

Why do mobile phone-based smoking cessation interventions struggle and how can we make them more effective?

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Abstract

Tobacco epidemic has become one of the major threats for public health. Several intervention techniques have focused on this issue. However, due to high cost and inadequate accessibility, a vast majority of the smokers are unable to receive benefits from these interventions. Wide availability of mobile phones and growing number of users inspired researchers to utilize mobile phones as a cost-effective, accessible medium for designing smoking cessation interventions. Though promising, these interventions are struggling to support users' needs. In this paper, we conduct a systematic review of 69 articles available in four major databases (PubMed, Web of Science, ACM Digital Library, and IEEE Xplore). Our objective is to identify areas where cessation techniques succeeded and areas that remain challenging. We propose a set of implications guided by theories of cognitive dissonance, health behavior change, and assistive technologies that can inform future research, and guide the design of smoking cessation interventions.

Keywords: Mobile phone; Smoking Cessation; Text Message; Smart phone-based App

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1 Introduction

Among all the health threats the world has ever confronted to date, World Health Organization (WHO) identified tobacco epidemic as one of the biggest, resulting in the death of six million people every year.¹ In addition, WHO cautioned that failing to take urgent action may lead to a yearly death rate exceeding eight million by 2030. Center for Disease Control and Prevention (CDC), the national public health institute of USA, reported that, around 443,000 premature deaths occur every year in USA due to direct smoking or secondhand smoking.² Moreover, another 8.6 million people in USA suffer from a variety of illness caused or triggered by smoking. Unfortunately, despite such incredible health risks, around 46.6 million US adults are still involved in smoking.

CDC reported that about 70% of the US smokers are eager to quit smoking and more than 40% of these smokers make an attempt to quit every year.² However, according to American Cancer Society (ACS), only 4% to 7% of US smokers who intend-to-quit are successful on any given attempt without medicines or external help.³ Face-to-face behavioral treatment is considered effective for being successful in cessation efforts, typically in higher income countries. However, only 4% to 7% of smokers in USA are accessing behavioral treatment (Ybarra, Holtrop, Bosi, et al., 2013), pointing to a need of more accessible options to assist smokers in their cessation efforts.

International Telecommunication Union reported that, in 2013, the world population was 7.1 billion while the number of mobile phone subscriptions was 6.8 billion.⁴ Considering this wide penetration of mobile phones along with the fact that only a few number of people has access to face-to-face medical or behavioral treatment for smoking cessation, researchers are paying greater attention to the design of interventions based on accessible technologies such as mobile phones and Internet (Balmford, Borland, Benda, & Howard, 2013; Civiljak, Stead, Hartmann-Boyce, Sheikh, & Car, 2013; Fjeldsoe, Marshall, & Miller, 2009; Free et al., 2009; Riley, Obermayer, & Jean-Mary, 2008; Rodgers et al., 2005; Shahab & McEwen, 2009; Whittaker et al., 2012). **Researchers identified several key advantages of using mobile technologies for smoking cessation:** ease of access, adaptive advice based on individual's needs, and cost-effectiveness compared to personalized help by a trained counsellor (Balmford et al., 2013).

¹ <http://www.who.int/mediacentre/factsheets/fs339/en/>

² <http://www.cdc.gov/chronicdisease/resources/publications/aag/osh.htm>

³ <http://www.cancer.org/healthy/stayawayfromtobacco/guidetoquittingsmoking/guide-to-quitting-smoking-success-rates>

⁴ <http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2013-e.pdf>

Although mobile phone-based smoking cessation interventions are gaining popularity, **outcomes of many such interventions are still not optimal**. Abroms et al. showed that most available smart phone-based apps for smoking cessation **do not follow clinical practice guidelines** (Fiore et al., 2008) proposed by the US Department of Health and Human Services (Abroms, Padmanabhan, Thaweethai, & Phillips, 2011). Whittaker et al. pointed out that while mobile phone based interventions may benefit in short-term cessation efforts, their **long term impact is still unknown** (Whittaker et al., 2012). Research in this area thus suggests that existing mobile phone-based interventions are still in their initial and struggling phase and deeper research is warranted to identify strategies to enhance their effectiveness. In this paper, we aim to take a step toward this direction by exploring the current state of mobile phone-based smoking cessation interventions to identify areas where cessation techniques have succeeded, and areas that remain challenging and would greatly benefit by research.

