Medication Management Strategies of Older Adults to Support Medication Adherence

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Abstract

Background: Medication adherence is a pervasive problem in medicine; approximately half of U.S. adults do not take their prescriptions as directed. Older adults are a particularly vulnerable population due to the greater likelihood of taking medication and the desire to “age in place.” Home medication management is understudied in older adults, including factors that impact the development and effectiveness of strategies under both routine and anomalous circumstances. This interview study is an exploration into how older adults manage their medication in their homes and what contributes to or detracts from adherence.

Objective: The purpose of this study was to (1) understand how older adults develop medication management strategies; (2) identify strategies that lead to adherence; (3) learn more about how older adults think about their medication; and (4) explore interventions that increase medication adherence.

Methods: This study utilized a qualitative, semi-structured interview design to elicit information about daily routines and perceived barriers to and facilitators of adherence. Participants were recruited through the Osher Lifelong Learning Institute at Tufts University, and interviews were conducted over video conference. Thematic, qualitative analysis was performed by reviewing and coding recordings and transcripts.

Results: Twenty-two participants aged 50 and older were interviewed. Participants reported not receiving guidance about medication adherence from healthcare providers, and instead developing strategies on their own, with more than half (59%) using trial and error. The medication management strategies developed by study participants were all unique. These strategies, for most participants, encompassed their prescription medication as well as any vitamins or supplements they took with no demarcation between what was prescribed or recommended by a doctor or what they discovered independently. Pill cases (77%) were more popular than pill bottles (23%) for storage of daily medication. Most participants (86%) stored their pill cases or bottles in visible locations in the home, and those using pill cases developed unique routines for refilling them. Participants overwhelmingly relied on at least two routines or objects as reminders to take their medication. When nonadherence occurred, it was generally associated with a change in routine, such as oversleeping, receiving a phone call, missing a mealtime, or traveling. Finally, participants varied in how they identified their prescription medications, based on name, appearance, or purpose.

Conclusions: Participants in our study varied considerably in their home medication management strategies and developed unique routines to remember to take their medication as well as to refill their pill cases. While this study was small, the analysis suggests that there are opportunities for providers to provide adherence guidance to older adults, especially when receiving their first long-term prescription or when their regimen changes, and to design better aids to adherence that leverage established daily routines.

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Introduction

Background

Medication adherence—defined as taking medication as prescribed—is a crucial part of aging well. Studies have shown that 50% or more of U.S. adults do not take their prescriptions as directed and that medication nonadherence is responsible for as many as 33%-69% of hospital admissions and 125,000 deaths annually.[1–3] The World Health Organization (WHO) emphasizes the importance of medication adherence, stating 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 treatment."[4]

There is a rising trend in medication nonadherence across all ages, sex, and race groups in the US.[5] The greatest concern, however, is for older adults. According to population estimates by the United Nations World Population Prospect report, 1 in every 4 persons will be aged ≥65 years by 2050 in Europe and Northern America.[6] This represents a doubling in the >65 years population– approximately 9% in 2019 to an estimated 16% in 2050. Aging populations require consistent medication adherence for health maintenance; approximately 67% of U.S. adults 45-64 years of age take at least one prescription drug, rising to 88.5% for those 65 and older.[7]

Older adults are underrepresented in research on medication adherence, and may face some unique barriers compared to the average population.[8,9] For instance, there is a consistently strong preference to "age in place" by older populations, preferring to remain within communities instead of institutional care.[10] However, home settings are associated with medication nonadherence.[8,11] Identifying barriers to medication adherence related to home medication management, specifically related to unintentional nonadherence, may lead to successful strategies to aid older adults.[12] Forgetting to take medication is one of the most common contributors to unintentional medication nonadherence and is particularly relevant for older adults desiring to age in place.[12]

There have been many interventions to aid in individual medication adherence, generally specific to a disease or treatment. Innovation in general prescription packaging, distribution, and education has been limited. Innovations in containers, labeling, and packaging include blister packs, PillPack, and a variety of adherence devices ranging from digital pill containers to dispensing devices.[13–16] Studies have shown limitations to many of these innovations, and, overall, no significant impact on adherence has resulted from the use of simple adherence devices.[17,18] Over 700 digital apps exist as reminders to improve medication adherence, but users often report technical difficulties like schedule inflexibility, since many do not take, or need to take, their medication at an exact time, as well as notification fatigue from daily timed reminders to take their medication.[19] Innovation in containers, packaging, devices, and apps therefore represent potential targets for improvement of adherence.

