How to Remember What to Remember: Exploring Possibilities for Digital Reminder Systems

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Digital reminder systems typically use time and place as triggers to remind people to perform activities. In this paper, we investigate how digital reminder systems could better support the process of remembering in a wider range of situations. We report findings from a survey and one-week diary study, which reveal that people want to remember to perform a broad spectrum of activities in the future, many of which cannot be supported by simple time- and location-based reminders. In addition to these examples of prospective memory, or 'remembering intentions' [53], we also find that people want support in 'retrieving' [53] information and details, especially those encountered through social interactions or intended for use in conversations with others. Drawing on our analysis of what people want to remember and how they try to support this, we draw implications for the design of intelligent reminder systems such as digital assistants (e.g. Microsoft's Cortana) and smart speaker systems (e.g. Amazon Echo), and highlight the possibilities afforded by drawing on conversation and giving material form to digital reminders.

CCS Concepts: • **Human-Centered Computing** → Ubiquitous and mobile computing; Collaborative and social computing; *Computer supported cooperative work*

General Terms: Design

Additional Key Words and Phrases: Reminders, memory, prospective memory, retrospective memory, digital reminder systems, intelligent personal assistants

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1 INTRODUCTION

Digital reminder systems serve as an aid to help people remember information, or do tasks they may otherwise forget. Remembering to carry out an intended action (e.g. packing a lunch bag at night) draws upon *prospective memory*. Popular mobile digital assistants such as Siri[1], Cortana[2], Alexa[3], and Google Assistant[4] have prospective reminder features and allow users to enter content about activities they wish to remember to perform. Use of these digital assistants is growing rapidly. Recent statistics show the number of people using virtual digital assistants is expected to increase from 504 million in 2016 to 1.8 billion in 2021 [11]. Digital assistants are pervasive, but rely on the user to input when, or where the reminder should be surfaced to them. Designing intelligent digital assistants that can offer reminders at the right places and times and in the right manner (i.e., subtle vs. explicit) is an important component to fulfilling Weiser's vision of seamless and invisible ubiquitous computing technology [66].

Reminder systems are well-suited to helping a person remember an important meeting at 9 a.m. or retrieve a grocery list upon entering a store. Such reminders are, respectively, described as *time-based* and *event-based*, where the activity is associated with a specific time, time range, or event, and research in this area has focused on time and location as cues to remembering [19,65]. However, it becomes challenging for reminder systems to support prospective memory when actions do not have a known time or location, such as remembering to pass on a message the next time one sees a friend. Less research has explored how to broaden event-based prospective memory using digital systems.

[1] https://www.apple.com/ios/siri/
[2] https://www.microsoft.com/en-us/windows/cortana
[3] https://developer.amazon.com/alexa
[4] https://assistant.google.com/

A separate body of work has explored and developed technologies to support *retrospective memory*, which includes memories of past events and general knowledge about the world. While this is distinct from prospective memory, it is also the case that people often try to remember information with a particular goal or event in mind; retrospective memory can be future-oriented. For example, a person might learn some information in order to pass an exam. Furthermore, retrospective memory can be relevant to prospective memory; remembering to pass on a verbal message the next time one sees a friend necessitates remembering the message (retrospective memory) as well as remembering to pass it on (prospective memory).

In this paper, we set out to understand more about what and how people try to remember in everyday life, be this retrospective memory about prior events and information, or prospective memory about actions a person intends to carry out. We report findings from a study designed to identify opportunities for digital reminder systems to facilitate both types of remembering, by investigating the following:

RQ1: What do people set out to remember in everyday life?
RQ2: What do they succeed in remembering, and what do they forget?
RQ3: How is remembering supported? What are the reminders, aids, and strategies that people use?

Findings from 280 survey responses and a one-week diary study show that what people set out to remember is more complex than can be supported by time- and location-based reminders, and reveal a richer set of strategies than digital reminder systems are currently able to support. Specifically, our findings emphasize the importance of information learned in conversation, and routines and behavior patterns, to remembering. Drawing on these findings, we explore how digital reminder systems could be used to more fully support remembering.

2 RELATED WORK

2.1 Memory Types

A large body of work in psychology has shown there are numerous types of memory, but for the purposes of this paper we will focus on two categorizations: *prospective* and *retrospective* memory. Retrospective memory refers to memory of events, people, and words that have been encountered or experienced in the past. Prospective memory refers to remembering to execute some action in the future, such as going to the dentist, and is commonly understood as being *time-based* or *event-based* [13]. Time-based prospective memory entails remembering to perform some action at a specific time or range of times, such as waiting at home for a package delivery service on a certain date. On the other hand, event-based memory entails remembering to do something when a particular situation arises, such as purchasing milk the next time you are at the grocery store.

Retrospective memory is comprised of various memory systems, including *semantic* and *episodic* memory [61]. Semantic memory refers to information about the world, such as presidential terms, state capitols, and names of people. Episodic memory refers to memory of specific events, such as a person's 18th birthday party or the last time they ate a meal with a close friend. Digital reminder systems typically support prospective memory, while a separate set of technologies are designed to support retrospective memory. Sellen and Whittaker [53] highlighted five types of remembering in their critique of 'total capture' approaches to developing memory technologies. 'Remembering intentions' is akin to prospective memory, while 'retrieving' information, 'recollecting' personal experiences, 'reminiscing' about these, and 'reflecting' on past experience all draw on retrospective memory. Sellen and Whittaker argue that rather than recording everything in support of memory (such as by using a lifelogging tool), there is a need to draw on what is known about human memory to create tools that cater for different types of remembering. In this paper, we investigate what people specifically try to remember in everyday life, in relation to both prospective and retrospective memory, and how we might design for this.

2.2 Support for Remembering

While digital reminder systems primarily support prospective memory, a far broader set of technologies aims to support retrospective memory. In this section, we review work in both areas.

2.2.1 Prospective Memory. As already mentioned, digital reminders are one of the services offered by intelligent digital assistants, including Siri, Cortana, and Google Assistant. These tools are most effective at aiding prospective memory when explicit times or locations can be offered as triggers. Prospective memory can also be supported through consumer technologies

such as digital list applications (e.g. Wunderlist[5]) and calendars (e.g. Google Calendar[6]). For example, people may create lists of things they want to accomplish that day, add events they plan to attend to a calendar, or simply save a folder of recipes they intend to cook during the upcoming week. Prior work lists several common external and internal memory aids and strategies (e.g. calendar entries, paper notes, photographs) [28], yet suggests widely used aids may not be the most effective [14]. The creation of more complex cueing behaviors may be supported through apps such as If This Then That[7] or Zapier[8]. Additionally, researchers have explored the use of sensors as prompts for digital reminders. Examples include the combination of motion detection and location to prompt ubiquitous and accessible reminders in the form of text messages [9,27,43,56].

