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Designing ApplTree: Usable Scheduling Software for People with Cognitive Impairments

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Background: Smartphone reminding applications can help overcome memory difficulties experienced by people with acquired brain injury (ABI). Cognitive difficulties with memory and attention make entering reminders into a device, and remembering to set reminders, challenging for this group. ApplTree is a reminding app with features that aim to address challenges. One app feature was push notifications (asking 'Do you need to set any reminders?') to support people to initiate use of the app to set reminders. Another app feature was a customisable user interface design to support attention and short term memory during reminder setting.

Methods: In a mixed-methods user study, five people with self or other reported memory impairment following ABI used ApplTree for at least four months. They received push notifications for at least two months and no push notifications for at least two months. Monthly participant interviews provided insight into user interface preference, app use, and push notification acceptability.

Results: Receiving four Push notifications per day doubled number of daily reminders set and 4 of the 5 participants found receiving them to be acceptable. This long-term field study uncovered issues relevant for clinicians and designers, including insights into the potential benefits of different user interface designs, the impact of family members on app use, and the importance of perceived need influencing use and acceptance.

Conclusions: Feedback provided insight into future considerations when designing reminding apps and using them in neuropsychological rehabilitation. This work highlights the benefit of user-led research into accessible design and use of assistive technologies.

Keywords: assistive technology; neuropsychological rehabilitation; cognitive impairments; mobile accessibility; reminding software; acquired brain injury

There are no conflicts of interest to declare.

Implications for Rehabilitation

- 'Unsolicited' push prompts are an easy to implement feature of reminding technology that is useful and acceptable for people with ABI in community rehabilitation.
- Observations provide insights about how people with ABI make use of reminding apps over time. This can inform those designing apps or providing reminding technology as part of neuropsychological rehabilitation.
- Participants differed on their preference of the two user-interface designs available in ApplTree. This highlights an area for future research because currently available reminding apps have a broad-shallow design which may not always be appropriate for people with ABI.

Introduction

By 2030, around 387 million people worldwide (4.9% of the estimated population) will have a neurological impairment from acquired brain injury (including stroke), or degenerative disease [25]. Cognitive impairment, including prospective memory impairment, is a common and extremely debilitating consequence of neurological damage or degeneration.

Prospective memory (PM) refers to the processes underlying the ability to remember what you were going to do or to successfully carry out future intentions [8, 31]. Memory for these delayed intentions needs to be maintained over time while other, unrelated tasks, are carried out. PM also involves cognitive processes including planning, task initiation, inhibition of distracting stimuli and self-monitoring [31].

Furthermore, those with memory impairment following acquired brain injury (ABI) can often experience other cognitive difficulties including impaired concentration, attention and judgement [40]. Such impairment to cognitive function can be particularly debilitating, preventing people from gaining employment, and negatively impacting health, social functioning and wellbeing.

Technology that prompts users about future intentions can help people to compensate for impaired prospective memory [2, 21]. Technology that can actively prompt the user about an event at the correct time improves task performance compared to pencil and paper methods [11, 17]. Smartphone scheduling software that sends reminders is an ideal technology to provide this support because users are likely to keep it nearby much of the time. By providing prompts, scheduling support and a means of communication with health professionals, technology has the potential to increase the cost-effectiveness of currently provided care by reducing the time spent in high-cost intensive care (e.g. live-in rehabilitation centres), and reducing the likelihood that people living in the community will require or return to care in rehabilitation centres [28].

However, uptake of prompting technology by people in community care after brain injury is limited [16]. The user interface (UI) design of scheduling apps developed for the general population may be unsuitable for people with impaired cognition [15]. It can also be difficult for those with prospective memory difficulties to remember to set reminders in the first place [13]. Additionally, people may have poor insight into their memory difficulties, and so fail to set reminders when they should as they believe they will not forget a future intention [15]. One solution to these issues is to have a caregiver set reminders on behalf of the person with neurological impairment. However, this may not always be possible or desirable [38]. Reminders could be private, or events may come up that caregivers are unaware of (e.g. spontaneous changes of plan).

