehensive sample of candidate MCH apps*

Each of the 34 keywords were entered individually into a separate search in March 2017. The resultant apps were merged and de-duplicated first within stores and then across stores for a total of 4,753 unique apps in the dataset (see figure 2.1). If an app was available on both platforms, the Google Play version was included for analysis because: (i) Google Play Store provided additional data such as user downloads, in-app purchase option, and presence of in-app advertisement; and (ii) as of 2016, android was the most popular smartphone operating system in the world (Statista, "n.d").

The Indiana University Institutional Review Board (IRB) deemed this study as non-human subjects research

*Step 3: Final App Inclusion and Exclusion*

To identify a final set of MCH related apps for analysis, a manual review of the app descriptions was conducted based on the inclusion and exclusion criteria that were identified for this study. Apps were included in the final sample if (i) description written in English language, (ii) target users judged to be pregnant women, to-be-parents and other care givers of infant children (i.e. 0-1 year of age as defined by Centers for Disease Control and Prevention (CDC), 2017), (iii) listed in the medical, health &fitness, books &reference, or education categories in Apple App Store OR listed in medical, health & fitness, books & reference, education, or parenting categories in the Google Play Store, (iv) described as intending to provide health education or user decision-making support.

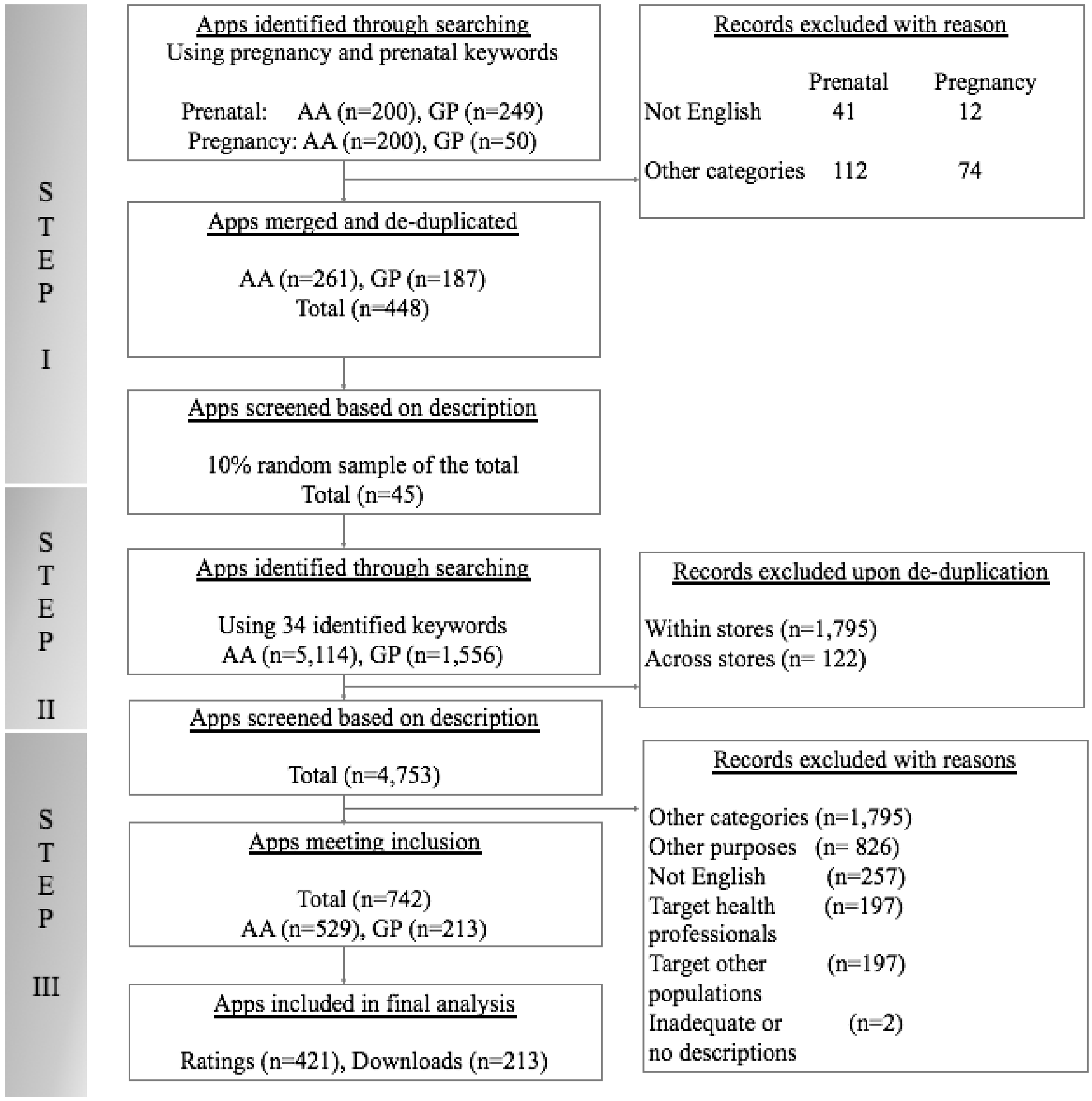
Apps were excluded if (i) targeted users judged as health professionals, providers, or students in health professions as primary users, (ii) had inadequate or no description provided, (iii) apps meant to be used by members or people associated with special programs or healthcare facilities (e.g. a clinic or hospital), (iv) solely calculated gestational age and/or due date (see table 2.1).

Table 2.1. Inclusion and Exclusion Criteria for App Selection

| **Inclusion Criteria** | **Exclusion Criteria** |
|---|---|
| App description written in English language. | Inadequate or no app description provided. |
| Target users judged to be pregnant women, to-be-parents and other care givers of infant children. | Target users judged as health professionals, health providers, or students in health professions, as primary users. |
| Listed in the medical, health/fitness, books/reference, or education categories in Apple App Store OR listed in medical, health/fitness, books/reference, education, or parenting categories in the Google Play Store | Apps meant to be used by members or people associated with special programs or healthcare facilities (e.g. a clinic or hospital). |
| Described as intending to provide health education or user decision-making support. | Solely calculated gestational age and/or due date. |

During this process, apps were coded by the primary reviewer (RB) as included, excluded, or unsure, based on the given inclusion and exclusion criteria. Apps that were coded as unsure were discussed with a second reviewer (CH). This process resulted in a total of 742 apps that were included in the analysis (n=529) from Apple App Store, and (n=213) from Google Play Store. For each app, an exhaustive list of app-related information was captured. Figure 2.1 provides a schematic representation of the decision sequence that led to the final sample of apps.

Figure 2.1. Schematic Representation of App Selection Process




*Note.* AA: Apple App; GP: Google Play

*Dependent Variables*

The first outcome variable was the average user ratings (i.e. "stars" 1 to 5) standardized as Z-scores, which reflects end users' perceived satisfaction. Critically, the Apple App store requires a minimum number of reviews before releasing average user ratings (i.e. small numbers are suppressed) and the Google Play store does not report ratings for un-reviewed apps. Therefore, these were all coded as missing values and omitted from the analysis. Of the 742 apps in my sample, 43.3% apps had no or suppressed user ratings, so the analysis reflects 421 apps (figure 2.1).

The second outcome variable was number of downloads, which was the measure of intention to use. The number of downloads was available on Google Play store apps only. This sample include 213 apps (figure 2.1). Number of downloads could only be extracted as one of 12 numeric range categories. For analysis, we further collapsed these into four categories (1-500, 500-5,000, 5,000-50,000, 50,000-50,000,000).

*Independent Variables*

Independent variables were App Store (Apple App store and Google Play store), prices in U.S. dollars, app developer type (healthcare and non-healthcare/unknown), days since last app update, primary categories/genre (medical, health & fitness, and other), content rating (age-restricted, not age-restricted, and unrated), in-app purchase option (yes/no), and in-app advertisement presence (yes/no). The predictor variables in-app purchase option, and in-app advertisement presence are available from Google Play store apps only.

(see appendix B for a complete description of the dependent and independent variables).

To categorize app developer type, a manual review of developer website provided by the app stores was conducted by the primary reviewer (RB). Based on the description provided, developers were categorized as healthcare developer if they were identified as one of the following: Government agency, US hospital system, US academic medical institution, medical specialty society, non-profit healthcare organization, consumer organization with health focus, US physician, third-party payer, pharmaceutical, medical technology company (Mendiola, Kalnicki, & Lindenauer, 2015). (see appendix C for a complete list of the categories and their descriptions). Alternatively, developers were categorized as non-healthcare/unknown, if based on the description provided, they were not classified into one of the above-mentioned categories, or in cases where the website was not provided, or where the description was written in a language other than English.

The app update age was based on the number of days since the new version was released. This was calculated by subtracting the date of the last update from the scrape date (i.e. March 31, 2017).

Only apps belonging to Books & Reference, Education, Health & Fitness, Medical, and Parenting genre, were included in this study. For the purposes of analysis, I combined apps belonging to Books & Reference, Education, and Parenting genre into a single category (other). This was to ensure adequate sample size in each of the categories.

The content ratings are associated with the appropriate age-restriction levels for each app. Both app stores have four levels of classification. The Apple App Store classifies it as 4+, 9+, 12+, and 17+ (iTunes Connect Developer Guide, 2017). The Google Play Store classification levels are everyone, low maturity, medium maturity, and high maturity (Google Play Console Help, “n.d”). For the purpose of analysis, apps with rating 4+ in App

Store and everyone in Play store were considered as “not age restricted”. Similarly, apps with ratings 9+, 12+, and 17+ and corresponding apps with ratings, low, medium, and high maturity from the Play Store were classified under “age restricted”. Apps with no developer provided ratings were classified as “unrated”.

**Data Analysis**

The unit of analysis adopted in this study was the app. Descriptive statistics were calculated to examine variable distributions such as the means and frequencies, and identify potential data anomalies, such as outliers or abnormal variable distributions.

The relationship between app characteristics and end users’ perceived satisfaction (user ratings), and intent to use (downloads) were examined in two separate regressions models. First, a multivariable linear regression assessed the relationship between app characteristics and standardized user ratings controlling for all other available app characteristics. The analysis was performed using SAS 9.4, and the level of significance was set at $p<0.05$. Second, the association between app characteristics and the number of app downloads were modeled using a series of ordinal logistic regressions. Each available app characteristic was modeled for price and standardized user ratings. Data analysis were conducted using STATA version 15, and the level of significance was set at $p<0.05$.

**Results**

Of the total 742 included apps in the sample, 515 (69.4%) were free. The average price of the apps was $0.99. Of the paid apps, the prices ranged from USD 0.99 (E.g. Labor Mate- contraction timer, and Natural Child Birth) to USD 99.95 (Drugs in Pregnancy and Lactation), with an average price of $3.25 and a median of $1.99. The number of days since last update varied from 14 to 2,888 (average 576 days). Only 213 apps (28.7%) were developed by healthcare organizations. For apps where user ratings were available, the average user rating was 3.79. Further, for apps where user download numbers were available, majority (31.0%) of the apps had download numbers greater than 50,000 (see table 2.2).

Table 2.2. Summary Descriptive Statistics for Independent and Dependent Variables

| Variables | Mean (SD) |
|---|---|
| Average User Ratings (no. of stars) [a.] | 3.79 (0.98) |
| App Price (including free apps) | 0.99 (4.06) |
| Update Age (days) | 576 (579.02) |
| | **Frequency (%)** |
| Downloads [b.] | |
| 1-500 | 43 (20.2) |
| 501-5,000 | 52 (24.4) |
| 5,001-50,000 | 52 (24.4) |
| 50,001-50,000,000 | 66 (31.0) |
| App Store | |
| Apple App | 529 (71.3) |
| Google Play | 213 (28.7) |
| Developer Type | |
| Non-Healthcare | 529 (71.3) |
| Healthcare | 213 (28.7) |
| Primary Category/Genre | |
| Health & Fitness | 393 (53.0) |
| Medical | 277 (37.3) |
| Other (Books & Reference, Education, and Parenting) | 72 (9.7) |
| Content Rating | |
| Not Age-Restricted | 478 (64.4) |
| Age-Restricted | 247 (33.3) |
| Unrated | 17 (2.3) |
| In-App Purchase [c.] | |
| Yes | 39 (18.3) |
| No | 174 (81.7) |
| In-App Advertisement [d.] | |
| Yes | 108 (50.7) |
| No | 105 (49.3) |

*Note.* a. 321 apps were not rated thereby reducing the total number to N=421
b. Variable user download was available only from the Google Play store, with N=213
c. Variable In-app purchase was available only from the Google Play store, with N=213
d. Variable In-app advertisement was available only from the Google Play store, with N=213

*App Characteristics Associated with User Ratings*

In the sample of apps with available user ratings (table 2.3), the only factor associated with increasing satisfaction was the Google Play store as the platform (β=0.33, *P*=0.005). Compared to the books & references, education, and parenting category, apps listed under the Health & Fitness genre were negatively associated with user satisfaction (β=-0.41, *P*=0.01). Other factors negatively associated with satisfaction included: older apps (i.e. increasing app age) (β=-0.0004, *P*=<0.0001), and apps with no age-restriction (β=-0.32, *P*=0.01). After controlling for other factors, developer type was not significantly associated with rating.

Table 2.3. Multivariable Linear Regression for Factors Associated with Standardized User Ratings (n=421)

| Variables | Estimates | SE | ***P* Value** |
|---|---|---|---|
| Developer Type Healthcare [b.] | -0.20 | 0.11 | 0.060 |
| Google Play Platform [b.] | 0.33 | 0.12 | **0.005** |
| Genre | | | |
| Books & Reference, Education, and Parenting | Ref | Ref | Ref |
| Medical Genre | -0.19 | 0.17 | 0.230 |
| Health & Fitness Genre | -0.41 | 0.17 | **0.010** |
| Update Age | -0.0004 | 0.00008 | **<.0001** |
| Content Rating | | | |
| Age-Restricted | Ref | Ref | Ref |
| Not Age-Restricted Apps | -0.32 | 0.13 | **0.010** |
| Unrated Apps | -0.51 | 0.32 | 0.100 |
| Price (USD) | 0.03 | 0.03 | 0.350 |

*Note.* a. The dependent variable is the standardized user rating Z-score.
b. The reference level for Platform "iOS", for Developer Type "Not healthcare developer"

*App Characteristics Associated with Downloads*

In the sample of apps with available user downloads (table 2.4), factors associated with user downloads were standardized user ratings (β=0.80, *P* < 0.001), in-app purchases (β=1.12, *P*=0.002), and in-app advertisement (β=0.64, *P*=0.02). Compared to the books & references, education, and parenting category, apps listed under the Medical (β=-1.63, *P*<0.001) and Health & Fitness (β=-1.29, *P*=0.002) genre were negatively associated with user downloads. Other factors negatively associated with user downloads included: price (β=-0.45, *P*=0.003), and older apps (i.e. increasing app age) (β=-0.0008, *P*=0.009). After controlling for other factors, developer type was not significantly associated with downloads (see appendices D-I for full details).

Table 2.4. Ordinal Logistic Regression for Factors Associated with User Downloads (n=213)

| **Variables** | **Estimates** | **SE** | ***P* Value** |
|---|---|---|---|
| Standardized User Rating | 0.80 | 0.20 | **< 0.001** |
| Price (USD) | -0.45 | 0.15 | **0.003** |
| Developer Type Healthcare | -0.14 | 0.30 | 0.630 |
| <u>Genre</u> | | | |
| Books & Reference, Education, and Parenting | Ref | Ref | Ref |
| Medical Genre | -1.63 | 0.46 | **<0.001** |
| Health & fitness Genre | -1.29 | 0.42 | **0.002** |
| Update Age | -0.0008 | 0.0003 | **0.009** |
| In-App Purchase | 1.12 | 0.36 | **0.002** |
| In-App Advertisement | 0.64 | 0.27 | **0.020** |

*Note.* a. The dependent variable is the level of downloads.

b. Each row comes from a separate model, controlling for price, and user rating. Full tables for each model appear in the Appendix.

c. The reference level for user downloads is "50,000-50,000,000"; for developer type "Not healthcare developer"; for Offers in-app purchase "no"; for Offer in-app advertisement "no".

d. Estimates show the relative magnitude, and direction (positive or negative) of the impact of the listed variables on the level of downloads.

**Discussion**

The Apple App and Google Play store contain numerous apps related to MCH, many of which have been downloaded hundreds of thousands of times. The majority of these apps were not developed by health care organizations/entities. Overall apps that belong to the Google Play store were associated with higher satisfaction. In addition, an increasing number of downloads was associated with user ratings, in-app purchase options, and presence of in-app advertisements.

A large majority of MCH apps included in this study were developed by non-healthcare organizations (71.3%), which could raise concerns pertaining to the accuracy and trustworthiness of in-app information. This is consistent with previous reports on limited or nonexistent health expert involvement in app development within other health domains such as urology (Pereira-Azevado et al., 2016; Scott et al., 2015). Prior studies that focus on evaluating the quality of mobile health apps have indicated missed opportunities pertaining to the timeliness and validity of the information that is being presented (Nilsen et al., 2012; Lupton, 2014). E.g. out of 218 apps for prevention of unintended pregnancy, around 40% apps do not mention modern contraceptives, and from the remaining 60% apps, less than 50% provide information on how to use them (Mangone et al., 2016). Similarly, from a sample of 10 free MCH apps only 40% apps provide information from evidence-based medical content (Scott et al., 2015).

While these concerns have garnered attention from public agencies such as the US Food and Drug Administration (FDA), presently, the FDA only regulates apps that act as medical devices (FDA, 2015). This calls for greater participation of healthcare organizations and other medical societies in app development, content review, and peer review process, to ensure app safety and accuracy (Pereira-Azevado et al., 2016). It may also be beneficial for healthcare organizations and experts to review, and "certify" health apps, similar to existing web certification, such as the Health on the Net Foundation (HON) Code of Conduct, where the reliability and integrity of health information is evaluated against established standards (Boudreaux et al., 2014). Our results show no differences in user downloads between healthcare and non-healthcare organizations. Therefore, if healthcare organizations in fact provide more credible information, fewer consumers may receive this information. Hence, healthcare providers, app developers, and policymakers may consider strategies to review and promote apps to consumers based on information accuracy and trustworthiness.

Cheaper apps with optional in-app purchases were associated with higher user ratings and downloads. Consumers tend to prefer apps that are free or of low cost with an ability to purchase additional features or functionalities via in-app purchases, as opposed to paying a higher price upfront (Ghose & Han, 2014; Pereira-Azevado et al., 2016; Peng, Kanthawala, Yuan, & Hussain, 2016). The number of user downloads also increased with average user ratings, thereby signifying that perceived satisfaction with these apps is an important indicator related to new user preferences. Other factors that may positively influence the number of downloads is the availability of updates (i.e. when was the app last updated), because this acts as a proxy of the app's evolution (Pereira-Azevado et al., 2016). An updated app is featured in "New & Updated Apps" category of the Google Play Store, thereby creating increased app awareness (Pereira-Azevado et al., 2016). On the other hand, average user ratings or perceived satisfaction decreases with apps having older update dates. It is also important to note that apps belonging to health & fitness genre tended to have lower perceived satisfaction (user rating) as well as intent to use (downloads), while apps belonging to medical genre were associated with fewer downloads. Further studies are needed to determine if this trend is specific to MCH apps or is applicable to apps belonging to other medical fields as well.