The contributions of this paper are as follows:

- a. We performed a systematic review of all the research articles available in four major databases (e.g., PubMed, Web of Science, ACM Digital Library, and IEEE Xplore) to gain a comprehensive overview of research on mobile-phone based smoking cessation interventions.
- b. We analyzed and coded all these articles using a qualitative analysis method inspired by grounded theory approach (Corbin & Strauss, 2008). We identified areas where mobile phone-based smoking cessation interventions are effective along with areas that require further improvement.
- c. We proposed a set of guidelines for designing next generation mobile phone-based smoking cessation interventions based on theories of cognitive dissonance, health behavior change, and assistive technologies.

2 Research Method

To gain deeper understanding of the current state of mobile phone-based smoking cessation interventions, we have conducted a systematic literature review of four major databases: PubMed, Web of Science, ACM Digital Library, and IEEE Xplore.

2.1 Search Strategy

We have followed a string based search method to identify the relevant research articles from the four databases. The search was carried out in August 2014. We have used the following string for our search process:

((mobile phone OR cell phone OR smart phone) AND (smoking OR tobacco))

One might argue that including additional specific keywords such as mobile Health, mHealth, or smoking cessation, lapse, and relapse, would improve search result. However, we intentionally excluded these keywords in our search criteria to collect as many related articles as possible. Additionally, we argue that articles that focus on smoking cessation, lapse, or relapse and contain one or more of these words would also contain our provided keywords (smoking or tobacco), and consequently, are already part of the result set.

2.2 Inclusion Criteria

An article was included in our final list for review based on the following criteria:

- The article must be written in English.
- The article must discuss about smoking cessation using mobile phone (e.g., text message based intervention, apps, professional counselling through mobile phone, and mobile phone-based web or email service for smoking cessation).
- The article must be peer reviewed (e.g., journal, conference proceeding, or book chapter).
- The article must pose a specific research question and utilize an established methodology to address that research question.
- We did not impose any restriction on the field of studies or publication year.

2.3 Review Procedure

We have collected all the research articles (n=668) from the four databases using the string search technique mentioned above. We have followed steps listed in Figure 1 to finalize the list of articles for the

systematic review process. At first, all 668 articles were imported to Endnote X4.⁵ Using Endnote, we have discarded duplicate articles (n=84) and articles that do not contain any author information (n=5). We have examined the titles and abstracts of the remaining articles (n=579). This stage helped us to discard articles (n=486) that were not relevant to our research topic (e.g., mobile phone-based smoking cessation). The remaining 93 articles were selected for the next round of reviews. In this stage, we have screened the entire text of 93 articles and discarded 24 additional articles due to the following reasons: not a Research Article (n=6), not relevant to our topic (n=8), abstract is in English but not the entire article (n=6), and full article is not available (n=4). Finally, we have performed a systematic review on the remaining articles (n=69). A complete list of these 69 articles is available in Appendix (some of the articles listed in appendix are also included in the reference section as they were refereed in the paper).