Furthermore, independently setting and adhering to a schedule is a common goal of neuropsychological rehabilitation and is a key part of an independent life [16, 26, 40]. This work describes the development and *in the wild* user evaluation of a smartphone app (ApplTree) with two design features built to overcome usability issues specific to those with cognitive impairment. A narrow/deep user interface could provide more guidance and therefore help people with attention and working memory difficulties to enter more detailed and accurate reminders than when using a broad/shallow UI. Unsolicited prompts (UPs - push notifications that ask, 'Do you need to set any reminders?') could help people with prospective memory and behavioural initiation difficulties to think about their schedules and set more reminders.

This work makes three central contributions: Firstly, we outline features included in the ApplTree reminding app that can help overcome usability issues described by people with ABI. Secondly, we present observations from an *in situ* study investigating the long-term use of this app by people with brain injury, highlighting issues relevant to clinicians, researchers and designers of assistive technology. Finally, we demonstrate the utility of the 'unsolicited prompting' feature of ApplTree as a method of increasing reminder setting for people with ABI living in the community.

Background

Assistive Technologies

Technologies that send timely prompts to people about everyday activities are an effective, low cost solution to support people with cognitive impairments and memory impairment. A systematic review and meta-analysis [17] found that prompting technology improves memory performance for people with memory difficulties after ABI vs. practice as usual or a paper diary/calendar (d = 1.27, large effect size, n=147).

There is also evidence that scheduling technologies can improve time-management and learning of routines for people with learning disabilities [5, 9]. The systematic review [17] found few papers that investigated smartphone apps (the state-of-the-art technology for delivering prompts) delivered through a clinical service. Furthermore, only three studies asked participants to set reminders independently, which is crucial to increasing functional independence. This potential positive impact will only be seen in practice if people have access to this technology (e.g. as part of their clinical rehabilitation). The positive impact of reminding technology use will be greater if people are able to use the technology independently when it is provided, and if the technology meets the individual needs of the users.

In the context of independently using a smartphone to set a reminder, users may not remember to, or think that they need to, enter reminders in the first place [14]; or it may be difficult for them to learn how to use the reminding technology [32, 35]. It is possible for a carer or family member to enter the reminders for the individual. Literature in neuropsychological rehabilitation highlights the efficacy of reminders set by a carer or third party in supporting memory [8, 17]. However, most people with ABI would need or want to set reminders independently. Indeed, learning to use aids to support memory is often a major aspect of rehabilitation after ABI [40].

Due to cognitive impairments impacting usability, those who could benefit most from reminding technology are the people for whom it is least accessible. Widehammar *et al.* report that support, training and education are still vital to overcome the barriers to uptake and use of assistive technology for people with cognitive impairments [36] Cognitive impairments can make device interaction challenging [15, 33, 35]. Lewis [23]

states that people with cognitive disabilities have the same type of problems as those experienced by the general population, but the consequences of running into difficulties might be more serious. De Joode *et al.* [20] reported the same finding in the ABI literature. They asked people with ABI (n=15) to complete tasks on a PC calendar in a rehabilitation setting compared to control participants (n=15). The authors report that people with ABI made the same sorts of errors as the control participants, but made them more often, and that people with ABI experienced a higher workload. Berget *et al.* [1] reviewed the literature on information searching using technology by people with cognitive impairment. They concluded that mechanisms should be created to support users navigating through text heavy pages.

Accessibility Guidelines

Bringing together findings from research involving people with cognitive impairment with different aetiologies, HCI researchers have developed web interface design guidelines for people with cognitive impairment. For example, the Web Accessibility Initiative has outlined features people with cognitive disabilities often rely on such as clearly structured content, consistent labelling and predictable interactions [7]. Recent WCAG2.1 guidelines are also relevant such as guideline 1.3; 'Creating content that can be displayed in different ways without losing information or structure' [12]. Common web recommendations include: Use visual cues - pictures, graphics, icons, and symbols along with the text; Use clear and simple text/simple language; Use consistent navigation and design; Use headings, titles and prompts; Minimize the number of choices on each page. ApplTree was designed with each of these recommendations in mind.