Another way to address adherence is counseling patients on home medication management practices. Healthcare providers can play an efficacious role in encouraging behaviors to improve adherence.[20,21] External influences such as reduced time for medical appointments and the increased use of mail delivery of prescriptions, necessitating fewer pharmacy visits, reduce opportunities for medication adherence guidance from doctors or pharmacists.

Medication adherence often relies on the development of a behavior that is repeated in response to a trigger, cue, or habit, that fits into a routine.[22] Triggers are actions that are taken or objects that are encountered that can help patients remember to take their medication. Habit formation is a main determinant of behavior change but can take many trials and errors to be established, especially when no guidance is provided by a provider or pharmacist.[23] Habit formation specific to medication is understudied, especially regarding the factors that may impact the development and sustainability of it within the context of both routine and anomalous circumstances.

Objectives

The purpose of this study was to (1) understand older adults' medication management strategies; (2) identify the strategies that lead to adherence and when such strategies fail; (3) explore novel interventions to increase medication adherence. This qualitative questionnaire-based study aims to identify home medication management practices used by community dwelling older adults with simple medication regimens.

Methods

Approach

Based on the results of a survey[24], we planned an interview study to learn in depth about the medication management experiences of older adults in their homes. We developed an interview guide and semi-structured interview process to elicit responses from older adults on their experiences with home medication management, including medication storage location selection and development of medication-taking routines, to characterize which factors positively influence

medication adherence.

The interview guide was developed to elicit information about how older adults manage their medications in their homes as part of daily routines and under anomalous circumstances such as travel. Interview questions asked participants to recount their medication routines and were designed to cover the three components to adherence—initiation, implementation, and persistence—to fully address the stages of adherence.[25] For the initiation phase, participants were asked who prescribed their medications, in what kind of encounter (in-person vs. virtual visit), and how their medications reached them (going to the pharmacy vs. mail delivery). Participants were asked about the extent of their provider's guidance on adherence practices. For the implementation phase, patients were asked about their home medication management practices, including how they administer, store, and identify their prescription medications. They were asked about any vitamins or supplements they take. Participants were interviewed about their daily practice of taking medication, about their strategies for ascertaining adherence, including alarms, apps, devices, and assistance from others, and about any stigma they experienced about taking medication or about visitors to their home seeing their medication. Finally, in the persistence phase, participants were questioned about disruptions in adherence due to disruptions in routine and other factors. Demographic questions were asked at the end.

Participants

Methods: Participants included a sampling of older adults recruited in July 2022 through the Osher Lifelong Learning Institute (OLLI) at Tufts University.[26] Participants were recruited by postings in the weekly email newsletter sent to OLLI members. Inclusion criteria were 50 years of age or older, taking 1-3 prescription medications on a regular basis (as opposed to taken on a short-term or an as-needed basis), proficient in English, and with no cognitive impairment.

Out of a total 22 respondents to recruitment, all consented and participated in the study. Ages ranged from 56 years old to 87 years old (M = 70.5, SD = 6.3 and 18 were female and 4 were male. All participants were white and had a bachelor's degree or higher educational status. All were community dwelling, living in a house or apartment alone or with a partner, and all all lived in an urban or suburban setting in Greater Boston.

Procedure

Semi-structured qualitative interviews were conducted with 22 participants during August 2022. The study was conducted during the COVID-19 pandemic, and owing to physical distancing protocols, all interviews were conducted via Zoom teleconferencing software. The duration of each interview was 30-45 minutes. Consent to participate was obtained at recruitment, and consent to record the interview was obtained at the start of each interview. The interviews were video-recorded and, subsequently, transcribed verbatim and analyzed. Thematic analysis was performed by reviewing and coding recordings and transcripts. Study protocols were approved by Tufts University Health Sciences Institutional Review Board.

Analysis

The aims of the analysis were to explore and understand experiences of the participants; therefore, thematic analysis was chosen as the analytic strategy. Thematic analysis is a qualitative descriptive approach that is used to identify, analyze, and report patterns within data and is useful for analyzing narratives.[27] Not all questions were coded as part of this analysis. For instance all participants reported not experiencing stigma about taking medication or about visitors to their home seeing medication in visible locations.