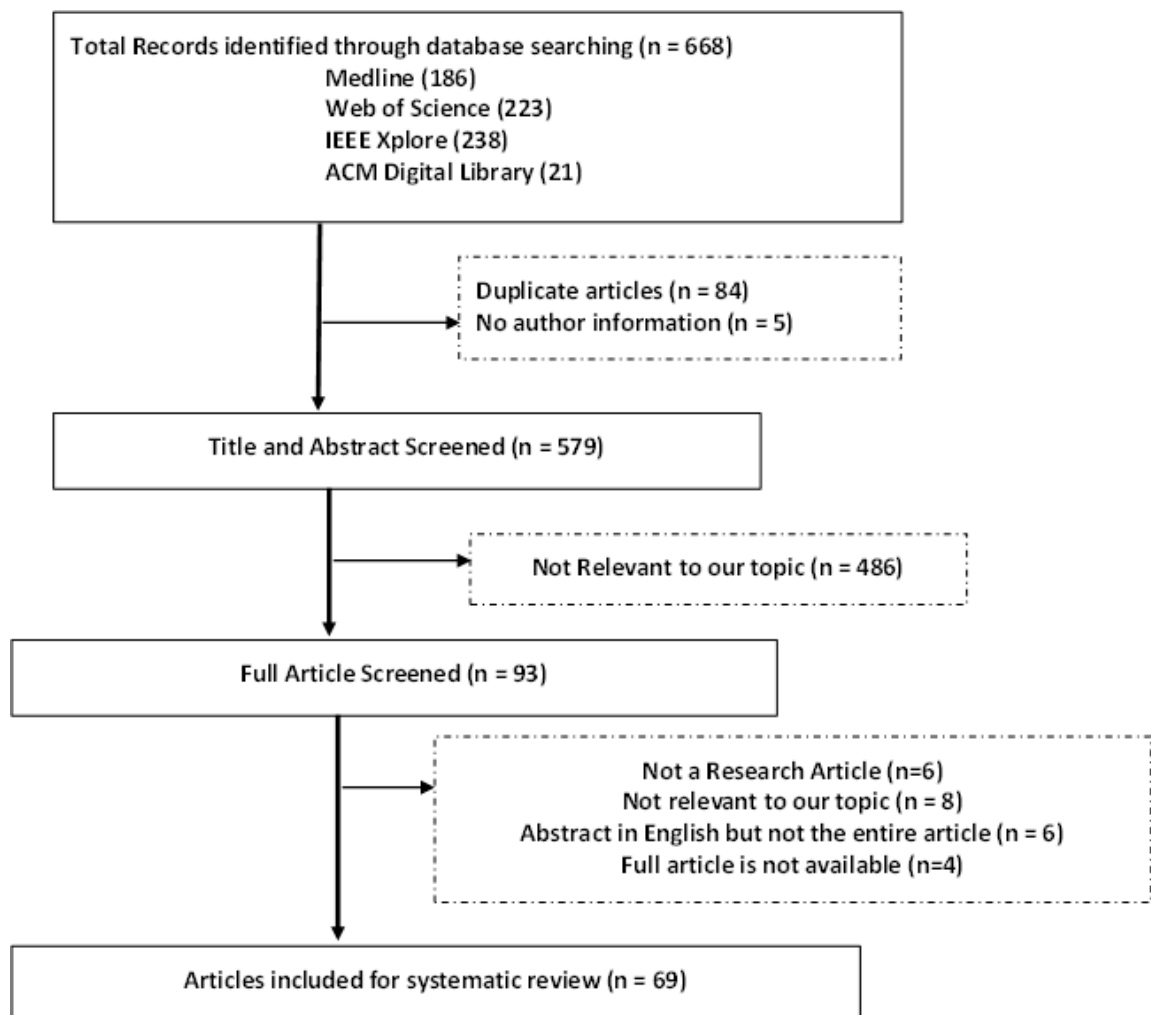


Figure 1: Summary of the article selection process for the systematic review.

2.4 Coding Procedure

We have utilized a qualitative analysis approach inspired by grounded theory (Corbin & Strauss, 2008) to code these 69 articles. For example, we started with a limited number of generic fields (e.g., number of users, article title) but allowed the article text to guide the inclusion of more fields. Both authors generated codes independently, and at the end of the coding process, merged the unique fields. Any disagreement was resolved through discussion and only the fields agreed upon by both authors were included in the final coding. These analysis phases resulted in the following fields: Research Question, Research Method, Major Findings, Limitations of the study, Demographic Information (users), Geographic Location (where the study was conducted), Duration of the study, Types of intervention, etc. We also collected the

⁵ <http://endnote.com/>

following meta-information: journal or conference name, author name, publication year, and keywords used by the authors.

3 Findings

In this section we report findings based on the coding and literature review of the selected articles. We discuss current state of existing smoking cessation interventions, identify features that researchers considered effective in helping abstinent smokers to maintain their state, and also point out features that are limiting the efficacy of these interventions.

3.1 General Findings

a. Mobile phone-based smoking cessation has started to gain more attention:

Year	Number of articles	As percent	As cumulative percent
2000	1	1%	1%
2001	0	0%	1%
2002	1	1%	3%
2003	2	3%	6%
2004	2	3%	9%
2005	2	3%	12%
2006	2	3%	14%
2007	0	0%	14%
2008	4	6%	20%
2009	4	6%	26%
2010	2	3%	29%
2011	7	10%	39%
2012	13	19%	58%
2013	22	32%	90%
2014*	7	10%	100%
Total	69	100%	

Table 1: Year-wise publication count (*partial year, up to August).

