ForgetMeNot: Active Reminder Entry Support for Adults with Acquired Brain Injury

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ABSTRACT
Smartphone reminding apps can compensate for memory impairment after acquired brain injury (ABI). In the absence of a caregiver, users must enter reminders themselves if the apps are going to help them. Poor memory and apathy associated with ABI can result in failure to initiate such configuration behaviour and the benefits of reminder apps are lost. ForgetMeNot takes a novel approach to address this problem by periodically encouraging the user to enter reminders with unsolicited prompts (UPs). An *in situ* case study investigated the experience of using a reminding app for people with ABI and tested UPs as a potential solution to initiating reminder entry. Three people with severe ABI living in a post-acute rehabilitation hospital used the app in their everyday lives for four weeks to collect real usage data. Field observations illustrated how difficulties with motivation, insight into memory difficulties and anxiety impact reminder app use in a rehabilitation setting. Results showed that when 6 UPs were presented throughout the day, reminder-setting increased, showing UPs are an important addition to reminder applications for people with ABI. This study demonstrates that barriers to technology use can be resolved in practice when software is developed with an understanding of the issues experienced by the user group.

Author Keywords
Assistive technology; memory rehabilitation; smartphone reminding; acquired brain injury; *in situ* study; field study

ACM Classification Keywords
LIFE AND MEDICAL SCIENCES; Assistive technologies for persons with disabilities

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INTRODUCTION
Acquired brain injury (ABI) includes trauma to the brain arising from a head injury (e.g. road traffic accidents and falls), cardiovascular events (e.g. stroke), illnesses or diseases (e.g. brain tumour or encephalitis). In the UK, there were 348,934 hospital admissions for ABI in 2013-14 [14]. Research from the USA indicates that males between the ages of 18 and 45 are at the highest risk of a head injury [27]. Prospective memory (PM), which involves forming, maintaining and carrying out future intentions, is often impaired after brain injury [37]. Other common problems include difficulties with planning and self-monitoring, and switching between or initiating tasks [6]. This can make it difficult for people to remember to carry out everyday tasks like taking medication and attending appointments, and to perform everyday activities such as personal care and shopping.

Smartphones are ubiquitous and are relatively low cost devices that offer applications that can support memory. Such technology is particularly suited to supporting PM problems using time-based alerts and reminders. Reminding apps are often designed as digital calendars or diaries into which reminders or alerts can be entered. Smartphone reminding software has been shown to be effective in helping people to compensate for memory difficulties [13,16]. They have an advantage over traditional memory aids such as paper diaries because they can actively prompt people ahead of their intended activities [30]. Most work in this area has focussed on the efficacy of the output of reminding devices (e.g. timely prompts) [7, 10, 19, 40], rather than the issues surrounding the accurate input of the reminders so that the user can receive the prompts [3].

It may be difficult for people with memory impairments following ABI to remember to set reminders in the first place. Additionally, if people have poor insight into memory difficulties, they may fail to set a reminder because they believe they will remember a future intention unaided. One solution to this is to have a caregiver or a family member set reminders. However, it may not be possible or desirable for a third party to enter reminders on behalf of the person with ABI [31]. For example, there could be issues with privacy or simply because events come up which caregivers do not know about (e.g. a spontaneous change of plan). Furthermore, setting and abiding by one's own

schedule is an important part of independent living and is one of the goals of neuropsychological rehabilitation [7,42].

In this paper, we use an *in situ* field study approach to investigate the actual issues impacting the use of a smartphone reminder app for people with memory impairments after severe ABI. We report observations and participant feedback that provides novel, real-world insights for designers and researchers developing mobile memory aid technology. To tackle the issue of initiating reminder setting behaviour we introduce unsolicited prompting as a feature in a bespoke smartphone reminder app (Forget-MeNot). Unsolicited prompts are simply periodic prompts that ask, 'Do you need to set any reminders?'. During the field study, participants set significantly more reminders when receiving UPs than when not receiving them. Feedback about the acceptability of the UPs informs the future development and use of UPs in mobile reminding software.

RELATED RESEARCH

Prompting Technology

Studies that investigated the use of prompting technology in a rehabilitation setting for people with ABI have tended to focus on efficacy of timely prompts rather than the barriers preventing independent use and reminder entry [3,10,40]. Studies that have investigated the barriers to independent assistive technology use and reminder entry for have done so using focus group or lab-based experimental studies [4, 17, 29]. The observational field study reported in this paper took place *in situ* within a rehabilitation centre which gives novel insights into the issues that prevent the use of smartphone reminding technology over a number of weeks.

Efficacy studies

Jamieson *et al.* performed a systematic review and meta-analysis of studies investigating the efficacy of reminding technologies for people with ABI. Their analysis found that the use of prompting technology was more effective (large effect size $d = 1.27$, $N = 147$) when compared to practice as usual or the use of a paper diary or calendar [16]. Only 5 of the 9 group studies included in this analysis had participants entering their own reminders. In the others, reminders were set by a third party such as a caregiver or the experimenters. This means that a large proportion of the evidence that prompting technology is useful for people with ABI has only investigated the output stage of reminding.

