Don't Forget Your Pill! Designing Effective Medication Reminder Apps That Support Users' Daily Routines

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ABSTRACT
Despite the fact that a third of all cases of unintentional medication non-adherence are caused by simple forgetfulness, the majority of interventions neglect this issue. Even though patients have access to smartphone applications ("apps") designed to help them remember medication, neither their quality nor effectiveness has been evaluated yet. We report the findings of a functionality review of 229 medication reminder apps and a thematic analysis of their 1,012 user reviews. Our research highlights the gap between the theory and practice: while the literature shows that many medication regimens are habitual in nature and the presence of daily routines supports remembering, existing apps rely on timer-based reminders. To address this disparity, we present design requirements for building medication reminders that support the routine aspect of medication-taking and its individual nature, and demonstrate how they could be implemented to move from passive alerts to a smarter memory and routine assistant.

Author Keywords
Smartphone apps; medication reminders; forgetfulness; habits; routines

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. H.5.2 User Interfaces: User-centered design.

INTRODUCTION
Medication non-adherence reduces the effectiveness of a treatment and imposes a financial burden on health care systems [23, 47]: in the USA alone, the estimated cost of non-adherence reaches $100 billion each year, including the cost of 10% of hospital and 23% of nursing home admissions [45]. The majority of adherence interventions developed to address this issue focus on intentional non-adherence and their aim is to educate people and change their attitudes and beliefs [18]. However, even motivated people can forget: forgetfulness accounts for 30% of cases of unintentional non-adherence [43] and around one million unwanted pregnancies each year are the result of non-adherence [37] and irregular use of the contraceptive pill ("the Pill"), with forgetfulness as one of the main causes [25, 41]. And yet, interventions explicitly addressing forgetfulness, especially for preventative therapies such as oral contraception, are not only few and far between, but also tend to focus on reminders alerting people to take their medication at a specified time [18, 46]. This focus on timed alerts disregards the fact that time-based tasks are more difficult to remember than tasks related to routine actions [34] and many medication regimens are habitual tasks that could be easily incorporated into a daily routine, which in itself also supports remembering.

The routine support could be provided by technology. With the increasing popularity of smartphones, people now have access to thousands of health-related applications ("apps") [27] that could help them remember their medication. Even though in recent years a few app reviews have been published (e.g. [10, 31, 33, 38]), to date, medication reminder apps have not been reviewed or evaluated by academic researchers, and as a result their effectiveness or the extent to which they meet users' needs are not known.

Our paper makes two main contributions and presents a new direction in research that could be exploited to support medication-taking. Firstly, we review the functionality of smartphone medication reminder apps and highlight the weaknesses of apps that take a "one size fits all" approach and support remembering by providing simple, timer-based reminders. Secondly, we propose a set of design requirements for building reminder apps that take into account the habitual nature of medication regimens. To demonstrate the feasibility of this approach, we illustrate these requirements with a use case scenario that describes how apps supporting medication routines could be implemented. We argue that by taking advantage of the habitual nature of many medication regimens and by incorporating routine support in addition to timer-based reminders, technology could be more effective in supporting the user and reducing unintentional medication non-adherence.

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REMEMBERING MEDICATION

Remembering to take medication is a prospective memory task and as such it relies on a set of cognitive processes responsible for completing actions at some point in the future [13]. There are two main types of prospective memory tasks: time-based tasks that need to be completed at a specified time (e.g. take medication at 9:00) or after a set period of time has elapsed (e.g. take antibiotics every 8 hours); and event-based tasks, where the task is linked to an existing event and the environment in which it takes place, e.g. taking medication with breakfast. Depending on individual circumstances, a medication regimen can be classified as either of these tasks.

All prospective memory tasks rely on cues, which can be internal (e.g. thoughts), external (reminders, notes, etc.) or paired with an event that triggers the task ("conjunction reminders") [20]. External and conjunction reminders are the most effective as they provide more cues [13, 30]. As a result, event-based tasks support memory more effectively than time-based tasks: they are easier to remember and the presence of a routine guides behavior and provides more contextual cues, increasing the adherence to a medical treatment [34] and supporting habit formation [5].

Habits & Routines

Habits are an effect of gradual learning of patterns of behavior and associations between the task or its features and the environment (e.g. location), especially when actions are regularly and frequently performed in a sequence [1, 49]. To be turned into a habit, a task should be simple [16, 28], be associated with an existing routine task [16, 34] and provide positive reinforcement [16, 28]. It also needs to be repeated enough times to become a routine behavior [1, 29].