Research has also specifically focused on supporting prospective memory in contexts where forgetting is anticipated. Through a diary study, Ramos et al. [46] investigated the process of forgetting, including how older adults realize they forget information and how they try to avoid forgetting. Although seniors tried using paper-based or location-based reminders to support remembering, and older adults are more likely to perform better at prospective tasks outside of lab settings [47], prospective memory incidents were the most common types of forgetting. The authors highlight the failure of existing digital reminder systems to help seniors with memory needs such as remembering names or facts not associated with a location in one's home [46].

More specifically, many consumer-facing medical reminder systems focus on helping people remember to take pills, a prospective memory task [40,56]. A review of more than 200 medication reminder apps shows that these systems remind people using customizable notifications, which primarily take the form of time-based reminders. This review also indicates that users prefer routine-based reminders, which are poorly supported [56]. This resonates with prior work reporting that spatial *and* temporal cues in seniors' homes are important for how and when they remember to take pills. Findings recommend medical reminder systems should leverage important components of a person's daily routine [27,40]. Indeed, research on systems to support medication adherence is beginning to suggest the importance of routines for improved context-aware reminders for older and younger adults [27,38,54].

2.2.2 Retrospective Memory. A host of consumer technologies also play a role in supporting retrospective memory. These include note-taking systems (e.g. Evernote[9]) and social bookmarking systems (e.g. Pinterest[10]), which help people collect content they wish to remember, as well as photo technologies, which help people capture records of particular moments, and the social networking sites they are used alongside. The latter can also cue remembering by surfacing photos at a later point in time (e.g. Facebook's On This Day feature). Research in this area has prompted the development of Pensieve, a tool that supports retrospective memory through reminiscence [41], and lifelogging cameras such as SenseCam [25]. However, work has also shown that capturing 'everything' is not always the ideal solution. For example, Petrelli et al. demonstrate the value of carefully curating triggers for specific memories when considering what one might wish to remember in the future [42].

Nevertheless, lifelogging tools may have a role to play in supporting retrospective memory by those with memory impairments [53]. For example, captured content can be used to support conversation. Bietti and Castello have shown that asking questions is a form of collaborative recall for family members with Alzheimer's [2], and deployments of Multimedia Biographies [8,55] and Biography Theatre [34] show how the technologies create a shared space for conversation and remembering. Collaborative remembering, where more than one person is responsible for recall, can be a useful approach here. Wu et al. describe interviews and observations with people with cognitive impairments to understand how people with amnesia, which damages the memory system, remember information and tasks [68]. They describe how people with amnesia depend on family members as an external memory aid, which supports existing work on collaborative remembering [2] and shows that families function as important units in the remembering process. However, problems occur with agreement and awareness when group sizes increase. This typically leads to one person in the group taking on the role as the primary organizer and 'knowledge keeper' [31], which can be burdensome and lead to more forgetting.

Taken together, this body of work suggests the importance of routines, spatial cues, and social units in support of remembering, both in the context of the health domain and more generally. It also highlights some of the intricacies of remembering in everyday life [9,43,62]. This resonates with findings from psychology, where research has shown that simply

[5] https://www.wunderlist.com/
[6] https://calendar.google.com/
[7] https://ifttt.com/
[8] https://zapier.com/
[9] https://evernote.com/
[10] https://www.pinterest.com/

creating a reminder or intention to do something is not enough to facilitate completing an action in the future. "Remembering is cued by the environment" [33] and reminders are most effective when they link the cue for remembering to the intended behavior [20,44,45]. In this paper, we aim to complement prior technical work that has explored the use of sensors other than time or place as triggers for reminders [9,27,43,57] with user research that investigates the strategies people adopt in their own efforts to remember information.

3 METHODS AND PARTICIPANTS

We deployed a survey and conducted a one-week diary study to understand more about what people feel they need to remember in everyday life, and how they go about doing so.

3.1 Survey

First, we created a survey, which we deployed online to people over the age of 18 years. In this survey, we asked about aids people typically use to remember information. For more context, we also used a recent critical incident approach [15], asking respondents to describe an example from the past week in which they needed to remember something and used an aid as a prompt or reminder. We also drew on research on transactive processes for remembering, which suggests memory performance may increase with shared remembering, especially for couples [23]. Therefore, for those who were married, we asked if and how their spouses typically help them remember, and vice versa. Lastly, we asked participants to describe how they would envision a new technology that could help with different memory tasks, what features it would have, and which tasks they would want help with most.

280 people in the United States, recruited by a survey panel company[11], completed the online survey (ages 19-82 years old, M = 53 years old, 55.8% = female, 80% = married). While one advantage of working with a panel company is that they can access a more diverse audience than we might be able to recruit on our own, a drawback is that we do not have full visibility into their recruitment process, and do not know how many people they reached out to in order to yield a certain number of responses. However, we did do manual inspection of the responses to identify obvious spam/junk responses and discarded those (these are not included in our count of 280 valid responses).

In the survey, people were asked to recall how they typically remember information, but we also wanted richer data on how people remember in the context of their daily routines. Therefore, we complemented the survey with a diary study.

3.2 Diary Study

We also designed a one-week diary study to capture everyday memory goals, as prior work describes how it is difficult to study external triggers and remembering outside of a lab setting [16]. To recruit participants, we emailed US employees of Microsoft. We also used a database of older adults (65+) interested in Seattle-area research opportunities, to recruit participants from an age group for whom remembering is challenging and who are not well-represented among Microsoft employees. 20 people (ages 19-68 years old, M = 43 years old, SD = 23 years, 13 = female, 10 = Microsoft employees) participated in the diary study.

Prior to starting the diary study, each participant completed a pre-survey. In this pre-survey, we asked participants to reflect on different types of memory by describing occasions when they had to remember episodic, semantic, time-based, and event-based content. They were asked to detail any artifacts they used to help remember this content, artifacts they would have wanted to use, and, if they could recall, aspects of this content that they forgot. To understand the usefulness and potential usefulness of collective remembering, we also asked about any artifacts that belonged to others and social interactions they used/would have wanted to use to remember content for each memory type. Lastly, due to the increase in intelligent reminder systems and the different affordances of technological compared to paper-based artefacts (e.g. storage of large amounts of data and synchronization across platforms), we asked participants to indicate the perceived potential usefulness of an intelligent digital assistant (e.g., Siri, Cortana, etc.) to help them remember information for each memory type using a 5-point Likert scale.