These studies reported positive user experiences and usability findings, For example, McDonald and colleagues reported that the majority of participants (9 out of 12) preferred using Google Calendar on a PC to a paper diary [19] and Svoboda and colleagues [30] found that the participants continued to use a mobile phone as a reminder up to a year after their study was completed. However, these studies offer little depth as participants were not asked for feedback during the trials when using the technology. Furthermore, there may have also been a selection bias towards recruiting participants who were keen to use technology for memory compensation. Unless the issues that impact perceived usability and acceptance of technology prior to use are investigated further, it will be difficult to tell if smartphone reminding software would be used spontaneously by people with ABI, if they would find it acceptable, or continue to use it without substantial training.

Barriers to Use

Baldwin and colleagues found four main themes after interviews discussing assistive technology use with people with memory impairments after ABI (n = 8): 1) Emotional barriers (e.g. feeling like others will evaluate you negatively for using memory aids); 2) Reverse effects (using the technology has the opposite effect to the intended one, e.g. becoming so fed up with continually being reminded that you stop wanting to complete the intended task); 3) Beliefs about memory (believing that relying on technology will impair your ability to remember) and; 4) 'it's not in my nature' (the idea that technology is not for you) [2].

De Joode *et al.* used a lab study approach to investigate the difficulties 15 participants with ABI had while entering reminders onto calendar software on a PC. Their findings echoed many of the themes described in other research, describing the internal factors such as cognition and emotion. They also described external factors such as software and environmental distractions that influence information processing and task execution. Analysis of errors showed that while people with ABI made the same kinds of errors as healthy controls, they made them more often and made a higher number of negative emotional comments during use [4].

A focus group study that investigated the issues which prevent the use of smartphone reminding apps reported that apathy (failing to initiate the use of memory aids and strategies in the first place), and poor insight and memory (not realising that they are likely to forget) were important barriers [17]. These issues present a particularly challenging problem for clinicians hoping to encourage a client to use any form of memory aid. Even if the client has received substantial training and is capable of using the memory aid, he/she may still forget to use it, or not appreciate that it is needed. In this paper, we test an app with unsolicited prompting, a feature designed to help people with memory difficulties , insight and motivation by prompting them to enter reminders.

Unsolicited Prompting

An advantage of technologies such as smartphone reminding apps over pencil and paper memory aids is that they can actively alert attention and aid memory with well-timed and relevant prompts [10]. After reminders have been entered into the device (e.g. a weekly schedule), the technology will alert the user (at a relevant time) to the events or tasks that they intended to perform. It is also possible to create software that will prompt the user prior to any input. This kind of alerting is unsolicited by the user and so these types of

prompts are referred to in this paper as Unsolicited Prompts (UPs). One difficult challenge with UPs is sending reminders about specific events before any information has been provided about the user's schedule. This problem might be solved by predicting the user's upcoming events based on previous input or by sensing the environment and prompting based on this information. For example, Google Now takes information from several synced applications such as email, weather forecasts and traffic updates to give relevant reminders. The Microsoft Band senses inactivity and prompts the user accordingly. These types of prompts, if accurate and timely, could be very useful for prompting people to perform everyday activities that they might otherwise forget.

In this paper, we focus on a different type of UP – one that periodically prompts participants to enter reminders into a smartphone reminder app asking, 'Do you need to set any reminders?'. This, like the UPs included in Google Now or Microsoft Band, could help overcome issues with insight and motivation which prevent the setting of reminders. However, this type of UP also has the additional advantages of a) not requiring the computation of additional information within the software to predict the content of the reminder and b) encouraging people to think about their memory tasks and manage their own schedule, which is a key part of neuropsychological rehabilitation after ABI [42]. If someone with memory difficulties after an ABI took note of a Doctor's appointment while on the phone, but became distracted and forgot to enter it into the app, a general prompt from the app could be enough. If later they made a mental note of a task they needed to do that evening, but did not believe they would forget it, the same UP from the reminder app might get them to set the reminder (especially if the prompt gave them the option to open the app).

Interruptions

One problem with a smartphone app providing UPs is that they may become annoying, which may lead people to stop using software. Prompts and 'push' notifications from mobile devices have become ubiquitous. Pielot *et al*. reported that 15 healthy smartphone users received on average 63.5 notifications per day and rated this as 'normal' [24]. However, the majority of these notifications were social messages that may be responded to in a different way to a prompt from a reminder app to actually do something. Shirazi and colleagues reported a large-scale study of mobile users' responses to different notifications [26]. They found that social notifications were generally responded to within 30 seconds and these social apps were unlikely to be 'blacklisted' by the user (so that notifications were prevented from appearing on the device).

Prompts from Calendar apps, the closest equivalent to the prompting app used in our study, were responded to after around 5 minutes and were blacklisted more often. This may be because non-social prompts were considered less important and therefore more irritating. Paul and colleagues used a one-word-response method to investigate the emotional experiences of receiving notifications [22]. They found that while people described receiving a social notification (e.g. an email or text from another person or a social media notification) with more positive words than negative, notifications which were not social were described with a similar number of positive and negative words. Of the negative words used, the most common was 'annoying'. These findings suggest that users may not necessarily attend or positively react to UPs in all cases.

