A State-Based Medication Routine Framework

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ABSTRACT

Forgetfulness is a primary factor of medication nonadherence, a problem that contributes to worse health outcomes and increased mortality among people with chronic conditions. Common strategies to address forgetfulness, such as timed reminders, have limited effectiveness. However, there is limited information about why these strategies fail. To address this gap, we conducted interviews with people who take medications daily and miss doses at least twice a month. We contribute a state-based Medication Routine Framework composed of four states (Wellness, New Task, Erratic, and Disruption) in two axes (regularity and time scale). Because most nonadherence due to forgetfulness occurs in nonroutine states (i.e., Erratic and Disruption state), we argue that improving technology for medication adherence requires designing for these states. In this paper, we describe each state in detail and discuss opportunities for adapting medication reminder strategies to overcome the challenges of nonroutine states.

CCS CONCEPTS

• **Applied computing** → **Consumer health**; • **Human-centered computing** → **Empirical studies in HCI**.

KEYWORDS

health, medication, adherence

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1 INTRODUCTION

While medications are prescribed as primary treatments for many chronic conditions, people still struggle to take their medications regularly. Almost half of the U.S. population takes prescribed medications [47]. However, behaviors deemed as not adhering to prescriptions (e.g., skipping doses, not getting the medication from a pharmacy [29]) are linked with adverse health outcomes and increased health costs. Over 100,000 preventable deaths and more than $100 billion in healthcare costs per year are attributed to nonadherent behaviors [55].

Mobile devices, such as smartphones, have been used in many interventions to promote medication adherence. Researchers have studied mobile applications, SMS messages, and smart pill bottles as tools to support medication management, with mixed results – around ⅔ of studies report some degree of improvement in adherence [4]. Additionally, hundreds of mobile applications are available for Apple and Android smartphones, several of high-quality [62]. Despite these many intervention studies and the large availability of mobile apps, levels of medication adherence have not improved in multiple decades [17]. Reminders have been shown to significantly improve medication adherence, but effect sizes are limited [15]. In a large-scale survey, respondents who used these reminders experienced similar levels of forgetfulness in comparison with those who did not use them [71]. To date, the most successful interventions included complex combinations of different elements, such as frequent interactions with healthcare providers, but these programs are costly and difficult to implement on a large scale [50]. Therefore, designing technology that effectively improves medication adherence remains an open challenge.

Mobile applications, smart pillboxes, and other tools target forgetfulness, a prominent cause of unintentional nonadherence [13, 78, 86], by providing reminders and tools for tracking medication habits. Healthcare providers also try to reduce nonadherence due to forgetfulness by prescribing simple regimens (e.g., only taking pills once a day) [86]. Due to the limited effectiveness of reminders, researchers have argued that technologies should support users' successful strategies, such as medication routines [70, 71]. However, this approach is unlikely to address routine disruptions, one of the primary causes of forgetfulness [71, 77]. Designing better tools to support medication management requires an in-depth understanding of people's lived experiences of forgetfulness as a cause of skipping medications.

In this paper, we identify unresolved issues with medication management, particularly related to missing doses, by answering the following research questions: 1) What strategies do people use to assist with remembering to take their regular prescribed medications? 2) In what situations do these strategies fail? 3) How do people experience forgetfulness caused by routine disruptions?

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To answer these questions, we conducted an interview study with 22 participants. Based on the results of this study, we present a Medication Routine Framework that represents four different states, or quadrants: Wellness state, New Task state, Erratic state, and Disruption state. Each state has specific characteristics that influence what strategies for remembering medications are most effective. In this paper, we characterize each state, describing what factors can lead a person to shift to a different state and the specific challenges associated with each state. Specifically, we find a lack of effective strategies for remembering to take medications in nonroutine states. Lastly, we discuss how these results reveal opportunities for technology to better support medication management.

2 BACKGROUND

2.1 Medication Adherence

Adherence is a crucial part of health management, defined as "the extent to which the person's behavior (including medication-taking) corresponds with agreed recommendations from a healthcare provider" [61]. The World Health Organization (WHO) declared medication nonadherence a worldwide problem, arguing that "increasing the effectiveness of adherence interventions may have a far greater impact on the health of the population than any improvement in specific medical treatments" [61]. Approximately 40%-50% of people with chronic diseases report nonadherence [39] and more than 30% of hospital admissions occur due to nonadherence to medications [42].

There are several different kinds of behaviors that can be classified as nonadherence [29]. The first is non-fulfillment, wherein the healthcare provider prescribes medication, but the patient does not fill the medication and does not take it [37]. The second type is non-persistence, when patients stop taking medication or discontinue after a certain point of time on their own, despite not being advised to do so by the provider. This type of nonadherence can be either unintentional or intentional. Unintentional nonadherence arises because of multiple barriers, such as forgetfulness, high cost of medication, medication regimen being too complex, fear of side-effects, or difficulty in taking the medication, such as injections [46]. Intentional nonadherence (i.e., choosing not to take medications) occurs due to a lack of knowledge about the benefits of certain prescriptions or the belief that they are not beneficial or needed [37, 46].

Researchers in the medical field have studied various interventions intended to enhance prescribed medication adherence. Randomized controlled trials (RCTs) assessed both adherence and clinical outcomes by continuously supporting patients in managing their medication in a tailored, patient-centric way. Researchers explored individualized interventions and care plans [30], motivational interviewing through phone counseling sessions [56, 67, 83, 88], refill reminders through phone calls [21, 35], counseling sessions with an alarm device [14], consultations using tools supporting goal-setting and self-reflection [80], home-based family interventions by a therapist [25] or trained family member [27]. Researchers investigated the effect of mobile text messages [8, 9, 60, 74, 87], mobile applications [31], remote support [12, 79], and financial incentives [6, 84]. In all of these studies, there was an absence of consistent evidence that could predict improved adherence with certainty.

In this paper, we focus on forgetfulness, one of the main causes of unintentional nonadherence. According to a WHO model, adherence is influenced by five dimensions: socioeconomic, healthcare-related, condition-related, therapy-related, and patient-related factors [54]. Forgetfulness is the most common patient-related factor, as 30-60% of patients claim it as the cause of nonadherence [13, 78]. Other reasons for unintentional non-adherence tend to be socioeconomic or healthcare-related, such as treatment costs and difficulty swallowing pills. Reducing intentional nonadherence requires extensive patient education and patient-provider communication. Although forgetfulness is a well-known cause of nonadherence, most commonly its causes are not explored in detail. For example, research participants are described as missing their medications because they "just forget" to take them (e.g., [13, 40]). Furthermore, existing strategies to address forgetfulness, such as timed reminders, are ineffective. HCI researchers have argued for designing to support the creation of medication routines [70], since these routines are more successful in comparison with reminders [71]. However, forgetfulness has been attributed to routine disruption [77], suggesting that having a medication routine is not enough to address forgetfulness. Therefore, we study forgetfulness in medication nonadherence with the aim of understanding in depth how it is experienced and to find novel opportunities for technological interventions.