As medications often need to be taken regularly and within a particular period of time, many regimens are *de facto* habitual tasks – patients learn to associate their medications with a specific time of day, location or event. According to the Medication Adherence Model [24], such patterned behavior is an important part of medication-taking, as it is personalized, unique for each individual and reflects their lifestyle and daily activities. As a result, timing (e.g. breakfast time) and the location (e.g. kitchen) are key elements of a routine, and make it more memorable, meaningful and reliable [24]. For example, the act of eating breakfast in the kitchen initially serves as a cue to take the medication and, with time, transforms the behavior into a habitual action. However, while routines can make repetitive tasks easier through the creation of automatic actions, they can also be dangerous when the task requires deliberation [36]. The automaticity of a behavior combined with disruptions to the routine increase the likelihood of omission and repetition errors [3, 12], which should be taken into account when designing a technology that utilizes routines.

Routines & Remembering The Pill

To better understand the role routines play in supporting habitual medication regimens, we conducted an online survey that explored women's strategies for remembering oral contraception. Preliminary results illustrate the impact of routines and technology on remembering the Pill regimen.

The survey was advertised on popular social networks, online forums and among students and university staff, and resulted in 971 complete responses. Possibly due to the nature of advertising channels, 76% of respondents were women aged 18-25 years old. The results showed that nearly half of the respondents reported completely missing the Pill at least once during the month preceding the survey, and during the same period 75% took it later than they should. When asked how they remembered the Pill, 61% said it was a part of their daily routine. It does not come as a surprise then that the most common causes of forgetting were changes in the daily routine (54%), being busy or distracted (47%), and simple forgetfulness (46%). Yet, women who relied on their daily routines forgot less often: in the routine group (N=589) 41% of women completely forgot the Pill at least once in the past month and 69% were late, compared to 56% and 86% respectively among those who did not mention daily routines (N=382). Chi-square tests for independence indicated significant ($p < .001$) associations between fewer forgetting incidents and the presence of routines, which is in line with the literature.

Only 25% of women mentioned using some sort of technology as a reminder, predominantly their cellphone's alarm clock. Dedicated medication reminder apps were used by 5% (N=45) of women, which came as a surprise given the age range of the majority of respondents and the fact that 66% of 16-24 year olds in the UK own a smartphone and are likely to download apps [32]. A quarter of women who used technology to support their memory also said that the Pill-taking was a part of their routine, which indicates that cellphones might have been used as a backup reminder.

Our preliminary findings show that women rely mainly on routines and this strategy increases their adherence. They also tend not to use technology, despite the fact that cellphones are ubiquitous and have capabilities to provide reminders and support routines. This suggests that users either do not see the need to use medication reminder apps or that apps in their current form are not fit for purpose. The following sections investigate this issue in more detail.

MOBILE REMINDERS

According to the latest statistics, 92% of UK adults own a cellphone and 39% own a smartphone [32]. The ubiquity of mobile devices, combined with their personal nature [44] and their functionality, such as text messaging, apps, or Internet access, make cellphones an effective platform for delivering health interventions [15, 26, 50]. Among cellphone-based interventions aimed at supporting remembering, text message reminders are the most widely used.

Text Messages

Text messages (SMS or short message service) have been used as reminders in several health interventions (e.g. [7, 14, 21]). For example, Hou *et al*. [21] evaluated the impact of SMS reminders on adherence to oral contraception. For three months, at a time chosen before the trial, 82 participants received a daily SMS reminder to take the Pill. The results showed that despite the daily reminders, the intervention did not improve adherence compared to the control group. Moreover, women who ended the trial with an excellent adherence record had felt at the beginning of the study that they would not need SMS reminders, which suggests that they either already used their own reminders or relied on a routine.

The study also shows that text messages are not flexible enough: they are simple timer-based reminders that require immediate attention. As each SMS was sent only once, women were not able to postpone the reminder if they could not take the Pill immediately, which suggests that smartphone apps with reminders that can be 'snoozed' might be better suited as a memory support tool.

Smartphone Apps

Smartphone users have easy access to thousands of health-related mobile apps [27]. Even though several reviews of health apps have been conducted, medication reminders have not been assessed to date. For example, a review of the top 500 medical apps available in Italian app stores conducted in 2012 [31] identifies 58 "health diaries", which includes "medication scheduling apps". However, no further information about these apps is provided. Another review from 2013 [10] describes over 160 medication adherence apps available for different types of smartphones, and although medication reminders were included, the focus was on intentional non-adherence and evaluating the apps from a pharmacist's perspective. Despite the fact that the effectiveness of the apps had not been formally evaluated at the time and their relevance to users' needs had not been assessed, authors concluded that these apps have potential to help with medication regimens.