Although smoking cessation is an active area of research for the last few decades, mobile phone-based smoking cessation is still in its infancy. However, research in this area is continuously gaining popularity and more researchers are designing smoking cessation interventions. In Table 1, we observe that, among the 69 selected articles, 49 articles (71%) were published in the last four years. This may be attributed to the recent proliferation of mobile technology, advances in smart phone technology design, and exponential increase of mobile phone users in the last four years.

b. Types of mobile-phone-based interventions for smoking cessation:

Intervention Type	Number of articles	As percent
Text Message	36	52%
Smart Phone-based App	7	10%
Both Internet and Text Message	7	10%
Counseling through Mobile Phone	6	9%
Indirect Intervention through Mobile Phone	6	9%
Both Text Message and Smart Phone-Based App	3	4%
Internet using Mobile Phone	2	3%
Multimedia Intervention	2	3%
Total	69	100%

Table 2: Intervention Type.

Researchers reported that as a delivery platform, mobile phone typically perform well for smoking cessation programs (Bentz, 2011; Free et al., 2009; Haug, Schaub, Venzin, Meyer, & John, 2013; Kong, Ells, Camenga, & Krishnan-Sarin, 2014). Researchers have utilized mobile phones in several ways, such as:

- **Text message:** Smokers receive different types of text messages (e.g., motivating message, performance statistics) from different members involved in the smoking cessation program (e.g., counselor, family, friends or cessation buddies) on regular intervals. From Table 2, we observe that, text message is the most popular intervention technique to date. $66.67\% \left(\frac{361713}{80} \cdot \frac{48}{53} \right)$ of the articles reported utilizing some form of text message based intervention (e.g., text message only, both Internet and text message, and both app and text message). In a recent study, Buller et al. suggested that text message-based smoking cessation programs are “*simple, well known, and delivered to a primary inbox*” and accordingly, performs better than app-based systems (Buller, Borland, Bettinghaus, Shane, & Zimmerman, 2014).
- **Smart phone-based app:** Many health apps are designed to help smokers in their cessation efforts. While a vast majority of the apps available in the Apple and Android app stores focus on helping smokers to quit, in a recent research, BinDhim et al. reported that 107 pro-smoking apps were also available in these stores (targeted to promote smoking) (BinDhim, Freeman, & Trevena, 2014). Moreover, Abroms et al. analyzed 47 iPhone apps for smoking cessation and reported that these apps rarely followed established clinical practice guidelines (Fiore et al., 2008) for smoking cessation (Abroms et al., 2011).
- **Internet based intervention using mobile phone:** Smokers receive help from the Internet (e.g., visiting dedicated website, email message, web groups) through their mobile phones (Fujioka, Kobayashi, & Turale, 2012).
- **Counselling through mobile phone:** Counsellors help smokers to quit smoking by providing mentoring, suggestions, or guidance via mobile phone (Burton et al., 2010; Gritz et al., 2013; Lazev, Vidrine, Arduino, & Gritz, 2004; Vidrine, Arduino, & Gritz, 2006; Vidrine, Arduino, Lazev, & Gritz, 2006; Vidrine, Marks, Arduino, & Gritz, 2012).
- **Multimedia intervention:** Smokers receive multimedia contents (e.g., video, audio, and text) aimed to help them in their cessation efforts (Whittaker et al., 2008, 2011).

c. **Indirect intervention through mobile phone:**

Mobile phone has been predominantly used as a mechanism for delivering different types of interventions. However, the impact of using mobile phones on smoking cessation goes beyond a delivery platform. For instance, Labonne et al. conducted a longitudinal study for three years (2003-2006) spanning 2,100 households of 135 communities in Philippines and reported that mobile phone ownership shifted the budget from tobacco consumption to mobile communication, resulting in monthly tobacco consumption reduction by 20% (Labonne & Chase, 2011). Surprisingly, a study conducted by Osaki et al. in Japan reported that they found no correlation between high mobile phone bill with decrease in smoking (Osaki, Ohida, Kanda, Kaneita, & Kishimoto, 2012).