2.2 Technology for medication management

Human-Computer Interaction (HCI) researchers have studied medication management practices and designed tools to support this work. Systems often include alerts as reminders and tracking of medication habits, however, both strategies have substantial limitations that reduce their effectiveness. To address these limitations, researchers have argued for different strategies that better align with people's lived experiences.

Researchers have utilized physical systems [3] and mobile phone apps [2] to address medication adherence. Providing reminders through alarms and notifications is one of the main strategies used to address forgetfulness. Researchers used mobile applications with reminders to aid medication management, such as UbiMeds [65], virtual pillbox [10], and MedCoach [41]. More than 90% of free mobile apps for medication management have a reminder feature [2]. Most interventions incorporate alerts and reminders for medication intake at a specified time (e.g., 8 AM) [2, 50, 81], a "one-size-fits-all" approach that does not fit users' unique daily routines [36, 68] and does not account for contexts such as doses that have been recently missed [34]. In the case of short-term treatments, reminders could be effective, but lose efficacy over time [76].

Tracking medication habits is a prevalent strategy for supporting medication adherence. More than 40% of free mobile apps for medication management provide a tracking feature [2]. Specialized devices have been created to monitor adherence automatically, such as smart pillboxes, wearables, and computer vision-based systems [3]. For example, smart pillboxes such as MedTracker [34] and CuePBox [75] use sensors to detect when a pill compartment is opened or closed. There are also several smart pillboxes available commercially, such as Med-Q[1] and MedMinder[2] that include

[1]Med-Q, https://lifesavingpillbox.com/
[2]MedMinder, https://www.medminder.com/

automatic pill dispensers with smartphone integration, alarm, and voice notification. Lee et al. developed dwellSense, a set of sensors that tracked three activities of daily living, including medication intake [44]. The dwellSense pillbox is an example of a passive reminder [20] that supports adherence by promoting awareness of daily habits [7, 32]. Researchers argued that there are shortcomings in tracking medications. For example, Ellis et al. [26] discussed how remembering to fill the pillbox is an additional overhead and can result in abandoning the pillbox altogether.

Designing systems capable of better meeting the needs, context, and preferences of users [22, 48] requires a holistic understanding of how people's existing medication management practices fit into their everyday lives [18, 53]. For instance, Palen et al. [58] described how older adults manage their medication at home, which is heavily dependent on the spatial setting and daily routine, such as frequency or time of visit to certain sections of the house. Furthermore, contexts such as frequent changes in medication, involvement of multiple stakeholders, and lack of proper communication, can lead to confusion and contribute to nonadherence [24].

There is a need for designing context-aware systems that are flexible, personalized, adaptive, and can not only accommodate changing contexts but also account for priorities and diverse needs of users [5, 48]. Prior work has used context-aware approaches to study medication management systems that fit into the context of users' daily lives. For example, as an alternative to timed reminders, Wan et al. [85] created the Magic Medicine Cabinet (MMC), leveraging the use of a frequently visited part of the house, the bathroom, to provide alerts and reminders using face recognition, smart labels, and audio notification. Tang et al. [73] built a multimedia healthcare system (MHS) that was based on a better understanding of patients' situations and preferences to provide adaptive and context-aware prompts. Siek et al. [63] developed an application for managing complex medication regimes that emphasized the importance of the physical aspects of reminders, such as color or appearance of pills, and recommended the use of features such as voice for alerts or relevant images for assisting in medication management. Whereas Slagle et al. [66] created a system to help people identify when to take medications within their daily routines while complying with the medication regimen (e.g., with food; before bed; not within an hour of other medications). Although context-aware systems can help people plan for and remember their medication routines, there was limited support for forgetting medications.

This paper contributes to this body of work by investigating how people experience forgetfulness, a primary factor of medication nonadherence [78, 86] that is not well understood [38, 68]. We present the results of a study on how existing strategies used to remember to take medications, including timed reminders and pillboxes, fail. Our findings reveal opportunities for future research and design to address these issues.

3 METHODS

We conducted interviews with 22 participants who took prescription medications regularly and often forgot to take medications to study people's experiences of forgetfulness as a factor of medication nonadherence. Through those interviews, we sought to understand their strategies to remember to take medications and what caused these strategies to fail.

3.1 Participants

We recruited participants online by posting on social media websites (i.e., Facebook and Reddit) and location-specific platforms (Nextdoor and Craigslist). Posts were primarily shared in groups for people with chronic conditions and whose rules did not forbid this type of content. Volunteers were asked to fill out a screening questionnaire. In total, we obtained 252 answers. The inclusion criteria were: at least 18 years old, takes prescribed medications at least once daily, and forgets to take medications at least once every two weeks. We contacted 41 people who fit the inclusion criteria by email and we interviewed 22 participants. The remaining 19 people either did not respond or did not attend the scheduled interview. Among the people who qualified, we purposefully prioritized contacting people who were underrepresented in the sample in terms of demographics, namely gender, age, and socioeconomic status. We were not able to seek diversity in terms of ethnicity because the screening questionnaire did not collect this information.

Participants' ages, detailed in Tables 1 and 2, ranged from 24 to 73 (median=48). Half of the participants (N=11) were women and half were men. Each person took between 1 and 17 prescribed medications (median=4) and most of them (N=16) took supplements such as vitamins. Most (N=16) took medications more than once a day and 6 participants took medications once per day.

Participants lived across 9 different states in the US East Coast (Connecticut, Massachusetts, Pennsylvania), Midwest (Illinois, Indiana, Iowa, Michigan), and West Coast (California, Washington). Most of them were White (N=15), while the remaining participants were Black (N=2), Latino or Hispanic (N=2), Asian (N=1), or Middle Eastern (N=1). One person did not disclose their ethnicity. Most participants had a 4-year college degree (N=11) or a graduate degree (N=2). Several had a high-school degree or some college credits (N=8) and one person did not disclose their level of education. Most interviewees reported an annual income between 40,000 and 80,000 USD (N=12), and the remaining participants had income above 80,000 (N=6) or below 40,000 USD (N=3). One person did not disclose their income. Most were employed (N=15), while others were retired (N=3), not working due to disability (N=4), or were stay-at-home parents (N=1).

3.2 Data collection and analysis

Interviews were held remotely using video-conferencing software and lasted between 30 and 60 minutes. Following a semi-structured interview method, we asked participants about their medication regimens, how they manage the medications, and in what circumstances they forget to take the medications. For example, the interview script included the following questions: "When do you usually take your medications?" "How important is it for you that you take your medications on time?" and "Do you use something to remind you to take your meds, like an app or an alarm?"[3] All interviews were audio-recorded and transcribed. We also collected pictures from most participants showing where they kept their medications (e.g., medicine cabinet). Participants shared the pictures by email

[3]The complete interview script is available at https://osf.io/ekx8u

Table 1: Demographic information for the research participants, including the number of medications taken and reminder strategies used at the time of the interview. The number of medications includes supplements and other non-prescription medications.