Rather than evaluating existing apps, some researchers have proposed their own solutions. For example, Silva *et al.* [39] designed a medication reminder app that allowed users to enter multiple medications, showed due times and taking instructions, and highlighted overdue doses. The app did not differ much from commercial apps, and since its focus was on reminders, routine support was not available. However, the authors created a set of functional requirements that address a number of accessibility issues, including automated reminders with different modalities (visual and auditory alerts) and the snooze option to prevent missing doses, which could be considered when designing a reminder system that takes routines into the account.

De Oliveira *et al.* [11] took a different approach: to help people develop routines, they designed an app that encouraged continuous use by adding a competitive element to medication-taking. Users were awarded adherence scores, which were then shared with their peers and displayed on a leader board. The game did not provide reminders and users had to remember by themselves, although the focus was on winning the game and taking the medication at a specific time rather than simply taking it every day. As a result, routines were not sufficiently well defined and users needed their own timer-based reminders.

Nevertheless, the approach taken by De Oliveira *et al.* shows that medication reminders do not need to focus on timer-based alerts and that reminder apps could support routines. Below we present two studies we conducted to investigate how commercial apps available for smartphones prevent forgetting and whether they support daily routines.

STUDY I: APPS FUNCTIONALITY REVIEW

As interventions tend to focus on timer-based reminders and our study showed that women who take the Pill tend not to use medication reminder apps despite their wide availability, we wanted to explore this issue in more detail. We conducted a review of existing apps to understand what functionality they offer, how they support memory, whether approaches other than timer-based reminders are available and to what extent the apps support routine behavior.

Method

As Apple and Android devices accounted for 86% of new smartphones purchased in 2012 [30], apps available in the UK versions of Apple iTunes Store [2] and Google Play [17] were included in the analysis. Free and paid apps, and full and limited ("lite") versions were included in the review and counted separately, as they offered different functionality. Similarly, apps available in both stores were treated as separate apps, as due to operating system differences their functionality and types of alerts differed. As the focus of the study was on smartphone medication reminders, apps for tablets, generic reminders and other health support apps were excluded.

Prior to the main analysis, a list of popular features was prepared based on the first 25 apps found in each store after searching for "medication reminder". Identified features were grouped into categories and used later to aid data collection. "Medication reminder", "pill reminder", "contraception reminder" and "birth control reminder" were used as search keywords to ensure a wide range of medication reminders was covered. Details of each app, including its name, user rating, number of user reviews, and the presence of feature categories identified during the initial analysis were recorded. Features not fitting into the predefined categories were also noted and later grouped to create additional categories.

In total, 229 medication reminder apps met the inclusion criteria (123 for iPhones and 106 for Android-based smart-

phones, including 15 available for both platforms). Among them, 86% were generic medication reminder apps and 14% supported a specific regimen, mainly contraception (25 apps). Their functionality is summarized in Figure 1 and described in more detail in the next section.

Reminder Apps Functionality

As expected, nearly all (97%) of identified apps offered timer-based reminders. Eight apps either did not have them listed on their description page or did not provide them due to version limitations. Most reminder apps (83%) supported multiple medications, and only contraception reminders and lite versions were often limited to a single daily dose. A third of apps (33%) imposed limitations on alert scheduling, e.g. by allowing only one alert per medication per day or not supporting time intervals such as alerts every X hours or X days. Surprisingly, only 39 apps (17%) offered an option to postpone a reminder ("snooze").

Some apps provided additional personalization features: customizable alerts allowing users to select different types of notifications such as pop-up messages, status updates or flashing lights (18%); customizable sounds (39%); and an option to add medication pictures to help with recall (21%). Over a third of apps (38%) allowed users to check their medication and regimen history, and export the data (7%) or email it to others (18%). In some cases (7%) users were able to add and track medication taken "as needed", e.g. painkillers, which were also included in their medication log. Six per cent of apps automatically tracked missed and late doses, highlighting them in the history report, and 5% offered statistics and charts describing usage trends, adherence rates and sometimes even treatment costs. In addition, 11% of apps, mainly contraception reminders, provided password protection, and 8% offered an option to back up the data or synchronize it with other devices.

