PEC Innovation 3 (2023) 100209

Contents lists available at ScienceDirect

PEC Innovation

journal homepage: www.elsevier.com/locate/pecinn

The use of the Capability-Opportunity- Motivation Behavior (COM-B) model to identify barriers to medication adherence and the application of mobile health technology in adults with coronary heart disease: A qualitative study

Linda G. Park [a,*], Fion Ng [b], Margaret A. Handley [c]

[a] University of California, San Francisco School of Nursing, Department of Community Health Systems, San Francisco Veterans Affair Medical Center, 2 Koret Way, Room 531A, San Francisco, CA 94143-0610, United States of America

[b] Department of Community Health Programs for Youth, San Francisco Department of Public Health, United States of America

[c] Departments of Epidemiology and Biostatistics and Medicine, Division of General Internal Medicine, University of California, San Francisco, United States of America

ARTICLE INFO

Keywords:
Medication adherence
Mobile health
Text messaging
Mobile applications
Focus groups
Qualitative research

ABSTRACT

Objective: Among patients with coronary heart disease, we sought to address the research questions of: 1) What is the acceptability of applying a technology-enabled approach to support medication adherence?; and 2) What are barriers to medication adherence using the Capability-Opportunity-Motivation Behavior (COM-B) model as a guiding framework?

Methods: Applying qualitative research methods, we employed a series of 3 focus groups per individual (total 9 sessions). Coded data from thematic analysis were mapped to the COM-B model components for meaningful associations.

Results: Fourteen participants were recruited (median age 69.5 ± 11, 50% female). Barriers to medication adherence were organized along these COM-B domains: psychological capability (forgetfulness, distractions, fear of side effects), physical opportunity (inaccessible medications, inability to renew prescriptions), reflective (burdening family members), and automatic motivation (medication fatigue, health decline).

Conclusions: Tailored text messaging and mobile phone apps were perceived as helpful tools for medication adherence. The COM-B model was useful to provide a comprehensive, theory-driven evaluation of patients' beliefs and motivations on whether to engage in medication adherence.

Innovation: To date, text messaging and mobile applications have not been widely implemented in the clinical setting and provide a major opportunity to innovate on approaches to address medication adherence.

1. Introduction

Cardiovascular disease is the leading cause of death worldwide, and in 2019, resulted in 17.9 million deaths according the World Health Organization [1,2]. Coronary heart disease (CHD) is the most common type of heart disease, with prevalence rates of 8.7% for males and 5.8% for females [3]. Clinical guidelines recommend evidence-based medical therapy for individuals who experience an acute coronary syndrome (ACS) or who undergo percutaneous coronary intervention (PCI) for secondary prevention [4]. However, medication adherence rates to cardiac medications are as low as 33–50% [5]. Despite the critical nature of taking antiplatelet medications to prevent in-stent thrombosis that can lead to myocardial infarction (MI) and death, a previous study showed one in seven MI patients treated with drug-eluting stents were not taking antiplatelet medications as prescribed [6]. Medication non-adherence is the number one problem in treating illness as more than half of individuals with chronic diseases do not take any or all of their medications correctly [7,8]. Low adherence rates have been associated with not only increased morbidity and mortality, but also intensified pharmacotherapy, increased and/or unexpected hospitalizations, and exacerbated disease [9,10].

The behavior of medication adherence can be broken down into three phases among adults who are prescribed medication: 1) initiation, involves the patient taking their first dose of medication, 2)

* Corresponding author.
E-mail address: linda.park@ucsf.edu (L.G. Park).

https://doi.org/10.1016/j.pecinn.2023.100209
Received 9 May 2023; Received in revised form 6 August 2023; Accepted 1 September 2023
Available online 7 September 2023
2772-6282/Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

implementation, corresponds to how the patient takes their medication over a period of time, and 3) discontinuation, when the patient stops taking a prescribed medication [11]. Over the three phases, many barriers may exist, such as lack of access (e.g., high costs, inability to obtain medications), forgetfulness, polypharmacy, and low health literacy, and therefore subsequent nonadherence [1,12]. Many interventions have been proposed, with mobile health technology (i.e. text messages/text messaging and mobile applications [apps]) becoming increasingly utilized as mechanisms to enhance medication adherence [11,13-16].

The use of technology can facilitate adoption and integration of medication taking by promoting behavioral strategies such as self-monitoring, social support, and coaching [17,18]. Several reviews have examined the potential for mobile health technologies such as text messaging and mobile apps to improve medication adherence [19-22]. Most authors agree on their strong promise to improve adherence behaviors but conclude there is insufficient evidence to draw a concrete determination given the heterogeneity of the studies and need to examine long-term efficacy [19-22]. Both text messaging and mobile apps provide convenient, inexpensive, and nonintrusive engagement with individuals. Use of mobile technology can particularly benefit those who have significant barriers to taking medications such as confusion of which medications to take, forgetfulness, and lack of social support. Text messaging is more widely used by all age groups; however, mobile apps offer many more features than messaging and can harness the full sensing and computational capacity to collect and analyze health-related data in real time to deliver health and behavioral interventions [23,24]. With the potential for mobile health technologies to provide a tailored, practical and inexpensive approach to mediate medication nonadherence, many interventions that have been developed to target medication non-adherence lack a theoretical basis, which has been linked with interventions' ineffectiveness [25,26]. However, utilization of health behavior theories and models has been shown to help researchers understand complex behaviors such as medication adherence, smoking cessation [27], and nutritional adherence [28].