	Demographics				Reminder Strategies			
#	Gender	Age	Education	Medications	Routine	Visual cue	Pillbox	Alarm
1	F	50	Some college	2	✓	✓		
2	M	48	Some college	8	✓		✓	
3	F	53	(no data)	5	✓			
4	M	73	High school	12	✓	✓	✓	
5	M	39	College	2		✓		
6	M	55	College	5	✓	✓	✓	
7	M	43	High school	13			✓	✓
8	F	70	Some college	4	✓	✓	✓	
9	F	28	College	2				✓
10	M	62	College	5	✓			
11	F	55	High school	12	✓	✓		
12	M	24	Master's degree	4		✓		
13	M	30	College	3			✓	✓
14	F	53	College	1		✓		✓
15	F	35	Some college	6			✓	
16	F	48	College	4	✓	✓	✓	
17	M	27	College	2	✓	✓	✓	
18	F	33	College	17	✓		✓	✓
19	F	69	Some college	7	✓			
20	F	50	College	2	✓	✓	✓	
21	M	39	Master's degree	2	✓	✓		
22	M	32	College	2	✓	✓	✓	

in advance and discussed them during the interviews, such as explaining where in the house the medications are kept and why they chose that location.

We analyzed the interview data inductively, following a Grounded Theory method [16]. First, one researcher read each transcript individually to become acquainted with the data. Then, each transcript was coded using an open coding technique, including in-vivo codes. Medication pictures were not coded, as they were used only for supplementing the interview data. A list of codes was created and revised through an iterative process involving comparing different data and reflecting on emerging themes. Preliminary findings were extracted by developing higher-level themes through axial coding and memoing. Then, we used selective coding to organize the emerging themes into a two-dimensional framework. Throughout the analysis process, themes were discussed and refined over synchronous meetings among co-authors. The findings that emerged from this analysis are described in the next section.

3.3 Definitions

We use the following terms to differentiate between similar, but distinct concepts in the paper:

Medication Regimen Instructions on taking medications, as prescribed by a healthcare provider. Example: take twice daily.

Daily habits Everyday life activities that tend to occur at specific times. Example: having breakfast at 8:00 in the morning.

Medication Routine Taking medication incorporated into specific daily habits. Example: taking a pill after breakfast and before going to sleep every day.

The results focus primarily on medication routines. The other concepts are incorporated in the findings to describe how they influenced medication routines.

4 FINDINGS

Participants attributed forgetfulness primarily to being unable to follow a regular medication routine. In this section, we first describe medication management under routine circumstances, in the long-term or short-term. Then, we present the challenges of remembering to take medications under nonroutine circumstances. Additionally, we report on challenges involved in medication management when prescriptions are not taken on schedule. Based on these findings, we present a framework and describe four different states of medication management.

4.1 Routine circumstances

In regular or typical circumstances, medications are organized on a routine. In long-term regular circumstances, a person takes prescriptions continuously following a schedule (e.g., after breakfast). In this context, activities associated with the medication routine

served as cues for taking medications, and several participants also used visual cues as an additional strategy for remembering. Timed reminders were only used by people who took medications three or more times daily. On the other hand, these reminders were the main strategy for remembering to take medications during a short-term routine. In this case, the person was taking a new or temporary prescription and the medication routine had not yet become a habit.

4.1.1 Long-term routine. Most participants who took continuous medication normally followed a medication routine (N=20). Strategies for remembering to take their continuous medications worked best in this context. Participants predominantly used two strategies to remember to take their medications: medication routines (N=15) and visual cues (N=12). Most participants used both strategies, while a few used only one of them.

Medication routines consisted of associating the act of taking medication to another action that the person does daily around the same time, such as having breakfast or going to sleep. As illustrated in the following quote by P6, taking medications with breakfast as a habit serves as a reminder:

> "I try to take my medications first thing in the morning right before or right after I eat [...] since it's part of that process of eating, I always had that as a second part of my routine. [...] It helps me not forget." (P6)

Like P6, most participants purposefully used this kind of association with another activity that is part of their daily routine as a strategy. A few participants described their thought process for associating an activity with the act of taking medications, as explained by P22:

> "I take them [...] before I get ready for bed and it's just it. I can do that and then do all my stuff to get ready for bed. So it's like an easy time to wind down from everything else that I'm doing. I'm not busy with work, I'm not busy with household chores or anything like that." (P22)

As shown in this quote, P22 chose a specific part of his daily habits to incorporate the task of taking medication not only because of timing but also due to his mindset being ideal for it.

In addition to the medication routine, several participants also used visual cues as reminders. To that end, they strategically placed their medication bottles or their pillboxes at a place in their home that was visible. For example, P11 explained that medications were kept on top of the microwave as a visual reminder (Figure 1):

> "They're in the bottles on top of the microwave in my kitchen so I can see them and get at them easily." (P11)

Since many participants used both the routine and visual cues as strategies, the medications were often placed in a visible position for when they were doing the other activity. For example, P20 kept prescriptions beside the coffee maker to remember to take them while making coffee in the morning:

> "I take most of them in the morning. [...] The kitchen counter by the coffee machine, that seems to be the best place to do it so that I make sure it's right there. Like a reminder, it's a nice reminder." (P20)

(a) P9 brought medications to take at her office.

(b) P11's pills on top of a microwave.

Figure 1: Examples of where participants kept their medications.

Participants who used visual cues did not always keep the medications openly visible, like P20. Instead, several people kept their medications in a cupboard or drawer that they would open to accomplish an associated task. For example, P22 kept his medications in a kitchen cabinet that he opened every morning:

> "I know I have to go into that kitchen cabinet every morning to get out my daughters' things for daycare, their lunch bags. Knowing I'll do that, I know all those go in there and see the medication and that's that." (P21)

Both medication routines and visual cues worked consistently well for participants in long-term medication routines. For them, timed reminders were redundant and less effective than the activity associated with the medication routine, as the reminder could ring at an inconvenient time.

In this context, participants who took medications three or more times per day often relied on timed reminders (N=4). For example, P18 took many medications throughout the day and needed the reminders to prevent missing doses:

> "I have labeled alarms on my phone. [...] I have 12 or 15 different alarms throughout the day for my meds." (P18)

Due to the complex regimen, it could be difficult to establish a medication routine without additional reminders. Similarly, P9 took medications three times every day, both at home and at work

(Figure 1). P9 described having timed alarms daily to remember to take them:

> "I have alarms going off at 8, 12, and 4:30. That's like, 'take your medication.' And then I have it with me at all times. I'll keep my medication in my purse. [...] It could be at home, or it could be somewhere else, though they're always with me." (P9)

Overall, the most common and most effective strategies for remembering to take medications were having a medication routine and using visual cues. Timed reminders were not useful, except for those who took medications several times per day. On the other hand, as explained in the following section, timed reminders were the primary tool used for short-term medication routines.

4.1.2 Short-term routine. Participants experienced short-term regular circumstances in two cases: when taking temporary (i.e., non-continuous) prescribed medications or after changes to their continuous medications (e.g., changing frequency or adding a new medication). In both cases, a medication routine would either be inadequate, due to the short amount of time, or it was still being established by the person, hence the need for an external reminder.