This study utilizes secondary data to assess the factors related to user ratings (perceived satisfaction), and user downloads (intent to use) for MCH apps. Future research may focus on collecting data from users pertaining to their behavior.

**Strengths and Limitations**

To our knowledge, this is a first study to determine the predictors of user ratings and user downloads for MCH apps using data from Apple App and Google Play stores. Further, this is a first study that quantifies app features and characteristics that influence user ratings of medical and health apps. This study utilizes a systematic approach of sampling MCH apps by applying a vigorous methodology to include the most comprehensive apps. The study employs a robust sample of MCH apps for analysis. Further, this study utilizes publicly available open source data.

Yet, there are few limitations. MCH apps are included from only two app stores and only information available in the app stores and developers' websites are collected. However, the app stores and developers' websites are the main source of information available to consumers too. Thus, the study simulates the information that is available to users before downloading an app. Further, each app store limits the number of search results that are returned upon scraping data from the app stores, i.e. first 200 for Apple App store, and first 250 for Google Play store, which was later reduced to 50 per scrape starting January 2017. Next, unlike Google Play store, Apple App store does not provide data on the number of downloads, hence, only apps from the Google Play store are included to assess the factors related to user downloads. Additionally, there is no data available on app discontinuation rates. Furthermore, this is a cross-sectional study assessing app characteristics at a given point in time (March 2017). Future studies should focus on conducting a longitudinal study to analyze the factors that influence user ratings and downloads over a period of time.

**Conclusion**

Apps belonging to the Google Play store have higher user ratings, while apps belonging to health and fitness genre, with older updates, and with no age restriction tend to have fewer user ratings. Furthermore, lower priced apps, with higher user ratings, in-app purchase options, and in-app advertisements tend to have high user downloads. No significant differences in user ratings or downloads are observed between apps developed by healthcare organizations and non-healthcare organizations. Healthcare providers, app developers, and policymakers may consider strategies to review and promote evidence-based and trustworthy apps to consumers.

**References**

Arnhold, M., Quade, M., & Kirch, W. (2014). Mobile applications for diabetics: a systematic review and expert-based usability evaluation considering the special requirements of diabetes patients age 50 years or older. *Journal of Medical Internet Research*, *16*(4), e104. doi:10.2196/jmir.2968

Apple Inc. iTunes. Retrieved from https://itunes.apple.com/us/genre/ios/id36?mt=8

Boudreaux, E. D., Waring, M. E., Hayes, R. B., Sadasivam, R. S., Mullen, S., & Pagoto, S. (2014). Evaluating and selecting mobile health apps: strategies for healthcare providers and healthcare organizations. *Translational Behavioral Medicine, 4*(4), 363-371. doi:10.1007/s13142-014-0293-9

Centers for Disease Control and Prevention (CDC). (2017). *Infants (0-1 year of age)*. Retrieved from https://www.cdc.gov/ncbddd/childdevelopment/positiveparenting/infants.html

Declercq ER, Sakala C, Corry MP, Applebaum S, Herrlich A. (2013, May). *Listening to Mothers III: Pregnancy and Birth.* New York: Childbirth Connection.

Derbyshire, E., & Dancey, D. (2013). Smartphone medical applications for women's health: What is the evidence-base and feedback? *International Journal of Telemedicine and Applications*, *2013*, 782074. doi:10.1155/2013/782074

Food and Drug Administration (FDA). (2015, February). *Mobile medical applications: Guidance for industry and Food and Drug Administration staff*. Retrieved from http://www.fda.gov/downloads/MedicalDevices/.../UCM263366.pdf

Ghose, A. & Han, S. P. (2014). Estimating demand for mobile applications in the new economy. *Management Science, 60* (6), 1470-1488. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2378007

Google Play Console Help. (n.d.). *Content ratings for apps & games*. Retrieved from https://support.google.com/googleplay/android-developer/answer/188189?hl=en

Google Inc. Google Play. Retrieved from https://play.google.com/store/apps

iTunes Connect Developer Guide. (2017, March). Identifying your app in iTunes connect. Retrieved from https://www.digitalmarketer.com/content/uploads/2014/04/iTunesConnect_Guide.pdf

Larsen, M. E., Nicholas, J., & Christensen, H. (2016). Quantifying app store dynamics: Longitudinal tracking of mental health apps. *JMIR Mhealth Uhealth, 4*(3), e96. doi:10.2196/mhealth.6020

Lee, Y., & Moon, M. (2016). Utilization and content evaluation of mobile applications for pregnancy, birth, and child care. *Healthcare Informatics Research, 22*(2), 73-80. doi:10.4258/hir.2016.22.2.73

Lupton, D. (2014). Apps as artefacts: Towards a critical perspective on mobile health and medical apps. *Societies,* 4(4), 606-622, doi:10.3390/soc4040606

Lupton, D. & Pedersen, S. (2016). An Australian survey of women's use of pregnancy and parenting apps. *Women and Birth, 29(4),* 368-375 doi: 10.1016/j.wombi.2016.01.008

Mangone, E. R., Lebrun, V., & Muessig, K. E. (2016). Mobile phone apps for the prevention of unintended pregnancy: A systematic review and content analysis. *JMIR Mhealth Uhealth, 4*(1), e6. doi:10.2196/mhealth.4846

Mendiola, M.F., Kalnicki, M., & Lindenauer, S. (2015). Valuable features in mobile health apps for patients and consumers: Content analysis of apps and user ratings. *JMIR Mhealth and Uhealth*, 3(2), e40. doi: 10.2196/mhealth.4283

Muessig, K. E., Pike, E. C., Legrand, S., & Hightow-Weidman, L. B. (2013). Mobile phone applications for the care and prevention of HIV and other sexually transmitted diseases: a review. *Journal Medical Internet Research, 15*(1), e1. doi:10.2196/jmir.2301

Nilsen, W., Kumar, S., Shar, A., Varoquiers, C., Wiley, T., Riley, W. T., . . . Atienza, A. A. (2012). Advancing the science of mHealth. *Journal of Health Communication, 17 Suppl 1*, 5-10. doi:10.1080/10810730.2012.677394

Node.js Foundation. Retrieved from https://nodejs.org/en/

O'Higgins, A., Murphy, O. C., Egan, A., Mullaney, L., Sheehan, S., & Turner, M. J. (2014). The use of digital media by women using the maternity services in a developed country. *Irish Medical Journal, 107*(10), 313-315.

Peng, W., Kanthawala, S., Yuan, S., & Hussain, S. A. (2016). A qualitative study of user perceptions of mobile health apps. *BMC Public Health, 16*(1), 1158. doi:10.1186/s12889-016-3808-0

Pereira-Azevedo, N., Osorio, L., Cavadas, V., Fraga, A., Carrasquinho, E., Cardoso de Oliveira, E., . . . Roobol, M. J. (2016). Expert involvement predicts mHealth app downloads: Multivariate regression analysis of urology apps. *JMIR Mhealth Uhealth*, *4*(3), e86. doi:10.2196/mhealth.5738

Rahman, Q. A., Janmohamed, T., Pirbaglou, M., Ritvo, P., Heffernan, J. M., Clarke, H., & Katz, J. (2017). Patterns of user engagement with the mobile app, Manage My Pain: Results of a data mining investigation. *JMIR Mhealth Uhealth*, *5*(7), e96. doi:10.2196/mhealth.7871

Robinson, F., & Jones, C. (2014). Women's engagement with mobile device applications in pregnancy and childbirth. *The Practising Midwife*, *17*(1), 23-25.

Scott, K.M., Gome, G.A., Richards, D., & Caldwell, P.H. (2015). How trustworthy are apps for maternal and child health? *Health and Technology*, *4*(4), 329-336. doi:10.1007/s12553-015-0099-x

Statista. (n.d.). *Global market share held by the leading smartphone operating systems in sales to end users from 1st quarter 2009 to 1st quarter 2017*. Retrieved from https://www.statista.com/statistics/266136/global-market-share-held-by-smartphone-operating-systems/

Tamrat, T., & Kachnowski, S. (2012). Special delivery: an analysis of mHealth in maternal and newborn health programs and their outcomes around the world. *Maternal and Child Health Journal*, *16*(5), 1092-1101. doi:10.1007/s10995-011-0836-3

Thomas, G.M. & Lupton, D. (2016). Threats and thrills: pregnancy apps, risk and consumption. *Health, Risk & Society*, *17*(7-8). doi:10.1080/13698575.2015.1127333

Tripp, N., Hainey, K., Liu, A., Poulton, A., Peek, M., Kim, J., & Nanan, R. (2014). An emerging model of maternity care: smartphone, midwife, doctor? *Women and Birth*, *27*(1), 64-67. doi:10.1016/j.wombi.2013.11.001

# CHAPTER 3

# THEORY BASED CONTENT ANALYSIS OF MATERNAL AND CHILD HEALTH APPS

## Introduction

Positive changes in maternal health behavior can significantly reduce adverse health outcomes for both mother and the baby (Bale & Lucas (Eds.), 2003). Traditional health communication methods such as face-to-face education, audio-visual training clips, and mass media have been successfully employed to promote healthy behaviors among pregnant women and new mothers (Daly, Horey, Middleton, Boyle, & Flenady, 2017). However, women are increasingly turning to digital sources for their information needs during pregnancy, and mobile health (mHealth) apps are among this new range of available technologies (Thomas & Lupton, 2016). As high as 86% women expressed interest in using a website or mobile application to help them gain a healthy amount of weight during pregnancy (Waring et al., 2014). Similarly, almost three quarters of pregnant women used at least one maternal and child health (MCH) app, with majority using these apps particularly for information seeking, tracking fetal and child growth, and monitoring changes within their own bodies (Lupton & Pedersen, 2016). Women have also described these apps as being more relevant and useful than other forms of health communication strategies such as pamphlets (Rodger et al., 2013). Pregnant women often face challenges to access in-person behavioral interventions during pregnancy particularly due to conflicting work schedules, lack of transportation, and a need for childcare for older children (Coleman-Phox et al., 2013). Women have expressed the feasibility of utilizing mobile apps for health promotion, and informed decision-making (Waring et al., 2014;

Daly et al., 2017). They also exhibit a heightened sense of control using a familiar device, to access, store, and share health information (Daly et al., 2017). Therefore, apps appear to be an ideal platform to deliver both simple and useful interventions (Zhao, Freeman, & Li, 2016).

Numerous healthcare related apps have been designed to promote behavior change, and are considered useful because of their popularity, connectivity, and increased sophistication (Hale, Capra, & Bauer, 2015). They have the potential for real-time data collection, graphic feedback, interactivity, and links to social media (Hale, Capra, & Bauer, 2015). Collectively, MCH apps have been frequently downloaded from app stores such as Google Play Store and iTunes and are considered an integral source of information for many pregnant women and new mothers, particularly in high-income countries (Daly et al., 2017). Thus, due to the possible positive implications for health promotion, there is an increasing interest from commercial companies, government agencies, public health organizations, and the general public to use apps as a tool for health behavior change (Zhao et al., 2016).

Although smartphone apps show potential for promoting behavioral changes during pregnancy, concerns regarding the quality of these apps have been raised particularly in the context of failing to provide evidence-based content and theory-based strategies (Lee & Moon, 2016; Azar, Lesser, Burke, & Palaniappan, 2013). Moreover, app descriptions do not offer advice or safety information to serve as tools for medical care (Lee & Moon, 2016). There is a gap between app concept, delivery, and translation into health behavior change (Zhao et al., 2016). A review of apps for prevention of unintended pregnancies have revealed that only 30% conveyed a clear message on how to prevent pregnancy (Mangone, Lebrun & Muessig, 2016). Further, evidence-based pregnancy prevention methods such as referral to pregnancy testing was offered by less than one third apps, and behavioral contraceptive counseling was also infrequently included (Mangone et al., 2016). Additionally, analysis of top-rated free apps primarily focused on weight management via diet/nutrition and/or anthropometrics tracking found that overall the apps received low scores for inclusion of behavioral theory-based strategies (Azar et al., 2013). Pregnant women have expressed a desire to utilize mHealth apps for effective decision-making (Daly et al., 2017), incorporating lifestyle changes, and ensuring better health outcomes (Willcox et al., 2015). Yet, it has been observed that app developers are primarily focused on user interface and keeping users engaged as opposed to incorporating theory-based behavioral strategies (Azar et al., 2013). Similar studies have been conducted to evaluate health and fitness apps (West et al., 2012; Cowan et al., 2013; Conroy, Yang, & Maher, 2014), cancer survivorship apps (Vollmer Dahlke et al., 2015), and smoking cessation apps (Choi, Noh, & Park, 2014).

There is a growing body of research conducted to analyze the utility of health-related apps for promoting positive health behavior change (Payne, Lister, West, & Bernhardt, 2015; Zhao et al., 2016). However, to date, no research has assessed the extent to which MCH apps are based on theory linked health behavior techniques. Prior studies have indicated that inclusion of behavior change techniques in interventions, is linked to effectiveness (Abraham & Michie, 2008). Abraham and Michie (2008) developed a taxonomy of behavior change techniques (BCTs) that are used to identify the techniques that enhance effectiveness of health promotion interventions. Each of these BCTs were grounded in one or more health behavior theories such as social cognitive theory, theory of reasoned action, or theory of planned behavior (Abraham and Michie, 2008).

The present study sought to determine the use and presence of BCTs in top 15 MCH apps from Apple App store and top 15 MCH apps from the Google Play store. A second aim was to assess the differences in the use of BCTs between paid and free apps and between apps developed by healthcare and non-healthcare developers.

**Methods**

*Study Design*

This study is a review and content analysis of popular, publicly available MCH apps available from Apple App and Google Play stores. The mHealth theory and behavior change taxonomy (mHealth app taxonomy) by Vollmer Dahlke et al. (2015) was used to assess the use and presence of BCTs in app content. Included apps were individually downloaded for content analysis using the mHealth app taxonomy framework. The Indiana University Institutional Review Board (IRB) deemed this study as non-human subjects research.

*Source of Data*

User reviews were obtained by scraping the Apple App Store (Apple Inc. iTunes) and Google Play Store (Google Inc., Google Play) platforms using the java-based scraper program, Node.js (Node.js Foundation). The scraping program functioned by submitting a keyword search to the respective app stores, which automatically retrieved select information about each app based on the stores' search algorithms. Each store returned apps in the same order as if the search was conducted by an end user. Only the first 200 app results for Apple App and the first 250 app results (later reduced to 50 starting January

2017) for Google Play stores were returned by the scraper program (Larsen, Nicholas, & Christensen, 2016; Mangone, Lebrun, & Muessig, 2016). It is understood that the app stores list more popular apps first as ranked by a non-disclosed proprietary search algorithm (Pereira-Azevado et al., 2016; Boudreaux et al., 2014). Therefore, the results of the scraping searches for this study contain those apps that were higher-ranked when searched and hence most likely to be accessed by store visitors.

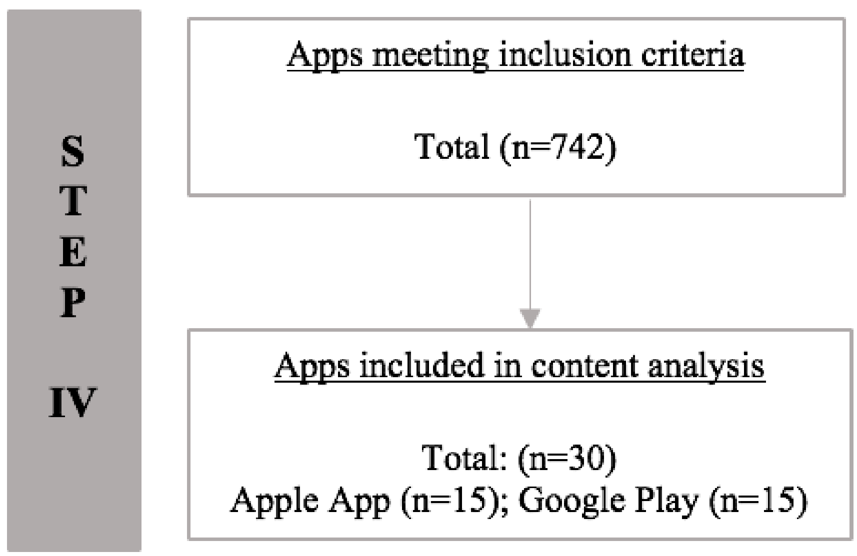
*Sample*

A four-step process was followed to create a dataset of MCH apps user reviews. Step 1 was identifying a list of relevant keywords that users might search when locating apps related to MCH (see appendix A for list of keywords). Step 2 was the scraping of the two app stores for candidate apps, merging results, and de-duplicating the resultant apps. Step 3 applied inclusion and exclusion criteria to identify those apps that were eligible for the study. (Steps 1, 2, and 3 are detailed in chapter 2) Step 4 identified a subset of popular apps from both stores for a full review. The data reflect app content as of May 2018.

Steps 1 through 3 identified 742 eligible MCH apps (Figure 2.1). If an app was available on both platforms, the Google Play version was included for analysis because as of 2016, android was the most popular smartphone operating system in the world (Statista, "n.d"). From this sample of 742 MCH apps, the top 15 apps from the Apple App and top 15 from the Google Play store were selected (see figure 3.1). This is based on the understanding that the app stores list more popular apps first as ranked by a non-disclosed proprietary search algorithm (Pereira-Azevado et al., 2016; Boudreaux et al., 2014). Furthermore, people tend to limit their attention to the first few results, and traffic to lower ranked results is low (Kitchens, Harle, & Li, 2014; Feng, Bhargava, & Pennock, 2007;

Eysenbach, G., & Kohler, 2002). Therefore, the apps included in this study are those that were higher-ranked and hence most likely to be accessed by store visitors (see appendix J for a list of apps included in this study).

Figure 3.1. Schematic Representation of App Selection Process for Content Analysis




*Analysis Framework*

The framework used for this study was adapted from mHealth theory and behavior change taxonomy (mHealth app taxonomy) for cancer survivorship apps by Vollmer Dahlke et al. (2015). The mHealth app taxonomy was derived from the original works of Abraham and Michie (2008), Webb, Joseph, Yardley, & Michie (2010) and Michie et al. (2013) with few changes based on characteristics of mHealth apps. Abraham and Michie (2008) developed a taxonomy of 26 behavior change techniques (BCTs) used for in-person behavioral interventions. The coding manual provides guidelines to review intervention descriptions for the presence of any or all of the 26 BCTs. Mean kappa values of 0.80 and 0.82 were observed while applying the taxonomy of BCTs to physical activity and health eating intervention descriptions respectively (Abraham & Michie, 2008). Later, Webb et al. (2010) used an augmented 40-item version (Ashford, Edmunds, & French, 2013) of the 26-item taxonomy of BCTs developed by Abraham and Michie (2008) to code the contents of internet-based interventions. The mHealth app taxonomy for cancer survivorship apps consists of 16 BCTs based on one or more health behavior or communication theories (Vollmer Dahlke et al. 2015). This framework was adapted with few changes based on the characteristics of MCH apps (see appendix L).