Specific Features for Usability

The web-interface design guidelines and research with those with cognitive impairment provide a foundation for accessible design. However, people with cognitive difficulties have diverse needs and there is a need for more research to understand the specific requirements for different groups [3]. Research with those with acquired brain injury can provide more specific information about the issues that need to be overcome for this group when setting reminders. For example, Sutcliffe and colleagues [33] investigated the use of a PC-based email client for people with ABI (n=8) and made user interface recommendations for users with different cognitive profiles. They suggested that people with a limited attention span would benefit from an interface which limits distractions and makes current task objects salient in order to support continuous engagement [33]. De Joode *et al.* [20] suggest that more appropriate software for people with ABI should have an interface which presents only a small amount of relevant information at a time and which uses step-wise serial data entry to minimise the burden on working memory and executive abilities. To meet this requirement ApplTree allows the UI to be toggled between narrow/deep and broad/shallow layouts. In narrow/deep, a small amount of information is on each screen, but there are a larger number of screens. In broad/shallow, a larger amount of information is presented on each screen but fewer screens are used. This feature gives users the option of personalising reminder setting to their preferred user interface. The user study allowed us to gather preliminary information about which UI the participants with ABI preferred and what advantages and disadvantages were mentioned when a reminder app with these UI variations were used over a lengthy period (at least four months).

People with memory impairment and poor insight may not remember to, or think that they need to, enter reminders in the first place. A recent paper by Jamieson and colleagues [9] demonstrated the potential utility of sending push prompts to help people remember to set reminders. Three people with severe memory difficulties after ABI living in a rehabilitation centre set more reminders when receiving six 'unsolicited' push prompts per day. However, this study only tracked phone use over four weeks and ideally app use would be studied over a longer period to understand how its use changes and develops over time. Furthermore, few reminders were set by participants during this study. The structured rehabilitation environment they lived in reduced the importance of setting reminders. Indeed, it is less structured and intensive community care where memory difficulties really need to be addressed. This is because, unlike during intensive rehabilitation, there is not a large staff to look out for the service user through the day and prompt them when necessary. Community care teams for brain injury often prioritise memory functioning and prompting technology can have a key role to play in helping to compensate for memory impairments [18, 28]. In the present paper, we investigate the impact of unsolicited prompts for helping people with memory impairments after a brain injury living in the community undergoing ongoing support or care.

One issue with receiving multiple push notifications from an app is that it may be perceived as annoying for users. Jamieson *et al.*[9]found that although two of three participants did find the UPs annoying, it did not prevent them from continuing to use the app. Previous work into smartphone interruptions has highlighted the high number of prompts healthy young smartphone users receive day to day (63.5 per day in one study [13]). This may serve to reduce the relative impact of individual push notifications both in terms of annoyance (one more prompt is a drop in the ocean) but

also in terms of the noticeability of each prompt. The type of reminder (specifically whether it is 'social' or not) has been found to impact its acceptance [29]. There is a lack of research investigating the impact of push notifications for setting reminders for people with acquired brain injury.

Studies that have investigated prompting technology for people with ABI have generally focused on the efficacy of timely prompts and not the barriers preventing reminder entry [4, 10, 21, 38]. Studies investigating the barriers to independent reminder entry for have used focus group or lab-based experiments [15, 20, 33]. This work addresses this limitation by describing an *in the wild* implementation of a reminder app designed with features to support people with ABI to independently set reminders. Participant feedback and field observations are used to gain an understanding of their use of the app and the benefit of the unsolicited prompting feature. The observational field study reported in this paper took place *in the wild* over several months and gives novel insights into the issues that impact the use of smartphone reminding technology, and the impact of unsolicited prompts to support reminder entry. A particularly important contribution is the involvement of people with memory difficulties after acquired brain injury who have a great need for reminding technology, but who are currently not able to make the best use of it.