Previous utilization of the Capability-Opportunity-Motivation Behavior (COM-B) — model has demonstrated success in understanding complex health behaviors such as medication adherence [26,29]. The COM-B model is one that helps to understand human behavior by hypothesizing the existence of an interplay between capability, opportunity, and motivation produce a certain behavior, which in turn can feedback to influence these initial components [30,31] (Fig. 1).

This model can also serve as a starting point in selecting interventions that are most likely to effectively address poor adherence [33]. The COM-B model looks at the possible relationships between systems level factors, allowing greater depth and precision of the relationships between adherence and individual factors [26] (Fig. 2). The COM-B model lies at the center of the Behavior Change Wheel (BCW), a systematic review of 19 frameworks of behavior change, used for designing and evaluating behavior change interventions [34] (Fig. 2).

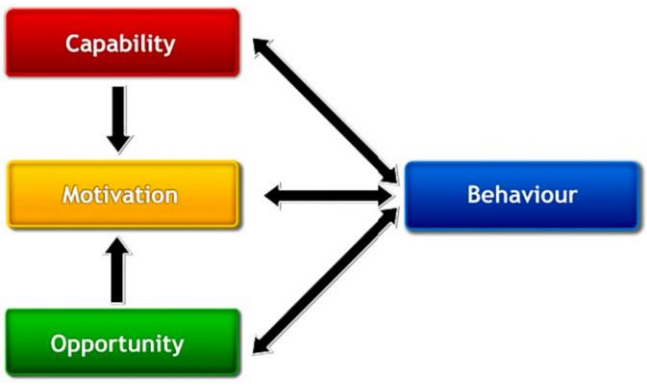

Fig. 1. The COM-B Model: A Framework for Understanding Behavior [32].

The model is made up of three domains: 1) capability, 2) motivation, and 3) opportunity. Each one of the three domains is further subdivided. Capability is subdivided into physical (e.g., physical strength, stamina) and psychological (e.g., comprehension, reasoning) [35,36]. Opportunity is subdivided into physical (e.g., resources, locations, physical barriers) and social (e.g., interpersonal influences, social cues, cultural norms) [36]. Sub-components of motivation are reflective processes (e.g., evaluations, self-conscious plans, beliefs) and automatic processes (e.g., emotions, desires, impulses) [36].

Given the previous success of the COM-B model in understanding complex human behaviors, it was selected as our guiding theoretical framework to identify factors that can affect medication adherence. Unlike quantitative research where an a priori hypothesis is normally provided, the same is not normally provided for qualitative research questions [37]. Thus, among patients with CHD who were prescribed dual-antiplatelet therapy after ACS or PCI, the purpose of this paper was to address the following research questions using a qualitative research approach: 1) What is the acceptability of applying a technology-enabled approach to medication adherence?; and 2) What are barriers to medication adherence using the COM-B model as a guiding framework?

2. Methods

2.1. Design and ethics approval

This paper presents the quantitative research that was conducted to inform the development of a theory-based randomized clinical trial (RCT). The RCT that was examining the efficacy of text messaging vs. mobile app as compared to website-control to improve adherence to antiplatelet therapy recently concluded and is currently in analysis stage. This qualitative research study applied grounded theory principles, which relies on the "emergence of concepts from the data collected" [38] and included focus groups with participants from a community hospital system. The UCSF Committee on Human Research and the John Muir Health Institutional Review Committee jointly approved the study.

2.2. Inclusion/exclusion criteria

Criteria for inclusion in the focus groups were the following: (a) ≥ 21 years of age, (b) history of ACS or PCI within one year, (c) current/former antiplatelet (thienopyridine) prescription (i.e., dual antiplatelet therapy included thienopyridine and aspirin); and (d) ownership of a smartphone. Exclusion criteria included: (a) cognitive impairment; and (b) lack of English proficiency/literacy.

2.3. Recruitment

We recruited focus group participants from 3 cardiac rehabilitation centers from February and August 2016 at John Muir Medical Center, where the principal investigator (LGP) has a clinical appointment through another department. A research associate recruited participants for the focus groups at the cardiac rehabilitation venues after posting and distribution of flyers. Approximately four rotating exercise physiologists and nurses at the cardiac rehabilitation programs assisted with identifying eligible patients. The research associate recruited each eligible patient face-to-face to participate in the focus groups before or after their cardiac rehabilitation sessions and obtained written consent. The decision to recruit from and hold focus groups in three sites reflected our goal to include participants from diverse socioeconomic and geographic backgrounds. Participants received $25 gift cards at the end of each focus group or interview.