Results

Sample Description

Five themes were identified corresponding to the stages of medication adherence: initiation, implementation, and persistence.

Theme 1: Participants' Experiences of Obtaining Medications

The first set of interview questions asked participants about who prescribed their medications and how they obtained them. The purpose of these questions was to start the interview with straightforward questions that were simple to answer. An additional goal was to learn if participants received counseling or advice from a physician or pharmacist regarding home management of medications, including where to put them or how to remember to take them.

None of the participants received guidance from a healthcare provider about how to devise an effective medication management strategy. Of 22 participants, over half (13/22, 59%) used trial and error which included trying different locations in the home or trying out a pill case after seeing one in a local pharmacy. Five participants devised a strategy

based on previous experience of helping someone else manage their medication. One participant who devised a strategy based on prior experience stated,

> *"I have managed medications in the past for my mother and aunt, both of whom are deceased, but they had pill cases [which are] pretty common. It seems [like] it's a good organizational tool. I didn't think a whole lot about it [and] went out and got a pill case when I first started having prescriptions." Participant 13*

The remaining 4 participants devised their medication management strategy using suggestions from a friend or family member.

Almost half of participants received prescriptions by mail delivery only (10/22), another 3 used a combination of mail and pharmacy pick-up, and the remaining 9 used pharmacy pick-up only. All but one (21/22) received a 90 day supply of their prescription medication.

Theme 2: Participants' Experiences of Taking Medications at Home

The second set of interview questions addressed how participants manage their medication in their homes. The question that was used to elicit participants' experiences was, "Can you walk us through your daily schedule for taking your medications, specifically when you take your medications and where you store them?"

Variance in medication storage containers among participants

All participants (22/22, 100%) responded with a description of their management practices, all of which constituted unique routines. Only 5 participants kept their medication in the prescription bottles it was received in. The majority, 17 participants, used pill cases to store their medication. Among the 17, there was considerable variance in the type of pill case used including the number of compartments. Seven of 17 participants used one weekly pill case with one slot for each day. One participant had a pill case with morning and evening compartments for each day. Five participants used two pill cases each week, dedicating one pill case to their morning medication and one pill case to their evening medication. Two participants used 2 pill cases each to be able to refill them together for a 2-week medication supply, one of them citing the inconvenience of refilling pill cases and the desire to do so as infrequently as possible. Referring to their pill case, one participant describes,

> *It's kind of a pain to fill so I kind of put it off…but if it's obviously empty [or if] there's maybe one slot to go, I'll say awesome, let's just fill it… I've got some time. -Participant 5*

One participant had a separate pill case for each of their medications, and another participant used a pill case that stored a 4-day supply of medication.

Perception of time in medication management

The majority (20/22, 91%) of study participants took their medication during a time range tied to a routine, such as eating a morning meal, while only a small number (2/22, 9%) reported taking medication at an exact time every day. One participant reported taking her evening medication,

> *Sometime after dinner and before going to sleep. It's probably a two, three, or four hour range there. -Participant 11*

Only a few (3/22, 14%) participants used a digital time-based reminder such as an Alexa or alarm reminder to manage their medication. These reminders were not from medication adherence devices or apps, which were not used by any participants.

Variance in pill case refill

Since pill cases are generally designed with "Sunday" to the left, we expected participants to have a weekend refill routine; instead there was variance in when pill cases were refilled and how participants remembered to refill them. Seven out of 17 participants relied on the visual cue of an empty pill case to refill it, however, this method did not typically lead to them refilling their case on the same day every week. One participant stated,

> *When I get to the point where something is empty, and I say, oh, time to refill. It should be every seven days, but sometimes I might forget. Or I don't know why. But it doesn't always work out to be every seven days. But anyway, whenever they're empty, then they need to be refilled. -Participant 7*

Ten out of 17 participants refilled on a specific day of the week consistently. One described the routine for refilling as,

> *Sunday morning, it's a routine. After breakfast, I drag [my medication] out. I have two different sets [of pill cases]. So I always have one in reserve in the closet with the bottles of the pills. I can easily take [the medication] on Sunday. I don't have to wait till I fill them in order to take pills [since] I already have a set ready. Usually after breakfast or when I have a chance during the day on Sunday, I'll go ahead and fill the one that I've just emptied in the previous week and put it in the closet. -Participant 17*

Variance in storage locations

Participants using prescription bottles only used one storage location for their bottles. Since pill cases need to be refilled, participants using pill cases used two storage locations: a primary storage location for the pill case itself and a secondary storage location for the prescription bottles used to refill the pill case.