After completing the pre-survey, participants received two brief questionnaires each day for one week. Questionnaires were sent by text message to the participant's cell phone and/or by email, according to their preference. The questionnaire sent

[11] More details about sampling methods from this recruitment panel can be found at https://www.cint.com/quality-standards/

in the morning asked people to describe what task or information they wanted to remember for that day. While the diary study did provide a more natural opportunity to collect data, people may be biased to think of primarily time-based intentions related to health since these are currently well-supported through reminder systems (e.g. medication adherence, fitness goals, and healthy eating goals [19,43]). Therefore, we created a schedule of prompts to trigger a variety of responses. This method is similar to that used in prior studies in which researchers guide the development of intention plans to study prospective memory [33]. We used the following prompt categories:

- **General**: List everything you want to remember today. This could include things to do, events, content about people/conversations, health content, etc.
- **People**: List everything you want to remember related to people and/or interpersonal relationships today. This could include people's names, information about a person, conversation details, etc.
- **Events**: List everything you want to remember related to events today. This could include appointments, meetings, birthdays, etc.
- **Health**: List everything you want to remember related to health today. This could include appointments, medication, healthy eating, etc.

MORNING		
Entry 1 (General)	Entry 2 (People)	Entry 3 (Events)
- Take my Groupon when I go to Novilhos at 6:30. - Ask Amy about their wedding gift from Karen and about airport transportation in September. - Contact Hal about Tuesday night. - Tell TJ happy birthday. - Place OTC order from Humana.	I want to remember the names of the people I need to speak to about transferring colleges, the list of steps I need to take to register for classes, and the time of my meeting with the breeder I'm buying a hedgehog from.	- Meeting with director - Pay mothers' bills - Pick up meds at pharmacy - Return shoes - Call and confirm Thursday event
AFTERNOON		
- I placed my OTC order from Humana pharmacy. - I left a message for Hal. - I asked Amy about her wedding gift from Karen. - I discussed airport transportation for September with Amy. - We had our dinner at Novilhos and used the Groupon. - I talked with TJ and wished him a happy birthday.	I remembered the names of the people to talk to	- Meet with director - Pick up mother's medication at Pharmacy

Table 1. Example morning and corresponding afternoon entries from participants' diary study responses

Since the diary study took seven days, participants received morning surveys with prompts for general, people, and events categories twice, and for the health category once. The varied prompt topics allowed us to gather diverse responses in a short time frame. However, we acknowledge that we asked participants to recall information from a limited set of categories and certain types of information may be overrepresented in their responses (e.g., events may be represented more than health). Asking them to recall information in the 'general' category is meant to serve as a catch-all and provide the opportunity for participants to describe information outside of the people, health, and events categories.

In the afternoon, our prompt asked participants to recall what they remembered to do from the list they created in the morning, and any aids they used to help remember this information. While we asked participants to refrain from using any external aids (e.g., post-it notes or written lists) to enter what they had completed, we were unable to verify compliance. We also asked participants to describe why they didn't complete a task or item listed earlier in the day to understand if non-

completion was due to tasks/information needs persisting longer than one day or due to forgetting. Lastly, we wanted to understand memory needs outside of day-to-day tasks, so we asked participants to describe information they would like to remember in the distant future. Out of the 280 questionnaires sent (2 questionnaires per day x 7 days x 20 participants), 246 were completed (87.8%). In Table 1, we provide examples of three representative diary study entries.

Both the diary study and survey are an effort to move beyond much of the prior work in this area, which in terms of the role technology plays in facilitating prospective memory, has tended to focus on medication adherence by older adults. The survey is free-form, allowing respondents to draw on events from any time in the past, while the diary study encourages participants to focus on what they want to remember to do that day, and what they were able to accomplish. We recruited diverse participants and explored a range of aims and strategies in relation to prospective and retrospective memory. We gathered detailed accounts through the diary study, and complement this with a larger and potentially more representative dataset collected through the survey. While both methods have their trade-offs, by combining the two, we hope to have gained a rich and holistic picture of what people try to remember and how they attempt to support this.

4 RESULTS

Below we report jointly on the results of the survey and the diary study, because common themes emerged across both. We used thematic analysis [4] to analyze the daily questionnaire responses and survey responses from participants. One researcher analyzed survey and diary study responses and identified clusters of similar concepts through open coding. To ensure quality of the data analysis, all researchers iteratively discussed and refined the themes through axial coding, which ground our findings and discussion of what people want to remember and the aids and strategies they use in support of this. We specifically highlight challenges participants identified using aids to remember time- and event-based information, difficulties in remembering information about people, use of memory aids and the generational differences we found here, and the importance of remembering for relationship development and knowledge sharing.

4.1 What did Participants want to Remember?

Participants indicated they wanted to remember many different types of content, in support of both prospective and retrospective memory. In this section, we draw on findings from the diary study especially to highlight challenges associated with time- and event-based prospective memory, personal goals, upcoming intentions, and retrospective memory.

4.1.1. Time-based Prospective Memory. Participants described wanting to remember to perform actions at specific times, such as the need to attend a "*teleconference at 1:00*" or "*a meeting at 3 PM to discuss future internship opportunities*". For these participants, calendars supported remembering to meet with their co-workers. However in other cases, creating a reminder with a calendar application was not sufficient. For example, one participant wanted to "*Make appt for cat grooming, follow up on case notes for damaged products, follow up on resolution of technical bug in website*". However, when asked which tasks were completed in the afternoon survey, she said "*None. I had a crisis at work to deal with and all my head plans went out the window*". She used Outlook to input these tasks but said, "*Task reminders on Outlook were ignored ... easy to do ... just don't log in to Outlook".* Calendar notifications cannot serve as reminders if a person does not turn on or use the application or device, or ignores the notifications. While the solution to this is clearly not to interrupt the user while they are dealing with a crisis, a way of revisiting and rescheduling reminders at a later point in time would be useful here.

Another issue with systems that rely on calendars is that some time-based tasks are difficult to express. For instance, when the time refers to a deadline, it is more difficult to set a timely reminder. As an example, a morning entry saying, "*I need to drive Don*[12] *home by 3 pm*" indicates a need for a reminder before 3 p.m., and perhaps when some other event occurs, such as the traffic being light enough to get to the destination on time. Other instances include "*finish ballot and mail by 5:00*" and "*do a short meditation sessions [sic] before going to bed*". Again, the latter example contains time- and event-based content, bedtime being temporal but also dependent on other events. This participant later reported that he "*didn't do a sufficiently long stretch as I got home late. Will actually do a short mediation before going to bed (not as long as I'd like to though). This is mainly because I got back home significantly later than usual*". This data extends previous work, which has described the challenge of storing reminders with imprecise timings [49], by highlighting additional complexities, including the need for digital reminder systems to cater for time-related reminders that relate to deadlines and that are conditional on other occurrences.

[12] All names have been anonymized to protect the privacy of participants.