2.4. Medication reminder mobile apps

After reviewing over 15 apps, the principal investigator (LGP)

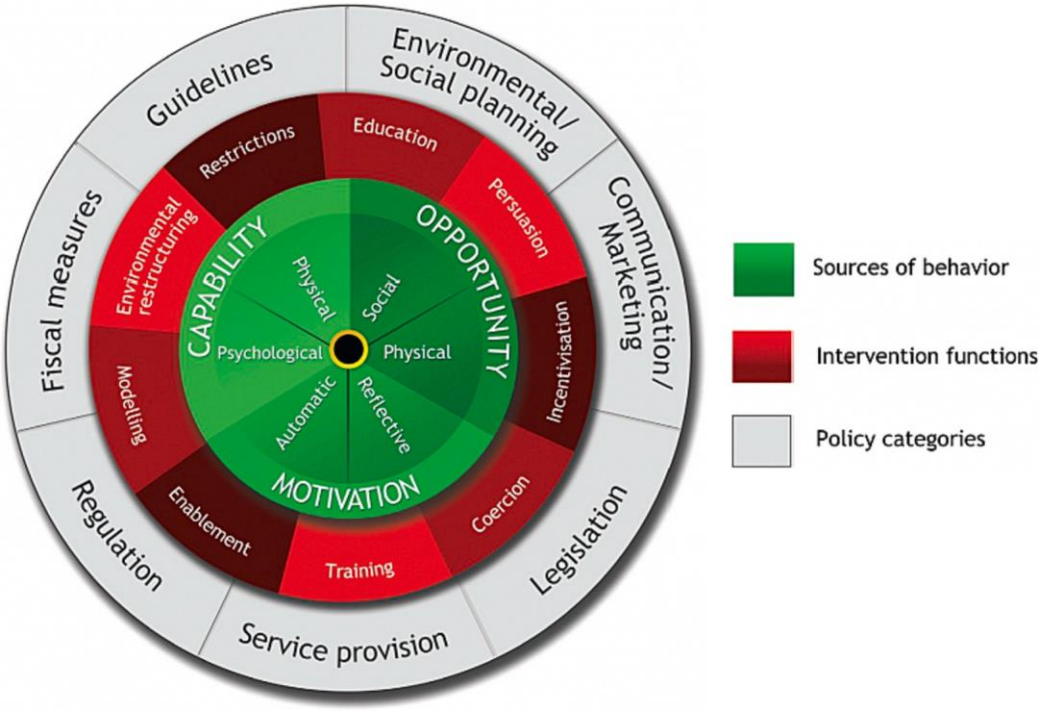

Fig. 2. Behavior Change Wheel [34].

selected Medisafe and Mango Health, both commercially available through Google Play, and Apple app stores, for their features, ease of use, high ratings from reviewers of health apps, and number of downloads. No member of the research team had any affiliation or connection with the apps manufacturers and distributors, nor had anything to gain financially from use of the apps in the study. The participants were asked to use an app for one week and then switch to the other app for the following week's trial thus ultimately using both apps. Medisafe and Mango are significantly different in their designs and displays yet had similar features to improve medication adherence through pill reminders, the tracking and monitoring of health measurements such as weight, blood pressure, and cholesterol count, and graphs charting medication history and mood. The latter features beyond medication tracking were not intentionally selected, however, were additional features that these popular apps included. Additional features included drug interaction warnings, and alerts for when medications need to be refilled. Features unique to MediSafe app included the ability to notify a primary care provider of medications the patient was taking, to notify family members if a patient had missed a dose, and to collect medication coupons and discounts. Features unique to Mango Health included custom health reminders (i.e., track food intake, and step count and to drink water), and a reward system where an individual could earn points from taking medications on time and have the opportunity to get rewarded (i.e., gift cards or donations to their preferred charity).

2.5. Focus group sessions

We held 3 focus group sessions per group for 1-hour each in a hospital conference room for a total of 9 sessions. That is, the same group of participants were scheduled to meet on 3 different occasions to discuss different topics, and there were 3 different groups. There was 1 week between the first and second sessions and 2 weeks between the second and third sessions to allow participants to use both mobile apps to become familiar with their basic features. The topics are listed in Table 1.

Table 1
Focus group topics.

Focus Group	Topic
First session	· Motivations for taking medications and ideas and experience with text messaging · Opinions on the content, frequency, and duration of text messages, and how to overcome text message fatigue and disinterest
Second session	· Ideas and experience with smartphone apps and use of mobile health apps · Questions about overcoming barriers on the use of apps for long-term medication adherence · Downloaded two medication reminder apps
Two weeks off for trial use of two mobile health apps (one week for each app)	
Third session	· Response to trial of health apps

2.6. Focus group discussion guide

The principal investigator (LGP) developed a question guide that lists factors related to engaging with text messaging and apps for medication adherence (Supplemental Table 1). The discussion guide was evaluated and revised by an expert qualitative researcher and pilot-tested among research team members. The questions were developed within the three major domains of the COM-B model and further categorized into the subdivisions of: a) psychological and physical capability; b) automatic and reflective motivation; and c) physical and social opportunity. The guide included both semi-structured and open-ended questions, allowing for new topics to emerge and be further explored [39]. The guide was used by researchers during each of the focus group sessions. All questions were asked to each participant to promote inclusivity. No questions were skipped during the focus groups.

2.7. Data collection and analysis

All focus groups and interviews were audiotaped and the digital recordings were transcribed. Each session was moderated by a qualitative researcher with >10 years of experience facilitating focus groups and

analyzing qualitative data. The principal investigator and an experienced research associate in qualitative research were present at all the focus group sessions and took notes on their observations. The focus group facilitator was the lead data analyst of the study. The facilitator and the research associate reviewed all transcripts for accuracy before beginning thematic analysis of the data using deductive coding. All the transcripts were coded using qualitative data management software, Atlas.ti version 7.0 software.