The perceived usefulness of the content of the notification is also important; Felt and colleagues found that if apps which are not perceived as useful keep sending messages then users become annoyed and more likely to delete those apps [8]. This may be a bigger issue for people with ABI as they often lack insight into their memory difficulties and so may not find a UP useful even when they do have something to remember. These issues may hinder the effectiveness and acceptability of UPs. However, these studies looking at mobile phone interruptions have been carried out with high functioning, healthy people who use a mobile phone regularly. Little is known about how interruptions are perceived by people with ABI. Rehabilitation researchers highlight the low employment rates [37] and social isolation of people with ABI [5] so this may not be a group who already receive high volumes of notifications. It is possible that users receiving a low volume of notifications may find unsolicited interruptions more acceptable than those already receiving many notifications throughout the day.

Study Aims

Using an *in situ* field study, we investigated the issues that impact the use of a smartphone reminder system by people with cognitive impairment including memory difficulties after acquired brain injury. We also evaluated the impact of unsolicited prompting on reminder setting and acceptability.

METHOD

Participants and setting

The study involved three adults with self-reported memory difficulties after ABI. It took place within a 25 bed post-acute rehabilitation hospital in the UK for people with severe ABI. This is a living environment with 24-hour support, staffed by nurses, support workers, psychologists, speech and language therapists, occupational therapists and physiotherapists. Each service user has his/her own room, there are two communal lounge areas, two dining room areas, a laundry room, exercise studio and a kitchen. Difficulties in carrying out future intentions (prospective memory difficulties) are extremely common amongst the group. Between 23 and 25 service users were living in the unit during the study. This study setting was ideal because it allowed close observation of service users living in their normal environment where they have to remember several

everyday tasks (e.g. medication, laundry, their daily rehabilitation schedule). University of Glasgow ethics committee and ethical approval from the rehabilitation organisation involved was granted for this study on 02.03.15 and 03.03.15 2014 respectively. All participants provided informed consent before taking part in the study. Two participants owned mobile phones (KT an iPhone and CD owned a feature phone). Before the study, KT reported previously using a calendar app to set reminders.

LE

LE is a 45 year old man who sustained brain damage after a fall in 2013 and has a history of previous injuries including a stroke, a traumatic brain injury (TBI) and recurrent seizures. He has difficulties with controlling his behaviour and with functional abilities such as self-care, cooking and cleaning. These have improved since admission to the unit. He has recently begun a vocational placement and has independent access outside the unit. He finds it difficult to initiate new behaviours which are not established habits. He also has difficulty maintaining his intentions and goals over more than a few minutes and so he is strongly driven by his environment. He has little insight into his difficulties and often does not understand the need for safety procedures or cognitive interventions. Staff reported that a reminder app could be helpful because he requires frequent prompting about activities.

KT

KT is 37 and sustained a severe TBI in a road traffic accident when he was 17. He has social skill deficits, disinhibition and psychiatric symptoms. Rehabilitation efforts have focused on his initiation of activities (morning routine and time keeping) and memory difficulties. He requires prompting to get out of bed in the morning and to ensure he is ready for rehabilitation sessions and vocational placements. Staff noted that KT sometimes requires prompting about everyday tasks such as doing the laundry. KT's memory difficulties, lack of motivation and apathy are issues that may benefit from prompting technology. He expressed that he dislikes being asked by staff members to do everyday tasks and so it was hoped that he might find prompts from technology more acceptable.

CD

CD is a 55 year old man who sustained a skull fracture in 2014 which led to left–sided brain injury. CD has severe memory difficulties, poor working memory and anxiety about his memory difficulties. He writes many notes because he is anxious about missing activities. However, he is also disorganized and has impaired short-term memory, so his notes often get lost or covered up leading to him forgetting things. A memory app could help because it would allow him to store his reminders in a phone which could alert him at the correct time. During the study period, CD had a rehabilitation goal of reminding the nurse about his medication, with the aim of moving to self-medicating safely.

Materials

ForgetMeNot app

ForgetMeNot is a simple smartphone reminder application designed and developed specifically for this study (Figure 1). The requirements for this design were developed by the research team in order to answer the research questions and complement the chosen methodology. The design requirements were a) that the app allows the user to set reminders for a specific time, b) that the app alerts the user at this time with an audio and visual prompt, c) that the app could be altered by the experimenter to include unsolicited prompts (UPs), d) that the app automatically logs the reminders set by participants and the participants' responses to the prompts.

The interface of the app was designed to be easy to read with large (the maximum text size which could allow all of the content to stay on one page), high contrast text (white and yellow text on a cyan background, and black text on white backgrounds). The home screen gave a choice of 6 types of reminders to set and no keyboard entry was required. Once the reminder has been chosen, a time can be selected for the alert to go off for that reminder. A standard Samsung time selector widget was chosen for the time selection screen. When the alert goes off, the text flashes continuously and a beep sounds along with a vibration every 30 seconds until the 'Done it!' button is pressed and the reminder is acknowledged. The reminders set for the day are logged automatically by the app (event selected and time) and can be seen by the user by selecting 'check today's reminders' at the top right of the reminder selection screen (seen on the top two screenshots of Figure 1). There is also the (hidden) option to allow a user to set prompts throughout the day. These are the unsolicited prompts (UPs) and, in the case of this study, the researcher set these at the beginning of the appropriate experimental phase. When the UP prompt activates it asks, 'Do you need to remember anything?' and flashes, beeps and vibrates every 30 seconds until an option is selected; 'YES' to this question allows a reminder to be set, and 'NO' closes the app. The participants' responses to this YES / NO question were logged automatically by the app and could be viewed by the experimenter. The event reminder and unsolicited prompts were programmed to override the volume controls on the phone so they would flash, beep and vibrate even if the volume on the phone was muted or in vibrate mode.