Primary storage locations were visible locations in the home for 19 of the 22 participants. The kitchen table was the most common primary storage location(10/22, 45%) and the bathroom counter was the second most common primary storage location(4/22, 18%). For the 17 participants using a pill case, 14 used a secondary storage location that was hidden from sight. The most common secondary storage location was the kitchen cabinet (7/22, 32%), followed by the bathroom cabinet, which five participants used.

Variance in triggers to take medication

All (22/22, 100%) participants relied on at least two triggers to remind them to take their medication. No two medication-taking routines were identical among participants.

Action triggers included eating a meal (10/22, 45%), getting ready for bed (5/22 23%), and brushing teeth (4/22, 18%); object triggers included a visible pill case (17/22, 77%) and a water glass (4/22, 18%). Since the majority of participants stored their medication in a visible area, they could see their medication container as they engaged in a routine; for example, of the 10 participants who took their medication during a meal, 8 stored their pill case or prescription bottle on the kitchen table or counter. Storing their medication in a visible area served as a second trigger, backing up the routine-based trigger. One participant recounted,

> *I have what I call my staging area, which is an area between my kitchen and my dining room. [My medication] stays in the [staging area] and since I take that medication right after dinner it's right there. As I'm clearing the table, after I put the dishes in the sink, I just go and I take the medication right after dinner, and it's visibly right there. – Participant 6*

Some triggers were tactile, not just visible. One participant used the spatial orientation of her pill bottles to manage medication adherence, reporting,

> *I came up with a scheme, where I keep the medicines on one side of my microwave, or my toaster oven. When I take it, I put it on the other side. – Participant 4*

The use of timed reminders or alarms were not common. Only one participant set Alexa to give an oral reminder to take her pill at 10 am every day, one participant used a phone reminder, and one participant used an alarm. None of the participants used medication adherence devices or apps for reminders.

Utilizing multiple triggers for adherence

As mentioned above, all participants relied on at least two triggers to remind them to take their medication, while (15/22, 68%) relied on three or more. One participant who relied on three triggers, taking medication with a meal, using a pill case, and placing it on the dining table, missed the first trigger but saw their pill case which acted as a fall back reminder.

Theme 3: Factors contributing to nonadherence

From the participants' descriptions of their medication management, the use of two or more triggers served as "a safety net" most of the time, providing multiple reminders to take medication. Yet even multiple triggers failed at times. The most common reported reason for medication nonadherence among participants was a change of routine (13), such as missing breakfast, waking up later in the day, or being distracted by a phone call. These events typically led to the absence of a specific trigger. For example, 1 participant who relied on eating breakfast as a cue reported forgetting to take her medication if she skipped breakfast,

> *If I have to go somewhere, first thing in the morning, that's a typical time when I forget. Because sometimes I don't even have time for breakfast or for one reason or another didn't get around to it. Then the next day, it's*

> *Monday, but I'm looking at the Sunday [compartment of the pill] case saying, 'Oh, I guess I forgot to take it yesterday.' – Participant 7*

Another participant acknowledged difficulties when her usual routine is interrupted or altered, reporting,

> *I just got distracted. I was on the phone with a friend. [Forgetting medication is] more apt to happen if I'm with my mom or somewhere other than in my own home because I'm out of the routine, even though I have the pill[s] with me. – Participant 17*

The second most common factor for nonadherence was travel. The 8 participants who reported nonadherence during travel cited reasons that included a change in schedule, not being able to store their medication in the same place, or not having the same triggers in their usual routine available. One participant recalled,

> *I have occasionally forgotten. Frankly, it's when I'm on vacation; even though I have them in the [weekly pill case], my routine is different on vacation. [The pill case is] not in my kitchen on vacation. I'm away at someplace. – Participant 19*

Another participant described how travel impacted her adherence:

> *Frankly, it's when I'm on vacation[that I forget to take my medication] even though I have them in the day of the week pill case. My routine is different on vacation. They're not in my kitchen on vacation. I'm away someplace. -Participant 14*

Another participant reported forgetting to pack his medication,

> *There was one time, I remember, when I left my pills home. So there were like three days where I was not taking the pills. – Participant 18*