Methods

Participants and setting

The study involved five community-dwelling adults that self-reported having experienced memory difficulties following an ABI. They were four women (DM (47 y/o), SW (63 y/o), MAC (41 y/o), AL (50 y/o)) and one man (NS (58 y/o)). On average

the participants experienced their ABI 13.1 years before the study took place (DM – 20 years, SW – 13 years MAC 1.5 years, NS 25 years, AL 6 years). Participants were recruited through a charity offering community support (but not formal rehabilitation) (NS, WS, MAC and DM), and a community treatment centre for people with ABI (AL). All participants were able to provide informed consent to take part in the study. Ethical approval was obtained from a National research ethics committee linked to the local health service (details withheld for anonymisation).

A convenience sampling method was used. We recruited people at the charity after attending several meetings and presenting on this research topic. These groups have around 10-15 people who consistently attend. We ended up with 4 participants who met the criteria and who wanted to take part. AL was recruited after taking part in another research study because she' and the community brain injury service she was receiving rehabilitation from' expressed interest in using a reminding app. At the start of the study, we asked participants if they used a calendar on their smartphone. NS said he used this very often and the others used it either very rarely (WS and DM) or never (CAM and AL). At the beginning, we also noted non-electronic calendar use. CAM and WS used this often, WS and MD used it sometimes and NS reported never using this. Of the four who used this, AL and MD said it sometimes helped their memory, WS said it rarely helped and CAM said it never helped.

Materials

ApplTree

ApplTree is an Android based reminding app developed as a platform to allow us to answer research questions involving user interface design and unsolicited prompting. The opening screen is shown in Figure 1. Unsolicited prompts can also be set by the

administrator. Unsolicited prompts and normal reminder notifications are also shown in Figure 1. The app allows a user with admin privileges to toggle between a Narrow/Deep and Broad/Shallow UI. The opening screen is the same for both UI conditions. The Broad/Shallow UI is shown in Figure 2, Narrow/Deep UI in Figure 3. The reminder setting functionality of the app is the same for both UI (narrow/deep and broad/shallow) and UP (on or off) conditions. Name, date, time, duration, notification, notes, repetition and loudness (how loud the prompt is) can be set for each reminder.

[Figures 1-3 about here]

Appltree was provided on Android Galaxy S7 phones. Participants with Android phones were asked if they would like to download the app onto their own phone, which participant NS did. The other four participants were given an S7 with ApplTree downloaded on it for the duration of the study (due to not owning a smartphone (AL), or having incompatible phones (SW, DM, MAC)). Each phone allowed access to the internet via Wi-Fi but did not have a SIM card.

Neuropsychological Tests

Standardized neuropsychological tests were given to participants. These tests offer an overview of the participants' cognitive profile, in the domains of memory, executive functioning, and perceived memory ability, compared to the general population. Tests performed were the Prospective Retrospective Memory Questionnaire (PRMQ, self-assessed memory ability) [4], the Rivermead Behavioural Memory Test (RBMT, objective measure of memory) [39], and the Delis-Kaplan Executive Function system (D-KEFs) letter/number switching sub-test (executive functioning) [6].

Procedure

We carried out an observational *in the wild* field study. ApplTree was provided to participants for an initial period of four months (although this increased in all cases for reasons described in the results section).

Prior to being given the app, the participants were asked to set six reminders that were created to be representative of everyday reminders that may be set using a reminding app. Three of these were set using Narrow/Deep UI and three were set using Broad/Shallow UI. The purpose of this was to give them training with the app, to ensure they were able to use it and allow the experimenter to help them overcome any issues with use. It also established which UI the participants preferred. Narrow/deep and broad/shallow were communicated with descriptions like 'side to side' and 'scroll up and down' and both UIs were demonstrated to participants before they used it. Their preference was asked for explicitly after they tried both options. Based on their preferences, three participants chose broad/shallow UI (NS, DM and AL) and two narrow/deep UI (MAC and WS).

During the *in the wild* study, participants were asked to use the app to set reminders as events arose in their daily lives. They met with the experimenter five times during the study. Once to set the example reminders, establish UI preference and learn how to use the app, then four times to get feedback about app use. They were asked to recount their experiences using the app since the last meeting and, once they had completed a UP phase, they were asked how they found the UPs.