The design of the ForgetMeNot app was not intended to be a solution to all smartphone reminder usability difficulties for this group. Rather, it was intended to be a usable and learnable platform that would allow us to study the use of reminding technology in a rehabilitation setting and test the impact of UPs on reminder entry. If UPs were found to be useful, then they could be added to other reminding software.

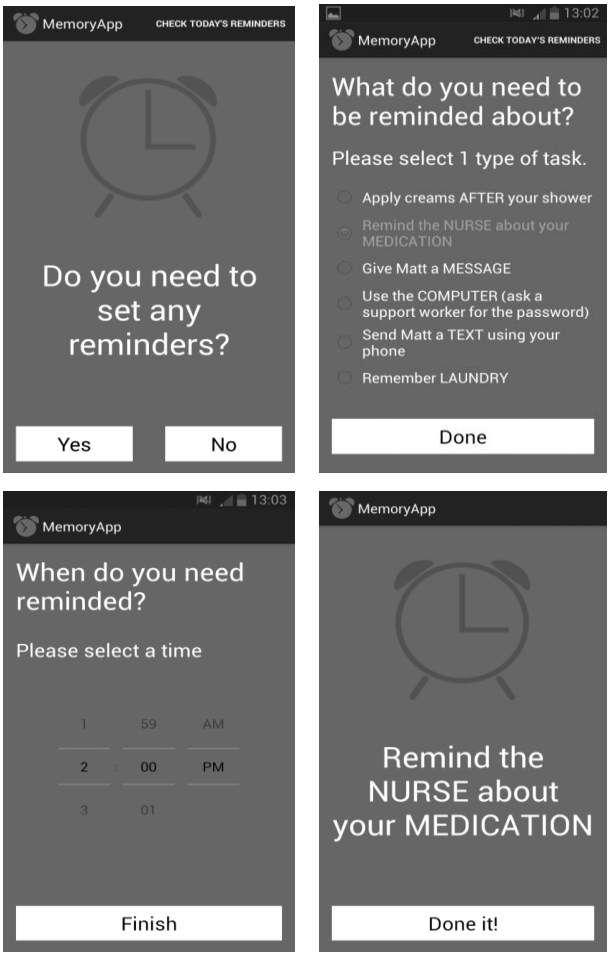

Figure 1. ForgetMeNot app. Top left: Unsolicited Prompt (UP) Top right: Task selection screen. Bottom left: Time selection screen. Bottom right: Specific reminder prompt. The task selections shown were the ones created for LE. KT and CD had slightly different tasks (see Table 1).

Hardware

ForgetMeNot is an Android app and it was provided on a Samsung Galaxy S3 smartphone (running Android version 4.3). Participants were free to use the phones for purposes separate from memory prompting (e.g. access Internet and make phone calls) and £10 of credit was given with each phone to cover text costs. We decided to provide phones for this study because two of the participants could not download the app onto their own phones. Furthermore, the experimenter had to manually enter the unsolicited prompts into the phone prior to the UP phase and so using participants own phones for this may have been perceived as intrusive.

Neuropsychological Tests

Several standardized tests were given to participants as part of their stay in the rehabilitation centre. These tests offer an overview of the participants' cognitive profile compared to the general population, in the domains of memory, executive functioning, attention, insight into their impairment and likely cognitive ability prior to their injury. Tests performed were the Wechsler Adult Intelligence Scale version 4 (WAIS-IV) [34], Test of Pre-morbid Functioning (TOPF) [35], the Behavioural Assessment of the Dysexecutive Syndrome (BADS) [41], the Cambridge Test of Prospective Memory (CAMPROMPT) [43] and the Rivermead Behavioural Memory Test (RBMT) [38].

Procedure

An observational *in situ* field study was carried out. ForgetMeNot app was provided to the participants for four weeks. At the beginning of the study memory tasks that participants often forgot to carry out were identified by the experimenter by talking to staff, asking the participants or referring to neuropsychological reports. Table 1 gives details of these activities. Additionally, we asked participants to pass a message to the experimenter and text the experimenter at a different time every day to create a larger set of reminders.

Initials	Daily tasks
LE	• Apply creams after shower • Ask to use the computer • Remember laundry • Remind the nurse about medication
KT	• Check schedule for vocational appointment • Have breakfast before leaving for a vocational appointment • Go to a rehabilitation session • Remind the nurse about medication
CD	• Ask to play a board game • Ask to use the computer • Remember laundry • Remind the nurse about medication

Table 1. Participants' daily tasks.