We used inductive, open coding, which involved the examination of the transcripts to tag actions, events, and components of perspectives and experiences related to medication itself or the acceptability of mobile technology for medication adherence. Initial codes were then compared and contrasted for similarities and variations, refined, and combined or split in some cases to build a final set of codes and categories. Thematic analysis involved coding the data to discover patterns and themes with an emphasis on the acceptability of using mobile technology and medication adherence barriers. Two researcher associates independently reviewed and coded the interview transcripts then applied deductive codes developed from the COM-B domains. The research associates engaged in member checking as part of the qualitative research methodology, reviewing the codes and categories based on their own understanding of the text and their observations at the focus group sessions. The facilitator/data analyst and the research associate met to reconcile differences. The coded data were then mapped to the COM-B components for meanings and relationships to emerge.

A cross-analysis was also done so that data from each focus group could be compared for similarities and differences. The resulting categories were further analyzed to provide insight on participants' experience with medication adherence or nonadherence and the barriers and facilitators to use of mobile technology.

3. Results

3.1. Sample characteristics and participation

We recruited a total of 14 participants from 3 sites, with 4–5 members per site, forming 3 focus groups. The median age was 69.5 ± 11 (range: 44–81 years) (Table 2). Each site had an even distribution of male and female participants.

For participation, there was a 95% attendance rate for the focus group sessions but overall 100% attendance among all participants when accounting for make-up individual interviews. Specifically, 2 participants from a specific focus group who were not able to attend 1 of their 3 scheduled sessions were interviewed separately, using the same discussion guides from the focus group that they missed.

3.2. Overall themes

The two major themes that will be presented are the use of technology for medication adherence and barriers to medication adherence. For technology use, we present patient resources on capabilities and preferences. For barriers, we present examples of circumstances that detract from medication adherence as well as how mobile technology helps to overcome barriers, both organized along COM-B categories.

Table 2
Participant demographics.

Patient Characteristics (*N* ¼ 14)	Total
Age, median (SD)	69.5 (11)
Female, No. (%)	7 (50)
White race, No. (%)	11 (79)
Married-Partnered, No. (%)	9 (64)
Employed, No. (%)	4 (29)
Retired/Not working, No. (%)	10 (71)
College graduate, No. (%)	10 (77)

SD: Standard deviation.

3.3. Use of technology for medication adherence

Capability. Participants in all three focus groups showed no capability-related problems with technology, with most of them having several apps that make daily living "convenient," facilitating activities. Examples of the apps participants used included banking, finding restaurants, travel, sports, weather tracking, news, shopping, home security, social media, hobbies, and pet monitoring. The use of health apps was limited to two participants who used Fitness Pal to keep track of their diet and exercise routine, specifically for the features of blood pressure monitoring. One participant had temporarily used a free app offered by his healthcare provider. Some participants named app features that would help them with medication adherence like medical history record-keeping and a calendar for doctors' appointments and prescription refills and renewals. None of the participants had any knowledge of the workings of a medication adherence app until their two-week experiment with the MediSafe and Mango Health apps. By the third session, all participants were able to articulate the advantages of using an app for medication adherence. A female participant summed up her feelings with using a health app: *"I am open, which kind of surprised me because like I said, I wasn't big on it when we started talking about all of it…. but after seeing MediSafe, ok, wow, this is actually rather cool. Oh, so yeah, I kind of did a whole 180° on it."*

They were unanimous in stating that text messages should be short. Text messages that contained more detailed information should be sent as a link or via email. Several suggested the phrase, "It's time to take your meds" over longer phrases or "cheerleader" type language such as "great job for taking your medications". There was no consensus on the frequency of text message delivery. Some wanted their reminders synced to their dosing schedule, while others wanted reminders on weekends when it did not feel routine or for medications taken in the evenings as the evenings seemed like a time where routines are more likely to be disrupted. One participant expressed a definite dislike for frequent reminders, stating, *"… I tend to think that it would be almost abusive if I received it (text message) every morning. Just getting it every single morning might be too much",* alluding to text message or alert fatigue.

We discussed the participants' capability, both physical and psychological, vis-a`-vis mobile technology. All 14 participants were regular users of text messaging and apps, although the reasons were not health related, but more so for reasons such as maintaining family/friend connectedness, and personal life management. Text messages were deemed as a quick and efficient way to communicate. All participants had high text messaging capability and were open to receiving texts reminding them to take their medications.

Preferences. Participants desired the ability to tailor text messages according to their individual needs and preferences. A female participant said, *"I think it (text messages) would be very helpful, but not sufficient because I will want some way to respond back, and say 'yes,' and have it not keep reminding me."* Another female participant pointed out, *"I want it tied to my medication, but it would be nice to have the option, you decide you don't need it, you just cancel it, right?"*

3.4. Barriers to medication adherence

The first session in the series of three focus groups discussed barriers to medication adherence that have been experienced by the participants. Table 3 below is a compilation of examples of barriers to medication adherence mapped onto the COM-B model.

Capability. One of the most frequent barriers in terms of psychological capability was forgetfulness. One of the participants stated, *"For me, I forget to take my pills. It's when unexpected things happen, pop up, that I get, that I forget."* Another participant attributed nonadherence to being *"human nature".*

Opportunity. Physical barriers that were cited included travel, preventing many individuals from accessing their medications (e.g., stowed in checked-in luggage), creating an opportunity to miss doses, as

Table 3
Barriers to medication adherence organized along COM-B categories.