4.1.2. Event-based Prospective Memory. In addition to wanting to remember to perform actions at or by some moment in time, participants also reported needing to remember to do something when some other event occurs, such as remembering to "*go to the gym at the [university name] when I get home*". The gym is the primary location here but going there is conditional on going home, perhaps because the participant needs to retrieve something or complete a task before leaving. Another example is "*remember to bring my clothes to work, so I can go bouldering afterward".* Again, bouldering will only happen if the participant remembers to take his clothes as he leaves home. Participants tended not to use calendars in cases like these, and this participant later reported, "*I remembered when my friends messaged me to go rock climbing*". The difficulty of remembering in instances like these is perhaps exacerbated by the fact that there is no obvious connection between the tasks (leaving home and going bouldering), and that they require doing something differently (this person does not always take his bouldering clothes when leaving his house).

4.1.3. Goals. Participants also wanted to remember to perform activities relating to more general personal goals. For example, P8 wanted to remember to "*chew the food sufficiently*" and P2 wanted to remember to "*drink three glasses of water".* While these examples have both time and event components, they are not linked to any one event. For example, P8's goal of thoroughly chewing food relates to meal times in general, and P2's goal of drinking more water presumably relates to a time frame but is not attributed to a specific moment within that range. Again, this raises challenges for reminder systems: these are persistent goals that may require recurring reminders, but designing these so that they are delivered in a timely way and so that the user does not habituate or become irritated by them is difficult, especially if they recur on a daily basis.

4.1.4. Upcoming Intentions. Many of the examples discussed so far relate to prospective memory in the very short term, but participants in the diary study also described what they wanted to remember further afield. Examples include wanting to remember to contact or meet with people, or to buy birthday gifts. These are not linked to a time or event, although they may come to be so later, as more concrete plans are formed to carry them out. This suggests a need for reminder technologies to support different phases, from loose intentions to the addition of precise timings and the building in of contingencies as the possibility for action becomes more likely or relevant.

4.1.5. Distant Retrospective Memory. While most instances in the diary study (45.3%) relate to remembering during the upcoming month, almost a further third (31.4%) describe the wish to remember something between one and ten years from the study. These examples tended to refer to retrospective memory; participants encountered people or situations that they did not want to forget, such as P7, who wanted to remember "*the contact info of a lady I met who I'm pretty sure is going to be pretty high up in the company in a few years*". In some cases, participants specified when they wanted to draw on these memories (for example, P20 wanted to remember "*great soccer skills [she] observed*" to discuss at the next family gathering), but in others the value is emotional rather than functional [53]. Examples come from P4, who wanted to remember "*previous conversations with my grandmother [and] biblical stories around Moses…*", and P14, who wanted to remember "*the inquisical [sic] nature of [his] grandsons*". In cases like these, it is not clear how, when or even if remembering should be explicitly prompted; rather, the desire seems to be to avoid forgetting as time passes.

4.1.6. Information from Social Encounters. There were also some short-term and pragmatic examples of retrospective memory in the diary study, being exemplified by P7's need to remember "*where I parked my car*". However, the overriding theme in examples of details to be remembered in the near-term was the problem of recollecting information exchanged in conversation. Diary study participants faced challenges remembering what others had said to them ("*One of my colleagues in the class reached out to me a few days before asking a question about the project but I still ended up forgetting about this*" (P5)) and details that they might wish to draw on in future conversations, such as "*their children's names and ages*" (P13). Some of the challenges here seem to relate to remembering information that is delivered as part of a social interaction, which may move onto other topics, and which is difficult to revisit or capture once the moment has passed. As one survey respondent noted, attention is as important as memory here: "*I remember what I pay attention to. If a technology would elbow me in the ribs when someone was telling me something important, I'd remember it. I don't have a problem with forgetting, but I have one with thinking about something else when I should be paying attention*".

4.1.7 Summary. In this first section, we have highlighted some of the needs and challenges associated with remembering. Our findings highlight how prospective memory must accommodate deadlines, dependencies, persistent goals, and upcoming intentions; how retrospective memory in the long-term is important but rarely connected to specific times or places for remembering; and how difficulties are associated with retrospective memory of information gained in social encounters. Next, we describe how people use aids and strategies in support of these.

4.2 How is Remembering Supported?

Aid type	% that typically use to remember (n = 280)	Younger adults (n = 149)	Older adults (n = 131)
Digital calendar	65.70%	58.9%	77.1%
Paper list	62.10%	63.1%	64.9%
Paper calendar	53.50%	54.6%	55.7%
Post-it note	50.0%	54.6%	48.1%
Timers	48.50%	58.9%	40.5%
Ask a person	40.70%	49.6%	33.6%
Digital list	37.80%	31.9%	46.6%
Specialized objects (e.g. pill storage boxes)	24.20%	14.9%	35.9%

Table 2. Memory aids reported in the survey and the percentage of participants that used them

Across the survey and diary study, participants reported using a variety of aids to support remembering. Findings from survey respondents, who were asked to indicate which mechanisms they currently rely on, show that digital and paper calendars, paper lists, and post-it notes were used by over half the sample (see Table 2), with digital calendars used by the greatest proportion of respondents, and paper lists and paper calendars also being used by the majority of participants. Notably, these data suggest that digital reminder systems are popular for both older and younger age groups.

To explore whether using one of these memory aids in a digital or paper format is associated with use of the other, we analyzed the relationship between digital and paper calendars and lists using Spearman's correlation coefficients. We found statistically significant, although weak, correlations between using a digital list and a digital calendar, and using a paper list and a paper calendar, suggesting that respondents may be inclined to use a class of tools (digital or physical) more so than mixing and matching (see Table 3).

	Paper list	Digital list	Paper calendar
Digital list	$r_s = 0.03$, $p > 0.05$	-	-
Paper calendar	$r_s = 0.29$, $p < 0.001$	$r_s = -0.13$, $p < 0.01$	-
Digital calendar	$r_s = -0.08$, $p > 0.01$	$r_s = 0.31$, $p < 0.001$	$r_s = -0.16$, $p < 0.01$

Table 3. Spearman's correlation coefficients for use of paper- and digital- lists and calendars.

We also looked at these relationships separately for people aged 65 and over (n = 131), and those younger than 65 (n = 149). Prior work indicates that older people face more difficulty holding multiple events in prospective memory [12], and it seems possible that cohort effects could result in differences between these groups, although trends in our data indicate that a greater percentage of adults aged 65 and over in our sample used digital calendars and digital lists than those aged below 65 (see Table 2). Spearman's correlation coefficients indicate statistically significant moderate relationships between use of paper calendars and paper lists, and between use of digital calendars and digital lists, for survey respondents aged 65 and over, as well as a statistically significant moderate negative relationship between use of digital and paper calendars (see Table 4). These

	Paper list	Digital list	Paper calendar
Digital list	$r_s = -0.01$, $p > 0.05$	-	-
Paper calendar	$r_s = 0.43$, $p < 0.01$	$r_s = -0.18$, $p < 0.05$	-
Digital calendar	$r_s = -0.21$, $p = 0.01$	$r_s = 0.25$, $p < 0.01$	$r_s = -0.30$, $p < 0.01$

Table 4. Spearman's correlation coefficients for use of paper- and digital- lists and calendars for participants aged 65 and over.