The theoretical models and framework originally used by Abraham and Michie (2008), Webb et al. (2010) and Vollmer Dahlke et al. (2015) that were included in the mHealth app taxonomy for MCH apps are as follows: control theory (CT) (Carver & Scheier, 1982), elaboration likelihood model (ELM) (Petty & Cacioppo, 1986), information-motivation-behavioral skills model (IMB) (Fisher, Fisher, & Harman, 2003), operant conditioning (OC) (Skinner, 1963), social cognitive theory (SCogT) (Bandura, 1977), social comparison (SC) (Festinger, 1954), social support on health behaviors (SS) (Cohen & Wills, 1985), theory of planned behavior (TPB) (Ajzen, 1991), and tailored health communications (THC) (Rimer, & Kreuter, 2006).

### Data Analysis

A coding manual was developed to identify the number and types of BCTs present in top 30 MCH apps (see appendix L) based on the works of Vollmer Dahlke et al. (2015). Included apps were individually downloaded on android, iPhone and iPad devices by RB for detailed analysis. Each app was scored on all 16 items from the adapted mHealth app taxonomy framework for MCH apps. Apps received scores ranging from 0-16 based on the number of BCTs identified. Fisher's exact test was used to analyze the differences in use of BCTs between paid and free apps, and between apps developed by healthcare and non-healthcare developers. All *p* values were two-sided.

### Results

A total of 30 top ranked MCH apps from both stores were included in the study. From the total sample, one app had to be excluded since it was not available in the Apple App store. This resulted in a total of 29 apps that could be coded.

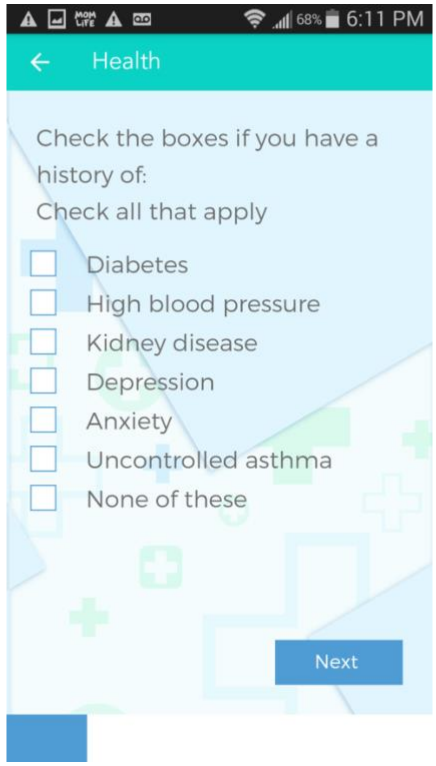
*Description of Apps*

Twenty-four (83%, 24/29) of the included apps were free, and the average cost of paid apps was USD 4.39, with a range of (1.99-8.99). The average star ratings for the apps was 4.38 with a range of (2.0-4.8). Twenty-one (72.4%, 21/29) apps were developed by non-healthcare developers. The number of BCTs were in the range of 2 to16, with a median of 6 BCTs, and average of 7.4 BCTs. The maximum number of BCTs were found in Ovia pregnancy and baby tracker developed by Ovia Health with a total of 16 BCTs (see appendix J for the number of BCTs per app).

*Review of BCTs*

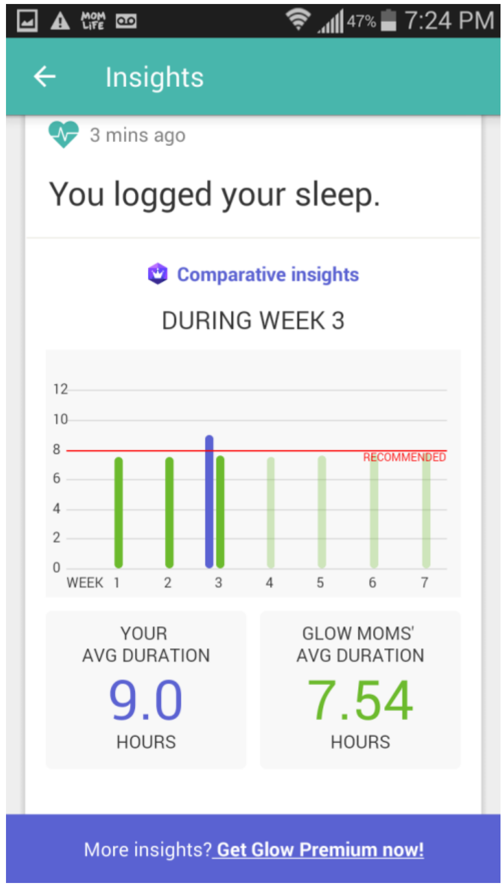
The number and percentage of BCTs for each category of MCH apps is shown in table 3.1. Fisher's exact test results for the differences in use of BCTs between paid and free apps, and between apps developed by healthcare and non-healthcare developers are shown in tables 3.1 and 3.2 respectively. Personalization was present in 89.7% apps. For majority of the apps, the personalization feature enables access to tools, information, or elements that are specific to the individual's needs and requirements. Within the sample, free apps had higher rates for personalization (95.8%) than paid apps (60%). Similarly, apps with healthcare developers had higher rates for personalization (100%) than those developed by non-healthcare developers (85.7%). Several apps requested specific information about the stages of pregnancy, or infant age, and provided macro or meso-level tailoring by offering opportunities to receive notifications, tips or reminders on daily, or weekly basis, along with the time of day. Macro tailoring was the most commonly found technique with 75.9%, followed by meso-tailoring with 41.4%. Few apps provided the micro-tailoring technique, which focuses on offering recommendations, or suggestions tailored to the unique individual. An example of micro-tailoring was found in the Ovia pregnancy and baby tracker app (picture 3.1). This app allows users to enter their individual preferences, medical history, and current signs and symptoms to tailor the exercise best suited during the pregnancy.

Picture 3.1. Micro-Tailoring in Ovia Pregnancy and Baby Tracker App




The health behavior linkage BCT was present in 58.6% apps, with 100% presence in apps developed by healthcare developers. There were significant differences in the use of this BCT between apps developed by healthcare and non-healthcare developers ($p$=0.01). Overall, apps received high scores on BCTs self-monitoring of goals (75.9%) and review of general or specific goals (79.3%). Both of these BCTs were present in all of the paid apps as well as all of the apps that were developed by healthcare developers. Examples in the area of review of general or specific goals included time trends of a health behavior such as number of hours slept in a week, or weight/height trends over a month (picture 3.2).

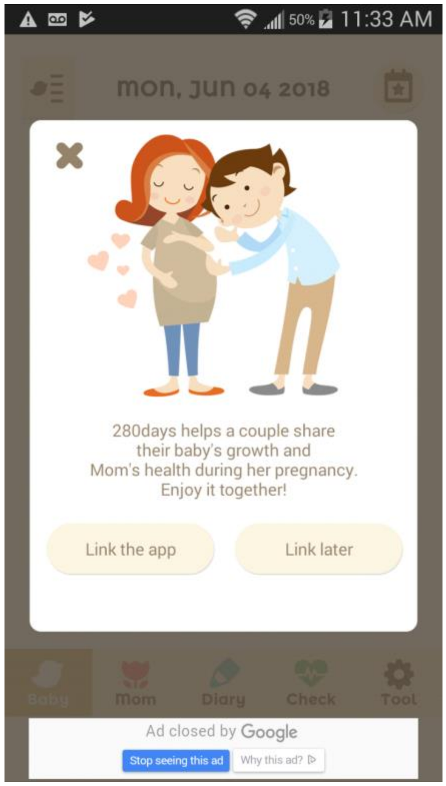
Picture 3.2. Review of Goals in Pregnancy Tracker & Baby Countdown- Glow Nurture App




Less than half (44.8%) apps coded positive for the BCTs 'provide instruction' and 'provide materials for education'. There were significant differences in the use of these BCTs between apps developed by healthcare and non-healthcare developers ($p$=0.01) and ($p$<0.01) respectively.

The BCTs active social influence and passive social influence were present in 44.8% and 31.0% apps respectively. The BCT on social norms which focuses on exposure to important others such as family members, partners, friends, or healthcare professionals was present in 34.5% apps. There were significant differences in the use of this BCT between apps developed by healthcare and non-healthcare developers ($p$=0.01). An example of an app that offers partner involvement is shown in picture 3.3. Passive social influence was also relatively low (31.0%).

Picture 3.3. Social Norms- Connects with Partner in 280days Pregnancy Diary




When it comes to self-efficacy, the BCT persuasion was present in 37.9% apps. There were significant differences in the use of BCT persuasion between apps developed by healthcare and non-healthcare developers ($p$=0.03). Overall, the scores for BCTs prompt for intention formation and action/behavior consequences were relatively low. One of the least found BCT in apps was prompt for specific goals, which involves planning and setting of specific goals within a given time frame.

Table 3.1. Fisher's Exact Test for Differences in BCT Use Between Free and Paid Apps

| BCTs | Total<br>N (%) | Paid<br>N (%) | Free<br>N (%) | Significance<br>(*P*) |
|---|---|---|---|---|
| Personalization | 26 (89.7) | 3 (60.0) | 23 (95.8) | 0.07 |
| Review of general or specific goals | 23 (79.3) | 5 (100) | 18 (75.0) | 0.55 |
| Macro tailoring | 22 (75.9) | 3 (60.0) | 19 (79.1) | 0.57 |
| Self-monitoring of goals | 22 (75.9) | 5 (100) | 17 (70.8) | 0.30 |
| Health behavior linkage | 17 (58.6) | 1 (20.0) | 16 (66.7) | 0.13 |
| Provide instruction | 13 (44.8) | 1 (20.0) | 12 (50.0) | 0.34 |
| Materials for education/information | 13 (44.8) | 1 (20.0) | 12 (50.0) | 0.34 |
| Social influence (active) | 13 (44.8) | 2 (40.0) | 11 (45.8) | 1.00 |
| Meso tailoring | 12 (41.4) | 1 (20.0) | 11 (45.8) | 0.37 |
| Persuasion | 11 (37.9) | 1 (20.0) | 10 (41.7) | 0.62 |
| Action/behavior consequences | 10 (34.5) | 1 (20.0) | 9 (37.5) | 0.63 |
| Social norms | 10 (34.5) | 1 (20.0) | 9 (37.5) | 0.63 |
| Micro tailoring | 9 (31.0) | 1 (20.0) | 8 (33.3) | 1.00 |
| Social influence (passive) | 9 (31.0) | 0 (0) | 9 (37.5) | 0.15 |
| Prompt for specific goals | 5 (17.2) | 0 (0) | 5 (20.8) | 0.55 |
| Prompt for intention formation | 4 (13.8) | 0 (0) | 4 (16.7) | 1.00 |

*Note.* Coding of apps for BCTs was mutually exclusive

Table 3.2. Fisher's Exact Test for Differences in BCT Use Between Apps Developed by Healthcare and Non-Healthcare Developers

| **BCTs** | **Total**<br>**N (%)** | **Healthcare**<br>**N (%)** | **Non-Healthcare**<br>**N (%)** | **Significance**<br>**(*P*)** |
|---|---|---|---|---|
| Personalization | 26 (89.7) | 8 (100) | 18 (85.7) | 0.54 |
| Review of general or specific goals | 23 (79.3) | 6 (75.0) | 17 (81.0) | 1.00 |
| Macro tailoring | 22 (75.9) | 8 (100) | 14 (66.7) | 0.14 |
| Self-monitoring of goals | 22 (75.9) | 7 (87.5) | 15 (71.4) | 0.63 |
| Health behavior linkage | 17 (58.6) | 8 (100) | 9 (42.9) | **0.01** |
| Provide instruction | 13 (44.8) | 7 (87.5) | 6 (28.6) | **0.01** |
| Materials for education/information | 13 (44.8) | 8 (100) | 5 (23.8) | **<0.01** |
| Social influence (active) | 13 (44.8) | 6 (75.0) | 7 (33.3) | 0.09 |
| Meso tailoring | 12 (41.4) | 3 (37.5) | 9 (42.9) | 1.00 |
| Persuasion | 11 (37.9) | 6 (75.0) | 5 (23.8) | **0.03** |
| Action/behavior consequences | 10 (34.5) | 5 (62.5) | 5 (23.8) | 0.08 |
| Social norms | 10 (34.5) | 6 (75.0) | 4 (19.0) | **0.01** |
| Micro tailoring | 9 (31.0) | 4 (50.0) | 5 (23.8) | 0.21 |
| Social influence (passive) | 9 (31.0) | 5 (62.5) | 4 (19.0) | 0.07 |
| Prompt for specific goals | 5 (17.2) | 3 (37.5) | 2 (9.5) | 0.11 |
| Prompt for intention formation | 4 (13.8) | 2 (25.0) | 2 (9.5) | 0.30 |

*Note*. Coding of apps for BCTs was mutually exclusive

## Discussion

This study aims at reviewing the presence and use of BCTs in popular MCH apps. There were differences in the number of BCTs present, with a median of 6 and an average of 7.4 techniques. These results are consistent with previous research on BCT use in cancer survivorship apps (Vollmer Dahlke et al., 2015), and physical activity/dietary apps (Direito et al., 2014; Middelweerd, Mollee, van der Wal, Brug, & Te Velde, 2014). This may call for a greater need to incorporate BCTs during app development process. Overall, studies have shown the effectiveness of the use of BCTs in interventions in bringing about desired behavior change outcomes (Michie, West, Sheals, & Godinho, 2018; Michie et al. 2013; Abraham & Michie 2008). Brown et al. (2012) highlighted the role of theoretically-designed interventions to achieve optimal weight gain during pregnancy. However, Studies focused on operationalizing theoretical constructs in mHealth apps have also shown a general lack of use of behavioral theories in app content (Azar et al., 2013; Cowan et al., 2013; West et al., 2012).

This study indicates that the most frequently used BCTs in MCH apps are personalization, review of general or specific goals, macro tailoring, self-monitoring of goals, and health behavior linkages. Previous studies that identify the use of BCTs in mobile health apps have shown personalization, macro tailoring, health behavior linkage, feedback on performance, self-monitoring of behavior, provide instruction, and specific goal setting to be present in mHealth apps (Schoeppe et al., 2017; Vollmer Dahlke et al, 2015; Middelweerd et al., 2014; Conroy et al., 2014; Cowan et al., 2013). Though previous reports have suggested that paid apps were more grounded in theoretical constructs than free apps (Cowan et al., 2013; West et al., 2012), this study does not find similar findings.

The differences in findings may be due to the fewer number of paid versus free apps included in the study. However, there were differences observed in the use of BCTs between apps developed by healthcare versus non-healthcare developers. Apps developed by healthcare providers tended to incorporate certain BCTs (health behavior linkage, persuasion, social norms, provide instruction, and provide materials for education/information) at higher proportions than those developed by non-healthcare developers. This may possibly indicate the need for healthcare participation in app development process to ensure higher quality MCH apps.

The MCH apps that were firmly grounded in theoretical constructs offered a number of BCTs such as personalization, tailoring, goal setting, self-monitoring, and social media engagement. Examples include Ovia Pregnancy & Baby Tracker developed by Ovia Health, I'm Expecting Pregnancy App developed by Staywell, I'm Pregnant/ Pregnancy App by BabyJoyApp, and Pregnancy Tracker Glow Nurture by Glow Inc. Three out of these four apps were developed by healthcare developers. An area which showed weaker representation among MCH apps was that of social influence and engagement. Social influence is an area that would possibly garner favorable attention by pregnant women and new mothers, as it may increase access to social support platforms such as Facebook, Twitter, and other pregnancy/parenting blogs. This area is considered to be important, given that pregnant women and new mothers often seek social support from their family, friends, and other women in similar phases of life (Lupton, 2017). Using the potential of social media and social engagement within these apps may be beneficial for users. Similar results were observed among cancer survivorship apps, another area that is strongly influenced by social ties and connections (Vollemer Dahlke et al., 2015).

The proliferation of MCH apps in the app market makes it difficult for consumers and healthcare providers to identify apps that are useful in promoting behavior changes. It is understood that apps grounded in BCTs and theory-based construct have a greater potential to initiate behavior changes. Though, currently we lack evidence on things like the optimal number of BCTs and exactly how the use of these techniques in apps affect actual health behaviors/outcomes. Future studies may focus on using the mHealth taxonomy framework, BCT taxonomy, and other theories/models to a larger sample of MCH apps to understand patterns of theory use across a broader spectrum. Studies may also focus on establishing guidelines for app developers in terms of the types of BCTs that will be essential given the focus of the mHealth app. Additionally, this study may be replicated in other health domains to gain a greater perspective of trends across the field of mHealth. Future studies may also focus on measuring behavior changes among pregnant women and new mothers upon the use of MCH apps.

**Strengths and Limitations**

A strength of this study was the use of an established framework to systematically rate the presence and use of BCTs in popular and commonly downloaded MCH apps. This study employs a systematic approach of sampling popular MCH apps for analysis. The present review includes popular apps from both Apple App and Google Play stores, which are two most popular stores globally. Apps were rated after downloading and using each of the app functionalities and features. Additionally, this is a first study that utilizes this approach to study app content in terms of presence of BCTs in MCH apps.

However, this study is not without limitations. Only popular apps were coded using the mHealth app taxonomy, leaving behind other apps which may have a greater representation of BCTs but were not included in this study. However, the focus of this study was on apps that were commonly used and available to users. The mHealth platform is highly dynamic with new apps and updates introduced almost daily, thereby such evaluations need to be updated continually. This study is reflective of app popularity as of March 2017, and app content as of May 2018. Inter-coder reliability for BCT coding was not tested for this study. Even though the coding manual was carefully tested prior to the actual coding, the scoring of content is subject to bias. Lastly, this study evaluated the use of BCTs in MCH apps but did not study the effectiveness of these apps in bringing about behavior changes.

**Conclusion**

This study determines that on an average MCH apps incorporate around 7 BCTs. MCH apps grounded in BCTs are alike in terms of offering multiple BCTs such as personalization, tailoring, self-monitoring of goals, and health behavior linkages. The present findings indicate a potential need for incorporating behavior change techniques within app content in a quest to improve effectiveness. With the ubiquity of mHealth apps, they act as a viable platform to deliver evidence-based interventions grounded in theoretical constructs. MCH apps hold huge promise in providing effective patient-centric interventions, but experience gaps in health behavior change translation.

## References


Abraham, C., & Michie, S. (2008). A taxonomy of behavior change techniques used in interventions. *Health Psychology, 27*(3), 379-387. doi:10.1037/0278-6133.27.3.379

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50* (2), 179-211. doi: 10.1016/0749-5978(91)90020-T

Apple Inc. iTunes. Retrieved from https://itunes.apple.com/us/genre/ios/id36?mt=8

Ashford, S., Edmunds, J., & French, D. P. (2010). What is the best way to change self-efficacy to promote lifestyle and recreational physical activity? A systematic review with meta-analysis. *British Journal of Health Psychology, 15*(Pt 2), 265-288. doi:10.1348/135910709X461752

Azar, K. M., Lesser, L. I., Laing, B. Y., Stephens, J., Aurora, M. S., Burke, L. E., & Palaniappan, L. P. (2013). Mobile applications for weight management: theory-based content analysis. *American Journal of Preventive Medicine, 45*(5), 583-589. doi:10.1016/j.amepre.2013.07.005

Bale, J.R., & Lucas, A.O. (Eds.). (2003). Institute of Medicine (US) committee on improving birth outcomes. Washington (DC): National Academies Press (US).