Many apps offered additional features that aimed to support memory: refill reminders (26%); user notes and a calendar view with medication times (26%); a database with medication information e.g. dosage and side effects (14%); or an option to alert other people about missed doses (8%). Less frequent options included time zone support to ensure medication is taken at the right time when travelling (10 apps); smart silencing, to ensure alerts do not go off when user is asleep or during a Pill-free week in oral contraception regimens (seven apps); the ability to track mood and side effects after taking each dose (eight apps); and an overdosing protection with alerts informing when a daily limit of a medication (mainly taken "as needed") has been reached (five apps). More complex apps also stored user's health information, e.g. their allergies or blood type (11% of apps) or health care provider and pharmacy details (16%), and provided treatment cost estimates and discount codes for medications (3%). Doctor's appointment reminders were also available in 18 apps.

Only four apps (2%) provided options supporting habit formation and regular medication-taking. One encouraged continuous use by allowing users to take care of a tree [42], while the other three rewarded users with points that either could be compared or shared with friends, or redeemed into vouchers for other apps.

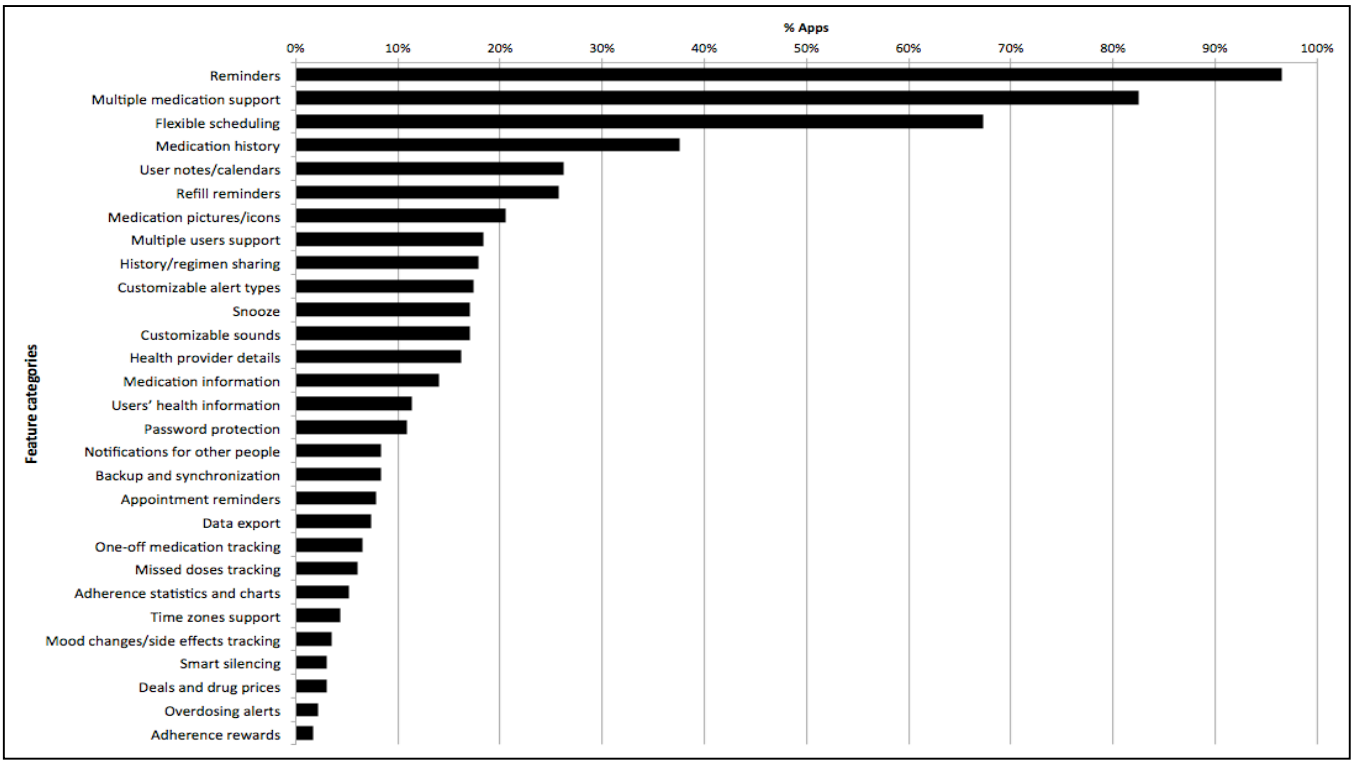

Figure 1. Functionality offered by smartphone reminder apps (N=229)

Types of Reminder Apps

As medication reminder apps provided functionality of varying complexity, based on their features they were grouped into three main categories:

- *Simple medication reminders (SMR)*. Apps offering basic functions supporting prospective memory, such as alerts, flexible scheduling, customizable alert types and sounds, snooze, etc.
- *Advanced medication reminders (AMR).* Apps providing options that support both prospective and retrospective memory, such as time zone support, overdosing protection, medication pictures, user notes, late doses tracking, medication log, smart silencing, etc.
- *Medication management apps (MMA)*. AMR apps that also help to manage health and medication regimens. As some of them support multiple user accounts, they can be further split into *personal medication management apps* and *family medication management apps*. They allow users to store their health information, doctor's contact details, provide appointment reminders, etc.