	Paper list	Digital list	Paper calendar
Digital list	$r_s = 0.06$, $p > 0.05$	-	-
Paper calendar	$r_s = 0.16$, $p < 0.05$	$r_s = -0.09$, $p > 0.05$	-
Digital calendar	$r_s = -0.01$, $p > 0.05$	$r_s = 0.32$, $p < 0.001$	$r_s = -0.07$, $p > 0.05$

Table 5. Spearman's correlation coefficients for use of paper- and digital- lists and calendar for participants aged under 65.

results suggest that members of this group who use a digital or paper system may use it for both calendars and lists, and that they may use either digital calendars or paper calendars, rather than relying on both. This may indicate the difficulty of maintaining multiple calendars. However, the different affordances of paper and digital systems do provide different benefits, and it is worth considering how systems could sync content across modalities (for example by using e-paper to create a persistent visualization of a digital calendar in the home), depending on context of the information to be remembered. Much weaker relationships are found for participants under the age of 65, with the exception of the statistically significant moderate correlation between digital calendars and digital lists (see Table 5), which suggests that members of this group who use a digital system may use it for both calendars and lists.

Having looked at overall patterns of memory aid use, we now look at the most salient categories, to highlight the ways in which they were used and the challenges associated with them.

4.2.1. Calendars. 47 survey respondents described using digital calendars to remember appointments during the week before the survey, giving examples like "*Outlook calendar with a 24 hour-prior alert to take car into shop for repair*" or "*I have medication that has to be taken every two weeks. I have my online calendar and the drug manufacturer send me reminders*". Some participants used multiple calendars, with one diary study participant reporting use of a paper calendar to supplement her digital calendar: "*All appointments are on my Google calendar, and on a purse-size paper calendar as well*". Where problems arose with calendars, it was often because participants forgot to refer to them. A diary study participant described needing to remember to pick up her dog from her husband's office. She "*had written it down in [her] calendar but forgot to look at that*". Digital calendars were noted for the possibility to create recurring reminders or notifications, although we have seen how these too can also be ignored when people are busy.

4.2.2. Lists. Use of paper was especially prevalent when it came to creating lists. A greater proportion of survey respondents indicated using paper lists than digital lists, and the diary study also highlighted the use of paper lists, with 16 participants describing how they had used these for multiple to-do tasks or to remember to purchase items. One participant said, "*I have to compile a written paper grocery shopping list at home before I can go shopping or I will forget everything*". In contrast, only five diary study participants had used a digital list to remember something within the past week. While paper cannot deliver notifications, it is perfectly adequate when creating lists with a short lifespan (one-time events for tasks that occur soon), and it may be easier to do this than create a digital list that would serve the same purpose.

It's also worth noting here that diary study participants described how the act of making a list of things they needed to remember as part of the study aided remembering what to do during the day. For example, P15 said, "*Listing everything I wanted to remember in the morning survey was like making myself a to-do list. Since it was Saturday I set out to accomplish those things as soon as I was done with the survey*". Similarly, P19 said, "*writing the list this AM helped me remember to fill vitamin box".* Although this was unintended, participants' responses validate previous research that describes how lists (e.g. shopping and to-do lists) are artifacts that are also important external memory structures [3].

4.2.3. Placement of Objects. Using specific objects as aids to memory was reported by just under a quarter of survey respondents, and seven diary study participants used an artifact to help them remember something. For example, one survey respondent noted, "*I needed to call my Credit Union ...to remember, I placed the physical file concerning credit union matters on top of my keyboard*"; another survey respondent said, "*had to take my mom to church the following morning so I wrote a paper note and set it on my desk the previous night where I would see it 1st thing in the morning*"; and a third mentioned, "*left the appointment card or a written list by my coffeemaker so that I would remember in the morning*". Others described using physical items such as keys and sponges; with one participant putting "*a sponge on my desk to remind [him] to take clothes out of the washer*". This sponge was put in a high-traffic location to prevent forgetting, strategic placement being a common theme in these accounts. Computers or desks, the kitchen, front door, bathroom mirror, or with car keys were the most frequent

locations used by survey respondents for visual reminders, so that they would encounter them during their daily routines. Placing content in this way was also used when other memory aids had failed. One survey participant reported, "*I needed to remember to send an email to request an action. I had the address on a sheet of paper so I took it out and laid it on top of my laptop. I'd forgotten to do it the past two days. I think I was embarrassed with myself for forgetting* [sic] *it and that helped me to pay attention and do it...".*

4.2.4. Collaborative Remembering. Prior work highlights the effectiveness of collaborative remembering strategies [22]. We saw some examples of participants effectively organizing use of memory aids with others, such as a survey respondent who described how his wife helps "*by insisting I write appointments and tickets for concerts, etc. in a big calendar we hang in the kitchen. Sometimes I forget to look at the calendar and she reminds me when she looks at it".* However, in other cases participants forgot content for others, or found that others were unable to remember on their behalf. One participant noted, "*I usually forget everything that my wife tells me to remember*"; a survey respondent wrote "*I asked my wife to remind me about my dentist appointment... She forgot too*"; and a diary study participant described relying on her grandson to remember what they needed to purchase, but she still forgot to get an important item: "*I relied on his memory for the tech things we were looking at but I should have made a grocery list ... I remembered most of the things we were going to get at the store but forgot the ice cream! Who forgets ice cream ???*"

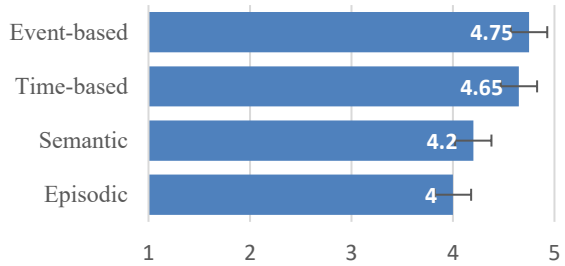

Figure 1. Mean perceived potential usefulness of a digital assistant to help people remember different types of information, according to diary study participants (n = 20), where 1 = not at all useful and 5 = extremely useful

4.2.5. Digital Assistants. Digital assistants were not one of the memory aids that came up in the survey or diary study. However, diary study participants were asked to rate on a 5-point Likert scale how useful they thought it would be to have an intelligent digital assistant to help remember different types of content (Figure 1). Participants rated this very highly for event- and time-based prospective memory, and also saw value in having an assistant support retrospective memory of information and events in their lives.