Barriers to Medication Adherence	Text Messaging Features	Mobile App Features
CAPABILITY		
Psychological		
Forgetfulness	Reminder to take medication	Reminder to take medication
Easily distracted	Reminder to take medication	Reminder to take medication
Fear of side effects		Information on drug interactions, including alerts on mixing with alcoholic drinks
Confusion as to what medications to take		Reminder includes name of what medication to take; medication sorter
	OPPORTUNITY	
Physical		
Inability to access medication when traveling (i.e., suitcase with pills in cargo hold of plane)	Advanced reminder a day before travel about medication needs	Advanced reminder a day before travel about medication needs; Calendar feature with alerts to help with planning medication needs for travel
Inability to renew or refill prescriptions pills (i.e., out of town)	Advanced reminder about refills and renewals of prescriptions	Advanced reminder about refills and renewals of prescriptions, which could be linked to Calendar feature
No access to or unavailability of necessities needed to take with medication like water or syringe	Reminder should include water or other necessities to take with medication	Reminder should include water or other necessities to take with medication
Unexpected events (i.e., last minute change of plans)	Reminder to take medication	Reminder to take medication
MOTIVATION		
Automatic		
"Pill fatigue" from too many medications to keep track of and take	Reminders may help to ease tension from "too many things to remember"	Calendar feature, information about medications and drug interactions, and reminders may help to ease tension from "too many things to remember"
Emotional difficulty in transitioning from a healthy individual to one who takes medications	Reminders may help to ease tension from "adjustment" problems	Calendar, information about medications and drug interactions, and reminders may help organize "new" life, and thus ease "adjustment" problems
Reflective		
Belief that it is in the nature of human beings not to follow orders	Reminders that require acknowledgement of the message so the alert cannot be ignored, to create routine and habits	Reward (e.g., gift cards) with adherence through the app
Fear of burdening family members with health responsibility	Brief text messages sent to spouses/partners asking, "did __ take his/her medication this week?"	Integrating the buddy system, for encouragement and accountability

No themes were identified for Physical Capabilities and Social Opportunity in the COM-B Model.

well as not having the necessary equipment to administer/take medications. Renewing medications has also posed challenges, either getting renewals in time, or encountering a logistical barrier to getting a renewal. As one participant stated, *"When your prescriptions change, that's the biggest trigger for me… first I tried different beta-blockers, and then I actually went off entirely. And every time you do that, I'm trying to remember refill your little box with the correct one, now that it changed, was hard for me"*. Another participant noted, *"And she had tried to get it refilled and she couldn't, and Medicare and they wouldn't fill it until she got here. And then she got here and the pharmacy wouldn't fill it, because they didn't have her on their record"*. There appeared to be no social barriers identified when it came to taking medications as scheduled but rather, interrelationships between participants and family members acted as facilitators to their medication adherent behaviors. As one participant mentioned, *"My wife takes almost as many as I do, and we remind each other, especially in the evening, have you taken your evening pills?"*

Motivation. Barriers were categorized as reflective, yielded themes related to not wanting to burden loved ones with caretaking and health management, and inherently surrendering their control over. Automatic barriers included the frequently cited phenomenon of "pill fatigue", and the emotional dips from transitioning to a more ill individual given the increase in medications to help manage their conditions.

Table 3 below shows the mechanisms whereby text messaging and apps can help overcome barriers to medication adherence and thereby change behavior. Column 1 lists the barriers to medication adherence, while columns 2 and 3 are text message and mobile app features that can help alleviate the barriers.

3.5. COM-B application to preferred features of text messaging and mobile apps

Overall, it appears that with text messaging and mobile apps, all participants agreed that reminder features are the preferred way to improve medication adherence. Supplemental Table 2 outlines participants' perceptions of overcoming barriers to medication adherence through text messaging or mobile apps and provides direct quotes, when applicable, according to the COM-B categories. With Capability, to overcome the Psychological barriers identified, tailored text messages and mobile app reminders or push notifications can help combat occasional forgetfulness or keep an individual on track with their dosing schedules even with last minute changes or events that occur. To address the fear of side effects and confusion related to what medications to take, suggested mobile app features included having available information on drug and food/alcohol interactions and reminders specifically stating which medication to take and when.

With Opportunity, mechanisms to overcome the Physical barriers to medication adherence would include an advanced reminder feature to mitigate any potential for missing an opportunity to take a medication. Travel plans seemed to pose many challenges for participants, with time changes that interfere with their typical home medication schedule, being in a new setting without access to their preferred pharmacy and encountering unplanned and unstructured events. One participant stated, *"When we're traveling, I think it [app reminders] would be very beneficial. Sometimes I forget to take it at night, because it's different. When you change things, and your habits, then something like this would be very beneficial."* When asked about his favorite app feature during mobile app testing, one participant stated, *"I think I like the idea that you could set up the reminder of when your prescription needed refilled, because that's always an issue for me, even though I get mostly 90 days."*

With Motivation, participants suggested text message reminders and mobile app features to include a calendar feature, and information on drug-drug/drug-food interactions. Getting a diagnosis of a cardiac condition was difficult for participants, particularly with the rigidity of the medication regimen. As one participant noted, text messages may be helpful, however, should have an option for customizable frequency: *"I know when I first start with medicine, it's always hard. A lot of texts might be okay. But you should also maybe have an option where you can change the frequency for something that simple like that."* To help with transitioning into this new normal for these patients, the use of text messages and apps with bite-sized pieces of information related to their medication or their condition may keep users more engaged in their health care management, as one participant shared, *"Well, I would appreciate information that*

told me something new that was involved. Here's your reminder; in addition, this is changing now… For years I took all my medication at one time… certain medications are more effective at night and some are more effective throughout the day. So that's helpful to me."