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215.

Boudreaux, E. D., Waring, M. E., Hayes, R. B., Sadasivam, R. S., Mullen, S., & Pagoto, S. (2014). Evaluating and selecting mobile health apps: strategies for healthcare providers and healthcare organizations. *Translational Behavioral Medicine, 4*(4), 363-371. doi:10.1007/s13142-014-0293-9

Brown, M. J., Sinclair, M., Liddle, D., Hill, A. J., Madden, E., & Stockdale, J. (2012). A systematic review investigating healthy lifestyle interventions incorporating goal setting strategies for preventing excess gestational weight gain. *PLoS One, 7*(7), e39503. doi:10.1371/journal.pone.0039503

Carver, C. S., & Scheier, M. F. (1982). Control theory: a useful conceptual framework for personality-social, clinical, and health psychology. *Psychological Bulletin, 92*(1), 111-135.

Centers for Disease Control and Prevention (CDC). (2017). *Infants (0-1 year of age)*. Retrieved from https://www.cdc.gov/ncbddd/childdevelopment/positiveparenting/infants.html

Choi, J., Noh, G. Y., & Park, D. J. (2014). Smoking cessation apps for smartphones: content analysis with the self-determination theory. *Journal of Medical Internet Research, 16*(2), e44. doi:10.2196/jmir.3061

Cohen, S., & Wills, T. A. (1985). Stress, social support, and the buffering hypothesis. *Psychological Bulletin, 98*(2), 310-357.

Coleman-Phox, K., Laraia, B. A., Adler, N., Vieten, C., Thomas, M., & Epel, E. (2013). Recruitment and retention of pregnant women for a behavioral intervention: lessons from the maternal adiposity, metabolism, and stress (MAMAS) study. *Preventing Chronic Disease, 10*. doi:10.5888/pcd10.120096

Conroy, D. E., Yang, C. H., & Maher, J. P. (2014). Behavior change techniques in top-ranked mobile apps for physical activity. *American Journal of Preventive Medicine, 46*(6), 649-652. doi:10.1016/j.amepre.2014.01.010

Cowan, L. T., Van Wagenen, S. A., Brown, B. A., Hedin, R. J., Seino-Stephan, Y., Hall, P. C., & West, J. H. (2013). Apps of steel: are exercise apps providing consumers with realistic expectations?: a content analysis of exercise apps for presence of behavior change theory. *Health Education & Behavior*, *40*(2), 133-139. doi:10.1177/1090198112452126

Daly, L. M., Horey, D., Middleton, P. F., Boyle, F. M., & Flenady, V. (2017). The effect of mobile application interventions on influencing healthy maternal behaviour and improving perinatal health outcomes: a systematic review protocol. *Systematic Reviews*, *6*(1), 26. doi:10.1186/s13643-017-0424-8

Direito, A., Dale, L. P., Shields, E., Dobson, R., Whittaker, R., & Maddison, R. (2014). Do physical activity and dietary smartphone applications incorporate evidence-based behaviour change techniques? *BMC Public Health*, *14*, 646. doi:10.1186/1471-2458-14-646

Eysenbach, G., & Kohler, C. (2002). How do consumers search for and appraise health information on the world wide web? Qualitative study using focus groups, usability tests, and in-depth interviews. *BMJ* (Clinical research ed.), *324*(7337), 573-577.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations*, *7*(2), 117-140.

Feng, Bhargaba, H.K., & Pennock, D.M. (2007). Implementing sponsored search in web search engines: Computational evaluation of alternative mechanisms. *INFORMS Journal on Computing*, *19* (1), 137-148

Fisher, W.A., Fisher, J.D., Harman, J. (2003). The information-motivation-behavioral skills model: A general social psychological approach to understanding and promoting health behavior. In *Social psychological foundations of health and illness* (pp. 82-106). Victoria, Australia: Blackwell Publishing, Ltd.

Google Inc. Google Play. Retrieved from https://play.google.com/store/apps

Hale, K., Capra, S., & Bauer, J. (2015). A framework to assist health professionals in recommending high-quality apps for supporting chronic disease self-management: Illustrative assessment of type 2 diabetes apps. *JMIR Mhealth Uhealth*, *3*(3), e87. doi:10.2196/mhealth.4532

Kitchens, B., Harle, C. A., & Li, S. (2014). Quality of health-related search results. *Decision Support Systems*, 57, 454-462. doi: 10.1016/j.dss.2012.10.050

Larsen, M. E., Nicholas, J., & Christensen, H. (2016). Quantifying app store dynamics: Longitudinal tracking of mental health apps. *JMIR Mhealth Uhealth, 4*(3), e96. doi:10.2196/mhealth.6020

Lee, Y., & Moon, M. (2016). Utilization and content evaluation of mobile applications for pregnancy, birth, and child care. *Healthcare Informatics Research, 22*(2), 73-80. doi:10.4258/hir.2016.22.2.73

Lupton, D. (2017). "It Just Gives Me a Bit of Peace of Mind": Australian Women's Use of Digital Media for Pregnancy and Early Motherhood. *Societies*, *7*(3), 25. doi:10.3390/soc7030025

Lupton, D. & Pedersen, S. (2016). An Australian survey of women's use of pregnancy and parenting apps. *Women and Birth, 29(4)*, 368-375 doi: 10.1016/j.wombi.2016.01.008

Mangone, E. R., Lebrun, V., & Muessig, K. E. (2016). Mobile phone apps for the prevention of unintended pregnancy: A systematic review and content analysis. *JMIR Mhealth Uhealth, 4*(1), e6. doi:10.2196/mhealth.4846

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., . . . Wood, C. E. (2013). The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Annals of Behavioral Medicine, 46*(1), 81-95. doi:10.1007/s12160-013-9486-6

Michie, S., West, R., Sheals, K., & Godinho, C. A. (2018). Evaluating the effectiveness of behavior change techniques in health-related behavior: a scoping review of methods used. *Translational Behavioral Medicine, 8*(2), 212-224. doi:10.1093/tbm/ibx019

Middelweerd, A., Mollee, J. S., van der Wal, C. N., Brug, J., & Te Velde, S. J. (2014). Apps to promote physical activity among adults: a review and content analysis. *The International Journal of Behavioral Nutrition and Physical Activity, 11*, 97. doi:10.1186/s12966-014-0097-9

Nagahawatte, N.T., & Goldenberg, R.L. (2008). Poverty, maternal health, and adverse pregnancy outcomes. Annals of the New York Academy of Sciences, 1136(1), 80-85. doi: 10.1196/annals.1425.016

Node.js Foundation. Retrieved from https://nodejs.org/en/

Payne, H. E., Lister, C., West, J. H., & Bernhardt, J. M. (2015). Behavioral functionality of mobile apps in health interventions: a systematic review of the literature. *JMIR Mhealth Uhealth, 3*(1), e20. doi:10.2196/mhealth.3335

Pereira-Azevedo, N., Osorio, L., Cavadas, V., Fraga, A., Carrasquinho, E., Cardoso de Oliveira, E., . . . Roobol, M. J. (2016). Expert involvement predicts mHealth app downloads: Multivariate regression analysis of urology apps. *JMIR Mhealth Uhealth*, *4*(3), e86. doi:10.2196/mhealth.5738

Petty, R.E. & Cacioppo, J.T. (1986). The elaboration likelihood model of persuasion. *Advances in experimental social psychology, 19*, 123-181. doi: 10.1016/S0065-2601(08)60214-2

Rimer, B.K. & Kreuter, M.W. (2006). Advancing tailored health communication: A persuasion and message effects perspective. *Journal of Communication, 56*(s1), S184-S201.

Robinson, S. M., Crozier, S. R., Harvey, N. C., Barton, B. D., Law, C. M., Godfrey, K. M., . . . Inskip, H. M. (2015). Modifiable early-life risk factors for childhood adiposity and overweight: an analysis of their combined impact and potential for prevention. *American Journal of Clinical Nutrition, 101*(2), 368-375. doi:10.3945/ajcn.114.094268

Rodger, D., Skuse, A., Wilmore, M., Humphreys, S., Dalton, J., Flabouris, M., & Clifton, V. L. (2013). Pregnant women's use of information and communications technologies to access pregnancy-related health information in South Australia. *Australian Journal of Primary Health, 19*(4), 308-312. doi:10.1071/PY13029

SAS Institute Inc. Analytics software and solutions. Retrieved from https://www.sas.com/en_us/home.html

Schoeppe, S., Alley, S., Rebar, A. L., Hayman, M., Bray, N. A., Van Lippevelde, W., . . . Vandelanotte, C. (2017). Apps to improve diet, physical activity and sedentary behaviour in children and adolescents: a review of quality, features and behaviour change techniques. *International Journal of Behavioral Nutrition and Physical Activity, 14*(1), 83. doi:10.1186/s12966-017-0538-3

Skinner, B. F. (1963). Operant behavior. *American Psychologist, 18*(8), 503-515. doi: 10.1037/h0045185

Statista. (n.d.). *Global market share held by the leading smartphone operating systems in sales to end users from 1st quarter 2009 to 1st quarter 2017*. Retrieved from https://www.statista.com/statistics/266136/global-market-share-held-by-smartphone-operating-systems/

Thomas, G.M. & Lupton, D. (2016). Threats and thrills: pregnancy apps, risk and consumption. *Health, Risk & Society*, 17(7-8). doi:10.1080/13698575.2015.1127333

Vollmer Dahlke, D., Fair, K., Hong, Y. A., Beaudoin, C. E., Pulczinski, J., & Ory, M. G. (2015). Apps seeking theories: results of a study on the use of health behavior change theories in cancer survivorship mobile apps. *JMIR Mhealth Uhealth, 3*(1), e31. doi:10.2196/mhealth.3861

Webb, T. L., Joseph, J., Yardley, L., & Michie, S. (2010). Using the internet to promote health behavior change: a systematic review and meta-analysis of the impact of theoretical basis, use of behavior change techniques, and mode of delivery on efficacy. *Journal of Medical Internet Research, 12*(1), e4. doi:10.2196/jmir.1376

Waring, M. E., Moore Simas, T. A., Xiao, R. S., Lombardini, L. M., Allison, J. J., Rosal, M. C., & Pagoto, S. L. (2014). Pregnant women's interest in a website or mobile application for healthy gestational weight gain. *Sexual & Reproductive Healthcare, 5*(4), 182-184. doi:10.1016/j.srhc.2014.05.002

West, J. H., Hall, P. C., Hanson, C. L., Barnes, M. D., Giraud-Carrier, C., & Barrett, J. (2012). There's an app for that: content analysis of paid health and fitness apps. *Journal of Medical Internet Research, 14*(3), e72. doi:10.2196/jmir.1977

Willcox, J. C., van der Pligt, P., Ball, K., Wilkinson, S. A., Lappas, M., McCarthy, E. A., & Campbell, K. J. (2015). Views of women and health professionals on mHealth lifestyle interventions in pregnancy: A qualitative investigation. *JMIR Mhealth Uhealth, 3*(4), e99. doi:10.2196/mhealth.4869

Zhao, J., Freeman, B., & Li, M. (2016). Can mobile phone apps influence people's health behavior change? An evidence review. *Journal of Medical Internet Research, 18*(11), e287. doi:10.2196/jmir.5692

# CHAPTER 4

# QUALITATIVE CONTENT ANALYSIS OF CONSUMER PERSPECTIVES ON MATERNAL AND CHILD HEALTH APPS

## Introduction

Globally, there is a growing demand for, and use of, mobile smartphone applications (apps) to disseminate prenatal and newborn health information and self-management tools effectively to pregnant women (Tamrat & Kachnowski, 2012; Rotheram-Borus, Tomlinson, Swendeman, Lee, & Jones, 2012; Declercq, Sakala, Corry, Applebaum, Herrlich, 2013; O'Higgins et al., 2014; Lee & Moon, 2016). The increase in acceptance of digital technologies is attributed to the fact that women find it extremely convenient to seek answers to their questions, with easy access to health-related information 24 hours a day (Hearn, Miller, & Lester, 2014). Further, these technologies may provide important social support especially when pregnant women feel isolated, time constrained, or need reassurance (Hearn et al., 2014) and apps have shown potential to produce positive health behavior changes (Hebden, Cook, van der Ploeg, & Allman-Farinelli, 2012). Maternal and Child Health (MCH) apps frequently appear on the iTunes and Google Play Store's list of most downloaded apps and some have been downloaded over five million times (Lupton & Thomas, 2015).

While popular, consumers often rate MCH apps lower (i.e. fewer star ratings) than other categories of apps (Derbyshire, & Dancey, 2013). Moreover, users frequently download apps they no longer use and the percent of users that discontinue (i.e. uninstall) health-focused apps in general approaches 50% (Krebs & Duncan, 2015). This disconnect between popularity, ratings, and usage may be driven by several factors. One reason could be price; MCH apps are priced higher compared to apps targeting other populations and health conditions (Derbyshire & Dancey, 2013). Alternatively, app efficacy may be the challenge. Apps with unclear or inaccurate clinical decision support could lead to poor end user choices and potentially undesirable outcomes (Buijink, Visser, & Marshall, 2013). Additionally, few MCH focused apps provide information grounded in evidence-based practice (Scott, Gome, Richards, & Caldwell, 2015). Moreover, apps often fail to provide sources of their information and lack warnings pertaining to the use of this information (Lee & Moon, 2016). Or, the reasons could be design and usability related. End users have discontinued apps, because, of their time-consuming data entry process, hidden costs, usage difficulty, lack of data privacy, and a failure to maintain interest (Krebs & Duncan, 2015). Areas needing improvements were associated with quality of graphics, speed of downloads, compatibility with other devices, ability to transfer data onto newer versions, and certification/affiliation with credible organizations (Derbyshire, & Dancey, 2013).

Mobile technology can be an effective platform to deliver resources and interventions, but consumer engagement remains a barrier for uptake and continued use (Nicholas, Fogarty, Boydell, & Christensen, 2017). Therefore, it becomes imperative to consider the consumer perspective of these apps to improve the utility of such resources (Nicholas et al., 2017). The objective of this study was to assess user self-reported experiences with MCH apps, perceived benefits, and general feedback by analyzing publicly-available customer reviews on two app stores.

## Methods

### *Study Design*

This study is a qualitative assessment of publicly available user reviews of a subsample of MCH apps. First, a set of MCH apps were sampled from the Apple App and Google Play stores. Second, user reviews were sampled from these MCH apps. Third, user reviews were qualitatively analyzed using a general inductive content analysis approach, where underlying themes were identified from the data. The Indiana University Institutional Review Board (IRB) deemed this study as non-human subjects research

### *Source of Data*

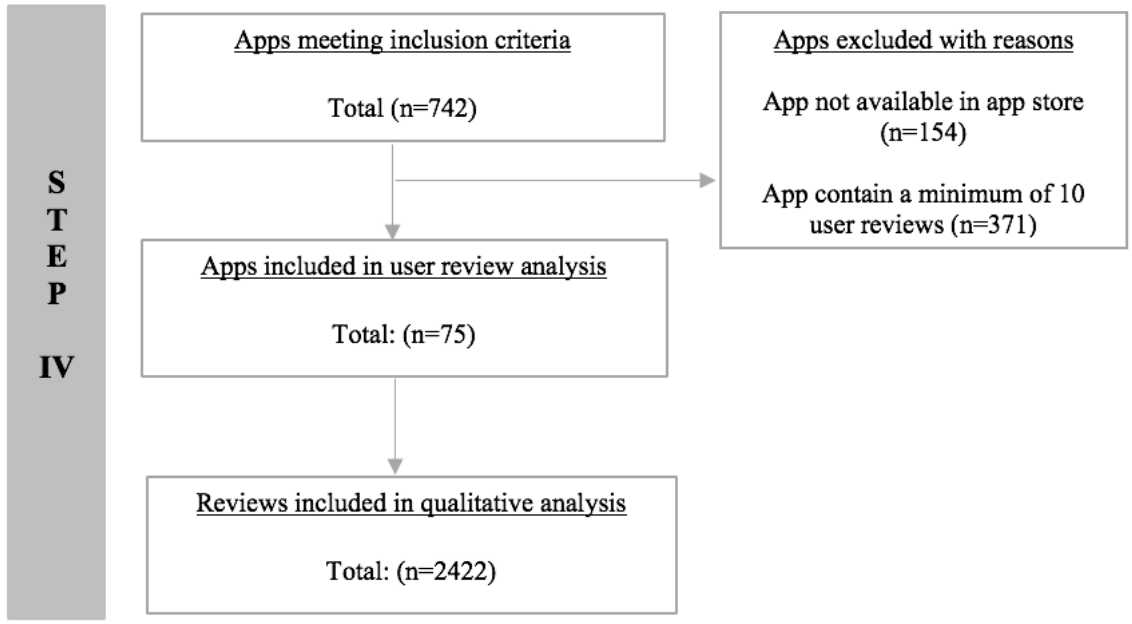
User reviews were obtained by scraping the Apple App Store (Apple Inc. iTunes) and Google Play Store (Google Inc., Google Play) platforms using the java-based scraper program, Node.js (Node.js Foundation). The scraping program functioned by submitting a keyword search to the respective app stores, which automatically retrieved select information about each app based on the stores' search algorithms. Each store returned apps in the same order as if the search was conducted by an end user. Only the first 200 app results for Apple App and the first 250 app results (later reduced to 50 starting January 2017) for Google Play stores were returned by the scraper program (Larsen, Nicholas, & Christensen, 2016; Mangone, Lebrun, & Muessig, 2016). It is understood that the app stores list more popular apps first as ranked by a non-disclosed proprietary search algorithm (Pereira-Azevado et al., 2016; Boudreaux et al., 2014). Therefore, the results of the scraping searches for this study contain those apps that were higher-ranked when searched and therefore most likely to be accessed by store visitors. In addition, the scraper program can search, and return results for, a specified app.

*Sample*

A four-step process was followed to create a dataset of MCH apps user reviews. Step 1 was identifying a list of relevant keywords that users might search when locating apps related to MCH (see appendix A for list of keywords). Step 2 was the scraping of the two app stores for candidate apps, merging results, and de-duplicating the resultant apps. Step 3 applied inclusion and exclusion criteria to identify those apps that were eligible for the study. (Steps 1, 2, and 3 are detailed in chapter 2) Step 4 scraped the two app stores for the text of user reviews of a subsample of these apps for this study. The data reflect app store content as of February 2018.

Steps 1 to 3 identified 742 eligible MCH apps (figure 2.1). Of these 20% were no longer available in the app stores at the time of data collection (and therefore were excluded). In order to have a robust set of reviews for analyses, those apps with fewer than 10 reviews were also excluded (37%). From the resulting apps (n=217) a simple random sample of 75 apps was selected. This sample size was sufficient to reach data saturation. Each app name was entered into individual scraper searches. Each scrape resulted in a maximum of 50 user reviews from the Apple App and 40 user reviews from the Google Play store (ordered by most recent review). In order to maintain consistency across platforms, the upper limit per app was set at 40 user reviews for a total sample of 2,422 user reviews (see appendix K for a list of apps included in this study). In addition to the text of the user reviews, the scraper program returned the star rating and review date.