Temporary medication prescriptions existed when the person had acute conditions, such as an infection, or was recovering from a procedure, such as surgery. For example, P2 recalled having timed reminders to manage his prescriptions during a few weeks, while recovering from heart surgery:

> "After the surgery, well I was taking medications every four hours. [...] It helped to have the reminders to do that every so often, but like I said, because my schedule has been simplified now where I'm actually just doing it you know, twice a day, it's not a problem." (P2)

As P2 explained, he returned to his previous routine a few weeks after the surgery, and the reminders became unnecessary. Similarly, participants such as P21 used timed reminders as a tool for creating a medication routine. Once the routine was established (i.e., long-term), the reminder was no longer needed:

> "[the reminder] worked well. I did it when I first started taking the medications until it became a habit." (P21)

In addition to timed reminders, we observed other strategies used for managing short-term prescriptions, as illustrated in the quote below:

> "when I do the kids' medication, if they're doing like 10 days antibiotics, I'll mark it on the calendar. [...] [and set a] reminder setting set on my phone." (P14)

The changes in prescriptions that characterize short-term routines were not rare or unexpected for many participants. For example, P15 explained why she took antibiotics for some time most years:

> "I do come down with like bronchitis or something about once a year and so I do get put on antibiotics." (P15)

Due to the short-term nature of the prescriptions, strategies such as medication routines were not effective in this context. Instead, participants relied primarily on timed reminders to remember to take their medications. However, as shown in the next section, none of these strategies were effective during nonroutine circumstances.

4.2 Nonroutine circumstances

In the case of nonroutine circumstances, participants were not able to follow a daily routine. This issue could be the norm for them (long-term) or temporary (short-term). Most participants only reported experiencing short-term nonroutine circumstances. Not following a daily medication routine represents a substantial challenge for remembering to take medications, since all of the main strategies described in the previous section tended to fail. Additionally, we did not observe any other successful strategies for remembering to take medications in nonroutine circumstances.

4.2.1 Long-term nonroutine. For those who had erratic lifestyles, there was an overall lack of regular daily habits, meaning that atypical circumstances were experienced daily. These participants continuously struggled with remembering to take their medications. While they still used strategies for remembering, such as visual cues, the efficacy was limited.

The lack of medication routine and daily habits was usually linked with their line of work. Factors such as frequent travel, different meetings, and timezone differences represented barriers for having regular daily habits. As a result, these participants were not able to create a medication routine and struggled to remember to take their medications. As illustrated by the following quote, P5 specifically attributed forgetting to take medications to the lack of a medication routine:

> "Unfortunately, I don't have a consistent time that I take them, so I end up forgetting a lot [...] I do forget to take it quite a bit. [...] My days are so haphazard, I have meetings and calls and appointments." (P5)

Similarly, P15 lacked a medication routine and was among the participants who struggled with remembering to take medications the most in the study. P15 explained:

> "I often forget to take them. [...] My schedule is pretty... It's not very stable. I kind of do things at different times of the day." (P15)

In this context of long-term atypical circumstances, participants reported using different strategies that could help them to remember to take their pills, however, these strategies had limited efficacy. For example, P5 used visual cues by bringing the pill bottles to work in a backpack. As he explained in the following quote, while this strategy sometimes reminded him, he still forgot frequently:

> "I found that [I'm] a little more consistent if it's in my backpack because I have to open when I get to work and I see it. [...] I think what works the best where I would say I'm like 70% consistent, or 60% so consistent is when I have it in my backpack." (P5)

Participants used similar strategies as described in previous sections. For example, P9 also brought her medications to work in her purse, and several others used visual cues as a strategy for remembering, however, this strategy was much less likely to be successful in nonroutine circumstances.

P5 had also tried to use timed reminders in the past, but the lack of consistent daily habits made finding the best time for the reminder difficult. As a result, the reminders would ring at inopportune times:

> "Even if I get a reminder and I'm in the middle of a call or a meeting, I'm not very good about remembering that later on like an hour later, hour and a half later. [...] I put reminders in my phone but I tend to be in the middle of something when it comes up." (P5)

On the other hand, for P15, the visual cue was only helpful in the evenings. The morning medications were often forgotten, as P15 explained:

> "Because the pillbox is in my room and I get up and I just I leave my room right away in the morning and then forget to take it with me. [...] One thing I know I'm always going to do is go to bed." (P15)

Overall, participants in long-term atypical circumstances faced the most challenges. Only a few participants in the study reported long-term experiences without following medication routines (N=3), but they consistently reported forgetting medications the most often. These participants struggled extensively to remember to take their pills and expressed frustration about this issue. They used the same strategies for remembering as people in typical circumstances, however, these strategies were fallible in the absence of a medication routine.

4.2.2 Short-term nonroutine. Experiencing changes in routine was the main factor that led to forgetting to take medications among people who normally had a medication routine. These changes caused them to shift into temporary atypical circumstances. Their strategies did not work in this case because the disruption caused them not to follow their usual daily habits and not be reminded by the activity associated with taking medications. Visual cues also did not work, mostly because people tended to be particularly busy and distracted because of the disruption. Lastly, alarms did not work well because they would ring at a time when they couldn't take the medicine, either because of being busy at that time or not having the medication with them.

There were a variety of events that could cause enough of a disruption to lead to forgetting, such as having an errand to run, meeting up with others, and even simply weekends. Therefore, these changes in routine were not rare for many participants. They were attributed as the primary cause of forgetting by participants who did have an established routine for taking their medications.

Among those who relied primarily on daily habits or visual cues as reminders, the routine disruption itself led to forgetting. In this case, people either did not follow the same steps they normally would (e.g., making coffee) or did so in a hurry, while distracted. P6 described a recent disruption of routine that led to forgetting due to being in a hurry:

> "The other day someone called me from Pennsylvania at six o'clock in the morning. It was nine o'clock there and it threw off my whole schedule. I was up and I got dressed and ran out of the house, and I was halfway down the street and I said, 'oh, I forgot my medication.' [...] I didn't come back for seven hours, so I was seven hours late." (P6)

Strategies such as timed reminders also tended to fail due to changes in routine. For example, P18 explained that activities such as going to a movie theater disrupted this strategy. The need to silence the phone made the alarm ineffective:

> "If I had to silence my phone for some reason, because that's my main tool for remembering, then I'm very unlikely to remember. I'm in a movie for example. [...] I'm not likely to hear it if it's on vibrate. So now I've told my husband, 'if you wanna go to a movie we can't go during these times because my meds are due.' " (P18)

Often, a change in routine indirectly led to forgetting. Participants thought about delaying their medications when there was a disruption that caused an impediment to their medication routine. Nevertheless, they were likely to forget to take the medications later in the day. For example, P3 described how the side effects of medication caused problems when she had to leave the house. For that reason, she would wait to take the morning medications until after returning home:

> "If I have appointments that morning, then I won't take it just because, for example, the water pill keeps my kidneys flush. So I have to make sure that I have access to a nice bathroom. I don't like using a whole bunch of public restrooms and so forth. If I'm on a regular routine that day, then my pill-taking will be regular. But if I venture out from the norm, then my routine is going to be disrupted." (P3)