Theme 4: Perception of Medication

Participants were asked about how they thought about their medication, e.g., prescription name, pill purpose, or pill appearance. In response to this question, 10 participants thought about it by the chemical name, 8 by the appearance of the pill, 2 by the medication's purpose, and 2 by the medication's generic name. One participant described medications as follows,

> *I can't name the one that I have been taking the longest, which is upstairs in the bathroom. [The medication for] underactive thyroid I just remember by the name Levoxyl. And I've always remembered it. The one downstairs I just recently started and it's a statin. I still don't know what the name of it is. But it's just for cholesterol. -Participant 14*

Another participant described,

> *I know all of them by their generic names. And when they're new, I think about what they're meant to do. But over time, I recognize them by their shape and color. On a day to day basis, I probably look for the shapes. And it really is off-putting when the pharmacy either changes the generic or I change my insurance plan and deal with the pharmacy benefits manager who happens to have a different generic. -Participant 20*

Furthermore, out of the 19 participants who took vitamins or supplements in addition to their prescription medication, 18 of them treated their medications the same, not distinguishing between what was prescribed by a doctor, recommended by a doctor, or something they were taking independent of their doctor. These 18 participants stored their vitamins and supplements in the same pill case as prescription medication, and they integrated them into their medication routine, rather than distinguishing between their prescription medications and their vitamins and supplements.

Theme 5: Interest in Adherence Device

Finally, we described a medication adherence device that used sensors that alerted someone only when they forgot to take their medication. This failsafe device was described as using the same principle as a seat belt, chiming only when you both forgot to latch it and turned on the ignition in a car. The device was described as using one sensor on the participant's prescription bottle or pill case and another sensor on a coffee pot, tooth brush, or another object related to the participant's daily routine. Seventeen of 22 participants were interested in using this device; 12 participants expressed interest in using the device immediately, whereas 5 were open to using the device if their medication routine got more

complicated or they experienced any cognitive decline. One of the those 5 participants talked about the need to use a device in the future, saying,

> *At this point now, I wouldn't [be interested in a device], because I just don't need it. But certainly, if I was struggling to remember to take them or if I had, like some people I know, this very, very complex regimen. So I would be open to it at some point, but not now. - Participant 9*

Out of the five participants who were not interested in the device at all, three explained that they saw no need to change their current routine, and two rejected the idea due to the potential notification fatigue or an unwillingness to use technology for adherence.

Discussion

Principal Findings

The purpose of this qualitative study was to explore the experiences of older adults regarding their medication management. In conducting this study, we realized that we had unwittingly made assumptions about medication management.

Medication management strategies need to encompass how people think about their medication, and not the artificial demarcation of prescription medication. For study participants, medication included prescriptions, vitamins or supplements recommended by physicians, and vitamins or supplements recommended by a friend or another source.

Another assumption we made was that people who use pill cases refill them on Saturday or Sunday, only to learn that refill strategies varied considerably. On a related topic, we had not realized the complexity of medication storage locations, not just for their visibility, but for the need to have primary storage, e.g., a storage location accessed daily for medication, and secondary storage, e.g., storage used for extra medication supply. Finally, the sheer variability in home medication management strategies was surprising and unexpected, especially for participants with relatively simple medication regimens.

Additional results from each theme are discussed below.

Theme 1: Participants' Experiences of Obtaining Medications

All study participants expressed that they received no guidance from a physician or pharmacist on any aspect of home medication management including how to establish a routine to be adherent. Of our participants, 13 out of 22 designed their own medication management regimens. A small number relied on prior experience helping someone else manage their medication or through the advice of a friend or family member. This lack of guidance from healthcare provider presents a missed opportunity to increase medication adherence from a trusted professional.[25] A survey found that 96% of middle-aged and older adult respondents were receptive to receiving guidance from a pharmacist or physician regarding their medication management.[25] This guidance could occur as part of a medication review in a doctor's office or during prescription pickup.

With almost half of participants receiving prescriptions by mail only (10/22), and another 3 using a combination of mail and pharmacy pick-up, and almost all receiving a 90 day supply of their prescription medication, less time is required to be spent in the pharmacy as part of obtaining prescriptions. While we expect that this may decrease the likelihood of running out of medication, it also serves to decrease the need to enter a pharmacy location and therefore may reduce the extent to which an older adult establishes a relationship with a pharmacist or asks questions at prescription pick-up or another time. Less time in the pharmacy may limit opportunities to explore adherence related tools, such as pill cases, which are often displayed next to or near pharmacies in retail stores. Finally, less explored consequences of the rise in mail delivery may be theft, or concerns about theft, and degradation of medicine by extreme temperatures, rain, or humidity.