d. **Economy and smoking:**

Economic Condition	Number of articles	As percent	GNI per capita (US dollar)
High-Income or High-Income OECD Countries	51	74%	GNI >=12746
Upper-Middle-Income Countries	3	4%	4125 < GNI < 12746
Lower-Middle-Income Countries	1	1%	1045 < GNI <=4125
Low-Income Countries	0	0%	GNI <= 1045
Multiple Countries (High and Lower-Middle Income)	1	1%	
Multiple Countries (High and Upper-Middle Income)	1	1%	
Not Applicable	12	17%	
Total	69	100%	

Table 3: Study conducted in countries based on economic condition (GNI = Gross National Income).

Based on economic condition, the World Bank has classified all countries of the world into the following categories: low-income, lower-middle-income, upper-middle-income, high-income, and high-income OECD members.⁶ According to WHO, among the total one billion smokers all around the world, nearly 80% lives in the low and middle-income countries.⁷ However, 74% research (51/69) on mobile-phone based smoking cessation has been conducted and focused on high-income countries (see Table 3). Only four of the discussed 69 articles reported studies conducted in the lower-middle and upper-middle income countries (Labonne & Chase, 2011; Shi, Jiang, Yu, & Zhang, 2013; Ybarra, Holtrop, Prescott, Rahbar, & Strong, 2013; Ybarra, Holtrop, Bosi, et al., 2013). One study was based on two countries (India and Australia) belonging to different income levels (high and lower-middle) (Ghorai, Saha, Bakshi, Mahanti, & Ray, 2013). We did not find any mobile based smoking cessation research which was conducted in a low-income country. As people usually behave differently based on economic and cultural conditions, we argue that, findings from high-income countries may not be directly applicable to low-income countries and further research should be conducted in low-income countries to obtain deeper understanding of the relationship between economy and smoking.

e. Impact of health literacy:

Health literacy (Ratzan & Parker, 2000) is an important issue all over the world. In USA, 99% of adult population (people of age 15 and older) can read and write.⁸ However, more than half of the US population does not possess necessary skills and strategies to be considered as health literate⁹ (i.e. they do not pose enough skill to efficiently function in the current healthcare environment). Researchers identified a direct association between low health literacy and poorer health results and higher mortality (Berkman et al., 2011). We argue that, it is very important to assess the health literacy level of a smoker before enrolling him or her in any smoking cessation intervention as lower level of health literacy may limit the expected benefit of any such intervention. Unfortunately, we found that, only one out of the total 69 coded articles discussed the issue of health literacy (Vidrine, Fletcher, et al., 2012).

3.2 Characteristics of successful smoking cessation interventions

Computer and other electronic aids increase the likelihood of cessation compared to no-intervention or generic self-help materials (Bock, Heron, Jennings, Magee, & Morrow, 2013; Borland, Balmford, & Benda, 2013; Chen et al., 2012; Riley & Augustson, 2013). For example, Johnston et al. suggested that mobile phone-based interventions show promise in increasing quit rates (Johnston, Lederhausen, & Duncan, 2013). Vidrine et al. performed a randomized trial with a group of HIV-positive population and reported that mobile phone based intervention increased the quit rate by 3.6 times when compared to usual care (Vidrine, Arduino, Lazev, et al., 2006). Mobile phone-based interventions have been reported to double the cessation rate in the short term (Free et al., 2009). In this section, we report **characteristics** of mobile-based technology that may have contributed to the success of such interventions.

- a. **Convenience and ease of use:** Mobile phone-based smoking cessation programs are reported as easy to use and understand (Whittaker et al., 2011), feasible and acceptable (Ybarra, Holtrop, Bosi, et al., 2013), convenient (Naughton, Jamison, & Sutton, 2013), and less intrusive (Douglas & Free, 2013). Whittaker et al. reported that text messages were preferred over email and web-based interventions due to ease of use (Whittaker et al., 2012). Users perceive such solutions as useful and innovative, predicting higher intention of long term use of text message based cessation programs (Andrews, Cacho-Elizondo, Drennan, & Tossan, 2013).
- b. **Access to support materials:** Mobile phone based solutions provide easy access to support materials such as information on the disadvantages of smoking, impact on health, and sometimes summarize the amount of money that could be saved due to cessation. Overall, these contribute to significant increase in awareness towards the disadvantages of smoking and benefits of quitting (Shi et al., 2013).