When participants decided to take their medications later, such as the example above, they had to rely only on their memory. Although changes in the medication routine were purposeful, and people intended to delay their medications rather than skip them, participants explained how they were much more likely to forget to take delayed medications. In this case, they did not have an established routine or other cues to remind them to take the medication later in the day. In the following quote, P8 talks about forgetting to take delayed medications, the most common cause of forgetting for her:

> "So I [pause] plan on doing it later and then, later never happens." (P8)

Experiencing symptoms of chronic conditions also could lead to forgetting medications, both directly and indirectly. A few participants missed medications because they experienced forgetfulness or lack of energy (e.g., depression). For example, P7 had multiple neurological conditions that affected his memory, making him more likely to forget his medications:

> "I have it [my Apple watch] remind me as well. Even with that and [reminders from] my wife and my son, I still miss. My mind is not exactly where it used to be after all my surgeries and all that, so I forget a lot." (P7)

For P11, a mental health condition made remembering and doing tasks such as taking medications more challenging:

> "I have bipolar disorder and that can be challenging on every single level. [...] It's hard to manage my constant mood ups and downs. When I'm up, I tend to be more on top of doing things like taking medications. When I'm low and I'm depressed, I tend not to care so much about things like that and I let things slip." (P11)

Participants whose illness symptoms interfered with their ability to remember to take medications (N=5) described these disruptions as short-term. It is possible that these issues could also affect medication management for longer periods of time.

Different symptoms led people to delay their medications on purpose. Similar to previous examples, people were more likely to forget to take medications that had been delayed. For example, P18 explained how migraine episodes created several barriers for taking medications:

> "The most likely time for me to forget to take my meds is when I have a migraine because being blind and throwing up is just like... It's not conducive for remembering things. And also because I can't see if my phone alarm goes off. [...] You know, I'm so nauseated and disoriented. Anyway, I tend to just turn it off. And also, if it's a pill that I'm supposed to take, I wouldn't be able to keep it down anyway. [...] But the problem is, especially with the pills, I tend to then forget. 'Hey, I still need to take that.' " (P18)

As illustrated by the examples above, people were particularly likely to forget to take their medications when they experienced atypical circumstances. Among those who normally had a medication routine, there were several different kinds of events and experiences that caused a disruption leading to temporary atypical circumstances. A few participants continuously faced these challenges, due to not having a medication routine.

4.3 Additional Medication Management Challenges and Strategies

4.3.1 Medication Constraints. After forgetting or delaying their medications, participants still faced challenges with taking them, even when they were able to remember later. These challenges were related to constraints or recommendations associated with their medications. Participants discussed how some of their medications had specific restrictions (e.g., must be taken on an empty stomach) that needed to be taken into consideration when deciding when to take the pill. These factors represented a challenge that made deciding on the fly on when to take medications more complicated.

This challenge would arise when they were not able to follow their medication routine. Normally, these factors were already incorporated into their regular routines, not requiring additional thought. Medications that caused drowsiness, for example, were usually taken at night, while those that should be taken on a full stomach were usually taken with a meal. In the following quote, P8 describes her routine of taking a medication that must be taken on an empty stomach:

> "The thyroid medication is supposed to be taken on an empty stomach, and you're not supposed to eat anything for an hour afterward. So typically I'll end up getting up at least once during the night to use the bathroom, so I just put keep my thyroid medication on the counter and when I use the bathroom in the middle of the night, I'll take that pill and I'll just go back to bed." (P8)

However, when there were disruptions to a routine, participants struggled to consider all of these aspects. For this reason, it could be difficult to take their medications later in the day, even when they remembered. In other words, purposefully deviating from the normal medication routine indirectly lead to missing doses.

These constraints could also contribute to a routine disruption. In this case, participants might not be able to follow their regular medication routine because it was not aligned with the constraint. For example, P3 described how she might need to find a different time to take a medication because of the sunny and warm summer weather:

> "It's been very warm lately, like between 85 and 90 degrees [30-32 Celsius] and that also disrupts my routine. Because for example, with high blood pressure medicine you're not supposed to take it when you're exposed to the sun. So you know, I have to take those when I know I'm gonna be inside and air-conditioned and not gonna be outside for an extended period of time." (P3)

Participants whose medications involved these constraints faced additional challenges when they were not able to follow their routine. Even if they did remember the medications, they needed to consider such factors when deciding when to take the medication.

4.3.2 Modifying the Medication Routine. In addition to strategies such as visual cues and timed reminders, participants adapted their medication routines to a time when they were more likely to remember. This strategy was possible because, among those who took medications multiple times per day, many had a specific time of the day when they were most likely to forget the medications.

Participants varied regarding what time in their medication schedule they were more likely to forget. For P11, it was most difficult to remember to take medications in the morning:

> "It's usually... I never forget to take my nighttime pills, but sometimes my morning pills - I get so busy doing stuff in the morning that I'm not sure whether I took them or not. And then I get to about noon and I try to remember whether I've taken them and I can't remember. And I don't want to take an additional dose so I just don't take them and I wait till the next day." (P11)

Similar to P11, several participants described having specific times when they were most likely to forget to take their medications. We did not observe specific patterns because different people remembered more consistently in the mornings or evenings.

To reduce the negative impacts of forgetting those medications, a couple of participants decided to take their most important medications at a time when they took medications most consistently. As P7 explained in the following quote, he and his wife decided to change the timing of a medication to make sure it would be remembered:

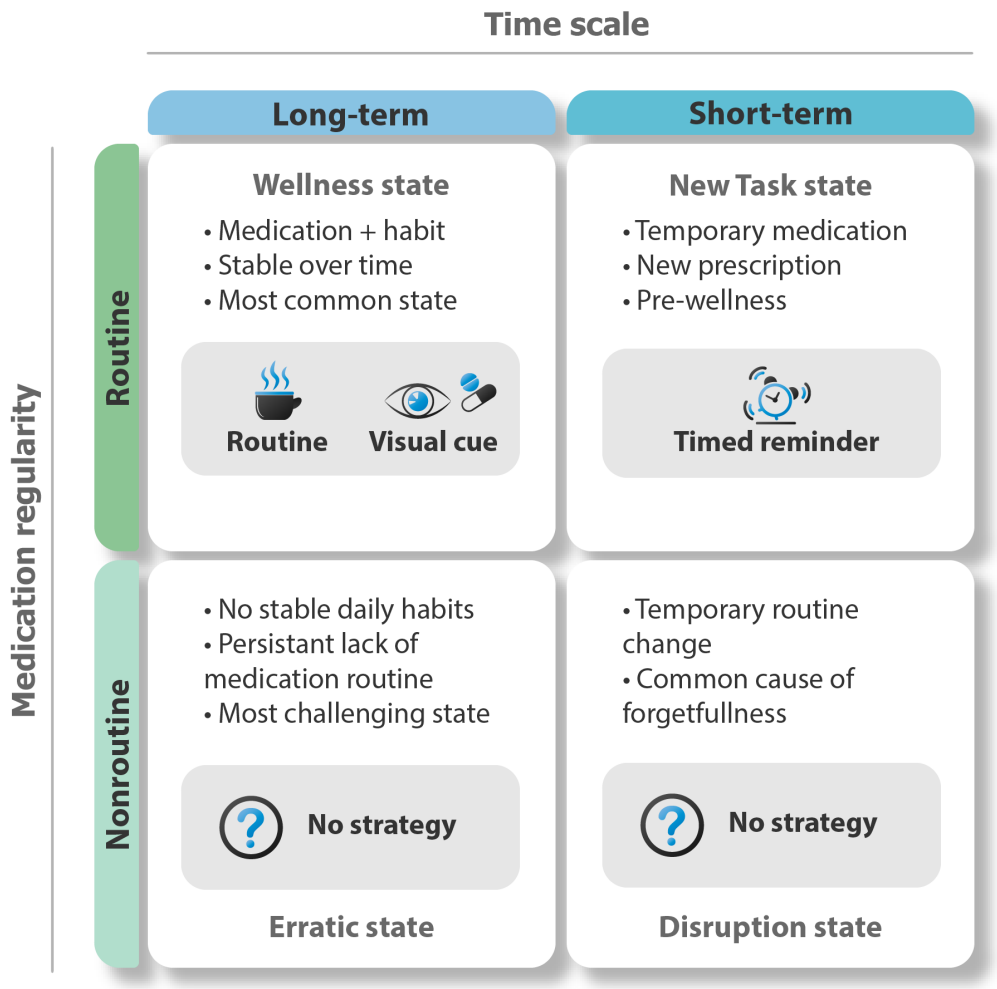

Figure 2: State-based Medication Routine Framework, illustrating its two dimensions: medication regularity (vertical) and time scale (horizontal). The main strategies for remembering to take medications (i.e., common and perceived as most effective by participants) are included in each quadrant. No strategies were described as effective for nonroutine states.

> "Probably a couple of times a week I may forget my noon meds, and that's what concerns me. I don't wanna miss those anymore. We actually had to switch one of the important ones to the morning time because I always take the morning meds. And we didn't want to miss any of those important ones, we actually did switch things around because I was missing them." (P7)

While this kind of change in medication routine did not reduce incidents of forgetfulness, it was a different way that people found to overcome its consequences.

4.3.3 Pillbox. While around half of the participants used a pillbox, this tool itself was not used as a strategy to remember to take medications. Instead, it served as a facilitator for a visual cue reminder and other management aspects, such as indicating *whether* the medication had been taken, remembering to take all of the medications, and making the task of taking pills easier and faster.

For instance, P16 explained that the pillbox was primarily a tool to indicate if the medications had been taken that day:

> "I don't remember if I took my meds that day or not [...] So my kids got the pillbox 'cause they were like, 'Mom, some days you're taking double-ups of your meds. Some days you're going without them.' " (P16)

Similar to P16, participants described various reasons for using the pillbox that were not related to having a reminder. For P2, this tool saved time and effort in comparison with opening several pill bottles:

> "Opening half a dozen bottles of pills every night and morning would be… so unorganized. So it has helped me a lot in just the fact that it's easy, and it's convenient to just have that one box of pills." (P2)

Overall, we observed several different strategies for managing medications to taking them consistently. The most common strategies were having a medication routine, visual cues, and timed reminders. People were most likely to forget their medications when they did not follow a medication routine (i.e., nonroutine circumstances) because their strategies tended to fail. We did not observe differences among participants of different ages or genders.

Participants demonstrated concern about the risks of missing a dose and frustration over forgetting. Several people described the adverse effects of missing medications. Most of the participants had tried multiple different strategies in the past to take their medications more consistently. However, they were not able to find an effective strategy for remembering their medications in atypical circumstances.

4.4 A state-based Medication Routine Framework

This framework is composed of four quadrants organized in two dimensions: medication regularity (routine or nonroutine) and time scale (long-term or short-term). Each of these quadrants represents a state with specific characteristics regarding medication management, including the strategies used as reminders and their effectiveness. The framework is illustrated in Figure 2. Most participants followed a "regular" medication routine most of the time (i.e., Wellness state), and occasionally deviated from it due to new or temporary medications (i.e., New Task state), or due to changes in their daily schedule (i.e., Disruption state). However, for a few participants, a lack of a routine was the norm (i.e., Erratic state).

We call the upper-left quadrant, long-term routine, a "Wellness state" because it encompasses what could be considered the ideal circumstances for the management of continuous medication: there is an established routine and the reminder strategies tend to work well. In this state, the most common strategies were the activities associated with the routine and visual cues. Timed reminders were used less often, most commonly among people who took medications three or more times per day. This state is in the long-term dimension because it applies to people who take continuous medication and are used to their regimen and routine. The routine typically was structured to incorporate medication restrictions (e.g., pills that must be taken while fasting were scheduled for early morning). While most participants in this study were predominantly in the Wellness state, it was not uncommon for them to shift temporarily into other states.

The upper-right quadrant, short-term routine, also involves regular medication routines, but it differs from the Wellness state because the routine is recent or temporary. For this reason, the routine is not established and it does not work as a reminder. Instead, people in this state tend to use timed reminders as strategies to remember to take their medications. In the case of new, but continuous medications, this state also serves as a "pre-wellness" period, when the medication routine is being established.

The lower-left quadrant, long-term nonroutine, reflects the circumstances of people who do not have a medication routine or who are not able to follow their routine for long periods of time. In this state, people experience disruptions frequently and do not have effective strategies for remembering to take their medications. This erratic lifestyle can be due to the nature of a person's profession.

Lastly, the lower-right quadrant, short-term nonroutine, represents the state of temporary lack of medication routine. This issue tends to happen among those who normally are in the Wellness state when they experience disruptive events that affect their ability to follow their medication routine. This state is the most common circumstance that leads to forgetting to take medications. Similar to the previous state, these disruptions cause normal strategies for remembering, such as routine, visual cues, and timed reminders to fail.

5 DISCUSSION

The Medication Routine Framework provides a detailed characterization of forgetfulness as a factor of medication nonadherence and reveals opportunities for design. Specifically, it illustrates how there is a lack of effective tools and strategies for managing medication in nonroutine circumstances. Previous studies have also found that medication routines are common and successful strategies to prevent forgetfulness, but they are rendered ineffective by routine disruptions [71]. Our findings support and extend prior work by providing an in-depth understanding of routine disruptions in medication management.

This work also speaks to different perspectives around medication adherence. Researchers have discussed how medication nonadherence can be framed either as a result of patients' ignorance and carelessness or as informed and purposeful decisions [23]. We illustrate how nonadherence due to forgetfulness is the result of effortful work that is poorly supported and that this issue can be addressed through better technology design.

5.1 Reflections on the framework

The framework presented in this paper has four different states for medication management in two dimensions: short-term or long-term and routine or nonroutine. At the time of the interviews, all participants were in long-term states. Most commonly, in the Wellness state. Still, participants recalled experiencing shifts between different states in specific contexts. Figure 3 depicts transitions between different states, as experienced by P2.