Theme 2: Participants' Experiences of Taking Medications at Home

Participants described a wide range of routines for taking their medication. Each routine was unique with varying degrees of complexity. Most integrated multiple tactile and visual triggers into their daily routines to prompt them to take their medication each day. It is possible that these adherence regimens are so varied due to a lack of physician or pharmacist guidance. Additional diversity was found in the unique locations where participants stored their medication and the timing with which they refilled them.

When participants described their experiences of home medication management, they included how they stored their pills. Pill cases were the most popular medication adherence device used at home. A possible reason for the high prevalence of weekly pill cases is that they provide direct feedback on whether or not someone took their medication using visual cues. Whether the slot in the pill case is empty or full is a straightforward indicator, unlike a prescription bottle, where users have no way of knowing if they took a pill that day unless they count pills. Weekly pill cases are also the most commonly seen medication adherence tool at pharmacies, though as evidenced by the interviews, the style and how they are used can vary greatly.

The most common primary storage location for pill cases was the kitchen, which was associated with a routine using food as a trigger for adherence. This may be because meal times are generally a stable component of a daily routine. Another possible factor explaining the popularity of a kitchen storage location could be that the participants enter the kitchen to complete specific tasks, as opposed to using it for long stretches of time. This may make a pill case be a visual cue.

Theme 3: Factors contributing to nonadherence

Participants, in describing their medication management strategies, referred to the use of multiple triggers that served as reminders to take their medication. Since triggers failed at times, they may be situated in the context that they occur in: an object or action without its usual context may be less effective as a reminder.

When asked to recount the last time they were nonadherent, participants described a disruption leading to a change in routine in their home or being in a different location due to travel. Since the recounted occurrences are events that are not under the control of the participant, developing a robust medication management strategy should accommodate these anomalies. During a change in routine, a trigger may not be present that is normally relied upon. It may be that more robust routines with multiple triggers endure disruptions better, or more creative triggers that are not disrupted by unexpected events are needed. It may also be that failsafe devices providing back up reminders help most under anomalous circumstances.

Theme 4: Perception of Medication

There was considerable variety in how participants referred to their medication. In our sample, most participants referred to their medication via the chemical name, followed by appearance. The use of chemical names could be a result of a higher health literacy in this sample group, since all individuals had a bachelor's degree or higher. Another factor influencing how people refer to their medication could be the number of medications that they take; it may be harder to keep track of chemical names as the number of medications increase, especially with the complexity of these names.

When pills are similar in appearance, which is the second most common mode of reference people rely on, more concerns arise related to medical error. It is worth investigating the correlation between how people think of their medication with medication adherence and if additional guidance from a physician or pharmacist should emphasize information on the medication name, appearance, and purpose to aid in accurate identification. This is especially concerning if there is a change in appearance due to a move to a new generic or a dosing change when the appearance is relied on for prescription identification.

Most participants thought of their medication as prescription medication, vitamins, and supplements, without categorizing differently what they were prescribed, recommended by a physician, or took of their own volition. Adherence is more critical for prescription medications but strategies to guide patients must address how they think about their medication regimen.

Theme 5: Interest in Adherence Device

Although none of the study participants currently used adherence devices or apps, more than two-thirds expressed interest in a failsafe device to assist with adherence only when needed. Only two individuals showed a lack of interest in such a technology. Additionally, most of the participants lived alone without others to remind them to take their medication, providing an opportunity where an adherence device might be beneficial. Only 1 participant currently relied on a general, as opposed to adherence, technology to assist with medication, in the form of a daily reminder from Alexa; this represents an opportunity for introduction of technology to improve adherence. A lack of current technology use did not deter participants from expressing interest in a device that integrated naturally into their routine.

Strengths and Limitations

Due to participant recruitment through the Osher Lifelong Learning Institute at Tufts University, our sample is not representative of the US Census for adults over 50 years of age. Subsequent studies will be conducted with a larger, more diverse, sample.

Our study participants skewed more educated, and hence they are likely to have higher health literacy skills, yet still experienced difficulties with adherence. A higher level of education is associated with higher socioeconomic status, however, none of the strategies deployed for medication adherence by participants were costly. Many participants were not working full-time or were retired, which may influence their daily routines and their ability to travel. Since most of our sample lived alone, they were less likely to be able to rely on others to remind them. Additionally, our sample size of 22 participants is too small to draw universal conclusions.