⁶ <http://data.worldbank.org/about/country-and-lending-groups>

⁷ <http://www.who.int/mediacentre/factsheets/fs339/en/>

⁸ <https://www.cia.gov/library/publications/the-world-factbook/fields/2103.html>

⁹ <http://www.nih.gov/clearcommunication/healthliteracy.htm>

- c. **Access to support groups:** People want to interact with other people working towards a common goal and mobile based interventions make it easy to connect, interact, and get support from others dealing with the same problem (Abroms et al., 2012; Whittaker et al., 2008).
- d. **Provide entertainment:** Providing enjoyment or fun is considered important for long term use of mobile phone-based interventions (Cocosila, 2010).
- e. **Access to role models:** Mobile phone based interventions can provide access to believable role models, which can enhance user experience in smoking cessation programs (Whittaker et al., 2008, 2011).

3.3 Why people fail to quit smoking

Despite tremendous focus on research, design, and utilization of smoking cessation interventions, it is still one of the most challenging behavioral health problems and a leading cause of death and serious health problems in USA and all over the world. Similar to many addictive behaviors, a vast majority of smokers who want to quit smoking lapse in their attempts, often resulting in total relapse (Kirchner, Shiffman, & Wileyto, 2012). A significant number of smokers (approximately 85-95%) who intend-to-quit and lapse, end up smoking again (Brandon, Tiffany, & Baker, 1986; Kenford et al., 1994). The reasons behind relapse vary greatly (Tindle, Shiffman, Paty, & Dang, 2006). In this section, we discuss some of the **key factors that may contribute to failed cessation attempts.**

- a. **Text messages may act as a reminder for smoking:** Abstinent users are vulnerable to smoking cues and mistimed text messages, which are supposed to support quit attempts, may act as smoking cues and trigger or result in increased urge to smoke (Douglas & Free, 2013).
- b. **Timing and frequency of text messages may not be optimal:** While text message based interventions are considered convenient, the timing and frequency of text messages influence the effectiveness. For example, researchers reported that, for many users, chosen intervention frequency may not be optimal (Douglas & Free, 2013; Pollak et al., 2013). In addition, people want to receive these messages in real-time to support their quit attempts, and pre-defined, scheduled text messages may not support their needs.
- c. **Social, physical, environmental, and other factors:** Craving for smoking can be triggered by many social, physical, environmental, and other factors. For example, researchers reported that periods of high stress can lead to lapse/relapse (Cohen, Sheldon; Lichtenstein, 1990; Marlatt, Curry, & Gordon, 1988; Swan et al., 1988). Various social events may trigger smoking by providing access to cigarettes, other smokers, and a pro-smoking environment (Macy, Seo, Chassin, Presson, & Sherman, 2007). In addition, a social environment may adversely influence the smoking cessation attempts and their duration (Macy et al., 2007). Many users, especially the addictive smokers, may be unable to cope with the physical effects of withdrawal, requiring medication in addition to text message based interventions to sustain their cessation attempts (Douglas & Free, 2013).
- d. **Adverse family and social environment:** Lack of family and social support may also reduce the chance of success in cessation attempts. For example, adolescents, whose parents consume alcohol and use tobacco, are more likely to drink and smoke (Ohannessian, 2009).
- e. **Integration of multiple technologies:** Researchers suggest that combining several smart device technologies along with counselling and assistance may yield better result (Pulverman & Yellowlees, 2014). For instance, Quitpal,¹⁰ a free smart-phone based app for smoking cessation designed by the National Cancer Institute, integrated various tools such as interactive calendar, reminders, trackers of amount of money and cigarette packages the user saved by not smoking, text message-based alerts, connections to social networking sites, creation and viewing of video diaries, and contact information for live health professionals (Pulverman & Yellowlees, 2014).

These findings shed light on the intricacy of smoking as a behavioral health problem. These research also point out that advancement in technology design such as utilizing lightweight sensors embedded

¹⁰ <http://smokefree.gov/apps-quitpal>

in mobile phones or on-body to identify the best moments to deliver an intervention may offer better cessation support. However, a solution solely based on technological advances may not be sufficient to address the many social, environmental, physical, or physiological facets that influence smoking and cessation efforts.