The study included two phases that each lasted two weeks during which the participants were given S3 Galaxy phones with the ForgetMenot app. The UP feature was included in one two-week phase and not the other. The order of the UP condition was randomly assigned for each participant using a coin flip. KT and LE had UPs for the first two-week phase and CD had UPs during the second two-week phase. The UPs were set by the experimenter to go off at six semi-random times during the day. The times were not completely random because we did not want to disturb people during their scheduled rehabilitation sessions (scheduled between 10am-11am, 11.30am-12.30pm, 1.30pm-2.30pm and 3pm-4pm on a weekday). The reminding tasks in the study only took place on weekdays between 9am and 8pm, although participants were free to set their own reminders for any time.

Participants were given a demonstration of how to use the app, during an hour-long session at the beginning of the study. This covered how to enter the app from the home screen, set a reminder task and time, check today's reminders, respond to prompts and how to respond to a UP. The main experimenter attended the rehabilitation centre every day during the study to collect the data. He helped with any

other issues to do with phone use such as keyboard use for text messaging, phone charging and screen navigation, throughout the study.

The experimenter met with participants in nine hour-long study sessions: one prior to the beginning of the study to gather information about which memory tasks to set prompts for; two near the beginning of each phase to ensure people understood how to use the phone; four on different days during study to interview participants about their use of ForgetMeNot; and two sessions at the end of the study to administer further neuropsychological tests when necessary.

Each reminder that was entered into the app was logged and accessed by the experimenter at the end of the study. This log was used to tally the number of reminders set by each participant. This was the primary outcome variable. A potential limitation to simply logging the number of reminders set by participants was that participants could set reminders in the UP condition within three button presses (pressing 'YES' in response to the UP, then 'DONE' and 'FINISH'). This could lead to reminders being set thoughtlessly in a desire to dismiss the UPs. Using the reminder logs and information about what time each intended task was supposed to be completed, we were also able to develop a tally of 'fidelity checked' reminders. This variable was developed as a check that participants were thinking through the reminders they set. A fidelity checked reminder was defined as a) a reminder set for an event that the participant did have to do that day and b) was set for between half an hour before and 5 minutes after the event.

Daily reminders – study and app design

Only six different daily tasks could be set using the app and reminders could only be set for the current day. We recognize that setting reminders for longer-term events (e.g. 'meeting tomorrow' or 'appointment next week') is a useful function of most reminder apps. However, participants in this study received their rehabilitation plans daily and had few longer-term activities to remember. The ForgetMeNot app and experiment were designed to allow accurate measurement of the effectiveness of UPs in an everyday setting. Whether the memory task is to be performed later in the day or in a month's time, the user still needs to remember to enter it into the calendar application. Furthermore, unexpected events that were not planned at the beginning of the week may occur daily and require revision of the initial plan and extra reminders to be added. This app and study allowed us to investigate everyday reminder setting and to test whether or not UPs are an effective and acceptable way to increase this reminder setting behaviour.

RESULTS

Neuropsychological Profile

Table 2 summarises the cognitive profile on each of the neuropsychological tests for the participants

.

Test	LE	KT	CD
WAIS-IV verbal comprehension score (description)	98 (average)	Not available	70 (Borderline impaired)
WAIS-IV full scale IQ (summary)	89 (Low average)	91 (Average)	74 (Borderline impaired)
TOPF predicted full scale IQ (description)	98 (Average)	115 (Above average)	89 (Low average)
RBMT percentile rank (95% CI) (description)	<0.1 (<0.1- 0.7) (Impaired)	0.5 (<0.1 - 3) (Impaired)	1 (0.2 – 6) (Impaired)
CAMPROMPT score (description)	8 (Borderline impaired)	6 (Impaired)	8 (Borderline impaired)
BADS age corrected score (description)	63 (Impaired)	81 (Low average)	73 (Borderline impaired)

WAIS-IV = Wechsler Adult Intelligence Scale version 4 [26]

TOPF = Test of Pre-morbid Functioning [27]

RBMT = Rivermead Behavioural Memory Test [30]

CAMPROMPT = Cambridge Test of Prospective Memory [34]

BADS = Behavioural Assessment of the Dysexecutive Syndrome [32]

Table 2. Cognitive profile on tests of intelligence, memory and executive function for the study participants.

Reminder Setting

Table 3 shows the average number of reminders and 'fidelity checked' reminders set by participants each day categorised by whether or not they were receiving UPs. The table shows that when not receiving Ups, LE set less than one reminder per day (mean = 0.7 reminders), KT set less than one reminder per week (mean = 0.1 reminders) and CD set 2.5 reminders per day. This increased markedly during the UP condition to a mean of 2.5, 1.7 and 6.3 reminders per day for LE, KT and CD respectively. The table also shows that this increase in reminder setting is also clear when only fidelity checked reminders were included. This confirms that the UPs were not just leading to an increase in reminder setting because thoughtless reminders were being set in order to dismiss the UPs.

Intervention Phase	Mean (SD) no. of reminders set per day		
	LE	KT	CD
With UPs	2.5 (1.7)	1.7 (1.5)	6.3 (2.6)
With UPs (fidelity checked)	1.9 (1.1)	1.2 (1.0)	2.5 (1.3)
Without UPs	0.7 (0.9)	0.1 (0.3)	2.5 (1.8)
Without UPs (fidelity checked)	0.7 (0.9)	0.1 (0.3)	1.2 (0.8)

Table 3. Mean number of reminders and fidelity checkedreminders set per day in each intervention phase for each participant.