Figure 4.1. Schematic Representation of User Review Selection Process for Qualitative Analysis




**Data Analysis**

*Descriptive Summary*

Descriptive statistics were used to summarize app characteristics such as app price, user star ratings, app platform, and review characteristics such as publish date and length of reviews. Descriptive statistics were calculate using SAS 9.4.

*Qualitative Analysis*

User reviews were analyzed using a general inductive content analysis approach (Hsieh & Shannon, 2005; Cho & Lee, 2014). This approach was appropriate given the study's descriptive aims and limited existing theoretical frameworks (Hsieh, & Shannon, 2005; Cho & Lee, 2014). Within this approach, themes were derived from the data itself, as opposed to using preconceived categories (Kondracki, Wellman, & Amundson, 2002). First, two coders (RB and KW) undertook a joint reading of a random sample of 30 user reviews to establish consistency on the textual unit of analysis, identification of categories, and formation of themes (Cho & Lee, 2014). Next, the same two coders independently read and identified preliminary codes from new sample of 200 user reviews. Through joint reading session, these preliminary codes were refined, collapsed, assigned descriptive labels, and arranged into a coding framework to be applied to the sample. To assess coding consistency, both coders independently analyzed a new sample of 100 user reviews. Agreement between the coders was high (Kappa 0.89). The two coders independently coded the entire sample and met regularly to resolve any coding discrepancies and to discuss themes that were detected in the data. All data management and analysis were conducted in Dedoose 8.0.39.

## Results

### *Description of Apps and Reviews*

Fifty-six (75%, 56/75) of the included apps were free, and the average cost of paid apps was USD 3.15. More than half (59%, 44/75) of the apps were from the Apple App store, and the remaining were from the Google Play store. The average star ratings for the apps was 4.1 with a range of (2.5-5.0). The oldest review in the data was written on July 5$^{th}$, 2009, while the latest review was published on February 13$^{th}$, 2018. The longest description was 403 words long and the shortest description was 1 word only. Three major and seven minor themes i.e. present in less than 10% of reviews were identified in the data (see table 4.1 for details).

Table 4.1. Prevalence of Major and Minor Themes Identified in the Data (n=2422)

| **Themes** | **Definition** | **Reviews N (%)** |
|---|---|---|
| **Major** | | |
| App Functionality | The user specifically talks about app functions/features and what it does either positively or negatively | 2119 (87.5) |
| Technical Aspects | The user specifically talks about aspects pertaining to how an app operates either positively or negatively, i.e. privacy, security of data, or other technology-based aspects. | 510 (21.05) |
| App Content | The user specifically talks about app content and the information it provides. | 349 (14.4) |
| **Minor** | | |
| Patterns of Usage | The user highlights the frequency and type of use. Whether the app is used for the first pregnancy, or the app is being used since a long time. | 219 (9.0) |
| Social Support | The user specifically talks about receiving from friends/family or offering support to other women while utilizing the app | 207 (8.5) |
| App Cost | The user specifically talks about the cost of an app, i.e. cost-effective, or waste of money | 201 (8.3) |
| App Comparisons | The user compares the app to other apps in the market | 104 (4.3) |
| Assists in Healthcare | The user specifically highlights the role of the app in offering clinical assistance. | 77 (3.2) |
| Customer Care Support | The user specifically talks about their interaction with the app customer care support either positively or negatively | 44 (1.8) |

*Note*. These themes were not exclusive

*Major Themes*

*App Functionality*

Around 87% of user reviews focused on commenting about the functionality of apps, i.e. app features, indicating that users frequently discuss about the functionality of an app while using them. The discussion about app functionality featured three main subthemes: (i) positive functionality experience; (ii) negative functionality experience; and (iii) suggested functional improvements.

*Positive Functionality Experience*

A majority of the reviews focusing on app functionality indicated an overall positive experience with the functionality of the app. Many of the positive reviews were geared towards an app's overall design and app features describing these apps as useful, helpful, as well as easy to use. Users mainly elaborated on app features that assisted in data recording and tracking of data pertaining to infant needs such as feeds, milk pumps, diaper changes, and sleep, akin to a *"one stop shop"*. Some of the other tracking features focused on recording height, and weight of the infant, and monitoring the trends over time, along with keeping a log of immunizations, and other health history.

> e.g., "Best tracking all app ever!, ibabylog is the best app I have! It helps me track everything from nap times, to meal times, to dirty diapers. Its best feature is that it helps you keep intact with breast feedings. You can track everything in between like medication, doctor visits, growth, anything you can think of. I love this app and I recommend it big time!"

Users have also expressed a general liking towards the feature of data sharing and syncing of data between two or more devices.

> e.g., "Awesome App!, My wife has been using MammBaby on her iPhone and now I am using it on my Android phone. It is definitely the easiest one to use and sharing feature is awesome!"

Some of the other features that have received favorable attention include baby heartbeat monitors, contraction timers, week-by-week fetal development stages, and diet/exercise tips and recommendations.

> e.g., "With countless pregnancy and newborn resources on the market, it can be hard for parents to know where to turn for information. This app is created by experts, for parents. As a mother, I appreciate the easy-to-understand and reassuring information found in the app. Like most

> pregnancy apps, the week-by-week updates are perfect. And the contraction timer came in handy on the big day! Thank you, Lamaze, for cutting the fuss and giving parents what we really need: power to make the best decisions for our family!"

*Negative Functionality Experience*

A frequent complaint pertained to app features that do not meet with user expectations. Reviewers expressed concerns over apps that present inaccurate calculations to the users, i.e. calculates wrong due dates, or height/weight/percentile calculations.

> e.g. "Inaccurate Percentile Calculation, I don't know how they're trying to calculate the percentiles by age, but it's clearly not working. None of the percentiles in the app have matched up with either the hospital's or the pediatrician's data for my son--by a long shot! Even without the doctor's records telling me he's somewhere near the 75th percentile, it's obvious that an 8 lbs. boy is NOT in the 30th percentile for weight for his age at 13 days old, as the app reports."

Users also highlighted issues pertaining to loss of data, or inability to sync data.

> e.g. "Have to leave app running or else you lose your contractions data. Isn't that kinda the point in having a contraction app? I will be deleting this one and finding something that actually will track my contractions."

Similarly, there were complaints about apps with no updates or ones with poor updates.

> e.g. "Terrible update!, Before this last update on 7/30, the app was fantastic! But now I HATE IT! It's too cutesy and it's hard to tell anything anymore! The photo section is far too large now when that is not the information that I need. The daily schedule section is MUCH more confusing, and I can't see any patterns. I will be deleting and finding a new app now! It is so confusing now. They went with trying to make it look cute instead of functional. Horrible app!!!!"

Finally, users reported that they discontinued the use of an app with inadequate features, with limited ability to track data, modify an inaccurate entry, or lack flexibility in using conversion metrics, i.e. mg to oz or kg to lbs.

> e.g. "I deleted it after one time, this app is terrible. It just tells you how much weight you should gain. It doesn't track your weight or monitor your progress. It doesn't even save any information. You can find this same

> information on several sites or easily figure it out on your own. And either way, if you want to keep track, you would have to do it yourself anyway. I deleted the app after the first time I tried it and realized it was useless."

*Suggested Functional Improvements*

Along with critiquing an app's functionality/features, users often provided additional recommendations pertaining to features that could be additionally added to improve their overall experience with the app. Reviewers often had a bucket list of requests to customize an app and tailor it to their specific needs and requirements. Table 4.2 provides a summary of suggestions for functional improvements. Some of the more common recommendations focused on data visualization or trends data (for height, weight, feedings, or immunizations), ability to export or print data, additional tracking facilities, or capabilities to sync data between two or more devices.

Table 4.2. Suggested Functional Improvements for MCH apps

| Requested Features | Direct Quotes |
|---|---|
| Export Data | "Helpful, but..., I would love to be able to export or print data. Otherwise helps me keep track of my preemie between Dr visits." |
| Data Visualization and Trends Data | "The only thing that would make it better in my opinion would be to have a graph of each activity to show any types of trends. Knowing that my baby has slept 14% more in this 7-day period vs the last 7 days is maybe interesting, but not helpful when I'm trying to see any patterns of when he's sleeping and for how long. Having a graph that shows when he sleeps each day for a week would be so helpful for getting into more of a natural routine with the baby." |
| Additional data tracking: symptoms, weight, illness, pumping, feedings, medications. | "Wish it had a medicine tracker and reminder, Wish the app helped with keeping track of when a dose of the medication was given and help with reminders for the next dose." |
| Alerts/ Alarms/ Reminders | "A Great App!!, I use this app all the time! I pretty much rely on it! The only thing I've noticed that I'd like them to add is an alarm feature for medicines." |
| Data sync between devices, and data integration across apps | "I wish they could allow for other apps to feed info into it. For example, I use a digital thermometer that connects to my phone. If it could sync with this app it would be perfect!" |
| Edit or delete incorrect data entries | "I wish I could edit time entries in case I look to see which side but forgot to click a new entry. But overall, great and easy to use." |

*Technical Aspects*

The second most common theme (21.05%) that users discussed in their reviews were associated with the technical aspects of an app, i.e. aspects pertaining to how an app operates. Users preferred apps with a user-friendly app interface, free from advertisements or forced ratings, and ones that did not occupy large phone memory space.

e.g.: “Adverts and forced rating is annoying”

Majority of the comments, however, were geared towards technology failures such as apps that crashed or froze on users, thereby, rendering it useless for further use.

> e.g. “Unfortunately, it crashes frequently (usually in the middle of the night when I'm trying to time nursing sessions) and multiples times in a row at that (I think my record is 7). Incredibly irritating when you're sleep deprived, it's 2 am, and all you want to do is get back to sleep not continuously open an app all, so it can hang for 30 seconds then crash.”

Users have also criticized certain apps that were extremely slow to load the information/content, or stream videos.

> e.g. “Generally good, a little slow, switched to this app once the written log from our lactation consultant ran out of space. It's been very helpful for tracking feedings and diapers. I find, however, that it runs really slowly sometimes in terms of entering information and the nursing/pumping timer.”

Other reasons cited as causes for discontinuing app use were inability to register oneself, not available offline, and other glitches associated with syncing data or loss of data.

> e.g. “It no longer lets me register or log in, and every time I open it I get the message that its opening for the first time, with a long wait. I probably won't use it when I'm in labor because of this.”

Few users also recommended certain technical improvements that would help enhance their overall experience with the app. These recommendations pertained to app availability on multiple devices and app platforms, or making an app aesthetically pleasing (improved user interface, fonts, or image quality).

> e.g. "LOVE, I absolutely love this app, I just wish they would make it Apple Watch compatible as well!"

*App Content/Information*

Reviews related to app content or information typically referred to the "wealth of information" these apps had to offer. Users appreciated apps providing detailed information, daily/weekly tips and reminders, latest and updated content, and evidence-based articles.

> e.g. "An evidence-based app you can trust, the information provided by Lamaze comes from evidence-based research, so you know you're not getting the 'fluff' that you read in other pregnancy or parenting apps."

New parents or first-time moms/dads expressed their satisfaction with apps that met with their increased information needs. Few users also suggested that certain apps were better organized and offered greater support as opposed to seeking information on the Internet. Other users indicated a greater satisfaction with using an app for information seeking over traditional use of books.

> e.g. "Yes!, Love love love this app, used it for my first pregnancy and it put me at such ease being a first time mom, I love how they have something to say everyday because you get so anxious being pregnant and just want the baby and this app helps you calm down and understand every stage. I love that you can put pictures at the bottom and see your progress before the birth of your child."

However, not all found the content of these apps to be beneficial. Some users articulated a general dislike towards apps that had very brief content, contained basic information that could be found on the internet, or comprised of a number of typos or grammatical errors, making it incomprehensible. This was especially true for paid apps, where users had higher expectations in terms of content quality.

> e.g. “Underwhelming application., I cannot speak to the integrity of the information this application gives you, A friend of mine told me to purchase it as I was expecting. For the price I expected much more. The Videos section simply opens their YouTube page in a web browser. And the very limited information the application gives you could fit on one sheet of paper. I was expecting for suggestions on how to deal with or enrich my child's experience during her leaps, but instead I only found a very brief description of what was happening developmentally. Certain aspects of the application just don't work at all, you can tell this application was outsourced to international developers for whom English is a second language. I would perhaps give this application three stars if it were free, but considering I paid for it I was expecting more. I'm sure all the information in this app can be found online with little effort. Save your money on this one.”

Few users were also disapproving of apps that contained unrelated information, or was very narrow in scope, i.e. covered a selective range of topics which was not applicable to many.

> e.g. “I didn't put five stars because I disapprove the zodiac stuff, I don't find it useful, fun, or educational (on the contrary).”

Further, there were reviews that offer suggestions to improve app content. Most of the recommendations were geared towards offering the content in a different language and adding additional content,

> e.g. “I've got a son with one of the rarest of rare genetic diseases that I thought would be awesome for this app it's called Spinal Muscular Atrophy Respiratory Distress also known as (Smard 1)”

or to simplify the information to account for the lay audiences.

> e.g. “Hard to understand, the information is correct. However, it would be extremely helpful to nursing mommies if they understood what the medical mumbo jumbo meant!”

*Minor Themes*

*Patterns of usage*

Over nine percent reviewers described their patterns of app usage by identifying the length/duration and frequency of use. Some of them were long time users, utilizing these apps for multiple pregnancies. Users have also highlighted their frequency of usage with some users using these apps almost daily. Also, a large majority of app users tend to be first-time parents who use MCH apps for information-seeking, tracking their pregnancy or infant needs, or to connect with other parents for moral support.

> e.g. “Great app!, I don't normally write reviews for apps but this app is amazing. I am a new mom and I use it throughout the day, every day. I use it to keep track of feeding and sleeping trends.”

*Social Support*

Over eight percent of all reviews referred to apps that acted as a safety haven for users, since these apps connected pregnant women/ mothers to a larger community of app users, thereby offering social support that is typically needed by many during this period. First-time mothers especially found these communities useful to lessen their anxieties over issues where they had minimal experience, and found these communities encouraging.

> e.g. “Awesome video blogs, never seen video blogs from other moms before and it helped me feel like I wasn't the only one. Same goes for the forum. Really good to connect to other moms.”

However, few reviewers were not satisfied with their interactions within such communities. A handful of women faced some level of cyber bullying by others in these communities, especially those who had differing perspectives or values pertaining to child care. Such negative experiences were geared towards strong opinions, biases, and immaturity of other users.

Users also expressed an overall appreciation for apps that had capabilities to sync their data with other caregivers especially their spouse, family members, or significant others. These features helped parents stay abreast with their infant's activities at all times.

> e.g. "Great app, I didn't know a lot about pregnancy and it has helped a lot with the different stages. It has even given my wife some comfort because I know things when she asks me questions."

*App Cost*

Generally speaking, app users preferred apps that were free or had a very low cost associated with it. Users were willing to purchase apps with enhanced capabilities such as data sync on multiple devices, additional tracking features, or data visualization functions. Users were also willing to pay for a 'pro' version to eliminate advertisements and pop-ups and appreciated apps that were aesthetically appealing.

However, users were disapproving of apps that were labelled as free on the app store, but offered very limited functionalities, and required an upgrade (pro-version) to enjoy additional features. Users called such apps as "misleading", "unfair", or "false advertising". Similarly, users were very critical of apps that were paid and did not meet their expectations. Users associated price with quality, thereby, voicing extreme distress if the app faced any technical issues, provided basic information, or contained mediocre features.

> e.g. "Lot of glitches, poor info, no matter what article I click on- every other page starts with the same header: "Article good fats from bad ones" and then an incomplete sentence about using safe household cleaners.... I tried to leave a review ON one of these pages- because EVERY page asks you for a review, and it said "sorry we couldn't complete your review right now." I cannot imagine who would pay 6.99 for this. (Or that they raised the price from 4.99???) I downloaded it for exercises but they don't have videos to show the exercises so I'm better off just going back to YouTube."

*App Comparisons*

Around four percent of users compared certain app features either in a positive or negative context, with other apps that they used in the past or were currently using. Users also compared paid apps with apps that were offered for free to establish whether the app was worth the purchase or not.

> *e.g.* “Meh, Really... I have a ton of other baby apps that give more details on my baby's development and what I should be eating. This app is lacking a lot of details I wouldn't waste my money on going "premium". I'll stick with the bump and nurture. Thanks

*Assists in Healthcare*

Around three percent app users established the role of MCH apps in healthcare management. Consumers especially found these apps useful for keeping track of babies who were underweight, short for age, premature at birth, or with congenital birth defects. They confirmed the role of these apps in recording accurate data that could then be reported effectively to their pediatrician.

> e.g. “I have used this for the last six months with no troubles. It's quick, intuitive, and easy. I have three kids and this baby was a newborn ICU baby, and this made life simpler with multiple caretakers/doctors who want all the details (and not great communication between all the people involved in baby's life.) and exhaustion from all the demands. What a lifesaver!”

A minority of reviews were initiated by the health care professional (HCP), where they specified either using these apps for information-seeking or to monitor patient progress. HCPs have also indicated making recommendations for certain apps to their patients.

*Customer care support*

Users particularly cared about customer care responsiveness in addressing their questions, promptness in fixing issues, as well as fulfilling their requests for additional features. Consumers expressed distress over situations where they paid for an app and did not receive adequate developer support.

> *e.g.* "Doesn't work at all, I purchased this app and was so excited after reading the reviews. However, this app is crap! Took my money but does not work at all, nothing. Stays on one page and that's it. I can't get in touch with app support either. Don't waste $$$ or time. I have tried reinstalling it several times and still crap."

**Discussion**

To our knowledge this is a first study that evaluates consumer preferences on mobile apps targeted towards MCH using publicly available user review data from Apple App and Google Play stores. The element of MCH apps that users were most interested in were related to the functionality of apps i.e. app features. Users were satisfied with apps that offered advanced features such as data monitoring and tracking, or data syncing abilities across different devices. Similarly, users were highly critical of apps that did not meet user expectations in terms of their functionality and were prompted to discontinue the use of apps with limited functionalities. A large number of comments concerned loss of data, or inability to edit an incorrect entry. The overall emphasis on app functionality is consistent with previous literature which highlight the role of user satisfaction with app functions to be one the major caveat in consumer app usage (Milward et al., 2016; Nicholas et al., 2017). In addition, users also offered suggestions or recommendations in terms of app features that would improve their overall experience with the app. This is again consistent with prior reports in other domains (Iacob, & Harrison, 2013; Scheibe, Reichelt, Bellmann, & Kirch, 2015; Nicholas et al., 2017), indicating that consumers are not fully content with the available features, and their needs are often inadequately addressed.

Consumers prefer apps that are easy to use, with an aesthetically pleasing interface, and those that occupy less memory space. While reasons cited for discontinuation of app use centered around technical issues such as crashing or freezing of apps while in use, slow download speed, and too many pop-ups or forced ratings. Derbyshire and Dancy (2013), Anderson, Burford, & Emmerton (2016) and Frie et al. (2017) have reported similar results for women's health apps, health & fitness apps, and weight loss app use. An app that crashes often is deleted by users before any engagement with key functions has occurred (Milward et al., 2016). Thus, app developers may consider careful consideration of technical aspects of these apps before releasing them for use (Milward et al., 2016). One of the major aspects of consideration for app use is the quality of information or content that these apps provide. When it comes to content, users typically value tailored information pertaining to their condition and actionable solutions for its effective management (Mendiola, Kalnicki, & Lindenauer, 2015). Guerra-Reyes, Christie, Prabhakar, Harris, & Siek (2016) indicated that pregnant women and new mothers often seek information from apps on topics such as establishing breastfeeding, solving breastfeeding problems, infant health issues, and topics that are uncomfortable to discuss with healthcare providers. Overall women reported a positive experience with pregnancy apps, but few reported issues with what they perceived as validity, accuracy, and timeliness of the information that was being presented by certain apps (Guerra-Reyes et al., 2016).