The experimenter used this session to obtain data files from the phone with the types and number of reminders set and, in sessions prior to UP phases, four unsolicited prompts were added between 9am and 8pm for each day participants were in the UP phase. They were added at intervals spaced out by at least 2 hours (e.g. 9am, 11am, 2pm

and 5pm). Each participant remained in the study until they had completed at least two months with the app receiving UPs and two months not receiving UPs. If meetings with participants had to be delayed, the UP condition they were in was extended until the meeting could be held. Order of the no UP months (A) and UP months (B) was randomly assigned for each participant. The order for DM and MAC was BABA, ABBA for WS, AABB for NS, and BBAA for AL. It was planned that participants would have one month at a time in the UP and non-UP conditions and for the participants to take part for at least four months. For reasons such as holidays, delays in attending the sessions with the experimenter and the loss of study phones, participants' time spent in the study and time in UP and non-UP conditions varied. Phases were therefore defined as the time between sessions with the experimenter when the UP condition could be changed, and the data could be obtained (see Table 2). When describing the data repeated reminders were counted only once.

Feedback from each study session was transcribed and the transcript was coded by the experimenter who conducted the interviews. Descriptive thematic and in vivo codes (for detail and specific experiences) were developed. Coded phrases were then discussed in meetings with the research team. Focused Coding identified the important issues by virtue of the number of comments that covered each sub-theme [30].

Results

Neuropsychological Profile

Table 1 summarises the cognitive profile on each of the neuropsychological tests for the participants. The tests provide a summary of self-reported prospective memory ability (PRMQ), memory functioning (RBMT), and executive functioning (DKEFS). All participants had either self-reported memory difficulties (below average or impaired

level on PRMQ or RMBT memory tests) or reduced executive function (below average or impaired on D-KEFs letter number switching).

[Table 1 about here]

Reminder Setting

For all participants, different circumstances prevented them from completing the study in the minimum four months. MAC, WS and AL were unable to meet for at least one of the monthly scheduled meetings. MAC had to be given a new phone after theirs was lost. WS had a delay in the study due to an illness.

Table 2 shows the number of reminders set in each phase by the five participants. Table 3 shows that when not receiving Ups, participants set a mean of 0.35 reminders per day. This increased to 0.66 reminders per day when the participants were receiving UPs. All participants apart from NS and AL increased in the number of reminders they set when receiving vs. when not receiving UPs.

[Tables 2 and 3 about here]

Insights from User feedback and Field Notes

Choosing App UI Type

App Use

Each participant was given ApplTree with the UI that they preferred. WS and MAC preferred the narrow/deep user interface because they found it helped guide their reminder entry. Though DM preferred to use the broad/shallow UI, she commented on the positive aspect of the narrow/deep interface:

"I think it was good in that it decompartmentalised issues, and appointments and times and making notes and stuff which I felt was easier to… break down the issue and tackle each of them by themselves. I found that quite good." (DM meeting 1)

NS, DM and AL preferred the broad/shallow UI because it was what they were used to with Google Calendar (NS) and because they could get an overview of the information they were entering into the app. DM said:

"…I found being able to scroll down was smoother… my thought processes - it was just easier to scroll down - to get where I wanted to go." (DM meeting 1)

During each monthly meeting with the experimenter, participants were asked to talk about their use of the app over the previous month. All five participants gave some positive feedback about their use of the app. Most of the positive come from DM and WS, who used the app more frequently than the other participants.

Usefulness of app

WS made comments in the first monthly meeting after receiving the app (meeting 2) about the usefulness of receiving reminders at the correct time, and discussed the benefits of digital reminding vs. a paper calendar:

"It's been very good actually. There have been times when I've forgotten I had something on and the phone has reminded me, and that's what you want it for really."