The most common shifts were between the Wellness state and the Disruption state. Typically, participants were in the Wellness state most of the time and experienced disruptions every few days. After the disruption was finished, they would return to the Wellness state.

We also found that people would shift into the New Task state when prescribed a new medication. Then, after incorporating the new prescription into their medication routine, they would shift to the Wellness state. Alternatively, if they were not able to incorporate it into the routine, they would shift to the Erratic state instead. Although we did not observe shifts between the New Task and the Disruption state, such shifts could occur when a disruption takes place while the person is in the New Task state.

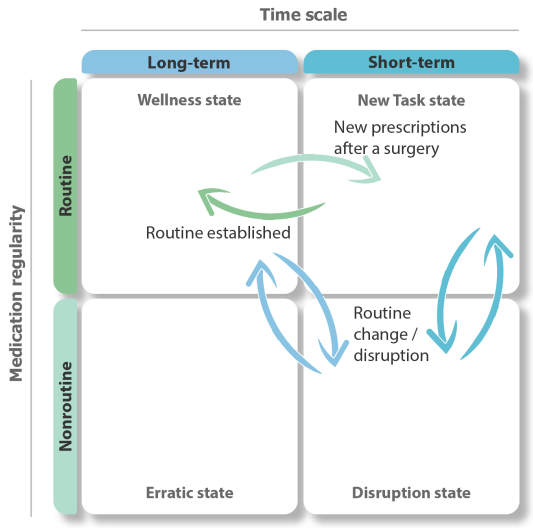

Figure 3: Diagram illustrating state changes in the Medication Routine Framework, as experienced by P2. The shifts between the Wellness state and the Disruption state are the most common transitions among participants.

While the Erratic state was uncommon, it seemed to be the most challenging state for remembering to take medications. We also observed that it is the most stable state since participants rarely described shifting between this state and one of the other states. Given that this state was influenced by external factors, such as professional responsibilities, shifting away from this state likely would depend on these factors. In addition, those in this state would not shift into the Disruption state, given that disruptions are commonplace. At the same time, occasional days when there were no disruptions would still not characterize routine circumstances, given that people in this state did not tend to have medication routines. While important for any person who manages medications, those in the Erratic state particularly needed tools that could support them to remember to take their medications. Those who were in this state might include working single parents, gig workers, students, and people who have multiple part-time jobs. Therefore, supporting medication management for the Erratic state would benefit lower socioeconomic status populations.

5.2 The role of routine in medication management

The framework highlights that medication routines are crucial for taking medications consistently. In alignment with previous work, we find that the habit itself serves as a reminder, and additional strategies for remembering, such as visual cues and timed alarms, are most effective in routine circumstances. Most missed medication due to forgetting happens in nonroutine states. Research in Cognitive Science indicates that routines are successful tools for medication adherence because everyday tasks are easier to remember when they are part of a routine, compared to when they are only timed [59].

These results are consistent with prior work that found busier people tend to be less adherent because they are often otherwise engaged when a cue would occur (i.e., Erratic state) [54, 59, 71]; medications can be missed when there are changes in routine or distractions (i.e., Disruption state) [51, 71]; and medication management is particularly challenging when there are changes in prescriptions (i.e., New Task state) [24, 64]. Researchers have also found that people rely on their daily "temporal rhythm," visual cues, and on the location of the medication as strategies for remembering [33, 45, 57, 71]. Additionally, prior research has found that medication management strategies differ between long-term and short-term prescriptions [71] and between complex and simple medication regimens [45]. While no participant discussed purposefully concealing medications due to privacy concerns, as reported by Palen et al. [57], several people stored their pills "out of sight" in drawers, cabinets, or bags. **Our results support these findings from prior work and extend them by characterizing the four states in the framework and describing how different medication reminder strategies are used in each state**.

Those who have a regular medication routine and are normally in the Wellness state have successfully integrated their medication tasks into their everyday lives. Integrating wellness practices into everyday life is one of the key aspects for current HCI research on technologies for self-care [52]. Researchers have argued for supporting routines by educating users on effective contextual cues [70], as increasing success in self-care routines could result in benefits for self-care. Routines are used for self-care tasks beyond medication management [1], such as exercise and meditation. Disruptions to self-care activities caused by non-health factors have been described as conflicts (i.e., incompatibilities between health needs and personal or professional needs) that are burdensome to address because they require making trade-offs between self-care needs and elements of a person's personal or professional life [11]. Therefore, there is an opportunity for future work to study nonroutine contexts for other facets of self-care and investigate whether elements from this framework also apply to self-care activities other than medication management.

5.3 Supporting medication management in nonroutine circumstances

Our results have revealed a lack of effective medication reminder strategies and tools for nonroutine circumstances. Both the Erratic state and the Disruption state involved similar challenges that contributed to forgetfulness and that were not addressed by reminder strategies. Therefore, we provide a better understanding of factors associated with medication nonadherence caused by forgetfulness, highlighting opportunities for interventions in this space.

Despite their limited effectiveness for nonroutine states, timed reminders are currently the main strategies for addressing forgetfulness. For example, they are primary features of most mobile apps for medication management [68]. We found that they are most effective for the New Task state, and are used in the Wellness state in the case of complex medication routines. Prior work has also argued that timed reminders do not meet people's needs [22] and suggested additional features, such as addressing routine disruptions [68].

Our findings also highlight that forgetfulness is an aggravating factor of intentional nonadherence, in addition to causing unintentional nonadherence. Many participants explained how they forgot to take their medications when their intention was, instead, to take them at a different time than usual. Although intentional, this temporary change in medication routine causes a disruption that makes them more likely to forget. Prior work has discussed how people might need information about what to do after missing a medication dose (e.g., waiting until the next day, taking it as soon as possible) [63, 64]. Providing this kind of information could help in this situation as well since uncertainty about changes from the usual routine might contribute to hesitation and forgetfulness.

We argue for research that focuses on quadrants other than the Wellness state, particularly the Disruption state. More research is needed to understand how to address both nonroutine states effectively. Nonroutine contexts in self-care are not well understood because they are difficult to study. They might not be frequent or predictable. Additionally, potential research participants might have limited availability during nonroutine times in their lives [53]. Still, our results clearly show that addressing this issue would be very impactful for promoting medication adherence and, as a result, improving health outcomes for people with chronic conditions. In this study, most data about nonroutine states were retrospective and limited to short-term circumstances. Further research is needed to investigate people's experiences with nonroutine situations in different contexts. Specifically, studying nonroutine states among underserved populations (e.g., part-time employment with variable schedule) could build on this work to promote health equity [72].

There are several opportunities for researching and designing for nonroutine circumstances. Instead of timed reminders, it should be more effective to design technology that can identify a good time to provide a reminder. Context-aware systems can use data from personal devices and ambient sensors to learn a routine, detect nonroutine events, and find a good time for triggering reminders [19, 38, 43, 48]. Extracting data from calendars could help to identify these periods, since a study found that most calendar events are nonroutine activities [19]. Location can also be used to trigger timely reminders, as users might find it convenient to take medications when they are in the room where they are kept. Additionally, predicting when the person might be in the Disruption state could be useful so the reminder could be provided even earlier than the usual medication routine. This kind of feature could be more effective in comparison with waiting until after a pill was missed. Anticipating routine disruptions could also be used to remind users to prepare in advance, for example, by taking their medications with them when they leave the house to run an errand.