App cost was recognized as an important consideration for app adoption and utilization. Majority of users preferred free apps, however, users were willing to pay for apps, if they offered sophisticated features, comprehensive information, and were of superior quality. These results are consistent with other studies (Pereira-Azevedo et al., 2016; Peng, Kanthawala, Yuan, & Hussain, 2016), and it has been reported that as high as 77% users used only free apps (Peng et al., 2016). While some users discussed a negative experience with app-based communities, most women expressed their enthusiasm in terms of the social support they received from fellow mothers going through similar experiences. Women value peer experiences and knowledge on important topics such as breastfeeding or infant care, and in turn offer similar support to others in need. Women often use these platforms to discuss topics that are sensitive in nature, e.g. sexual activity during and after pregnancy or feelings of hopelessness (Lupton, 2017). The anonymity offered in such communities provide an opportunity to raise issues that they otherwise would not discuss with family, friends, or healthcare providers during in person visits (Lupton, 2017). Aside of being a part of an ongoing community of app users, women have also cherished the ability to engage their partners and other family members in maternal and child healthcare and support. Information-seeking during pregnancy and postpartum was relatively higher among first-time mothers who use these apps to track stages of pregnancy week-by-week or to monitor infant development. Women also report using these apps for multiple pregnancies and some engage with MCH apps almost daily.

Increasingly, users are using MCH apps to assist them in health literacy, monitoring, self-management, as well as clinical decision-making. Reviewers elucidated the role of MCH apps in improving patient-provider communication by aiding in data tracking, which helps improve recall and increased preparedness for doctor visits. Certain apps offer additional features where users can print their reports or directly email them to their providers. This increased use of mobile apps during pregnancy and postpartum periods, also highlight the importance of providing evidence-based information, especially due the vulnerable nature of these phases (Robinson & Jones, 2014). Very few reviewers discuss the availability of evidence-based content or express a desire to identify the scientific sources of information that is being presented to them. This may be credited to the fact that users are more concerned with the overall appeal of an app in terms of functionalities, features, content, or usability, as opposed to verifying the credibility of this information. Hence, healthcare providers, app developers, and policymakers may consider strategies to review and promote apps to consumers based on information accuracy and trustworthiness. Future research may focus on evaluating the quality of MCH app content and information.

Further, there is increased satisfaction among users whose needs and viewpoints were adequately addressed by the app developers. This highlights the fact that consumers value increased involvement in app development and delivery process, which may increase their engagement and long-term usage. For example, consumer preferences for weight loss apps call for greater personalization of an app, i.e. allow for choice of a theme or design, to increase user satisfaction (Frie et al., 2017).

**Strengths and Limitations**

A major strength of this review is that it analyzes consumer attitudes and perspectives towards MCH apps using a large and diverse sample of publicly available user reviews data from Apple App and Google Play stores. This study utilizes a systematic approach of sampling a comprehensive set of user reviews for analysis. Importantly, to our knowledge this is a first study that utilizes this particular methodology and sampling strategy to study user perspectives for MCH apps.

This study is not without limitations. First, it is likely that the user reviews on the app store may not be representative of a larger population of app users. However, the study employs a robust sample of user reviews using a strategic approach to capture a more diverse sample of app users, which probably could not be achieved using other exploratory methods such as interviews or focus groups. Second, our results may not be generalizable to apps belonging to other health domains, e.g. app utilization for monitoring infant needs may not be applicable to other populations such as diabetes, or weight loss apps. Though, concerns about technical issues, loss of data, ease of use, or app updates may apply to other app categories as well. Third, there is a possibility of fake reviews to increase the app demand (Hill, 2018), but the large number of reviews per app should compensate for this challenge.

**Conclusion**

This review extends the literature by emphasizing the features of MCH apps that are particularly important to users. These results may be beneficial for app developers to consider during the app development process. Overall, consumers value low cost apps that have high quality content, superior features, smooth technical aspects, and are easy to use. Users consider app developer responsiveness an integral part of app use, as it makes them empowered in the process of app development and delivery. These consumer perspectives are essential for mHealth sustenance, as currently no best-practice guidelines exist for the app environment. Increasingly users are utilizing apps for healthcare management and informed decision-making. Thus, healthcare providers, app developers, and policymakers may consider strategies to review and promote evidence-based and trustworthy apps to consumers. Future studies may focus on assessing user experiences utilizing other qualitative methods to garner detailed perspectives on long-term app usage. This study should also be replicated in other health domains, to gain a greater sense of consumer perspectives in the field of mHealth. Future studies may also focus on developing a framework for consumers to evaluate app quality for effective app comparisons and usage decisions.

**References**

Anderson, K., Burford, O., & Emmerton, L. (2016). Mobile health apps to facilitate self-care: A qualitative study of user experiences. *PLoS One, 11*(5), e0156164. doi:10.1371/journal.pone.0156164

Apple Inc. iTunes. Retrieved from https://itunes.apple.com/us/genre/ios/id36?mt=8

Boudreaux, E. D., Waring, M. E., Hayes, R. B., Sadasivam, R. S., Mullen, S., & Pagoto, S. (2014). Evaluating and selecting mobile health apps: strategies for healthcare providers and healthcare organizations. *Translational Behavioral Medicine, 4*(4), 363-371. doi:10.1007/s13142-014-0293-9

Buijink, A. W., Visser, B. J., & Marshall, L. (2013). Medical apps for smartphones: lack of evidence undermines quality and safety. *Evidence-Based Medicine, 18*(3), 90-92. doi:10.1136/eb-2012-100885

Cho, J.Y., & Lee, E. (2014). Reducing confusion about grounded theory and qualitative content analysis: Similarities and differences. *The Qualitative Report*, 19 (32), 1-20. Retrieved from https://nsuworks.nova.edu/tqr/vol19/iss32/2/

Frie, K., Hartmann-Boyce, J., Jebb, S., Albury, C., Nourse, R., & Aveyard, P. (2017). Insights from Google Play Store user reviews for the development of weight loss apps: Mixed-method analysis. *JMIR Mhealth Uhealth, 5*(12), e203. doi:10.2196/mhealth.8791

Guerra-Reyes, L., Christie, V. M., Prabhakar, A., Harris, A. L., & Siek, K. A. (2016). Postpartum health information seeking using mobile phones: Experiences of low-income mothers. *Maternal and Child Health Journal, 20*(Suppl 1), 13-21. doi:10.1007/s10995-016-2185-8

Iacob, C., & Harrison, R. (2013). *Retrieving and analyzing mobile apps feature requests from online reviews*. Paper presented at the Proceedings of the 10th Working Conference on Mining Software Repositories, San Francisco, CA, USA.

Declercq ER, Sakala C, Corry MP, Applebaum S, Herrlich A. (2013, May). *Listening to Mothers III: Pregnancy and Birth.* New York: Childbirth Connection.

Derbyshire, E., & Dancey, D. (2013). Smartphone medical applications for women's health: What is the evidence-base and feedback? *International Journal of Telemedicine and Applications, 2013*, 782074. doi:10.1155/2013/782074

Forman J., & Damschroder, L. (2007). Qualitative content analysis. In L. Jacoby & L. Siminoff (Eds.), *Empirical methods for bioethics: A primer (Advances in bioethics, volume 11)* (pp. 39-62). Oxford, UK: Emerald Group Publishing Limited.

Google Inc. Google Play. Retrieved from https://play.google.com/store/apps

Hearn, L., Miller, M., & Lester, L. (2014). Reaching perinatal women online: the Healthy You, Healthy Baby website and app. *Journal of Obesity, 2014*, 573928. doi:10.1155/2014/573928

Hebden, L., Cook, A., van der Ploeg, H. P., & Allman-Farinelli, M. (2012). Development of smartphone applications for nutrition and physical activity behavior change. *JMIR Research Protocols*, *1*(2), e9. doi:10.2196/resprot.2205

Hill, S. (2018). *Can you really trust app store ratings? We asked the experts*. Retrieved from https://www.digitaltrends.com/android/can-you-really-trust-app-store-ratings/

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research, 15*(9), 1277-1288. doi:10.1177/1049732305276687

Kondracki, N.L., Wellman, N.S., & Amundson, D.R. (2002). Content analysis: Review of methods and their applications in nutrition education. *Journal of Nutrition Education & Behavior, 34* (4), 224-230. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/12217266

Krebs, P., & Duncan, D. T. (2015). Health app use among US mobile phone owners: A national survey. *JMIR Mhealth Uhealth*, *3*(4), e101. doi:10.2196/mhealth.4924

Larsen, M. E., Nicholas, J., & Christensen, H. (2016). Quantifying app store dynamics: Longitudinal tracking of mental health apps. *JMIR Mhealth Uhealth*, *4*(3), e96. doi:10.2196/mhealth.6020

Lee, Y., & Moon, M. (2016). Utilization and content evaluation of mobile applications for pregnancy, birth, and child care. *Healthcare Informatics Research, 22*(2), 73-80. doi:10.4258/hir.2016.22.2.73

Lupton, D., & Thomas, G.M. (2015). Playing pregnancy: The ludification and gamification of expectant motherhood in smartphone apps. *M/C Journal, 18*(5), Retrieved from http://www.journal.media-culture.org.au/index.php/mcjournal/article/view/1012

Lupton, D. (2017). “It Just Gives Me a Bit of Peace of Mind”: Australian women’s use of digital media for pregnancy and early motherhood. *Societies*, *7*(3), 25. doi:10.3390/soc7030025

Mangone, E. R., Lebrun, V., & Muessig, K. E. (2016). Mobile phone apps for the prevention of unintended pregnancy: A systematic review and content analysis. *JMIR Mhealth Uhealth, 4*(1), e6. doi:10.2196/mhealth.4846

Mayring P. (2000). Qualitative content analysis. *Forum of Qualitative Social Research, 1*(2), Retrieved from http://www.qualitative-research.net/index.php/fqs/article/view/1089/2385

Mendiola, M. F., Kalnicki, M., & Lindenauer, S. (2015). Valuable features in mobile health apps for patients and consumers: content analysis of apps and user ratings. *JMIR Mhealth Uhealth, 3*(2), e40. doi:10.2196/mhealth.4283

Milward, J., Khadjesari, Z., Fincham-Campbell, S., Deluca, P., Watson, R., & Drummond, C. (2016). User preferences for content, features, and style for an app to reduce harmful drinking in young adults: Analysis of user feedback in app stores and focus group interviews. *JMIR Mhealth Uhealth, 4*(2), e47. doi:10.2196/mhealth.5242

Nicholas, J., Fogarty, A. S., Boydell, K., & Christensen, H. (2017). The Reviews Are in: A qualitative content analysis of consumer perspectives on apps for bipolar disorder. *Journal of Medical Internet Research, 19*(4), e105. doi:10.2196/jmir.7273

Node.js Foundation. Retrieved from https://nodejs.org/en/

O'Higgins, A., Murphy, O. C., Egan, A., Mullaney, L., Sheehan, S., & Turner, M. J. (2014). The use of digital media by women using the maternity services in a developed country. *Irish Medical Journal, 107*(10), 313-315.

Peng, W., Kanthawala, S., Yuan, S., & Hussain, S. A. (2016). A qualitative study of user perceptions of mobile health apps. *BMC Public Health, 16*(1), 1158. doi:10.1186/s12889-016-3808-0

Pereira-Azevedo, N., Osorio, L., Cavadas, V., Fraga, A., Carrasquinho, E., Cardoso de Oliveira, E., . . . Roobol, M. J. (2016). Expert involvement predicts mHealth app downloads: Multivariate regression analysis of urology apps. *JMIR Mhealth Uhealth*, *4*(3), e86. doi:10.2196/mhealth.5738

Robinson, F., & Jones, C. (2014). Women's engagement with mobile device applications in pregnancy and childbirth. *The Practising Midwife*, *17*(1), 23-25.

Rotheram-Borus, M. J., Tomlinson, M., Swendeman, D., Lee, A., & Jones, E. (2012). Standardized functions for smartphone applications: examples from maternal and child health. *International Journal of Telemedicine and Application*, *2012*, 973237. doi:10.1155/2012/973237

Scheibe, M., Reichelt, J., Bellmann, M., & Kirch, W. (2015). Acceptance factors of mobile apps for diabetes by patients aged 50 or older: a qualitative study. *Medicine 2.0*, *4*(1), e1. doi:10.2196/med20.3912

Scott, K.M., Gome, G.A., Richards, D., & Caldwell, P.H. (2015). How trustworthy are apps for maternal and child health? *Health and Technology*, *4*(4), 329-336. doi:10.1007/s12553-015-0099-x

Tamrat, T., & Kachnowski, S. (2012). Special delivery: an analysis of mHealth in maternal and newborn health programs and their outcomes around the world. *Maternal and Child Health Journal*, *16*(5), 1092-1101. doi:10.1007/s10995-011-0836

# CHAPTER 5

# CONCLUSIONS

This dissertation provides important insights into the popularity, use, and effectiveness of mHealth apps as interventions to provide health education and/or decision-making support for maternal and child health (MCH). These findings make a number of contributions to the mHealth research literature. First, the results of the study presented in Chapter 2, reveal that apps belonging to Google Play store are associated with increased satisfaction (user ratings). While, apps within health & fitness genre, with older updates, and no age-restrictions are related with lower satisfaction. Similarly, lower priced apps with high star ratings, in-app purchase options, and in-app advertisement presence were associated with higher intent to use (user downloads). On the other hand, apps belonging to medical and health & fitness genre are related to lower intent to use. Knowledge of factors related to ratings and downloads may benefit app developers and help inform marketing and development strategies. Large majority of MCH apps are developed by non-healthcare developers, which may raise concern about the quality of MCH app content. Moreover, no differences in ratings or downloads are observed between apps developed by healthcare and non-healthcare developers. Therefore, if healthcare organizations in fact provide more credible information, fewer consumers may receive this information. This also indicates that consumers do not consider developer type while deciding on app use.

Second, in terms of information quality presented in Chapter 3 we observe that popular MCH apps on an average include 7.4 behavior change techniques (BCTs) with a median of 6 BCTs. Prior literature has highlighted the role of BCTs within interventions in bringing about desired behavior change outcomes. This may call for a greater need to incorporate BCTs within app content during the app development process. Furthermore, differences in the use of BCTs are observed between apps developed by healthcare and non-healthcare developers. This may signify the need for healthcare participation during app development process to ensure greater value to behavior change.

Finally, in terms of net benefits presented in Chapter 4 we see that consumers value apps that are low cost and easy to use, with superior features, smooth technical aspects, and high-quality content. Increasingly, women are utilizing MCH apps for healthcare management, social engagement and informed decision-making. Overall, consumers value their authority in app development and delivery process. These consumer perspectives are important for consideration as currently, no best-practice guidelines exist for the mHealth app environment.

These results have a number of implications for app developers, clinicians, public health practitioners, and consumers. For app developers, especially healthcare developers, it may be important to consider strategies that focus on consumer perspectives during app development to ensure higher app uptake and use. It may also be useful for app stores to categorize apps based on app developers, and list apps developed by healthcare organizations especially within the health & fitness and medical genre, higher up for easier access to consumers. For healthcare practitioners, it may be important to review and promote apps developed by healthcare organizations, and those that are grounded in theoretical constructs. For consumers, it may be important to identify their goals for app use and select the best app suited for their needs and requirements.

This dissertation provides a number of future topics worth consideration. First, this study utilizes MCH app data to understand the app characteristics that are related with intent to use and increased app satisfaction. Future studies may focus on understanding user characteristics that are associated with user behavior patterns such as app uptake and perceived satisfaction. Second, this study has a cross-sectional design, future studies may focus on adopting a time-series design to evaluate the factors that influence user behavior patterns. Third, this study analyzes the presence and use of BCTs within popular MCH apps. Future studies may focus on understanding the effects of MCH apps in bringing about desired behavior changes. Fourth, this study is limited to the use of BCTs in popular MCH apps, while, future studies may replicate the study design to include a larger sample of MCH apps to understand patterns of theory use across a broader spectrum. Fifth, while this study focuses on evaluating app characteristics, use of BCTs, and user perspectives for MCH apps, future studies may focus on exploring these trends in allied mHealth domains. Sixth, future studies may also explore how to best incorporate BCTs during the human centered designing process. Seventh, future studies may focus on utilizing qualitative methods to assess user experiences and consumer perspectives on long-term app usage. Eight, future studies may evaluate user characteristics of app users and other online groups for social support. Ninth, future studies may potentially test the interrelations between DeLone and McLean’s IS Success Model in the context of mHealth. Finally, studies may also incorporate clinician perspectives on value of MCH apps in clinical practice, and in improving patient-physician communication.

Overall, the results from this study are useful to researchers, app developers, policymakers, and healthcare providers. Researchers can use these results to extend knowledge of mHealth app delivery, uptake and translation to behavior changes among pregnant women and new mothers. Future studies should identify gaps in mHealth app literature and strive to identify a unified framework incorporating behavior change techniques and other best-practice guidelines for app content development. Clinical practitioners can use these findings in identifying MCH apps worth recommending to their patients for health education and/or decision-making support. These findings may also be important to app developers in considering marketing strategies, along with harnessing the possibility of involving healthcare professionals during content development process. To conclude, this research extends knowledge on mHealth app delivery and practice and opens the door for future research within this area.