4. Discussion and conclusion

4.1. Discussion

To our knowledge, this is the first paper to explore perceptions of using mobile health technologies (text messaging and mobile apps) for medication adherence and barriers to medication adherence in patients with a history of CHD in a high income country using the COM-B model as a theoretical framework. Our qualitative analysis revealed that text messages and mobile apps can help improve medication adherence in older adults with CHD who are prescribed dual antiplatelet therapy. As an organizing framework, application of the more comprehensive and dynamic COM-B model resulted in the identification of meaningful medication adherence barriers across multiple COM-B components, affirming the complexity of medication adherence as a health behavior.

Application of the COM-B model revealed that older adults with a history of CHD experienced barriers in their psychological capability (forgetfulness, easily distracted, fear of side effects and uncertainty with their medication regimens), their physical opportunity (inability to access medications or appropriate medication supplies such as syringes when traveling, problems renewing their prescriptions, and encountering last minute changes) and automatic motivation (medication or "pill" fatigue, and emotional difficulty when acknowledging decline in health status). There were no barriers identified within Social Opportunity, which in this study reflects social support and influences. In one study that utilized the COM-B model to explore barriers to medication in those with cardiovascular disease from low income countries (i.e., Ghana and India), the Social Opportunity questions asked about stigma of disease and religious and cultural beliefs. The authors observed that the participants who did not share their diagnosis with family member and relied on religion and prayer as a cure for their disease had lower medication adherence rates [40]. In this present study, questions under Social Opportunity may not have elicited a response targeting one's fear of stigma of disease or cultural beliefs.

Reminders via text messages and mobile apps have been cited in previous literature as a helpful tool in promoting medication adherence [15,41-43]. In our study, participants' preferences for text message features to combat barriers included having reminders via text message with specific instructions on how to properly take their medication. Suggested features for mobile apps centered around advanced reminders (i.e., prior to travel, or for prescription refills), with the addition of important drug information (e.g., how to take the medication, side effects, drug-drug and drug-food interactions). While there are many notable benefits of text message delivery to personal devices, the preferences for frequency of message delivery are varied. Participants admitted that receiving the same text message alerts repeatedly over a long period of time could generate "message fatigue", a pitfall that spans across various digital delivery mediums including text messaging, as well as phone calls, digital banners in mobile apps, and push notifications. Message or alert fatigue has also caused providers to ignore airlines on clinical decision support systems, diminishing the systems' effec-tiveness and contributing to serious adverse consequences for patients [44,45].

"Pill fatigue"/polypharmacy was highlighted as an Automatic Motivation. This finding aligns with other published literature demonstrating that increases in both the number of prescribed medications and regimen complexity are correlated with lower medication adherence in older adults [25,46]. Complex regimens can be difficult to manage, as they can involve a variety of formulations, multiple daily doses and, in some instances, special administration instructions (e.g., take 1 h before food). Research has noted that taking fewer drugs is associated with improved adherence [47]. However, while this is not always possible, simplification of drug regimens, and providing patients better explanations behind the reason(s) for them taking medications has been a proposed intervention for those with polypharmacy [48].

The authors recognize that reminders may be more beneficial for those who experience unintentional nonadherence than those with intentional nonadherence. Unintentional nonadherence is a passive process in which individuals do not take medications because of forgetfulness, carelessness, or other challenges with health literacy, [49] whereas intentional non-adherence is an active decision that individuals make to not take their prescribed therapy [50]. The question guide did not explore or analyze responses as either falling into intentional or unintentional nonadherence; however, this differentiation is crucial as interventions that may be effective for unintentional nonadherence (e.g., reminders) might not be effective for intentional nonadherence. Future work should identify strategies for both types of nonadherence. In addition, with the new taxonomy for describing medication adherence as a health behavior, it is known that barriers can exist in any of the three phases of adherence (i.e., initiation, implementation and discontinuation) [11]. Our study explored the implementation phase as our study included individuals who experienced a cardiac event, attended cardiac rehabilitation, and were prescribed dual antiplatelet therapy. Understanding the phases where medication adherence drops may be helpful in the development of more direct and targeted interventions. Since the 'initiation' and 'discontinuation' phases of adherence were not explored, it could limit the comprehensiveness of the findings and warrants further work to address all three phases.

While this qualitative study highlighted insightful feedback, there are several limitations to consider. First, the sample size was relatively small with a total of 14 participants. The sample population was comprised of older adults with ACS and/or PCI who owned smartphones and were recruited from three sites under a single healthcare institution in the San Francisco Bay Area. Therefore, it is difficult to determine generalizability of these findings to older adults with multiple or of another co-morbid chronic disease diagnosis, cognitive impairment, socioeconomic disparities, or those with mood disruptions. Exclusion of cognitively impaired individuals may present a bias in the study outcomes, and we recognitive these populations are particularly important for rexearch concerning medication adherence and potential use of technology-driven reminders with caregiver support. In addition, up to about one third of patients who have experienced an acute cardiac life event also have depression, which has been associated with suboptimal medication adherence [9]. A systematic review and meta-analysis conducted by Crawshaw et al. [9] found that depression was a major predictor of medication adherence and was the most studied psychosocial barrier to adherence. Future research may want to examine whether the ideas and perceptions generated from this study will be similar to those of different age (i.e., middle-aged adults), racial, ethnic, socioeconomic, and geographic backgrounds.