3.4 Limitations of smoking cessation interventions utilizing mobile phone

While an increasing number of researchers are utilizing mobile phone-based smoking interventions, they also pointed out several important challenges that need to be addressed to make such interventions more effective:

- a. A vast number of research focus on smokers who intend-to-quit as they are the likely beneficiaries and early adaptors of such interventions. However, it is difficult to recruit people, especially young adults who intend-to-quit for participating in such studies (Whittaker et al., 2011).
- b. Researchers have provided guidelines to enhance the efficacy of smoking cessation programs. However, available smart phone-based apps rarely adhere to the established guidelines (Abroms et al., 2011). For example, no apps recommended “*calling a quit line*” and only a minority recommended “*use of approved medication*” (Abroms, Lee Westmaas, Bontemps-Jones, Ramani, & Mellerson, 2013). Research shows that environment has an influence on successful cessation attempts (Ohannessian, 2009). Burton et al. suggested that integration of a field outreach program along with a phone counselling for a longer period of time may facilitate cessation for smokers whose environment is hostile (Burton et al., 2010). This may shed light on the low adherence rate reported for popular smoking cessation apps (Abroms et al., 2013).
- c. There is limited and incomplete understanding of why and how mobile-based interventions facilitate smoking cessation (Johnston et al., 2013). Whittaker et al. reported similar findings stating that mobile based interventions provide benefit on long term cessation outcomes; however, the results were heterogeneous with some studies resulting in no effect (Whittaker et al., 2012).
- d. Perceived ease of use, monetary value, and annoyance are significant mediating factors that drive use and effectiveness of mobile phone-based interventions (Andrews et al., 2013). Many users participating in these studies consider the timing and frequency of intervention as ineffective. Researchers also found that users considered the effect of text-message based interventions to be short lived (Naughton et al., 2013).

4 Implications for Design

Research suggests that around 90% of the smokers trying to quit ultimately relapse within a few weeks (Liu, Li, Lanza, Vasilenko, & Piper, 2013). While smoking cessation interventions assist users in achieving short-term result, less than 30% of the smokers who intend-to-quit, achieve long-term abstinence (Fiore et al., 2008). In this section, we propose five design implications targeted to assist researchers in designing next generation mobile phone-based smoking cessation intervention. These guidelines are informed by research in the area of health behavior change, assistive technology design, and theories of cognitive dissonance. Although these implications are not exhaustive, they point to factors that we believe needs to be considered for better intervention design.

4.1 Personalized design of intervention

Smoking is a critical behavioral health problem and personalization can be imperative in assisting users in their cessation efforts (Naughton et al., 2013). Cognitive dissonance theory suggests that it is imperative to remind users about their intentions (Aronson, 1969) and “*reminding what they want to be*” can bring positive lifestyle change (Morris, 2012). Different people intending to quit fail in their attempts for different reasons. Enwald also pointed out the importance of tailoring communication as general communication often fails to support people’s health information needs (Enwald, 2013). Interventions targeted to assist users in their cessation effort thus need to consider individual differences and incorporate knowledge about user’s intentions and needs in the design. For example, interventions designed for pregnant smokers may not work for teens and adolescents who smoke to be perceived as “*cool*.” An intervention targeted to pregnant women may highlight bad influences of smoking on her fetus and congratulate her

on her efforts to quit smoking. On the other hand, sharing information about popular sports icons or musicians who do not smoke might be more effective for motivating teens.

4.2 Just-in-time-delivery of the intervention

Identifying the appropriate time for initiating and delivering a text message based intervention is imperative. Research suggests that users want to receive text message in real-time when they crave (Naughton et al., 2013). In addition, miss-timed message can potentially act as a smoking cue and trigger craving. With the advent of variety of lightweight sensors, it is becoming increasingly feasible to predict when an abstinent smoker may experience high craving (Rahman et al., 2014). For example, GPS sensors embedded in the mobile phones or embedded in the car can detect ahead of time if there are smoking advertisements or tobacco shops in a user's planned route and suggest an alternate route when possible. If the user follows the suggested alternate route, an intervention delivery may not be needed. However, if the route is unavoidable and the user is getting closer to the tobacco joint, initiating intervention may influence user's decision about smoking. A complementary approach to this automatic identification and triggering of interventions would be to enable users to report their moments of high craving with light weight mechanisms (e.g., pressing a "help me!" button on the phone). Further research is warranted to examine the influence of just-in-time intervention in assisting users in their cessation efforts.