"…if you only had the calendar then you might write things down there but unless you made a point of going to look at it… whereas that prompts you." (WS meeting 2)

MAC was also positive about the app saying she hoped it would quickly become available to use after the study was over. AL commented about the app's positive impact on her schedule setting and memory. In her case, it was the process of entering reminders using the app that helped her remember:

> *"…just putting it (a reminder) on and being able to look at it (is good). So even if I don't hear the reminder, just putting it on and thinking is there anything I have to do today. And also… I know where it is. It's not going to be on some piece of paper somewhere."* (MAC meeting 2)

DM made a similar comment about the benefits of simply setting the reminders:

> *"(When I put information) into the app, into the phone it cemented it in my head what was happening and what I was doing that day. So it helped me anyway just by actively putting that information into the phone. Em, because when the phone reminded me I thought, 'well I know it!' But no no no it was good, yeah."* (DM meeting 2)

This comment suggests that sometimes the prompts were not even necessary for AL and DM because the process of entering the reminder into the app had helped them to consolidate the information about their future intentions. When further asked about this reminder setting behaviour, DM said:

> *"I would set it in the morning. I suppose I would look at it every so often to see if there was anything else I needed to do. So I'd say maybe three or four times during the day I would check to see if there was anything else."*

"I think repetition for me is the key. That by doing it and writing it down as well or typing it into the phone, or something, does help because it cements it - makes it more permanent in my brain." (DM meeting 3)

Use of app developing with expertise

Another important observation was that the participants' repertoire with the app grew over the months of the study particularly for participants WS and DM who used the app more often. For example, after the third month using the app WS said:

"I have started using it more. I have been setting more different kinds of things – reminders for wee simple things, rather than big things – appointments or dates."

"I've upped the sound cos the subtlety was lower so I made it higher." (WS meeting 4)

This illustrates the benefit of consistent use of software. She also began to use different features of the app as her confidence with it grew. For example, she started setting different subtlety levels to suit her needs. DM summed this up when she said:

"Once I had done it a few times it was easier because I knew what you were expecting me to put in." (DM meeting 3)

AL also mentioned initial difficulties she had with touchscreen interaction and the need to get used to using the device over time (she had never used a smartphone before the study):

"The only thing is getting these wee dates and times – these wee fiddly bits. That's what I find slightly irritating. But that's just… me getting used to… where you're supposed to put your fingers." (AL meeting 2)

Limitations of app function

There was also plenty of critical feedback about ApplTree during the feedback sessions. For example, MAC asked for a feature to confirm that she had seen a reminder or done the activity. DM wondered if the app could notify you when events clashed. NS and SW discussed the very large number of medication reminders that can take up all the space on the calendar. NS brought up a similar issue about the readability of the calendar screen. If there was a reminder on the day then it was highlighted in blue. However, with multiple different reminders on different days, NS felt it would be helpful to have some information on the calendar screen about which event or events were on each day, so that a glance could give you the information needed. All participants had some difficulty receiving unsolicited prompts and notifications from reminders they set because they did not hear the alarm or feel the vibrations, or because they had the phone in their bag. WS, who was using the app with Narrow/Deep UI, initially found it frustrating to have to enter (or at least consider) all the information when entering a reminder:

"Sometimes (when setting a reminder) you only want a small amount of input, this (this app) made me go right to the end. You might want to put everything in, but you might not need to." (WS meeting 3)

It may be easier to set a quick reminder for which only a limited amount of information is required when using the broad/shallow user interface. DM had an interesting issue

with the app that highlights a problem with the use of reminding apps for people with memory impairment:

Experimenter:

"Were there any negative consequences of using the app?"

DM:

"No there was just that time that I got this notification and I thought 'oh my son's got a Doctor's appointment for a flu jab!' and just hustled him up and hustled him out and it turned out I hadn't made the appointment after all."

Experimenter:

"So you remembered to make a notification about your son needing a flu jab, but forgot to actually set up the appointment?"

DM:

"Yes." (DM meeting 4)

In this case she received the prompt about a time she had set aside to go to the Doctor. However, this reminder was linked to, and dependent upon, another intention (call the Doctor to make an appointment) that she failed to carry out.