4.2.6. Summary. In this section, we have described aids and strategies that participants used to support memory. Our findings indicate the usefulness of creating recurring reminders and notifications through digital calendars, and of being able to quickly create paper-based lists. Material things, including specific objects, paper lists, and post-it notes, also have the advantage that they can be strategically placed, prompting memory at the appropriate moment when encountered as part of one's daily routine. We've described how collaborative remembering can work but is also subject to failure when people forget to consult or record relevant information. Finally, we've shown that participants are open to the possibilities offered by digital assistants, despite the low prevalence of use of these in the sample. In the next section, we look at the importance of remembering.

4.3 Why is it Important to Remember?

Needless to say, memory is extremely important in daily life. Remembering what needs to be done, and what information is relevant to support that, allows people to be productive and has implications for health (e.g. in medication adherence) and wellbeing. Values that were highlighted in the data we collected highlighted social motivations for remembering and include the role of memory in helping people remember details about others and share information with them. Both of these play a role in relationship development, and are our focus here.

4.3.1 Remembering Details about Others. As we've noted, information learned in social encounters was noted by participants as being important and often challenging. Here we develop this idea further, drawing on examples in which participants described wanting to remember information about others in order to build or develop relationships with them. For example, P21 gave the following account:

> "*The woman with the apples Adam met was Jill. She told him she was the first woman to design software for Boeing in the 1970's. When he makes cider again he will have me come help and if he can he will introduce me to Jill if we pick apples at her house…for my benefit and for developing my relationship with Adam."*

This participant is expecting that remembering details about one of Adam's friends will build rapport between herself and Adam, as well as smoothing her introduction to Jill. Similarly, P6 wants to remember "*a conversation with a girl I respect and admire… in case we ever run into each other again".* He thinks it would be important to remember this because "*It helps you get closer to people. Being able to ask 'do [you] still feel this way about that?' I think it could make an otherwise awkward greeting more comfortable".* P4 also wanted to remember details from an interaction with someone, in this case, her grandmother: "*[I want to] remember the details of my lunch with my grandmother today…because it could bring my grandmother and I closer together to recall fun memories*". This example refers to a close and long-term relationship rather than one that is beginning, but here too there is an expectation that the relationship can grow if she can draw on the experiences they have shared together.

Participants also described how remembering special events (e.g. birthday and graduation details) are important in building relationships. For example, P19 wanted to remember a birthday present idea for one of her friends. "*Her birthday is not until October, but I'd want to start making it well in advance of that*" because "*if I remember my thinking on this and make what I'm planning, she'll appreciate it as being particularly personal to her*". Remembering details about special events in one's life signals intimacy, which contributes to relationship development [10], and forgetting such details may have consequences for the relationship. This was noted by P21: "*Juli gets pissed if anyone forgets her kids [sic] birthdays*".

4.3.2 Knowledge Sharing. Participants also described wanting to remember more general information and recommendations, so that these could be shared with others. For example, P17 said she would want to remember "*which moving company to use and the price*" a month from now, because "*other family members would need this information*"; P8 wanted to remember *"[BT] restaurant doesn't have a great tofu curry, but the fried icecream [sic] is really good"* because he *"might go there again/ recommend it to other friends"*; P10 wanted to remember "*rent around [city name] can be around $800…*" in a year's time, in case others "*…are looking to live in the [city name] area*"; and P19, who had "*just finished the first novel by author Steven Rowley*" wanted to remember "*his name, so that I can be alert to any future writing he does*" and then share this with her sister, because "*sis read the book before me and she would want to know if he writes new stuff, too".* While P17 and P19 need to retain some information, having anticipated who it is useful for, P8 and P10 are unsure as to when their knowledge and recommendations will be relevant.

4.3.3. Summary. Remembering details about others, and sharing information and knowledge with them, is an important component of human relationships. Our findings indicate that while sometimes people can articulate ways in which remembering information will support a future social interaction (e.g. remembering details about Jill when picking apples at her home, or remembering Juli's son's birthday in time to buy a gift), in other cases, details need to be retained until some presently unknown future event. Of course, human memory is triggered by cues in the environment, and so if someone were to ask P8 about the restaurant he visited, or if he were to find himself there with friends, he may well remember to recommend the ice cream without need of a memory aid. But where details are more specific (e.g. prices or company names), and for users with memory impairments, being able to quickly find details of past experiences may be valuable. Cues that could support this include location and people. Finally, it's worth noting that some of the examples above suggest the need for slightly more complex reminders. For instance, a system might proactively alert P19 when Steven Rowley publishes his new book, and remind her to contact her sister about this too.

5 DISCUSSION

Our survey and diary study findings allow us to consider how technologies could better support a range of circumstances in which people can articulate a need or desire to remember something, whether to perform some future action (prospective memory) or draw on prior knowledge and experience (retrospective memory). We reflect on this here, before suggesting practical guidelines to inform the design and improve the usefulness of digital reminder systems.

5.1 Creating Reminders for Different Types of Memory

Our first research question asks what people set out to remember in everyday life. Our analysis highlights examples of prospective and retrospective memory. In this section, we consider each category in turn, considering implications for digital systems that remind the user to perform some action (prospective memory) or remind them of some prior event or piece of information (retrospective memory). Following Sellen and Whittaker's critique of 'total capture' as an approach to developing technologies to support human memory, we focus on the potential values digital reminder systems could offer to users. In doing so, we will also explicitly refer to Sellen and Whittaker's 'five Rs': recollecting, reminiscing, retrieving, reflecting, and remembering intentions [53].

5.1.1 Prospective Memory: "Remind Me To...": As we have noted, prospective memory is equivalent to Sellen and Whittaker's 'remembering intentions'. This is typically categorized as time- or event-based, and is best supported by digital reminder systems when a time or location can be specified. However, in our analysis we see an alternative way of thinking about the support that digital reminder systems could offer users. Specifically, there is value in catering for a spectrum of intention types, from the *highly-specified* time- and event-based, to *upcoming intentions*, which are currently on the horizon but not yet fully formed, to *persistent goals*, which carry over from day to day. We deal with these in turn.

Digital reminder systems already offer good support for some highly-specified intentions. For example, Cortana allows users to enter a grocery list and an associated grocery store location, so that they will be reminded of the list on entering the store. This requires the user to anticipate the specific event (entering the store) at the time of storage (creating the list). However, we also saw plenty of examples where times and events for the triggering of a reminder could not be specified. Sometimes this was because the time or event could not be anticipated; asking a colleague a question the next time a person sees them is an example of this. Das et al. developed a system to explore movement (e.g. standing, walking) and environmental cues (e.g. temperature, motion) as cues for prompting a user with a mobile device [9], and our analysis suggests that people are an additional salient cue for delivering reminders. In other cases, a time could be articulated, but the system would need to recognize that this refers to a deadline rather than the time at which an action should be performed. And in other cases still, a system would need to understand that the reminder is conditional on multiple events, or on the combination of a time and an event. Our data show how easily people can express complex deadlines and dependencies; the challenge is to design and build reminder systems that are able to cater for these nuances.