Field Observations

Phone Use

Participants did not set a large number of reminders, especially when they were not receiving the UPs (Table 3). Field note analysis also offers some insights into why this might have been.

In many of their comments KT and LE allude to their belief that they did not have much to be reminded about, either because they did not believe that they had anything to remember or because they did not believe they would forget. It was also the case that the rehabilitation centre where the study took place had a very set schedule and there was little chance that participants would experience very negative consequences of forgetting. For example KT said,

> *"Eh… Well I don't really have a chance to forget because I've got a timetable. I've got various things that remind me and that". KT*

Additionally, as part of their rehabilitation, service users in the unit were provided with, trained and prompted to use pencil and paper memory aids and memory aid strategies. For example LE said,

> *"Well I like my diary, I like keeping my diary 'cos I put everything in there" and, "...I write everything down. It's just… I don't really need that (points to phone) I write it all down". LE*

If other memory techniques were being used (for example LE using his diary and prompts in his room) then these may have contributed to performance of memory tasks, perhaps meaning that participants were supported with their memory as well as they could be with memory aids separate from ForgetMeNot. Additionally, especially in the cases of LE and KT, there were indications that they may have stopped using or ignored the phone, during at least some of the intervention days. For example, KT put the phone off for a day during the first week of the UP phase and LE stated that he put it away in his drawer at one stage preventing him from perceiving the prompts saying,

> *"I've put it in my drawer so I might hear a faint beep". LE*

LE was often observed to have put the phone in a drawer, saying that he was keeping it safe. He had to be prompted to keep the phone in his pocket a number of times during the first week of use.

Finally, CD also used pencil and paper memory aids and used his own phone to make notes of future events, though these did not prompt at set times. An unusual aspect of CD's use of ForgetMeNot, especially during the UP phase, was the number of reminders which he set that did not pass the fidelity check. He was observed to be setting several reminders per day on ForgetMeNot, all of which had the same content, namely to remind the nurse about medication. The majority of these were not 'fidelity checked' reminders because this memory task only had to be completed a maximum of two times per day. In spite of these reminders he repeatedly forgot to remind the nurse at the right time. When asked about this he revealed that he was setting this reminder in order to receive the auditory notification at the set time. However, he was entering different content into his own feature phone to match these reminders. When the ForgetMeNot notification fired it would remind him that he had something to do and he would look at the notes on his phone to find out what the task was. In the following conversation he describes this method,

> *"See when I get my diary of what I've got on today, where is it? Oh it's just in there. Ok so that's all the things I've got on. Putting that (paper diary) in that (phone). But it's all under…" CD*
>
> *"The sort of options that you get?" Experimenter*
>
> *"Aye it's under your medication. I just write it all in and put it in there as I know it's a basic whatever…" CD*
>
> *"And then you use that phone (his own feature phone) to back it up?" Experimenter*
>
> *"Yeah. I've not put it all in regularly but normally I do." CD*

The tasks he would input into the phone did not match the events that he was entering into his feature phone. For example, he would remind himself about going food shopping, attending rehabilitation sessions and going to the betting shop. Therefore, the way that CD used the app was to remind himself about his own tasks outside the research study, using prompts about the experimental tasks. He did not always carry out these experimental tasks but the prompts did remind him to check his schedule.

The insights which can be gained from field notes taken during this lengthy trial testing the efficacy of ForgetMeNot and UPs highlight the advantages of single case experimental design studies with embedded involvement from the researcher. The rich details that can be obtained can be used to help interpret and understand the findings and can inform future research in this area. For example, the insights described here highlight the importance of cognitive factors (such as insight into memory difficulties) and the environment and context (a highly structured rehabilitation setting) which influence the use of a technological memory aid intervention.

Unsolicited Prompts

During the weeks in which UPs were received, participants were asked what they thought about the UPs and why, as well as how they felt about the frequency and timing of the UPs. When first asked about the UPs after they had been introduced, KT reported that he had noticed them but usually pressed the 'no' option. He said,

> *"Well they (the UPs) all say the same thing. Presumably you'd have to go and check the phone but eh… I don't know I just always press no". KT*

The next week he was observed to have put the phone off and stated that this was because, 'it kept going off. It was annoying.' When asked if he ever found it useful to press the 'yes' option to set reminders he said, "No because I did press 'yes' a couple of times and it just came up with the same options. Unless I sent you a million texts, I didn't have anything to remember". He then agreed that he didn't think that he had enough to remember to justify it going off all the time, though this did not seem to be specific to the events entered into the phone. For example, he went on to say,

> *"There is just not enough going on here for me to have to remember anything to merit a device like that, you know". KT*

This may be interpreted to mean that KT did not feel that he needed to remember very much within the rehabilitation centre and this was why he chose to respond to the UPs by pressing 'no'. During the study period staff noted that KT did forget many events including tasks for which he could have used ForgetMeNot to set a reminder for. For example, he would often fail to check the schedule for vocational appointment or have breakfast before leaving for a vocational appointment. Therefore, it seems that KTs lack of insight fed into his lack of motivation; he did not perceive his memory failures and so did not believe he had anything to use the app for. Alternatively, he may have had insight into his memory difficulties but not believed that the tasks he needed to perform in the rehabilitation centre were important enough to merit setting a reminder. Whether caused by lack of motivation or insight, it was this perceived lack of need for reminding that made the UPs annoying to KT.