Conclusions

Regardless of the type, complexity or functionality offered, all apps focus on timer-based reminders: their main purpose is to remind users about medication at a specific time. As a snooze option is rarely available and alerts cannot be postponed, users are expected to react immediately so that the reminder is not forgotten [9]. The apps seem to be designed to encourage users to rely on them, even though over-reliance on external cues can be associated with increased number of omission errors [12]. Despite the fact that medication-taking is a habitual task, functions that explicitly support the creation of routines are not available.

In essence, many apps (especially SMR) are nothing more than SMS alerts or alarm clocks packaged as medication reminders and could be easily replaced by a smartphone's default functionality with no loss to the user. Moreover, since all cellphone alarm clocks allow users to postpone the reminders, in many cases they may be a better option. AMR expand the alarm clock's functionality by allowing users to check later whether a medication was taken. Their options such as time zone support and smart silencing help to manage medication-taking in situations when the routine changes. MMA, the most advanced group, provide the same functionality as AMR and add treatment support and health monitoring, although the unique features they offer do not support remembering or habit formation in any way. In addition, local health care providers may not always support automatic refills or accept automatic emails with medication history from the app.

Our results highlight disparities between the medication reminder apps' functionality and prospective memory and habit literature. Even though research suggests that routines are key in supporting medication-taking, these apps focus on timer-based reminders, neglecting the habitual nature of medication regimens. They do, however, offer functions that could guard users against the dangers of a routine. For example, some AMR and MMA allow users to view their medication history to check whether a dose was taken. They also provide features such as time zone support or smart silencing that help in situations when a routine changes. In our next study we investigate how useful users find these and other features, and to what extent medication reminder apps meet their needs.

STUDY II: APPS REVIEWS' ANALYSIS

Method

Forty apps out of 229 identified in Study I were selected for the analysis, representing the most reviewed 10 apps in each category (MMA were divided into personal medication management apps and family medication management apps to ensure an equal coverage of apps with varying complexity and available functionality). For each app, 50 reviews were recorded; if an app had fewer than 50 reviews, all available reviews were noted. Only apps from Google Play were reviewed as, due to technical limitations, it was not possible to copy comments from the iTunes App Store application.

During the data collection phase, all reviews were sorted by "Helpfulness" to ensure a mix of positive, negative, new and old reviews was included. Each review was classified in terms of its general sentiment (positive, negative, neutral) and its type (general praise, complaints, comments on functionality, feature requests, other). Codes describing the content were added to each review by the first author and discussed later with the second, although we did not collect a measure of inter-rater reliability, which is typical of many textbook methods [40]. Thematic analysis [6] was used to make sense of the data.

Types of User Reviews

In total, 1,012 reviews were collected. Based on the overall sentiment and the content of a review, user comments were divided into two main groups: general comments presenting users' attitudes towards the apps, and comments mentioning specific functionality. Over a half of the reviews (595 or 59%) fell into the latter category, and these reviews were further divided into descriptions of existing functionality (42% of reviews) and "feature requests" (17%), in which users demanded specific changes or wished certain options were available. The remaining 417 reviews (41%) were general praise comments (e.g. "So far it's worked like a charm!"), complaints (2%; e.g. "Really unhelpful app"), or other miscellaneous comments (1%). As online ratings tend to be skewed towards the extremes and users predominantly post positive reviews [8, 22], comments not mentioning functionality were excluded from the analysis.

User Preferences

Even though feature requests, positive functionality reviews and negative functionality reviews were analyzed separately, the results of all three analyses showed that the most important features and characteristics of a medication reminder app were reliable reminders, customization, good usability and positive user experience.

As medication routines are unique for individuals, reliable and customizable alerts were the most important feature. The customization was especially important for users on complex (multiple medications or multiple doses per day) or irregular regimens (e.g. an oral contraception regimen with Pill-free weeks).

> *"I have one med I take every 3 days, this app had no problem letting me schedule that, other apps did!"* – Review #737

In general, users expected the apps to offer functions that help them with their regimen. Due to their limited functionality, many SMR were seen as lacking and not useful.