Tracking whether the medication was taken is also important to determine if additional reminders should be activated later in the day. This kind of tracking can be done automatically by smart pillboxes and pill bottles (e.g., [34]) or it can be based on self-reported data [19]. Tracked medication data could also be used to prevent reminders when the person is in the routine state since they could be redundant while still creating a cognitive burden in that case. Because reminders are only triggered when necessary, this context-aware approach might also mitigate known issues of timed reminders, such as losing efficacy over time due to alarm fatigue [76] or serving as a barrier to establishing a medication routine [69].

5.4 Supporting problem-solving in medication management

Our results reveal opportunities for designing to support different kinds of problem-solving related to medication management.

First, managing medication-related constraints is a prominent challenge in nonroutine states. Depending on the specific recommendations or restrictions associated with a specific prescription, a person's ability to take it depends on different external factors, such as meal times and side effects. Taking all of these kinds of information into consideration when designing a medication management system could greatly reduce the cognitive burden associated with resolving these constraints in real time. Slagle et al. [66] have designed a system that supports this process through a 24-hour day planner that highlights appropriate times for scheduling medications in advance. This approach could be extended to create automated reminders for nonroutine states that take into account medication constraints to determine the ideal time for taking that medication in real-time. By combining this kind of feature with context awareness, a system could effectively support medication management among people in the Erratic state who use it continuously. In addition, automating the work of making decisions informed by medication constraints could be applicable in other situations, such as supporting people in the process of tinkering with their medication routines to improve them.

Second, the data collected in medication management systems could be useful for collaborative problem solving involving healthcare providers [44]. Even with context-aware reminders, people might struggle to take their medications at certain times. Tracking medication habits (e.g., using smart pillboxes or calendars [82]) could help to create awareness and identify patterns that could be resolved by updating prescriptions (e.g., changing from taking a pill twice a day to only once). Providing awareness of specific challenges related to following a medication routine could empower patients to communicate with healthcare providers to find alternative prescriptions or regimens that would be more effective for their person's specific needs. This data-driven problem-solving approach could be particularly beneficial for people in the Erratic state to find a routine that is compatible with their day-to-day lives. This approach could follow recommendations from prior work on the use of patient-generated health data during a clinical encounter, such as supporting annotations and providing custom views for different stakeholders [28, 49].

5.5 Limitations

The methods used in this study have certain limitations. Because we recruited participants with diverse chronic conditions, the results reflect broad experiences with medication management. Facets of medication management that are specific to certain illnesses or medication regimens might not be included in the findings. In addition, healthcare providers who prescribe medications are important stakeholders whose perspectives are not investigated in this study. We acknowledge that patients might have challenging experiences communicating with healthcare providers about medications - especially when polypharmacy is concerned. Participants' medication regimens are self-reported and might not correspond exactly with what has been prescribed to them.

The results are likely influenced by participants' demographics and by the recruitment criteria. For instance, the minimum threshold for nonadherence might have excluded participants whose medication management strategies are more successful. This study did not focus directly on the complexity of participants' medication regimens. While we found that more complex regimens do impact states and strategies (e.g., using timed reminders even in the Wellness state), there might be other aspects related to regimen complexity that are not reflected in the results. For example, in the case of polypharmacy, preventing drug-drug interactions could represent additional constraints for medication management. Additionally, the framework is based only on the interview study. Although out of the scope of this paper, we plan to refine the framework in the future based on a systematic review of the literature on medication adherence.

6 CONCLUSION

Forgetfulness is a primary factor of medication adherence. Although mobile technology has been used extensively to address forgetfulness, its efficacy is limited. Aiming to identify actionable novel insights about technology design for medication adherence, we investigated how people experience forgetfulness as a factor of medication nonadherence. In this paper, we introduce a Medication Routine Framework characterizing four states of medication management: Wellness, New Task, Erratic, and Disruption. We describe what medication reminder strategies are used in each state and discuss how a person might shift between different states. We find that most nonadherence happens in nonroutine (i.e., Erratic and Disruption) states. Therefore, we argue that designing more effective contextual systems to support medication adherence requires focusing on these states.

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A APPENDIX: PARTICIPANT INFORMATION

Table 2: Detailed demographic information for the research participants, including the types of medications taken, routines, and cause for forgetting.

Demographics					Medications					Reminder Strategies			
#	Gender	Age	Education	Occupation	#	Prescribed	Other	Routine / Time	Disruption	Routine	Visual cue	Pillbox	Alarm
1	F	50	Some college	Assistant	2	✓	✓	Morning, evening	Distracted	✓	✓		
2	M	48	Some college	Clerk	8	✓		Morning, evening, bedtime	Distracted, illness, not home	✓		✓	
3	F	53	(no data)	Full time job	5	✓	✓	Morning, afternoon	Errands, not home	✓			
4	M	73	High school	Retired	12	✓	✓	Morning, bedtime, meals	Distracted, not home	✓	✓	✓	
5	M	39	College	Marketing	2	✓		Any time	Lack of routine		✓		
6	M	55	College	Manager	5	✓	✓	Morning	Distracted, phone calls, work	✓	✓	✓	
7	M	43	High school	Disability	13	✓	✓	Morning, afternoon, evening	Distracted, illness, not home			✓	✓
8	F	70	Some college	Retired	4	✓	✓	Before sunrise, morning, any time	Distracted, side effects, not home	✓	✓	✓	
9	F	28	College	Insurance	2	✓		Morning, noon, afternoon, any time	Distracted, illness, not home				✓
10	M	62	College	Sales	5	✓	✓	Morning, evening	Distracted	✓			
11	F	55	High school	Disability	12	✓		Morning, bedtime	Distracted, illness	✓	✓		
12	M	24	Masters	Student	4	✓		Morning, evening	Distracted		✓		
13	M	30	College	Software Developer	3	✓	✓	Morning (twice), evening	Distracted			✓	✓
14	F	53	College	Full time job	1	✓		Morning, evening	Distracted, not home		✓		✓
15	F	35	Some college	Clerk	6	✓		Morning, bedtime	Lack of routine, distracted			✓	
16	F	48	College	Manager	4	✓	✓	Morning	Distracted	✓	✓	✓	
17	M	27	College	Analyst	2	✓	✓	Morning, evening	Distracted	✓	✓	✓	
18	F	33	College	Freelancer	17	✓	✓	Morning, bedtime, meals	Illness, not home	✓		✓	✓
19	F	69	Some college	Retired	7	✓	✓	Morning, afternoon, bedtime	Distracted, not home	✓			
20	F	50	College	Homemaker	2	✓	✓	Morning, evening	Distracted	✓	✓	✓	
21	M	39	Masters	Project Manager	2	✓	✓	Morning, lunch, afternoon	Distracted	✓	✓		
22	M	32	College	Teacher	2	✓	✓	Evening	Distracted, not home	✓	✓	✓	