Lastly, participants were limited to those taking 1-3 medications and experiencing no cognitive decline. A more representative sample of older adults would need to include those with numerous medications with complicated schedules, and those who are experiencing varying levels of decline, which would add additional barriers to adherence.

Despite these limitations, this study has strengths. The interviews provided an in-depth look at home medication management through the participants' experiences, thus helping to deliver the data presented in this paper. Face to face interviews lasting 30-45 minutes through Zoom enabled us to gain more insight and details than we would have discovered through a survey; in fact our prior survey work led us to design an interview guide to get a deeper understanding from individuals.

Future Directions

Our future work will build on this study. One goal is to create educational interventions that lead to improved adherence under routine and anomalous circumstances and eliminate or reduce the trial and error process used by many. Ideally this would be delivered by providers at the time of receiving a prescription or at the time of nonadherence becoming apparent.

Related to this, and in support of patient-physician communication about adherence, another goal is to develop a scale for home medication management, much like those for medication adherence but focused on home practices. This scale could be used by physicians when prescribing medication to determine how likely a patient is to be adherent based on their current lifestyle, or by pharmacists or family caregivers to provide guidance in developing an individualized medication management strategy.

Another goal is to design and test medication adherence devices that take a failsafe approach to helping older adults live independently longer. Current medication adherence devices and apps rely on time-based triggers rather than routine-based triggers. Our study found that participants managed their medication in the context of a routine yet their routines did not take place at an exact time but rather upon rising or in the morning. Alerts or reminders based on a specific time may be jarring when the routine timing is variable - and even more jarring if the person has already taken their medication yet still receives a reminder to take it. This may result in notification fatigue or in turning off notifications. Thus, we plan to design and test a medication adherence device that reminds users to take their medication only when their current routine fails them. Given the high interest from our participants when asked about this new medication adherence device, this has the potential to support older adults who are aging in place.

Given that study participants' medication management strategies treated prescribed medication the same way as vitamins and supplements, we would like to further explore the implications of this. Home medication management strategies, to be effective, should match how the person thinks about their medication. This should include any medication, prescription or non-prescription, that a patient is committed to being adherent to. Related to how people think about medication is pursuing further the implications of identifying medication by name, appearance, or purpose. The especial concern is if there are transitions due to a change to a generic or in dosing, and the ensuing challenges faced with a task such as sorting pills into a pill case.

Related to this, a future study will seek to better understand the selection and use of pill cases over prescription bottles, and the implications in terms of the ease of taking pills, the impact on remembering to take medication and not taking extra doses, and making refilling more convenient. We plan to further explore, for both types of containers, how to support developing more robust triggers that function both under routine and anomalous circumstances.

A final interest stemming from this study is the influence of home environments. We noted that participants who lived alone could develop a medication routine with substantial triggers with no limitations in terms of where they can place medication. Yet these same individuals lack someone in the home to remind them to take their medication.

Conclusions

The findings of this study provide important insights into the challenges and opportunities of improving medication

adherence in older adults. Based on the findings of our study, participants had self-designed home medication management strategies formed without physician or pharmacist guidance. This represents an unexplored opportunity for improving adherence through patient education delivered by providers or provider discourse with patients. This qualitative study suggests that there are opportunities to improve adherence guidance to older adults, especially when receiving their first long-term prescription or during a regimen change. It further suggests the opportunity to design better aids to adherence that leverage established daily routines.

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Data Availability
The data sets generated and analyzed during this study are available from the corresponding author on reasonable request.

Authors' Contributions
The study was designed by LG, assisted by MR and DW. LG conducted the interviews assisted by MR. The thematic analysis of the interviews was conducted by two authors, MR and DW, who independently replayed the interview recordings and used the transcripts to develop a list of preliminary codes, which were then reviewed by three of the authors, LG, MR, and DW, and collated into potential themes until consensus was reached about the themes. MR and DW selected candidate quotes to illustrate the themes. Finally, three of the authors, LG, MR, and DW, collated the themes into descriptive text and reviewed the chosen quotes to find exemplars for each theme. EM assisted in writing, reviewing, and editing the manuscript.

Conflicts of Interest
None declared.

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