> *"Uninstalling. Seems to do nothing more than what I can get my alarm to do. In fact, my alarm is better as I can snooze it if I'm not around my medicine at the moment."* – Review #392

Users appreciated the role of back-up reminders in situations when their routine changed and liked alerts that were visible until they took their medication.

> *"I only take one medication, but on days where my routine changes, I often forget to take it. This app has definitely been extremely helpful. No more non-compliance for me!"* – Review #380

> *"Love this app! I like how the pill icon stays in* [the] *bar until you confirm you took the pill. Never miss my meds!"* – Review #143

Customizable apps also allowed users to select relevant, meaningful and discreet alerts that not only helped them remember and provided notifications appropriate for a given situation, but also protected their privacy.

> *"It's useful and doesn't just flash a message across my screen in an embarrassing way."* – Review #318

Because of the issues with stability, apps were often seen as unreliable. Users frequently complained that apps would sometimes stop working, lost data and the alert schedule after software updates or froze their smartphone. Smaller incidents such as alerts that occasionally did not work or confusing functionality also reduced users' trust.

Conclusions

Results show that functions desired and liked by users tend to be those that support remembering and to some extent could support the individual nature of daily routines: reminders, flexible scheduling, and customization. These are also features mentioned by Silva *et al.* [39] on their requirements list. Reminders in all their forms (timer-based reminders, additional alerts, snooze) help users to take medication on time and guard them against changes in the routine. The ability to customize and schedule alerts in a flexible way could help to adjust them to an existing routine. However, while all these features have the potential to support unique daily routines, they have not been explicitly designed to do so, nor are they able to facilitate the creation of new routines.

DISCUSSION

Both studies show that despite the number of options and varying levels of complexity offered by medication reminder apps, they predominantly focus on the provision of timer-based reminders. In many cases these reminders offer very little benefit to users and as the snooze option is often not available, they do not differ much from SMS reminders or simple alarm clocks available on cellphones. In addition, with only 18% of apps providing customizable alerts, they take a "one size fits all" approach and disregard the fact that medication routines are personalized and unique to each individual; simple timer-based reminders are not able to support them well enough. To be effective, these reminders should combine different modalities, including subtle status bar notifications [4], and allow users to select alert types that suit their needs depending on their capabilities and social context [48].

Currently available medication reminder apps neglect the habitual nature of medication regimens, even though smartphone apps have capabilities to support habit formation and many behavior change apps already do so, e.g. those encouraging physical activity by providing regular feedback [35]. And yet, commercial medication reminder apps do not try to replicate or adapt this approach. Instead, they teach users to rely on technology that is often unreliable and can easily break. As a result, while users acknowledge the role of routines in medication-taking (see for example Review #380 earlier), they do not consider these apps to be a tool that could help them create or maintain daily routines. Users do not see the lack of routine support as a problem, nor do they ask for it in their feature requests, which suggests that they might not be consciously aware of the importance of habitual behavior in supporting medication-taking or they do not expect that technology could address its routine aspect. After all, timer-based reminders are all that is available and all they know.

However, despite their weaknesses, smartphone apps have the potential to successfully support the creation of sustainable habits and to provide additional reminders when needed. Features provided by some AMR and MMA could support daily routines: personalized alerts matching a complex regimen could be incorporated into an existing routine and serve as back-up reminders. Similarly, some apps already offer functions, often in the form of a medication log, that help to establish whether a medication was

taken. While such a log in itself does not actively support remembering, it can reduce omission and repetition errors.

The design of medication reminder apps could be modified to shift the focus from timer-based reminders to a smart routine support. Based on the prospective memory and habit literature and our research findings, we present design requirements for building medication reminder apps that take into account the habitual and personal nature of many regimens, utilize the benefits of a routine behavior, and guard against the dangers of the automaticity it brings.

DESIGN REQUIREMENTS

To effectively support medication-taking and be a reliable system that supports individuals and their habitual behavior, a reminder app should (i) help to create a new routine, (ii) allow users to set up and customize back-up notifications for situations when the routine is disrupted, and (iii) provide a way to check whether a medication has been taken. We now describe each requirement in more detail.

1. Routine Creation

As associating a new task with an existing routine helps to build a new habit [16, 34], the app should suggest pairing medication-taking with an existing routine. This could be done explicitly by asking the user to specify their existing routine or providing a list of examples to choose from; or implicitly by simply letting them know that people in general find it easier to remember their medication when they take it right after a regular task, e.g. eating breakfast or brushing their teeth. As users' preference for customization highlighted in Study II emphasizes the fact that they want to be in control and that routines are unique for each individual, the routine creation should take that into the account and allow them to select a routine event that best fits their schedule and their needs. They should also be able to modify the settings when their daily routine changes.