Impact of use of memory aid on family

The use of a reminding intervention also had consequences for the family of the participants. MAC discussed an argument with her husband after he inadvertently took the phone and lost it. The stress of losing the phone was exacerbated by her memory

impairment and the care dynamic between MAC and her husband. When she realised he had lost the phone she said:

> *"I said but that's my phone for prompting, to help me with my memory. He said, oh, don't make me feel any worse!"* (MAC meeting 3)

This highlights the stress of having a device that is useful - if it gets broken or lost then it means that support has been lost. MAC went on to say she was 'lost without it'. If this device is lost or broken by a relative who has in some ways a responsible or carer role then this can lead to feelings of guilt, not only about losing an expensive device but about causing the person they care for to lose a device that was helping them cope.

Unsolicited prompts

Participants were asked about the unsolicited prompts and gave mixed feedback. DM, MAC, AL and WS all stated that found them useful. MAC was very positive about the prompts and described how they made the reminder setting process easier:

> *"I found them a lot easier to use when it was doing that than when I wasn't being prompted because at times you were forgetting that you had the phone so… When (the UPs) didn't come through it was a case of having the phone constantly at hand, waiting for anything you could put straight in."* (MAC meeting 5)

WS also commented on the usefulness of UPs to extend her own ability to reflect on the tasks she needed to do:

"I use my mind and brain quite often to try to remember things so quite often I might have remembered some things myself, but I was reminded, 'oh yes I need to do this!' So it did help me quite a bit." (WS meeting 4)

However, NS perceived the unsolicited prompts as annoying:

"If I could have got into the settings and switched them off then I would have." (NS meeting 5)

The reasons for this were that the prompts felt invasive and because there were just too many:

"Yeah you know, 'do you have something to do today?' I saw a movie about brainwashing and 'do you have something to do?' was the line and they would click in…"

"I received a lot of notifications - I was showing my phone to (staff member at Headway charity) and he said - 'wow, you have so many notifications!' So he took them all off which may negate the study." (NS meeting 5)

One reason for NS disliking the prompts more than the others was that he was able to use the app on his own phone, which meant he received more notifications (ApplTree notifications plus the normal ones he got from apps on his phone). Another reason was that he already successfully used another reminding app:

"I didn't use the app I used this app (commercial reminding app) because it links to Google and it shows some of the reminder on the calendar screen. I didn't dislike the app (ApplTree), I just thought it wasn't finished." (NS meeting 5)

This may explain the fact that NS set fewer reminders than the other participants and may also explain why receiving the UPs did not result in increased reminder setting for him (Tables 2 and 3).

Perceived need and insight

Some participants felt that the unsolicited prompts were not necessary for them. For example, in one of the feedback sessions DM said:

> *"Last week I was on holiday, I had my husband with me and my children – I didn't need reminding. If anything (came up) someone would remind me."* (DM meeting 4)

At other times participants said they thought the UPs may be useful to somebody else with more severe memory difficulties:

> *"I think for some people with more memory loss they may be more crucial."* (WS meeting 4)
>
> *"They weren't very helpful for me personally but for some other people they may work. Depending on how they feel about technology."* (WS meeting 4)
>
> *"Maybe even just a line of text that saying, 'remember you have something to do today.' I mean people may stick that on their fridge, I mean, 'have you anything to do today?' Some people may do that – that may be one of their coping mechanism."* (NS meeting 4)

This highlights the importance of perceived need as a mediating factor in the acceptability of reminding interventions. The acceptability of the potentially intrusive intervention of receiving four unsolicited prompts a day, having a clear sense that these are useful and required, is important. However, this can be difficult in the context of brain injury rehabilitation as insight into memory difficulties can often be impaired. The participants in this study all had quite good insight into their memory difficulties and

their needs. However, DM did mention that she would have switched off the UPs even though she later recognized that she needed them;

"I think if I'd had the choice I would have turned them off. But if I had I might have missed something that I needed to do." (DM meeting 5)

DISCUSSION

The contribution of this work is threefold. First, we have described design features (UPs and personalised toggle between broad/shallow and narrow/deep UI) that can be added to an app to address difficulties people with ABI are likely to have when using reminder apps. ApplTree was developed using feedback from users with ABI detailed in previous studies [13, 15]. Second, we have revealed issues that impact the use of assistive technology for people with ABI by detailing the issues expressed by participants when using an app over several months. Thirdly, we have illustrated the utility of unsolicited prompts for increasing reminder entry for people with acquired brain injury.