In addition to highly-specified but complex reminders, our analysis also highlighted the challenges people have in remembering details from social interactions with others, including when those interactions include someone asking for something to be done. Proactive reminder systems have been developed [69], and research in this space includes McGregor and Tang's recent work on detecting reminders from conversations in meetings [35]. Additionally, systems such as Gmail and Facebook Messenger have begun to prompt users to save reminders about activities inferred from text conversations. There are plenty of challenges in this space; conversation may include explicit reminders (e.g., 'Remember to pick up the kids') or implicit requests (e.g., 'The grass needs watering'), and McGregor and Tang's research shows how a lack of contextual information may result in ineffective reminders being created (i.e., those that do not provide enough context for the user to understand them, or that result from a misinterpretation of the conversation). However, relying on the user to create the reminder can also be problematic if they have forgotten what they were supposed to be doing as the conversation ends. Possibilities for design include capturing specific details from speech but enabling the user to correct and embellish these soon afterwards. Further research might explore how phrases in conversation could be stored in the short-term and used to underpin a dialogue between human and machine through which reminders can be created. Involving the user in the process of creating the reminder may further support prospective memory; prior work shows that conversations with others may help with prospective remembering tasks [30], and we have seen in this study that creating a list then helped participants remember what they intended to do.

Our analysis also highlights the importance of what we have called 'upcoming intentions': things that need to be done, that are on the horizon, but that may not be clearly formed as an actionable task just yet. These can be difficult to articulate and suggest the need for digital reminder systems to cater for more freely-formed entries: intended activities that the user does not want to forget about, but is also not yet ready to act upon. Free-form content lends itself best to lists, which our data indicates are more commonly created using paper than digital tools. We might consider how to design technologies that better support the flexible capture of upcoming intentions, which could then be gracefully transitioned to the form of a digital reminder once they can be more fully specified. To give a simple example, a user might record a voice memo and ask to be reminded of it at a time of their choosing. Using speech-to-text technologies, these could be represented in the form of a list,

ordered by the time at which they are expected to become relevant, and turned into a highly-specified reminder once the user is ready to add a time or event as a trigger. Our data also includes examples whereby upcoming intentions are conditional on some other event. The participant that wants to tell her sister about Steven Rowley's new book, when it is published, is an instance of this, and indicates how digital reminder systems could play a proactive role in supporting an intended action by, in this case, alerting the user when the book is published.

Finally, our analysis shows that some actions do not need to be remembered just once, but become relevant at multiple times during the day and this can be the case every day. Some of these persistent goals have no completion point (e.g. the intention to chew food thoroughly is relevant at every meal time), while others have a target that is reset (e.g. the intention to drink three glasses of water every day). Remembering to drink more water or practice programming problem sets are goal-based activities that cannot be associated with specific end times or dates. Goal-setting and adherence research emphasizes the importance of reminders and appropriate cueing strategies [17,20,27,37,43–45], but goal-based reminder apps primarily focus on health goals and outcomes [1,27,43–45,54] at present. Our data highlights an opportunity to explore how reminder systems can help people make progress on non-health related goals such as communicating with other people or learning new information.

5.1.2. Retrospective Memory: "Remind Me Of..." The remaining four of Sellen and Whittaker's five R's – recollecting, reminiscing, retrieving and reflecting – all draw on retrospective memory. Perhaps due to the nature of our research questions, much of our data relates to one of these: *retrieving*, without encompassing the need to re-live (recollect), reminisce, or reflect on the memory in question. We begin by considering how we might support retrieval using digital reminder systems, before addressing recollecting, reminiscing, and reflection.

Digital reminder systems are typically used to help people remember to perform actions in the future, yet our analysis highlights that information learned in the past is also a key part of what people feel the need to remember in their everyday lives, with details that are either about people or that others would find useful being especially salient. We saw how participants sought to retrieve information they believed would be relevant or otherwise of value to friends and family members (see also [21]), and wished to retrieve details about newer acquaintances that could establish trust, build rapport, and facilitate future bonding. According to Altman and Taylor's social penetration theory, disclosing personal, intimate information is key to strengthening relationships [60]. Sharing knowledge is also known to benefit weak ties by offering an alternative perspective on a topic [18], and is at the same time of value to the person sharing the information by building social capital and expanding his or her network.

These social benefits of remembering highlight the value of capturing memories in a form that can be easily retrieved and shared with others. Research on supporting retrospective memory for the purposes of conversation often focuses on a richer experience of recollection or reminiscing, especially in the context of people with memory impairments [2,68]. However, here we see the value of retrieving simple pieces of information in human relationships. This suggests the need to *create resources that can easily be drawn upon in conversation*. There are many challenges associated with this. As noted, Sellen and Whittaker have argued against a 'total capture' approach, and we do not advocate attempting to support retrieval of everything here. Rather, our analysis suggests that it is often the details, such as names of people, recommendations, and prices or other specifics, that people feel they need support in remembering. For some of these, having an easy way for users to record key details may be sufficient. Again, voice memos or digital notes that can be easily created and searched could be a simple but effective resource for users. A further avenue worth exploring is the possibility that digital reminder systems could identify key details from conversations and add them to a repository, especially as our analysis indicates that information acquired through social interaction can be especially susceptible to forgetting. While this does raise complex ethical and privacy considerations [63], the benefits to certain populations may justify use in some scenarios, and designs in which information is stored only following some explicit action by the user (or perhaps by multiple users, for example in the context of a meeting), may enable use in others. Vemuri et al. have begun to explore how recorded audio can help people recall answers to questions, but not within the context of natural conversation [64]; this needs further research.

Retrieving previously captured resources obviously necessitates that they can easily be accessed. Where content is either expressed verbally or captured through conversation, speech-to-text technologies could help support search and retrieval later; however, a key problem here is that the user may have forgotten the specifics of the information that has been stored. Helping users retrieve information they only vaguely remember will be made easier by capturing as much contextual information as possible [48]; further, this could also be used to proactively offer details in very specific cases such as recommendations that are relevant to a precise location, or the recurrence of a weekly meeting in the workplace. An alternative possibility here is that

digital reminder systems could remind users of information they have stored when it is requested by others. For example, if digital reminder systems were integrated with social media tools, they could prompt the user to respond to an information-seeking request from a contact [36], and so support the user in sharing information and relationship building.