Another potential ethical consideration is that not every older adult with a chronic condition owns a mobile smartphone, can afford one, or is adept at using all the features of a smartphone, highlighting socioeconomic and technology proficiency disparities. Therefore, it is important to make technology equitable and accessible to older adults who do not own a smartphone. In addition, it is vital to consider patients' health and technology literacy levels to provide adequate training on how to use the features of the smartphones and various health apps that would promote self-management.

4.2. Innovation

To date, text messaging and mobile applications have not been widely implemented in the clinical setting and provide a major opportunity to innovate on approaches to address medication adherence. This paper presents a theory informed approach that is innovative and rigorous, given that much of the focus is on the technology and not

patient input for improving adherence engagement for specific barriers. We must engage multidisciplinary healthcare providers in playing active roles with patients in the management of their medication use. Practitioners who are on the front lines of clinical care (nurses, advanced practice providers, physicians, pharmacists) can work with industry leaders in patient-facing technology to collaboratively address barriers to medication adherence.

4.3. Conclusion

Our application of the COM-B model highlighted several clinically meaningful barriers to medication adherence, with proposed ideas for text messaging and mobile app interventions to improve medication adherence. This work further validates that medication adherence is a complex health behavior that stems from a multitude of influencing factors. Therefore, to properly and effectively address medication adherence in the older adult population, researchers and clinicians should explore patients' beliefs and motivations for adhering or non-adhering to their medication regimens from multiple levels (e.g., individual and systems level) as well as knowledge gaps as described above. Specifically, it is important to engage in these topics with diverse communities and vulnerable populations for medication nonadherence (i.e., those with depression, cognitive impairment, and intentional nonadherence).

Funding

Dr. Park was supported by the National Center for Advancing Translational Sciences of the NIH under Award Number KL2TR001870. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

CRediT authorship contribution statement

Linda G. Park: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Fion Ng:** Formal analysis, Writing – original draft, Writing – review & editing. **Margaret A. Handley:** Methodology, Writing – review & editing.

Declaration of Competing Interest

None declared.

Acknowledgements

We acknowledge Dr. Ofelia Villero for her significant contributions to this project and manuscript. We would like to thank the individuals who participated in the focus groups. We appreciate the support of John Muir Health in allowing us to conduct our research.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pecinn.2023.100209.