2. Back-Up Notifications

Back-up notifications guard against changes in the routine and remind users about their medication if their circumstances change. As users value customization and flexible alert schedule, they should be able to control when and how they are notified. They should also be able to snooze their notifications if they are not able to respond immediately. The mechanisms behind back-up notifications could be simple and based on the app usage patterns (as demonstrated later in the Use Case Scenario), or more complex, taking full advantage of smartphones' capabilities, e.g. the app could combine location data with usage trends and provide smarter, context-aware back-up notifications. It could also make use of the user's calendar to anticipate future routine changes.

However, there is a danger that users who are used to timer-based reminders might start using back-up notifications as primary alerts. Thus, these notifications should be subtle or indirect, and designed in a way that will prevent them from becoming the main reminder.

3. Post-Completion Check

The reliance on routines introduces the dangers of automatic behavior and increases chances of omission and repetition errors [3, 12] as users may not remember if they completed the task already. Therefore, users should be able to check whether a dose has been taken. Medication logs in existing apps already provide this option. A back-up notification could also serve as a post-completion check feature: as long as the notification is visible, users know they still have not taken their medication (see Review #143 earlier).

Use Case Scenario

The following scenario describes the use of a hypothetical app based on these design requirements. We use oral contraception as an example of a typical habitual regimen.

Ms. Smith is prescribed contraceptive pills that need to be taken every day at the same time. She downloads and installs the app, and on the welcome screen is asked to enter the details of her regimen. Ms. Smith enters one dose per day and indicates that she wants to take it at 8 every morning. The app then informs her that combining medication-taking with an existing routine supports remembering and, based on the regimen details she entered, suggests she takes the Pill after one of typical morning routine events such as brushing the teeth or eating breakfast (Figure 2a). *Ms. Smith then selects the option that matches her routine: taking the Pill after eating breakfast. Next, she is told that back-up reminders will pop-up approximately an hour after her specified time and that she is able to change the type of the alert. After setting up the app, she puts the blister pack into her bag to have it at hand the next time she needs to take the Pill.*

The next morning, about 30 minutes before the specified time, a subtle message shows up on her smartphone's notification bar, reminding her to take the medication after breakfast, which further reinforces the association between the medication-taking and the daily routine. About an hour later, another, a more prominent notification shows up, asking whether she took her Pill earlier. Ms. Smith can select 'Not yet' or 'I did!' (Figure 2b).

The app registered frequent 'Not yet' responses and after a week asks Ms. Smith if the time of the day is working for her. Ms. Smith has been really busy lately, and as a result she had modified her usual routine and had been buying breakfast on her way to work. If not for the back-up notifications, she would have missed the Pill a couple of times. The app now suggests selecting a new routine, e.g. taking the Pill after brushing her teeth (Figure 2c).

After Ms. Smith selects the new routine, the app starts monitoring the responses again. If the 'I did!' responses are consistent, after three months the app asks how useful the early morning alert is. As Ms. Smith stopped paying atten-