Sellen and Whittaker's remaining three R's are recollecting past experiences, reminiscing about these for emotional or sentimental reasons, and reflecting on them by reframing or otherwise looking at them differently. These differ from retrieval in that they relate to episodic, rather than semantic, memory, and have an experiential aspect to them in the mental re-living of an event, emotional engagement with it, or reflection on it. Examples of this type of retrospective memory in our analysis often related to a desire *not to forget* rather than to remember something for its functional value. Of course, there are plenty of existing technologies that support the capture of cues to memory; photos, videos, audio recorders, and lifelogging tools are amongst these [5,24,39], and tools like Pensieve and Facebook Memories support reminiscing [41], potentially in collaboration with others in the case of the latter. Additionally, a good deal of research has explored how retrospective memory and reflection can be supported [50,51,67]. Here we constrain ourselves to considering the types of content that users might articulate to a digital reminder system that they do not want to forget. In this case, supporting explicit capture by the user of as many cues to memory as possible, and encouraging a re-visiting of the memory every so often, perhaps by reminiscing or reflecting on it with others, are both important. Equally important though, is to recognize that episodic memory can change over time, therefore supporting re-interpretation and reflection is as important as designing for recollecting and reminiscing.

5.2 Giving Form to Digital Memory Aids

Our second and third research questions asked what do people succeed in remembering and what do they forget, and how is remembering supported? Our analysis highlights the value of creating recurring reminders and notifications with digital systems, of being able to quickly create paper-based lists, and of being able to place material things so as to prompt memory appropriately. In this section, we highlight the advantages of digital memory aids, and consider how some of the strengths of physical memory aids might inform the design of digital reminder systems.

Participants rated digital reminder systems as potentially very useful, and our analysis shows that digital memory aids were valued for the recurring reminders and notifications they provide. We have already discussed how being able to specify when a reminder is delivered could be extended to deal with different types of timing, such as deadlines, upcoming intentions, and persistent goals. We have also noted that digital reminder systems could prompt users to create reminders at specific moments, perhaps drawing on details captured from interactions. Another possibility would be to more generally encourage the user to create reminders at particular moments in the day. While unintended, we saw how list creation helped participants in our diary study think about what they wanted to do that day and accomplish this. We understand that creating a morning to-do list may have led to conscious rehearsal and affected the success of recalling these events when completing the afternoon survey, but we cannot determine if this happened, or if it is different from how participants remember to-do lists outside of the study. However, our results are in line with previous work, which shows that the act of creating a plan motivates people to initiate the corresponding action [3,17]. Digital reminder systems may benefit from routinely prompting users to make entries. Resurfacing these at the end of the day could remind them of forgotten intentions and aid planning to do these at another point in time.

Our analysis highlights a different set of advantages for paper and material memory aids. Prior research has emphasized the advantages of paper [53]: writing on paper is quick, it is flexible and can be laid out spatially, it is persistent and easy to refer back to, it is simple to edit and annotate, it can be made visible to others and is easily edited by them, too. We have already discussed how supporting the creation of free-form reminders and creating visualizations of these could be beneficial for users, perhaps by combining voice memos, speech-to-text technology, and interfaces that display reminders but also allow the user to filter and search through these. Surfacing reminders at appropriate moments is another value that digital reminder systems can support. Existing work investigates how to store reminders with abstract notions of time so they can be delivered at the right moment [49]. More generally, knowledge about a person's spatio-temporal routines could provide context for delivering daily reminders. For example, these systems could learn that it is appropriate to show a to-do list when a user passes by the bathroom mirror each morning. If the mirror is part of the Internet of Things, these reminders could be delivered visually and ambiently, rather than on a personal device or through a conversational agent. Prior work has emphasized that the spatio-temporal distribution of objects around the house helps older adults with medication adherence [27], but the implications for digital reminder systems are much broader than this scenario.

Making reminders visible in the home also means that they can be used as a resource by multiple family members. Existing conversational agents (including Siri and Cortana) tend to be associated with individual user accounts, although smart speakers (e.g. Amazon Echo, Google Home) provide mechanisms for creating and accessing reminders by anyone in the home. Although these devices are situated, they do little to provide the benefits of situated displays (e.g. [6,32,52]) in the home, including the leaving of messages and reminders for others. Research shows that the placement of paper and other material objects plays into social routines [1,7,26,27,38,40], and studies of the home highlight how material objects support awareness and serve as reminders for family members [7,58,59]. If smart speakers could recognize individual users, they could begin to play a role in passing on reminders from one household member to another. More promising, though, is the possibility of designing digital reminder systems that interact with programmable objects. Services such as IFTTT and Zapier allow users to create conditional statements triggered by contextual information to perform an action. These services have the potential to enable users to interact with intelligent agents to create complex reminder systems that incorporate material things with highly customizable triggers and context-aware behavior. By designing digital systems to work with technology-enabled artifacts, we might 'give form' to reminders, the placement of which could then support awareness and play into routines that are located in space.

6 CONCLUSION

We conducted a survey and a diary study to learn more about what people want to remember in everyday life, and how they try to support this, with the aim of drawing implications for the design of digital reminder systems. We relate our findings to Sellen and Whittaker's five R's, and show that remembering intentions (or prospective memory) entails a spectrum from highly-specified to-dos to upcoming intentions, or activities that are currently on the horizon. Digital reminder systems should support a transition across this, and when a reminder can be specified, they need to cater for different types of temporal information, including deadlines and persistent goals, and different types of location information, including fine-grained indoor localization methods but also programmable objects that can be located within the home.

Examples of retrospective memory in our data emphasize retrieval of information, and we suggest that this could be done 'in collaboration' with a digital reminder system. Collaborative remembering has been shown to be emotionally richer, to support remembering of more details, and to help people process events that took place [23]. We suggest that digital reminder systems could provide details that may otherwise be forgotten, thus playing into the perceived advantages of prosthetic memory tools, which are appreciated for their accuracy [29]. Digital reminder systems could capture details from conversations and meetings, or proactively identify opportunities for retrieval, through integration with friendsourced queries gleaned from social network sites [36], or with the user's own search alerts.

The importance of recollection, reminiscing and reflection is also noted, but here the role that digital reminder systems may play is less clear. Participants were conscious of memories they did not want to lose, and perhaps cues to these (such as photos) had not otherwise been captured. Enabling free-form recording of verbal or text-based accounts of such memories, and encouraging their re-visiting, could support recollection, and perhaps also reminiscing or reflection in the future.

In conclusion, our analysis shows that intelligent digital reminder systems could provide significant value to users by reminding them to do actions in the future, but also by reminding them of information acquired in the past. Designing reminder systems to support the formation of reminders, for example by providing missing details, and making those reminders visible in different locations and to different people, so that they can become part of a person's or household's routine, open up new and fruitful possibilities.

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