References

[1] Zullig LL, Ramos K, Bosworth HB. Improving medication adherence in coronary heart disease. Curr Cardiol Rep 2017;19(11):113.
[2] Santo K, Redfern J. Digital health innovations to improve cardiovascular disease care. Curr Atheroscler Rep 2020;22(12):71.
[3] Tsao CW, et al. Heart disease and stroke statistics—2023 update: a report from the American Heart Association. Circulation 2023;147(8):e93–621.
[4] Chinwong S, et al. Association between medication adherence and cardiovascular outcomes among acute coronary syndrome patients. Res Social Adm Pharm 2021;17(9):1631–5.
[5] Khatib R, et al. Adherence to coronary artery disease secondary prevention medicines: exploring modifiable barriers. Open Heart 2019;6(2):e000997.
[6] Spertus JA, et al. Prevalence, predictors, and outcomes of premature discontinuation of Thienopyridine therapy after drug-eluting stent placement. Circulation 2006;113(24):2803–9.
[7] Osterberg L, Blaschke T. Adherence to medication. N Engl J Med 2005;353(5):487–97.
[8] World Health, O. Adherence to long-term therapies : Evidence for action. Geneva: World Health Organization; 2003.
[9] Crawshaw J, et al. Identifying psychosocial predictors of medication non-adherence following acute coronary syndrome: a systematic review and meta-analysis. J Psychosom Res 2016;90.
[10] Kubica A, et al. Assessment of adherence to medication in patients after myocardial infarction treated with percutaneous coronary intervention. Is there a place for newself-reported questionnaires? Curr Med Res Opin 2019;35(2):341–9.
[11] Vrijens B, et al. A new taxonomy for describing and defining adherence to medications. Br J Clin Pharmacol 2012;73(5):691–705.
[12] Zullig LL, et al. Patient-reported medication adherence barriers among patients with cardiovascular risk factors. J Manag Care Spec Pharm 2015;21(6):479–85.
[13] Kao C-K, Liebovitz DM. Consumer mobile health apps: current state, barriers, and future directions. PM&R 2017;9(5, Supplement):S106–15.
[14] Michie S, et al. Developing and evaluating digital interventions to promote behavior change in health and health care: recommendations resulting from an international workshop. J Med Internet Res 2017;19(6):e232.
[15] Park LG, et al. A text messaging intervention to promote medication adherence for patients with coronary heart disease: a randomized controlled trial. Patient Educ Couns 2014;94(2):261–8.
[16] Chow CK, et al. TEXT messages to improve MEDication adherence and Secondary prevention (TEXTMEDS) after acute coronary syndrome: a randomised clinical trial protocol. BMJ Open 2018;8(1):e019463.
[17] Bosworth HB, et al. Medication adherence: a call for action. Am Heart J 2011;162(3):412–24.
[18] Davies MJ, et al. The attitudes of pharmacists, students and the general public on mHealth applications for medication adherence. Pharm Pract 2015;13(4):644.
[19] Adler AJ, et al. Mobile phone text messaging to improve medication adherence in secondary prevention of cardiovascular disease. Cochrane Database Syst Rev 2017;4(4). Cd011851.
[20] Mikulski BS, et al. Mobile health applications and medication adherence of patients with hypertension: a systematic review and meta-analysis. Am J Prev Med 2022;62(4):626–34.
[21] Park LG, Howie-Esquivel J, Dracup K. A quantitative systematic review of the efficacy of mobile phone interventions to improve medication adherence. J Adv Nurs 2014;70(9):1932–53.
[22] Peng Y, et al. Effectiveness of Mobile applications on medication adherence in adults with chronic diseases: a systematic review and meta-analysis. J Manag Care Spec Pharm 2020;26(4):550–61.
[23] Kumar S, et al. Mobile health technology evaluation: the mHealth evidence workshop. Am J Prev Med 2013;45(2):228–36.
[24] Teyhen DS, et al. Incentives to create and sustain healthy behaviors: technology solutions and research needs. Mil Med 2014;179(12):1419–31.
[25] Patton DE, et al. Theory-based interventions to improve medication adherence in older adults prescribed polypharmacy: a systematic review. Drugs Aging 2017;34(2):97–113.
[26] Jackson C, et al. Applying COM-B to medication adherence: a suggested framework for research and interventions. Eur J Health Psychol 2014;16:7–17.
[27] Kumar R, et al. Correction to: health providers' and pregnant women's perspectives about smoking cessation support: a COM-B analysis of a global systematic review of qualitative studies. BMC Pregnancy Childbirth 2021;21(1):613.
[28] Khani Jeihooni A, et al. The application of the theory of planned behavior to nutritional behaviors related to cardiovascular disease among the women. BMC Cardiovasc Disord 2021;21(1):589.
[29] Heneghan MB, et al. Applying the COM-B model to patient-reported barriers to medication adherence in pediatric acute lymphoblastic leukemia. Pediatr Blood Cancer 2020;67(5):e28216.
[30] Jones S, et al. Promoting adherence to nebulized therapy in cystic fibrosis: poster development and a qualitative exploration of adherence. Patient Prefer Adherence 2015;9:1109–20.
[31] Katangwe T, et al. The community pharmacy setting for diabetes prevention: views and perceptions of stakeholders. PLoS One 2019;14(7):e0219686.
[32] Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci 2011;6(1):42.
[33] Jones S, et al. Promoting adherence to nebulized therapy in cystic fibrosis: poster development and a qualitative exploration of adherence. Patient Prefer Adherence 2015;9:1109–20.
[34] Michie S, A.L, West R. The behaviour change wheel: A guide to designing interventions. London: Silverback Publishing; 2014.
[35] Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci 2011;6:42.
[36] Michie S, Atkins L, W. R. The behaviour change wheel: A guide to designing interventions. London: Silverback Publishing; 2014.
[37] Casula M, Rangarajan N, Shields P. The potential of working hypotheses for deductive exploratory research. Qual Quant 2021;55(5):1703–25.
[38] Chun Tie Y, Birks M, Francis K. Grounded theory research: a design framework for novice researchers. SAGE Open Med 2019;7. 2050312118822927.

[39] Busetto L, Wick W, Gumbinger C. How to use and assess qualitative research methods. Neurol Res Pract 2020;2(1):14.
[40] Mishra P, et al. Exploring barriers to medication adherence using COM-B model of behaviour among patients with cardiovascular diseases in low- and middle-income countries: a qualitative study. Patient Prefer Adherence 2021;15:1359–71.
[41] P´erez-Jover V, et al. Mobile apps for increasing treatment adherence: systematic review. J Med Internet Res 2019;21(6):e12505.
[42] Thakkar J, et al. Mobile telephone text messaging for medication adherence in chronic disease: a meta-analysis. JAMA Intern Med 2016;176(3):340–9.
[43] Anglada-Martínez H, et al. Feasibility and preliminary outcomes of a web and smartphone-based medication self-management platform for chronically ill patients. J Med Syst 2016;40(4):99.
[44] Kesselheim AS, et al. Clinical decision support systems could be modified to reduce 'alert fatigue' while still minimizing the risk of litigation. Health Aff (Millwood) 2011;30(12):2310–7.
[45] Muench F, Baumel A. More than a text message: dismantling digital triggers to curate behavior change in patient-centered health interventions. J Med Internet Res 2017;19(5):e147.
[46] Kardas P, Lewek P, Matyjaszczyk M. Determinants of patient adherence: a review of systematic reviews. Front Pharmacol 2013;4(91).
[47] Stoehr GP, et al. Factors associated with adherence to medication regimens in older primary care patients: the steel valley seniors survey. Am J Geriatr Pharmacother 2008;6(5):255–63.
[48] Pasina L, et al. Medication non-adherence among elderly patients newly discharged and receiving polypharmacy. Drugs Aging 2014;31(4):283–9.
[49] Wroe AL. Intentional and unintentional nonadherence: a study of decision making. J Behav Med 2002;25(4):355–72.
[50] Lehane E, McCarthy G. Intentional and unintentional medication non-adherence: a comprehensive framework for clinical research and practice? A discussion paper. Int J Nurs Stud 2007;44(8):1468–77.