When interviewed in the first week of the UP condition, LE stated that he did not find the UPs annoying saying,

> *"No it's not annoying beeping me, no. I've put it in my drawer so I might hear a faint beep." LE*

However, at a later time he did report feeling frustrated with the notification, "No my memory is fine. I get to stage when that goes 'beep' I think not again!" This quote echoes comments made by KT indicating that UPs were annoying when they were not perceived as necessary either because he believed he would remember, or because he did not believe there was anything to remember. For LE, his belief was highlighted when he said,

> *"right, so when it goes in my pocket that's the alarm going off to tell me to take my medicine. But I don't do medicine, it gets brought to me. So the alarms for the medicine is not really my problem. The staff give me my medicine. I can't go… give me the meds!" LE*

This comment also highlights the fact that LE did not believe he was required to ask the nurse for medication even though this task was communicated to him at the beginning of each study phase. If LE forgot to ask the nurse for medication, the nurse would bring the medication to him at the end of their round. The structured environment of the rehabilitation centre, and LE's lack of insight into his memory difficulties meant that he had little motivation to complete this task even if he received a prompt to do it.

In contrast to LE and KT, CD had a positive attitude towards the UPs throughout the UP phase. He indicated that he did not find the UPs annoying and when asked about the number of prompts he said,

> *"There's never too many you know. If you need them, it's just if you've got them and done it all – but it's nothing against it you just don't need it. I just press no. As you say just press no. Ah I'm just, it's new to me so I'm amazed". CD*

This did not change throughout the two weeks of the UP phase, and CD indicated that he felt the prompts from the app could help to compensate for memory impairment, though he did feel anxious when using the phone in general. For example,

> *"I think yeah it's terrific. I'm still lacking that confidence with it but that's me, it's nothing to do with the phone, I've nothing against the phone at all. Yeah I can see, I can see how handy it can be. In fact, I'll end up probably I need, that's my brain there, my thoughts". CD*

The difference in attitudes towards the UPs between participants illustrates the importance of understanding insight into memory difficulties and motivation for rehabilitation, and the influence this can have on the acceptability of prompts. For example, KT and LE indicated that they did not set reminders because they did not believe they had anything to remember and reported that they felt their memory was fine. As a consequence, the UPs were occasionally perceived as annoying by these participants, especially into the second week of the UP condition. In contrast, CD was anxious about his memory, motivated to remember his schedule and appreciated that the app could really help

with this. He was very happy to receive the UPs and perceived them as helpful.

When asked about the frequency of the UPs, KT and CD both stated that they thought the number of UPs was about right. CD was happy with the semi-random firing of the UPs, while KT indicated that, 'first thing in the morning, before my brain has engaged' would be the best time to be prompted. He elaborated by saying,

> *"You could just set the alarm and it goes off. Now normally you'd just remember, but… no it helps to let you know. It's like you wrote a letter to yourself (from) last night you know". KT*

DISCUSSION

Unsolicited prompts

The number of reminders set per day increased markedly with the introduction of UPs. This was also the case when only fidelity checked reminders were included in the analysis. This shows that all participants noticed the prompts and used them to open the app and set reminders. The setting of timely reminders, that passed the fidelity check to prompt a future intention was considerably more frequent when prompted by an UP than when they had to initiate this action with no prompt.

Overcoming the Barriers to Use

The field notes illustrated several barriers to the use of smartphone scheduling software in ABI rehabilitation. For example, LE left the phone charging in his drawer throughout the day because he wanted to keep it safe and because he did not feel like he needed the reminders. KT turned the phone off because he found it annoying and did not think it was useful. CD was initially concerned about using the phone because he felt he might break it. These barriers are difficult to overcome, however the success of the UPs in increasing the use of the device (Table 3) even amongst participants who were observed to have low motivation for using the software and little experience using smartphone technology is very encouraging. The increase in use of the app occurred for all three participants and this suggests that UPs which prompt people to enter reminders at random intervals during the day may be useful for overcoming some of the barriers to the use of prompting technology. This increase in use during the UP condition was especially prominent for CD who had good insight into his memory impairment and was highly motivated to use the device, indicating that other users with good insight into their difficulties, who are motivated, may also particularly benefit from UPs.

The ages of the participants may also have been a barrier. The participants were 37, 45 and 55 and the two older participants had very little experience with smartphones. It is likely that younger people with ABI would be more used to owning and using smartphones and this might mean they would find them easier to use and be less likely to have negative user experiences (such as worrying that they will break the device or that it will be stolen).

Methodological Considerations

Small N case studies such as this can have real value in HCI for health, especially when investigating hard to reach populations. For example, Wilson *et al*. (N = 1 with ABI) was an influential study that foreshadowed an RCT of the NeuroPage prompting device, and many subsequent studies testing reminding technology in clinical practice [39]. The Archipel [1] (N=1) and GUIDE assistive technologies [21] (N=2) have also been further developed and researched following small case studies. In the current paper, a rich contextual longitudinal study is reported with 3 people with severe ABI in an acute rehabilitation centre with very distinct cognitive profiles and behavioural issues. Close observation of their use of a reminder app during their on-going rehabilitation allowed those difficulties to be linked to the use of the app. For clinicians, the insights are extremely useful because they can recognise similar difficulties and traits in their own clients. This is one argument for the use of single case experimental design and case study methods in clinical research [32]. For both researchers and designers, this study design is valuable. In this case, it allowed us to detail issues that occur for people with specific difficulties, in specific settings. This offers insights for the future not always available when studying heterogeneous populations grouped by disease aetiology.