4.3 Incorporating social aspects in the intervention design

Mobile phones have now access to tremendous amount of information about people, their social circles, and environment and this information can be utilized to design better interventions. Research on health behavior change has pointed out the effectiveness of incorporating social aspects not only to motivate people but also to sustain the motivation for longer periods of time (Consolvo, McDonald, & Landay, 2009; Morris, 2012). Incorporating game-like features in the interventions can make it entertaining, which may motivate more people to engage in the intervention (Cocosila, 2010). For example, a message incorporating how good a user is doing in comparison with his/her friends, colleagues, or even general population can support self-efficacy and motivate users in continuing their efforts. Similar strategy has been considered effective in the domain of alcohol consumption and substance abuse where normative feedback has been suggested to influence positive behavior (Miller & Rollnick, 2002; Moreira & Foxcroft, 2008).

4.4 Balance is key considering frequency of interventions

It might be tempting to deliver many interventions to remind people not to smoke or to inform them about the associated health risks; however, research suggests that delivering too many interventions may be perceived as "*irritating*" and less effective (Douglas & Free, 2013; Pollak et al., 2013). In addition, the Transtheoretical model of health behavior change indicates that different stages of quitting may require different levels and frequency of intervention (Prochaska & Velicer, 1997). Each of the six stages of behavior change (precontemplation, contemplation, preparation, action, maintenance, and termination) may require interventions that vary in terms of content, frequency, and timing. For example, during the precontemplation and contemplation phases, when a smoker is anticipating to quit smoking, (dis)advantages of (smoking)quitting may be more effective. However, in the maintenance phase, when users start experiencing "*cessation fatigue*", success stories of quitters may be used to sustain motivation (Liu et al., 2013). Number of delivered interventions is also critical. While too many interventions may become burdensome, insufficient interventions may result in missed opportunities to intervene. Timing of intervention delivery is imperative as research in the domain of assistive technology suggest that users may not be cognitively, physically, or socially available to engage in a delivered intervention (Sarker et al., 2014). As a result, content, frequency, and timing of intervention needs to consider users' needs, preferences, and contexts, however, achieving the right balance considering all these factors is complex and need deeper research.

4.5 Hybrid system

Pulverman et al. proposed using a hybrid system combining several features of smart phone and apps along with easy access to healthcare professional (online or in-person) (Pulverman & Yellowlees, 2014). As text message based interventions have already shown great promise (Buller et al., 2014), we argue that, the successful hybrid system should incorporate text message as an intervention option as well.

5 Conclusions, Limitations, and Future Work

In this paper, we aimed to identify major challenges associated with mobile phone-based smoking cessation interventions. We explored four major databases: PubMed, Web of Science, IEEE Xplore, and ACM Digital Library and performed a systematic review of all relevant research articles available in these four databases. One limitation of our work is the selection of a subset of the databases, which may result in missing articles available in other databases (e.g., PsycINFO, SCOPUS, CINAHL Plus, and EMBASE). In addition, in our search string, we used mobile phone, cell phone, and smart phone as keywords and did not include the compound versions of these words (e.g., smartphone). This may also result in some missing articles. However, we believe that the 69 selected articles enabled us to identify important challenges in supporting smoking cessation. We also propose strategies for designing successful mobile phone-based smoking cessation interventions. Our offered implications are guided by theories from cognitive dissonance, health behavior change, and assistive technology. Currently many smoking cessation apps are available in the app stores, and a large number of people are not only using them but also providing reviews and feedback. In future, we intend to quantitatively analyze and mine all the texts available (e.g., app content and user reviews) pertaining to these apps. We believe that a deeper analysis of the user-provided texts will enable pattern discovery, and provide meaningful insight for the design of effective smoking cessation interventions.

6 References

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Appendix: List of 69 Articles Selected for Systematic Review

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