# APPENDICES

## Appendix A: List of Keywords (n=34)

| Snowball Keywords | Frequency of use |
|---|---|
| Pregnant/pregnancy | 170 |
| Prenatal | 63 |
| Baby/babies | 56 |
| Child/children/childhood | 29 |
| Parents/parenting/parenthood | 22 |
| Birth | 14 |
| Mom/mum | 12 |
| Labor/Delivery | 8 |
| Fetus/fetal | 6 |
| Maternal/Maternity | 5 |
| Breastfeeding | 4 |
| Mother/Motherhood | 4 |
| Infant | 3 |
| Obstetrics | 3 |
| Antenatal | 3 |
| Conception | 3 |
| Postnatal/postpartum | 2 |
| Gestation/Gestational | 2 |
| Newborn | 1 |
| Intrapartum | 1 |
| Lactation | 1 |

## Appendix B: Description of Dependent and Independent Variables

| Variables | Type | Description |
|---|---|---|
| ***Dependent Variables*** | | |
| User ratings | Standardized Zscore | The average star ratings users assign to each app. Available from both Apple App and Google Play Stores. |
| User Downloads | Ordinal Categorical<br>1-500=1<br>50-5000=2<br>5000-50,000=3<br>50,000-50,000,000=4 | Number of downloads for each app. Available from Google Play Store only. |
| ***Independent Variables*** | | |
| Operating System | Binary Categorical<br>Android=1<br>iOS=0 | Whether the app belongs to the iOS or the Android platform. |
| Price of apps | Continuous | Actual price of the app in USD if the app is paid. |
| Types of developers | Binary Categorical<br>Healthcare=1 | The developers of the apps are classified intro different categories. |

| | | |
|---|---|---|
| | Non-Healthcare/Unknown=0 | |
| App update age | Continuous | Days elapsed since the last updated. |
| Categories/ Primary Genre | Nominal Categorical<br>Health & Fitness<br>Medical<br>Other | Developer provided category for each app. |
| Content rating | Nominal Categorical<br>Not age restricted<br>Age restricted<br>Unrated | The age-appropriate age restriction for the app content provided by developers for each app. |
| In app purchase option (Google Play only) | Binary Categorical<br>Yes= 1<br>No=0 | Whether the app offers additional features beyond a basic functionality for an extra cost. Available from Google Play Store only. |
| In app advertisement option (Google Play only) | Binary Categorical<br>Yes=1<br>No=0 | Whether the app displays advertisements or pop-ups. Available from Google Play Store only. |

## Appendix C: Categories of Healthcare Organizations

| | |
|---|---|
| Government agency | Apps developed by a government agency such as US Food and Drug Administration (FDA) or Centers for Disease Control and Prevention (CDC). |
| US hospital system | Apps developed by a US hospital system such as Eskenazi Health or Mayo Clinic. |
| US academic medical institution | Apps developed by a US academic medical institution such as IU Health University hospital or Harvard Medical School. |
| Medical Specialty Society | Apps developed by medical specialty society such as The American College of Obstetricians and Gynecologists or American Academy of Pediatrics (AAP). |
| Non-profit healthcare organization | Apps developed by a non-profit healthcare organization such as March of Dimes Foundation or Save the Children |
| Consumer Organization with health focus | Apps developed by a national consumer company that is health focused such as WebMD or Walgreens |
| US physician | Apps developed by a US board-certified physician. |
| Third-party payer | Apps developed by a third-party payer such as Aetna or Anthem. |
| Pharmaceutical or medical technology company | Apps developed by a pharmaceutical or medical technology company such as Eli Lilly or Medtronic. |

Note: the categories for types of healthcare organizations have been adapted from Mendiola et al. (2015)

## Appendix D: Ordinal Logistic Regression for Effects of Standardized User Rating and Price on User Download

| | Estimates | SE | *P* Value | 95% CI | |
|---|---|---|---|---|---|
| Standardized User Rating | 0.80 | 0.20 | **<0.001** | 0.41 | 1.18 |
| Price (USD) | -0.45 | 0.15 | **0.003** | -0.74 | -0.16 |

a. The dependent variable is the level of downloads.
b. The reference level for user downloads is "50,000-50,000,000".
c. Estimates show the relative magnitude, and direction (positive or negative) of the impact of the listed variables on the level of downloads.
d. N=213

## Appendix E: Ordinal Logistic Regression for Effects of Standardized User Rating, Price, and Developer Type on User Download

| | Estimates | SE | *P* Value | 95% CI | |
|---|---|---|---|---|---|
| Standardized User Rating | 0.78 | 0.20 | **<0.001** | 0.39 | 1.17 |
| Price (USD) | -0.44 | 0.15 | **0.003** | -0.74 | -0.15 |
| Developer Type | -0.14 | 0.30 | 0.63 | -0.73 | 0.45 |

a. The dependent variable is the level of downloads.
b. The reference level for user downloads is "50,000-50,000,000"; for developer type "Not healthcare developer".
c. Estimates show the relative magnitude, and direction (positive or negative) of the impact of the listed variables on the level of downloads.
d. N = 213

## Appendix F: Ordinal Logistic Regression for Effects of Standardized User Rating, Price, and Genre on User Download

| | Estimates | SE | *P* Value | 95% CI | |
|---|---|---|---|---|---|
| Standardized User Rating | 0.71 | 0.20 | **<.001** | 0.31 | 1.10 |
| Price (USD) | -0.47 | 0.15 | **0.001** | -0.76 | -0.19 |
| Medical Genre | -1.63 | 0.46 | **<.001** | -2.53 | -0.73 |
| Health & fitness Genre | -1.29 | 0.42 | **0.002** | -2.12 | -0.46 |

a. The dependent variable is the level of downloads.
b. The reference level for user downloads is "50,000-50,000,000"; app genre "Other Category".
c. Estimates show the relative magnitude, and direction (positive or negative) of the impact of the listed variables on the level of downloads.
d. N = 213

## Appendix G: Ordinal Logistic Regression for Effects of Standardized User Rating, Price, and Update Age on User Download

| | Estimates | SE | *P* Value | 95% CI | |
|---|---|---|---|---|---|
| Standardized User Rating | 0.73 | 0.20 | **<.001** | 0.34 | 1.12 |
| Price (USD) | -0.37 | 0.15 | **0.01** | -0.67 | -0.07 |
| Update Age | -0.0008 | 0.0003 | **0.009** | -0.001 | -0.0002 |

a. The dependent variable is the level of downloads.
b. The reference level for user downloads is "50,000-50,000,000".
c. Estimates show the relative magnitude, and direction (positive or negative) of the impact of the listed variables on the level of downloads.
d. N = 213

## Appendix H: Ordinal Logistic Regression for Effects of Standardized User Rating, Price, and In-App Purchase on User Download

| | Estimates | SE | *P* Value | 95% CI | |
|---|---|---|---|---|---|
| Standardized User Rating | 0.68 | 0.20 | **0.001** | 0.30 | 1.07 |
| Price (USD) | -0.40 | 0.15 | **0.007** | -0.69 | -0.11 |
| Offer In-App Purchase | 1.12 | 0.36 | **0.002** | 0.40 | 1.82 |

a. The dependent variable is the level of downloads.
b. The reference level for user downloads is "50,000-50,000,000"; for offers in-app purchase "no".
c. Estimates show the relative magnitude, and direction (positive or negative) of the impact of the listed variables on the level of downloads.
d. N = 213

## Appendix I: Ordinal Logistic Regression for Effects of Standardized User Rating, Price, and In-App Advertisement on User Download

| | Estimates | SE | *P* Value | 95% CI | |
|---|---|---|---|---|---|
| Standardized User Rating | 0.71 | 0.20 | **<.001** | 0.32 | 1.10 |
| Price (USD) | -0.36 | 0.15 | **0.02** | -0.66 | -0.07 |
| Offer In-App Advertisement | 0.64 | 0.27 | **0.02** | 0.11 | 1.18 |

a. The dependent variable is the level of downloads.
b. The reference level for User downloads is "50,000-50,000,000"; for Offer in-app advertisement "no".
c. Estimates show the relative magnitude, and direction (positive or negative) of the impact of the listed variables on the level of downloads.
d. N = 213

## Appendix J: Number of BCTs per App

| App | Developer | Platform | BCT Scores (N=16) |
|---|---|---|---|
| Pregnancy Tracker & Baby App | BabyCenter | Android | 10 |
| Pregnancy + | Health & Parenting Ltd | Android | 10 |
| Pregnancy & Baby \| What to Expect | Everyday Health | Android | 10 |
| I’m Expecting - Pregnancy App | MedHelp, Inc - Top Health Apps | Android | 13 |
| Feed Baby - Baby Tracker | Penguin Apps | Android | 5 |
| Ovia Pregnancy & Baby Tracker | Ovuline, Inc. | Android | 16 |
| Moms Chat & Pregnancy Tracker | Wunderkind Media and Technology Corp. | Android | 11 |
| I'm Pregnant / Pregnancy App | Pregnancy & Baby App | Android | 13 |
| Pregnancy Calendar | Vladimir Fedrushkov | Android | 5 |
| Pregnancy Week By Week | Jollymobi | Android | 10 |
| Feed Baby Pro - Baby Tracker | Penguin Apps | Android | 5 |
| Pregnancy Tracker Glow Nurture | Glow Inc | Android | 13 |
| The Bump Pregnancy Tracker | XO Group Inc. | Android | 9 |
| Pregnancy Calculator and Tracker | Mobile Dimension LLC | Android | 6 |

| | | | |
|---|---|---|---|
| 280days: Pregnancy Diary | amane factory inc. | Android | 7 |
| Baby Nursing - Breastfeeding Tracker | Sevenlogics, Inc. | iOS | 5 |
| Sprout Pregnancy | Med ART Studios | iOS | 5 |
| Labor and Contraction Timer | Michael Kale | iOS | 2 |
| Pregnancy Countdown – Weekly Fetus & Mother Development plus Tips, Information and Checklists | Pregniful Solutions LTD | iOS | 7 |
| Parenting Reminder - a Day, a Tip | AAWE Development Inc. | iOS | 5 |
| Baby Tracker (Feed timer, sleep, diaper log) | Nighp Software LLC | iOS | 5 |
| Sprout Baby (Feeding, Sleep & Health Tracker) | Med ART Studios | iOS | 5 |
| Pregnancy Health Help & Advice FREE! The Ultimate Pregnant Lady Survival Guide Handbook and Maternity Fast Tips Kit | Michael Quach | iOS | 1 |
| Pregnancy ++ | Health & Parenting Ltd | iOS | 11 |
| Baby Log - Activities, Growth and Milestones | BHI Technologies, Inc. | iOS | 5 |
| MammaBaby - Breastfeeding Logger | Life'n Stats | iOS | 6 |
| WebMD Baby: Feeding, Diaper, and Sleep Tracker | WebMD | iOS | 9 |
| Eat Sleep: Simple Baby Tracking | Make Sail, Inc. | iOS | 3 |
| Contraction Master | Bill Snebold Design | iOS | 3 |

## Appendix K: List of Apps Included in Qualitative Analysis

| Platform | Title | Developer | Number of Scraped Reviews | Star Ratings | Price |
|---|---|---|---|---|---|
| iOS | Pregnancy & Baby \| What to Expect | Everyday Health, Inc. | 40 | 4.5 | 0 |
| iOS | Baby Nursing - Breastfeeding Tracker | Sevenlogics, Inc. | 40 | 4.5 | 0 |
| iOS | BabyBump Pregnancy Pro with Baby Names | Alt12 Apps, LLC | 40 | 4.5 | 0 |
| iOS | iPregnancy (Pregnancy App) | Gregory P. Moore, MD | 40 | 4 | 3.99 |
| iOS | Pregnancy Countdown – Weekly Fetus & Mother Development plus Tips, Information and Checklists | Pregniful Solutions LTD | 40 | 3 | 0 |
| iOS | Baby Tracker (Feed timer, sleep, diaper log) | Nighp Software LLC | 40 | 4.5 | 0 |
| iOS | MammaBaby - Breastfeeding Logger | Life'n Stats | 40 | 4.5 | 0 |
| iOS | iPregnant Pregnancy Tracker Free (iPeriod's Pregnancy Companion) | Winkpass Creations, Inc. | 40 | 4 | 0 |
| iOS | Growth: charts for baby and child tracking | Clafou Apps | 40 | 4.5 | 0 |
| iOS | The Wonder Weeks | Domus Technica | 40 | 2.5 | 1.99 |
| iOS | Pregnant Dad | SB Apps | 40 | 3.5 | 1.99 |
| iOS | iBabyLog: Baby Breastfeeding Timer, Nursing Tracker and Sleep, Diaper, Activities Log | Palanati Group, LLC | 40 | 4.5 | 0 |
| iOS | Pregnancy Weight Calculator & Baby Bump Weight Gain from Mobile Mom | Rebellion Media | 40 | 3.5 | 0 |
| iOS | Contraction Timer Deluxe | Deltaworks | 34 | 4 | 0.99 |

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|---|---|---|---|---|---|
| iOS | Baby Tracker & Digital Scrapbook \| Kidfolio Pro | Alt12 Apps, LLC | 40 | 4.5 | 0 |
| iOS | BabyTime Baby Feeding Timer - Breastfeeding & More | Enhancient | 40 | 4.5 | 2.99 |
| iOS | Contraction Timer and Fetal Kick Counter | Quality Work Software llc | 10 | 3.5 | 0.99 |
| iOS | Genetics & Birth Defects: Medical Dictionary and Terminology of Human Genetic Code and Evolution | Michael Quach | 10 | 3 | 0 |
| iOS | Hatch Baby - Breastfeeding, Sleep, & Diaper tracker | Hatch Baby, Inc. | 40 | 4.5 | 0 |
| iOS | MyDueDate - pregnancy progress tracker | Aspyre Solutions | 38 | 3 | 0.99 |
| iOS | Milk Maid | Michael Kale | 40 | 4.5 | 2.99 |
| iOS | WomanLog Pregnancy Calendar | Pro Active App | 21 | 4 | 0 |
| iOS | Contraction Timer - Time labor contractions | PENGUIN APPS PTY LTD | 40 | 4.5 | 0 |
| iOS | Pregnancy Pounds - Weight Tracking App | Squallsoft LLC | 16 | 4.5 | 3.99 |
| iOS | Happy Pregnancy Ticker | SOFTCRAFT SYSTEMS AND SOLUTIONS PRIVATE LIMITED | 11 | 4 | 0 |
| iOS | Baby Kicks Monitor - Fetal Movement & Kick Counter | Maxwell Software | 11 | 5 | 0.99 |
| iOS | Positive Pregnancy with Andrew Johnson | Michael Schneider | 30 | 4.5 | 2.99 |
| iOS | Totally Pregnant - A Total Pregnancy Experience | 40weeks | 40 | 3.5 | 0 |
| iOS | Kids' Wellness Tracker | McNeil-PPC, Inc | 40 | 3.5 | 0 |

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|---|---|---|---|---|---|
| iOS | Contraction Timer Lite | Michael Kale | 20 | 4 | 0 |
| iOS | Breastfeeding Central | Andrew Rae | 30 | 4 | 3.99 |
| iOS | Pumping Tracker - Breast Milk Pump Log for Mama | LINKLINKS LTD | 40 | 4 | 0 |
| iOS | Baby Daily Activity Tracker tools iCareRoom Free | Yangwoo Park | 18 | 4 | 0 |
| iOS | Pregnancy — Tracker, Assistant & Calendar | Aliaksei Khanenia | 18 | 5 | 0 |
| iOS | Prenatal Yoga - Pregnancy Fitness | Dawnsun Technologies LLC | 20 | 3 | 0 |
| iOS | Baby Log PRO - Feed Timer Breastfeeding Tracker | ChuChu Train Productions | 12 | 4.5 | 1.99 |
| iOS | Baby Care (Feeding, Sleep and Diaper Track & Log for Newborn) | Yi Ding | 11 | 4 | 2.99 |
| iOS | Baby Kick Counter & Monitor - Fetal movement and pregnancy tracker. | BabymedLLC | 17 | 3.5 | 0 |
| iOS | Which Boob? Simplified breastfeeding tracker for nursing Moms | Christopher Hardy | 20 | 4.5 | 0 |
| iOS | Pregnancy View | Fertility Council | 12 | 4.5 | 0 |
| iOS | Baby2Body. | Baby2Body Limited | 25 | 3 | 0 |
| iOS | Breastfeeding Myths - Guide for Lactation | Jorge Gregorio Martin Bello | 10 | 4.5 | 0 |
| iOS | Expectful | Expectful LLC | 40 | 5 | 0 |
| iOS | Hear My Baby - Baby Heartbeat Monitor App | Fat Cigar Productions Ltd | 37 | 4 | 3.99 |
| Android | Feed Baby - Baby Tracker | Penguin Apps | 40 | 4.5 | 0 |
| Android | BabyBump Pregnancy Pro | Alt12 Apps, Inc. | 40 | 4.5 | 0 |

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|---|---|---|---|---|---|
| | | | | | |
| Android | I'm Pregnant / Pregnancy App | Pregnancy & Baby App | 40 | 4.4 | 0 |
| Android | Feed Baby Pro - Baby Tracker | Penguin Apps | 40 | 4.6 | 8.99 |
| Android | Pregnancy Calendar and Tracker | Mobile Dimension LLC | 40 | 4.8 | 0 |
| Android | Baby Tracker - Feed,Diaper Log | NIGHP SOFTWARE | 40 | 4.6 | 0 |
| Android | Baby Connect (activity log) | Seacloud Software | 40 | 4.7 | 4.99 |
| Android | Breastfeeding Tracker Pumping | Whisper Arts | 40 | 4.4 | 0 |
| Android | Baby Manager - Breastfeeding | InnMov Software | 40 | 4.7 | 0 |
| Android | First Time Pregnancy | amiiSolutions | 40 | 4.3 | 0 |
| Android | Glow Baby for Breastfeeding | Glow Inc | 40 | 4.6 | 0 |
| Android | Pregnancy Companion by OBGYN | EmbraceHer Innovations, Inc. | 40 | 3.9 | 0 |
| Android | Easy Contraction Timer | Cuberob | 40 | 4.3 | 0 |
| Android | Prenatal Lullabies Lite | IMOBLIFE INC. | 40 | 4.2 | 0 |
| Android | LactMed | National Library of Medicine at NIH | 40 | 4.3 | 0 |
| Android | Babylog - daily/growth tracker | ForestApps | 40 | 4.6 | 0 |
| Android | ANMOL | Ministry of Health & Family Welfare | 40 | 3.7 | 0 |
| Android | YOUR BABY'S HEARTBEAT ANYTIME! | Fetal Beats Inc. | 40 | 2.7 | 0 |
| Android | Prenatal Yoga (PRO) | Daily Yoga Software Technology Co. Ltd | 40 | 3.2 | 0 |

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|---|---|---|---|---|---|
| Android | Full Term - Contraction Timer | Mustansir Golawala | 40 | 4.2 | 0 |
| Android | Pregnancy Workouts by Power 20 | Power 20 | 40 | 4.3 | 2.99 |
| Android | latchME - breastfeed easier | Jonathan Goldfinger | 40 | 3.5 | 0 |
| Android | Moms Into Fitness | Moms Into Fitness, Inc. | 40 | 3.6 | 0 |
| Android | MammaBaby Breastfeeding Logger | MammaBabyAndroid | 38 | 4.5 | 0 |
| Android | Pregnancy to Parenting | Lamaze International | 40 | 3 | 0 |
| Android | MuM | Techtree IT Systems Private Limited | 21 | 4 | 0 |
| Android | See Baby Pregnancy Guide | EHD | 24 | 3.9 | 0 |
| Android | Pregnancy Health & Fitness | SparkPeople | 13 | 3.4 | 0 |
| Android | Breastfeeding Solutions | Nancy Mohrbacher Solutions, Inc | 15 | 4.5 | 4.99 |
| Android | Pregnancy yoga Exercises | Home Fitness | 25 | 3.9 | 0 |
| Android | Contraction timer for labor | Henry Naftulin | 15 | 4.4 | 0 |

**Appendix L**

**<u>Coding Manual for mHealth Behavior Change Techniques in Maternal and Child Health (MCH) Apps</u>**

**2018**

**An adapted version of the coding manual from the works of**

**Vollmer Dahlke et al. (2015)**

**General techniques in mHealth Applications with theory basis and description**

1. **Personalization:** (THC, SCogT, ELM)

   This is the provision of opportunities in the mHealth application to make elements of the application personal by the selection of tools or elements that are specific to the individual using the application. Personalization in the apps includes requiring that the user log in with a username and password. An example would be the ability to select pregnancy trimester or your due date to receive specific information pertaining to that pregnancy phase. Or to be able to select infant age to receive breastfeeding advice or infant foods suitable for that age group. Other examples would be the choice of "yes" or "no" to a specific capability of the application would be considered personalization.