Future Research

When to prompt

The purpose of our study was to investigate the impact of UPs, rather than to investigate when or how to present UPs. The UPs were received at semi-random times, within the hours possible given the participants' rehabilitation schedules. ForgetMeNot is limited as it requires a carer, clinician or researcher to enter UP times. However, UPs could also be programmed to prompt randomly, or even predict when to prompt based on environmental cues. Decision making algorithms which are informed by sensors could also help determine the best times to interrupt. For example, Fischer and colleagues showed that people reacted faster to notifications if they were delivered after finishing a call or reading a text message [9]. Ho and Intille suggest that notifications may be received more positively if they occur between two physical activities (e.g. walking or sitting) [15]. Alternatively, an algorithm could mute users' phones in a personalized way in order to avoid unwanted interruptions [25], which would allow notifications to be sent at any time without fear of an embarrassing disturbance. The present study has shown that UPs do lead to increased reminder entering. This effect could be enhanced if algorithms can predict and select the most opportune times to send UPs.

How to prompt

ForgetMeNot's notifications including the UPs were designed to be highly noticeable because we wanted to be sure that participants received the prompts. The UPs beeped and

flashed every 30 seconds if unanswered and this is likely to be more intrusive than the ideal UP. Future studies could test UPs which would balance nuisance with timely prompting. For example, some modalities of notification may be less disruptive than others [20, 33]. It is telling that, despite two participants reporting that the UPs were annoying, they still entered more reminders into the app during the UPs phase compared to the non-UPs phase. It seems that being annoyed with the app did not put people off using it or negatively impact the efficacy of its use during the two weeks in which users received the UPs. This echoes previous research by Mehrotra and colleagues [18] who suggest that people find notifications annoying/disrupting even when they acknowledge that they are useful.

We found that low motivation linked to a lack of insight into memory difficulties was an important barrier to use and to acceptability when the UPs increased use. The mismatch between perceived and actual memory ability has been reported by previous researchers in the context of reminder setting amongst the general population. Gilbert and colleagues found that both subjective confidence in memory ability and actual memory ability influenced reminder setting behaviour, even though the two were uncorrelated [12].

In rehabilitation settings, improving insight into memory difficulties is often a key goal [42]. This is a difficult thing to do, especially if people have difficulties remembering (and therefore learning from) their experiences [17]. The literature on software for behaviour change offers potential solutions to improving people's engagement with apps. Different techniques that might work include using prompts linking behaviours to their positive outcomes [11], or drawing on social comparison or social modelling [23]. Future research will help us understand what content UPs could prompt with to be more effective (e.g. 'you'll be on time if you set a reminder.' Or 'your friend has set a reminder for an event, do you want to?') Alternatively, habit formation techniques could allow people to compensate for scheduling difficulties sustainably, in cases where insight cannot be improved [28].

Our aim when designing ForgetMeNot and UPs was to make the UI simple (sacrificing flexibility/functionality) to reduce potentially confounding usability issues when investigating the impact of UPs. Ideally, an app would be designed to flexibly set any reminder with ease, not just preset ones. It could be the case that people will need more support and training to use more complex reminding apps and that reminding apps should be designed to be accessible. Research on how best to train use in rehabilitation, how best to design the UI of reminding apps for this group, and how best to support people to initiate reminding behaviour (e.g. UPs) should be combined to understand the optimal conditions for successful scheduling.

CONCLUSION

An *in situ* observational study in a rehabilitation centre demonstrated the barriers to reminding technology use in this context and showed that UPs can markedly increase reminder setting. The participants recruited in this study are representative of people with severe memory and executive impairments after ABI and the results offer some insight into how effective and acceptable UPs would be for this group in real world settings.

Smartphone users may receive high numbers of unsolicited notifications, often referred to as pro-active or 'push' notifications. In 1991, Weiser imagined future technology as quiet and invisible servants which create calm [36]. Phones which offer frequent notifications, especially ones which were not solicited by the user, are anything but quiet and invisible. In this study, we demonstrated the positive impact that such notifications can have, in this case increasing use of a memory aid app in a rehabilitation setting. Useful notifications may put people off using technology if they become a nuisance, and nuisance notifications may increase people's use of technology. With user-centred research it is possible to overcome the barriers to technology use to create solutions that are useful and acceptable for all users.

People with ABI often have cognitive difficulties including poor prospective memory which can be supported by reminder apps. However, PM difficulties can make it difficult for this group to remember to enter reminders in the first place. Unsolicited prompting from the reminding software is a potential solution to this problem. In this study in-situ observational methodology was used to test the impact of unsolicited prompts from a reminder app on reminder setting and user experience for people with memory impairments after ABI. It was found that UPs increased the number of reminders set. Reminding technology has great potential in memory rehabilitation and UPs could be a useful solution to a problem which people with memory impairments face when using this technology.

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