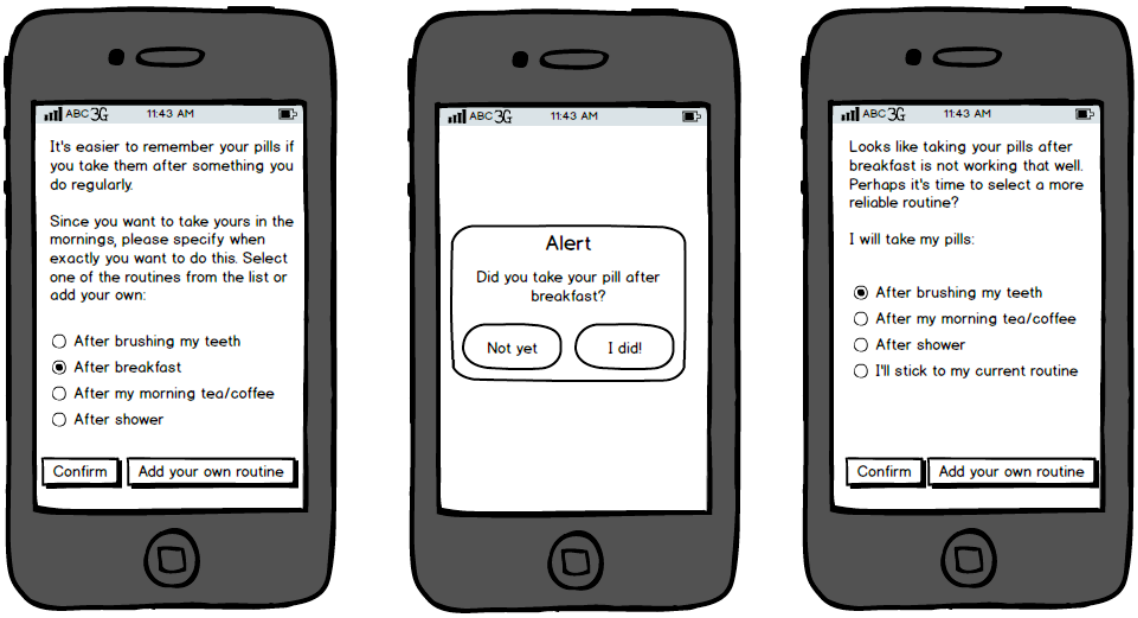

Figure 2. Sketches of a hypothetical app supporting routines. From the left: (a) setting up a new routine, (b) an example of a back-up notification, (c) adjusting the routine to user's behavior

tion to the alert, she indicates that she does not need it. The app then disables the alert and now provides only back-up notifications.

CONCLUSIONS

Forgetfulness is a major, albeit largely neglected, aspect of unintentional medication non-adherence. Even though it can have grave consequences, the adherence research tends to prioritize education and changing attitudes and beliefs over addressing forgetfulness, despite the fact that even motivated people forget.

Due to increasing popularity of smartphones, people have access to a wide range of health apps, including medication reminders aiming to support their memory. The studies we have presented are the first to evaluate medication reminder apps and to highlight weaknesses of timer-based alerts around which these apps are designed. They are also the first to investigate how technology could exploit the habitual nature of many medication regimens to reduce unintentional non-adherence. While the importance of daily routines has already been acknowledged in the treatment for chronic conditions (e.g. [19]), they were only a part of a wider intervention. In the context of preventative therapies, and oral contraception in particular, there are no studies focusing on remembering strategies selected by users themselves or on technology that supports them.

Despite the fact that the habit and prospective memory literature show clear benefits of combining medication-taking with accompanying routine events [16, 24, 34], our studies show that medication reminder apps available for the most popular smartphones do not support the routine aspect of medication regimens, even though they have capabilities to do so, and they often neglect the personal and unique nature of daily routines. To address this disparity between the theory and practice, and to show how the functionality of reminder apps could be extended to provide an explicit routine support and to match users' behavior, we presented a set of design requirements for building smart medication reminder apps. We illustrated them with a use case scenario, which is just one example of many ways in which the elements of a "routine-friendly" medication reminder app could work together to provide a smarter and personalized memory support. At this point the scenario and the app example are a concept that has not yet been fully evaluated. However, they already highlight the difference in approach between a routine-friendly user-centered medication support app and a "one size fits all" app that relies on timer-based reminders. Instead of passively reminding users to take their medication at a specified time, the app could be seen as an assistant that helps them achieve their goal and guides them towards developing a new behavior. The focus shifts from simple reminders that users learn to rely on completely, to a smart assistive technology that helps users to create their own personalized routines and intervenes when these routines are disrupted.

While this approach is best suited to support single dose long-term regimens such as oral contraception, it could be adapted to more complex regimens or even applied beyond medication adherence interventions. Remembering multiple daily doses requires multiple relevant trigger events to support the routine and identifying them might be difficult, especially when the doses have to be evenly spaced. However, understanding patients' daily routines could make it easier to tailor the regimen to their needs and to identify relevant trigger events, which then could be suggested by

the technology. Such smart routine support could also benefit other health-related behavior change interventions that rely on the creation of new habits, such as promoting healthy eating or regular exercises.

Even though more research is needed to understand how explicit the smart assistance should be and how best to implement each component, our example already demonstrates that this new approach is feasible. Current smartphones have capabilities to meet the three requirements defined above and to move from the simplest possible solution, i.e. a timer-based alert, to a more sophisticated technology that takes into account users' behavior and the unique nature of their daily routines. Our research shows that functionality of existing medication reminder apps could be expanded to incorporate the support for personalized daily routines, to add non-intrusive back-up notifications, and to allow post-completion checks. We also demonstrate that by embracing daily routines and the habitual nature of medication regimens, smartphone apps have a real potential to reduce medication non-adherence.

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