2. **Tailoring:** (THC, ELM)

   Coders are asked to annotate the score sheet for each mHealth application to indicate the app's capability to include an intervention element or component that is specific to the characteristics of the person using the app. Coders will be asked to score tailoring at three different levels in the initial assessment of the mHealth application:

   a) <u>Macro-tailoring at the group level</u>. In this instance the mHealth application can be adapted to adjust the intervention materials (including information) that the participant receives based on pre-tested characteristics. For example, an app may ask the user if she wishes to receive texts and/or assessments on diet, on exercise, prenatal vitamins, breastfeeding, or smoking cessation.

b) Meso-tailoring at the individual level. The amount or type of intervention depends on the individual needs of the participant. For example, the participant could select between texts delivered once a day versus once a week.

c) Micro-tailoring at the individual level. Specific techniques in the mHealth application are tailored to the unique individual. For example, personalized goal setting and reporting tailored to the individual's own needs and desires for physical activity. Or GPS tracking and reporting of an individual's walking or running activities.

* Note that all of these general techniques may be used in one mHealth application. It is possible to have personalization, macro-, meso- and micro-tailoring techniques. To score these general techniques the user or participant must be prompted to select an answer or provide input and make decisions in relation to the techniques.

**Specific techniques by determinant**

Scoring is accomplished by marking the technique with a 1 or 0 in each element or section of the sheet. A "1" indicates that the technique is present in the app, a "0" indicates that it is not present. Personalization and tailoring scoring are provided as additional elements for each major determinant.

**Knowledge/ Awareness**

3. **Provide information about health behavior linkages**: (IMB)

   Basic information about pregnancy and new motherhood, fetal development, prenatal/postnatal diet, breastfeeding, prenatal/postnatal exercise, and/or availability of resources for clinical or non-clinical purposes.

   If **personalized**- the user is prompted to select or provide personal answers about stages of pregnancy, type of delivery, or infant age.

   If **tailored**- the user is required to select actions or elements specific to the intervention and the way information or activities are delivered to them as a result of these choices.

4. **Provide information on action/behavior and consequences:** (TRA, TPB, SCogT, IMB)

   Information is provided about the cost/risk/benefits of action or inaction with respect to certain prenatal/postpartum behavior. This scoring would also consider risk-communication strategies such as persuasive communications for example, missing prenatal appointments, smoking cessation, or adherence to childhood immunizations.

   If **tailored-** to the users prenatal/postpartum phase (e.g. current behavior, clinical profile).

**Intention**

5. **Prompt intention/formation**: (TRA, TPB, SCogT, IMB)

   The mHealth application includes suggestions for general behavior setting or formulating desired outcomes of a behavior for healthy pregnancy/postpartum/infancy, e.g., take prenatal vitamins on time, maintain a healthy weight, exercise regularly, eat 5 fruits and or vegetables daily. It may be sometimes difficult to distinguish this from technique #3 & #4 under knowledge or awareness, but coders should look for language that indicates a specific action or activity. Also, note that this technique is different from the actual setting of a goal or behavioral objective to facilitate change or adherence, i.e. technique #6. Technique #5 does not involve planning exactly what will be done or when the behavior/action sequence will be performed.

6. **Prompts for specific goal setting**: (CT)

   This involves planning and setting a specific goal for what a user would do within a specific time and includes the specific context within which a behavior will be performed. This would include selecting or writing down (micro-tailoring) of a specific goal for example, “engaging in physical activity for 150 minutes each week”. Goal setting would include information on when, where, how to act in a specific behavior.

7. **Review of general or specific goals**: (CT)

   This involves using the mHealth apps in review of previously set goals or intentions and would require a suggestion of behavioral performance resulting from self-monitoring or tracking. An example would be review of tracking a goal setting for intake of a specific number of calories per day or number of minutes of physical activity for a week. Another example might be noting a set of questions to be asked at a healthcare provider appointment regarding morning sickness or fetal movements during the past week or month.

**Facilitation**

8. **Provide Instruction**: (SCogT)

   This technique involves telling or showing the user or participant ways to facilitate behavior change. For example, explaining "SMART" goal setting, or how to use an app's function to record questions on a mobile phone to ask a provider during an appointment, or recipes using nutritious foods. The function of the instruction must be directly related to behavior change, not for general use of the phone or the app. The facilitation may be in the form of written instructions, videos on YouTube that link from the app or images or cartoons that show a step-by-step instruction.

9. **Provide materials for education/information**: (SCogT)

   The app provides the pregnant women/new mother/caretaker with specific materials and information that are suggestions for behavior change. These differ from knowledge/awareness in that the education is specific to a behavior change or action. For example, information on breast engorgement or mastitis with prompts of when to contact a healthcare professional. Another example would be providing resources for breastfeeding friendly locations nearby.

**Self-Efficacy**

10. **Prompt self-monitoring of behavioral goals**: (SCogT)

    The mHealth app suggests that the person record brief notes or keep a journal or diary to record behaviors and actions related to health behaviors. Examples might be a journal of physical activity or prenatal/postpartum stress/anxiety or distress monitoring and actions taken to alleviate such as meditation or self-talk.

11. **Persuasion (verbal or written)**: (OC)

The mHealth app delivers messages (could be personalized or tailored) that is designed to strengthen efficacy/control beliefs pertaining to the execution of target or suggested behaviors. Examples may include often-used successful strategies, i.e. "choose whole wheat bread over white bread", or "park at the far end of the parking lot", or general tips. New beliefs may be induced, and or/new information provided to create new control or behavior beliefs.

**Social Influence**

12. **Provide information about peer behavior (peer passive)**: (SCogT)

The mhealth app provides information regarding what other pregnant women/new mothers/caretakers do and think in relation to targeted behavior change. This can be provided in the form of written anecdotes, YouTube videos, or may be presented as interviews or case studies.

13. **Provide opportunities for social comparison (Peer active)**: (SS, SC)

The mHealth app offers participation in Facebook, Twitter, or other social media and networking in which discussion and social comparison may occur. The focus is on providing social reference for the behavior change or activity. This technique should be scored when examples of group or peer discussion including personal stories of behavior are shared. For example, sharing physical activity, breastfeeding or diet goals with other moms.

14. **Mobilize social norms (Important others)**: (SS, SC)

The mHealth app provides exposure to the social norms of important others in relation to a healthy pregnancy/infancy or health behavior change. Important others may be family members, partners, friends, but also healthcare professionals, a celebrity or a recognized medical specialty organization such as The American College of Obstetricians and Gynecology (ACOG) and American Academy of Pediatrics (AAP).

**Acronyms:**

CT: Control theory

ELM: Elaboration likelihood model

IMB: Information-motivation-behavioral skills model

OC: Operant conditioning

SCogT: Social cognitive theory

SC: Social comparison

SS: Social support on health behaviors

THC: Tailored health communication

TPB: Theory of planned behavior

TRA: Theory of reasoned action

**CURRICULUM VITAE**

Rizwana Biviji

## EDUCATION

| | | |
|---|---|---|
| Indiana University Indianapolis<br>Richard M. Fairbanks School of Public Health<br>**Major:** Health Policy and Management<br>**Minor:** Epidemiology | Doctor of Philosophy (PhD) | 2018 |
| Indiana University Bloomington<br>School of Health, Physical Education, and Recreation<br>**Major:** Nutrition Science | Master of Science in Applied Health Science (MSAHS) | 2008 |
| Shreemati Nathibai Damodar Thackersey Women's University (S.N.D.T) Mumbai<br>**Major:** Food Science and Nutrition | Bachelor of Science (BHSc) | 2007 |

## PROFESSIONAL EXPERIENCE

### ACADEMIC

| | | |
|---|---|---|
| Indiana University<br>Richard M. Fairbanks School of Public Health<br>Department of Health Policy and Management | Adjunct Faculty<br>Associate Instructor | 2012-2018 |
| Indiana University<br>Richard M. Fairbanks School of Public Health<br>Department of Social and Behavioral Science | Research Assistant | 2015-2016 |
| Indiana University School of Medicine<br>Center for Aging Research | Research Assistant (Intern) | 2013 |
| Indiana University Bloomington<br>School of Health, Physical Education, and Recreation<br>Department of Applied Health Science | Associate Instructor | 2007-2008 |
| Indiana University Bloomington<br>School of Health, Physical Education, and Recreation<br>Department of Applied Health Science | Research Assistant | 2008 |

**NON-ACADEMIC**

| | | |
|---|---|---|
| Exemplar Life Care Pvt. Ltd Mumbai | Health Manager | 2011-2012 |
| Body Kraft Wellness Center Mumbai | Clinical Nutritionist | 2010-2011 |
| Indiana State Department of Health | Epidemiologist | 2009-2010 |
| Committed Communities Development Trust (CCDT) Mumbai | Community Nutritionist (Intern) | 2007 |
| Talwalkars Fitness Center Mumbai | Nutritionist (Intern) | 2006 |

**PUBLICATIONS**

**PEER REVIEWED ARTICLES**

Nahar, V.K., Ford, M.A., Brodell, R.T., Boyas, J.F., Jacks, S.K., **Biviji, R.**, Haskins, M.A., & Bass, M.A. (2016). Skin cancer prevention practices among malignant melanoma survivors: a systematic review. *Journal of Cancer Research and Clinical Oncology*, 142(6), 1273-1283.

Norwood, C.W., **Biviji, R.**, Knotts, A., Omenka, I., Stone, C., & Purviance, D. (2015). Fighting prescription drug abuse through state policy: The role of nursing in successful implementation. *Journal of Addictions Nursing*, 26(4), 203-207.

Vice, M.A., Nahar, V.K., Ford, M.A., Johnson, A.K., Davis, A.B., & **Biviji, R.** (2015). Risk factors for low bone mineral density in institutionalized individuals with developmental disabilities. *Health Promotion Perspectives*, 5(2), 147-152.

Nahar, V.K., Ford, M.A., Boyas, J.F., Brodell, R.T., Hutcheson, A., Davis, R.E., Beason, K.R., Bass, M.A., & **Biviji, R.** (2014). Skin cancer preventative behaviors in state park workers: A pilot study. *Environmental Health and Preventive Medicine*, 19(6), 467-474.

Henderson M.L., Chevinsky, J., **Biviji, R.**, & Mills, K. (2014). Improving patient-doctor communication about risk and choice in obstetrics and gynecology through medical education: A call for action. *The Journal of Clinical Ethics*, 25(2), 176.

**NON-PEER REVIEWED ARTICLES**

Comer, A.R., **Biviji, R.**, Church, A., Gray, W., Grodey, L., Guilkey, R., Harrawood, A., Kirlin, B. & Kunkel, M. (2016). Singapore's breach of its obligations regarding women's health under the United Nations Declarations of Human Rights – Article 25. Hearings of the United Nations Rights Committee, 24th Session, January 2016.

**Biviji, R.**, Cvorovic, J., & Coe, K. (2015). The health of Serbian Roma women: A research report. Equality Development and Globalization Symposium (EDGS) working paper No. 34.

**Biviji, R.**, Heinrich, L., Stemnock, L.W., & Thomaskutty, C. (2010). Diabetes in Indiana: A report on diabetes morbidity and mortality. Diabetes Prevention and Control Program, Indiana State Department of Health.

**Biviji, R.** (2010). Diabetes and tobacco = double trouble. *IN Control Diabetes*, 1(2), 1-2.

Indiana State Department of Health. (2009). *Indiana facts at a glance*. Diabetes Prevention and Control Program. Indianapolis, IN.

Indiana State Department of Health. (2009). Indiana: Diabetes and women. Diabetes Prevention and Control Program. Indianapolis, IN.

## PRESENTATIONS

**Biviji, R**., Vest, J.R., Dixon, B.E., Cullen, T., & Harle, C.A. Factors related to user ratings and user downloads of mobile apps for maternal and child health (MCH). Poster presentation at Academy Health Annual Research Meeting, Seattle, Washington, June 25, 2018.

**Biviji, R**. Assessing app characteristics that drive popularity of maternal and child health (MCH) apps. Oral presentation at University of Nevada, Reno, NV, November 28, 2017.

Cvorovic, J., **Biviji, R.**, & Coe, K. Cultural barriers and access to healthcare among Roma gypsy women in Serbia. Poster presented at 13th Annual Global Health and Innovation Conference, Yale University, New Haven, CT, April 16, 2016.

Cvorovic, J., **Biviji, R.**, & Coe, K. The health of Serbian Roma/Gypsies: A research report. Oral presentation at Global Health Interdisciplinary Symposium, Northwestern University, Chicago, IL, November 19, 2015.

**Biviji, R.**, Hansotte, E., Kirbiyik, U., & Hess, L. Effectiveness of mind-body therapies on reducing prenatal stress, anxiety, or depression: A systematic review and meta-analysis. Poster presentation at 143rd American Public Health Association Annual Meeting and Exposition, Chicago, IL, November 4, 2015

**Biviji, R**. Access to healthcare services during pregnancy and maternal health outcomes in developing countries. Roundtable presentation at 143rd American Public Health Association Annual Meeting and Exposition, Chicago, IL, November 3, 2015.

Norwood, C., Mullen, C., **Biviji, R.**, Church, A., Henderson, M.L., & Stone, C. Policy advocacy actions at the organization, state, and national levels: Using service learning to inform policy at state level. Oral presentation at 143rd American Public Health Association Annual Meeting and Exposition, Chicago, IL, November 3, 2015.

Cvorovic, J., **Biviji, R.**, & Coe, K. Culture and health of Serbian Roma/Gypsy. Oral presentation at Medical Humanities Conference, Western Michigan University, Kalamazoo, MI, September 24, 2015.

Cvorovic, J., **Biviji, R.**, & Coe, K. Culture and Health of Serbian Roma/Gypsies. Arizona State University, Phoenix, AZ, September 18, 2015.

Cvorovic, J., **Biviji, R.**, & Coe, K. Culture and Health of Serbian Roma/Gypsies. University or Arizona, Phoenix, AZ, September 14, 2015.

**Biviji, R.**, Cvorovic, J., & Coe, K. The health of Serbian Roma: A research report. Poster presentation at Cancer Research Day 2015, Indiana University, Indianapolis, IN. May 21, 2015.

**Biviji, R.**, Cvorovic, J., & Coe, K. The health of the Serbian Roma/Gypsies: A research report. Poster presentation at Research Day 2015, Indiana University Purdue University, Indianapolis, IN. April 17, 2015.

Henderson, M.L, Chevinsky, J., **Biviji, R.**, & Mills, K. Improving doctor-patient communication about risk, choice, and ethics in obstetrics and gynecology with medical education. Oral presentation at American Society for Bioethics and Humanities (ASBH) Annual Meeting, San Diego, CA, October 16, 2014.

Jain, N. & **Biviji, R**. Mental health: An area of concern among women in rural parts of northern India. Poster presentation at Indiana Joint National Public Health Week Conference, Indianapolis, IN, April 2, 2013.

## TEACHING EXPERIENCE

***Indiana University Richard M. Fairbanks School of Public Health***

### Instructor

H501: US Healthcare Systems and Health Policy (Spring 2014)

H501: US Healthcare Systems and Health Policy (MD/MPH) – online
(Summer 2017, Summer 2016)

H505: Introduction to Public Health Policy and Management – online
(Spring 2017, Fall 2015)

H120: Contemporary Health Issues in Public Health (Fall 2013)

H330: Global Public Health (Spring 2018, Fall 2017)

H346: Organization Behavior and Human Resources in Healthcare (Spring 2018, Fall 2017)

**Teaching Assistant**
S505: Introduction to Public Health Social and Behavioral Science – online (Fall 2015, Fall 2014)

H620: Patient Reported Health Outcomes (Spring 2015)

H670: Introduction to Public Health Policy and Management – online (Fall 2014)

A670: Introduction to Public Health Environmental Health Science – online (Fall 2014)

P300: Operations Management and Quality Improvement in Healthcare (Spring 2016)

H330: Global Public Health (Spring 2017, Fall 2016, Spring 2016, Summer 2015)

H346: Organization Behavior and Human Resources in Healthcare (Spring 2017, Fall 2016, Spring 2016)

H472: Applied Health Administration Capstone (Spring 2013)

H474: Health Administration Ethics Seminar (Fall 2012)

***Indiana University School of Medicine***

**Instructor**

P215: Basic Human Physiology Lab (Fall 2008)

***Indiana University School of Health, Physical Education, and Recreation***

**Teaching Assistant**
N220: Nutrition for Health (Spring 2008)

N231: Human Nutrition (Fall 2007)

H350: Complementary and Alternative Medicine (Fall 2007)

**SERVICE EXPERIENCE**

**Papers Reviewed for Journals**
JMIR mHealth and UHealth
Journal of Family Medicine and Primary Care

**Abstracts Reviewed for Conferences**
International Society for Disease Surveillance 2016 Annual Conference
American Public Health Association Annual Meeting and Expo

**University**
PhD Student Association, Vice President, 2015-2016
Public Health Corps Member, 2015-2016
Indiana University Student Outreach Clinic (IUSOC) Volunteer, 2014-2015
Presenter: 3 Minute Thesis (3MT) Presentation held at Preparing Future Faculty and Professionals: Pathways to your choice career, IUPUI, Indianapolis, November 15, 2017.
Facilitator: Protect our Patients Community Health Forum held at Indiana University School of Medicine, Indianapolis, February 26, 2017.
Moderator: World Food Programme at the Indianapolis Model United Nations 2013 Conference held at Indiana University Purdue University Indianapolis, March 13-14, 2013.

**Other**
Author: Policy 20154 "Prevention and intervention strategies to decrease misuse of prescription pain medications" that was approved and supported by the governing council at 143$^{rd}$ Annual American Public Health Association Meeting and Exposition, October 30-November 4, 2015, Chicago, IL.

Speaker: "Careers in public health", Genesis Academy, Phoenix, AZ, September 9, 2015

Student Researcher: Conducted a qualitative study to assess the nutritional needs of the patrons at Horizon House homeless shelter as a part of service learning for course S615 Culture and Qualitative Methods, Spring 2015. The report was presented and submitted to the organization with findings and recommendations.

Taskforce Member**:** Indiana Prescription Drug Abuse Prevention Taskforce to reduce the burden of prescription drug overdose, 2014-2015.

Panel Member**:** Indiana Minority Health Coalition (IMHC) Expert Panel for reducing the burden of Black infant mortality in Indiana, June 2, 2015.

Student Evaluator: Conducted a formative evaluation for Julian Center Circles program as a part of service learning for course P670 Advanced Data Analysis in Health Policy and Management, Summer 2013. The report was presented and submitted to the organization with findings and recommendations.

**AWARDS/HONORS**

2015 Graduate Student Travel Grant Award, Department of Health Policy and Management, Indiana University Richard M. Fairbanks School of Public Health.
2013 Graduate Student Travel Grant Award, Graduate Office, Indiana University Purdue University Indianapolis.

2012 Graduate Fellowship, Department of Public Health, Indiana University School of Medicine.

2008 Margaret Seberger Award for outstanding academic performance, Indiana University School of Health, Physical Education, and Recreation.

## ANALYTICAL SKILLS

Analytical Software: SAS, STATA, SPSS, NVivo, Dedoose, Meta-analysis software
Other Software Packages: Adobe Presenter/Captivate, Endnote, Microsoft Office.