Limitations and Methodological Considerations

We were not able to recruit a large number of participants for this study. Furthermore, it is possible that this convenience sampling method may have led to a group with more interest in assistive technology and other methods to support memory, and who are more engaged in their rehabilitation than the overall population of people with ABI. However, detailed case studies with small numbers of participants are valuable to the HCI and health literatures, particularly when they involve difficult to reach populations. An *n* of 1 study of an individual with ABI using the NeuroPage prompting device was an influential piece of work foreshadowing several investigations, trials and an RCT of the NeuroPage prompting device [37, 38]. Small *n* studies of the use of smartphone prompting for people with ABI in a live-in rehabilitation centre (N=3) [13] and

investigating GUIDE assistive technology that talks users with executive function difficulties through their morning routine [24] (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 5 people with ABI living in the community. Observation and feedback about their use of a reminder app allowed app use to be related to specific cognitive difficulties and needs. These insights are very useful for clinicians who may be able to recognize similar difficulties and requirements when working with clients in community rehabilitation. Indeed, this is one argument for the use of single case experimental design and small n-size research [40]. This small n study is valuable for both researchers and designers because it allowed detailed description the issues that occur for people with ABI living in the community. These insights may be missed in larger n-size studies involving heterogeneous populations with the same aetiology.

Providing the app on 4 of the 5 participants' own phones was not possible (SW and NS had iPhones, AL had no smartphone at the beginning of the trial and DM bought an iPhone one month into the trial). This highlights the challenges with *in the wild* research; it is often necessary to include participants who may not have phones that work with the app, especially when it is already difficult to recruit participants. Those participating in this study who were provided a phone did use it along with their own phone and were able to give relevant feedback about app use. However, future research would ideally investigate use on their own phone (we are currently developing a version of ApplTree that runs on iOS). Further challenges when supplying apps on participants' own devices include not having experimental control over type of device they are using, which may impact the performance of the app and the potential invasiveness of

checking data during the study (experimenters either need to get access to their device or set up a server to capture user data) and removing the app from their phone after use.

There were large variations in the length of time for the phases for individual participants, time in the study between participants and the technical success of the app during each phase. These difficulties highlight some of the challenges of undertaking technology research with groups receiving community-based treatment. It was not always possible to contact patients to meet them within the pre-determined study schedule and devices can be lost or stop working properly during the study.

Research, design and clinical considerations

Unsolicited Prompts and user interface

This work provides evidence that providing unsolicited prompts (UPs) makes a substantial impact on reminder setting behaviour. A previous study investigating UPs influence on reminder setting within a rehabilitation centre (n = 3) showed similar substantial increase in reminder setting [13]. This is the first time that unsolicited prompting has been tested with people with memory difficulties after ABI living in the community. For four of the five the participants in the study, the UPs were not perceived as annoying and the acceptability of the app was not negatively impacted. In the previous UP study, 2 of the 3 participants disliked receiving the prompts.

Only 2 out of 5 participants (NS and AL) did not show an overall increase in his reminder setting when receiving the UPs. However, NS did stop using the app completely during phase 2 (second no UP phase) and started again during the 3rd phase (first UP phase). This may demonstrate the benefit of UPs as it seems they re-initiated

his use of the technology. For AL, there was a technical issue that prevented the UPs from working properly during phase two (second UP phase). Push prompts are widespread but developers are likely to be cautious when using these in case they reduce acceptability. Our results suggest that push prompting can be an effective tool for increasing independent use of reminding software and does not decreasing acceptability enough to impact use.

Broad/Shallow is the default UI for most reminder apps that are available to download. Our work suggests a mixed opinion about narrow/deep user interface. Future work could explore which UI design leads to more accurate reminder setting.

The benefit of setting reminders

Participants AL, MAC and DM all discussed the benefit of setting reminders, not just because it would mean they received the reminder notification at the right time but also because the *act* of setting a reminder helps support their memory for the events. This finding is encouraging and highlights the benefits of goal setting and collaborative scheduling which are often incorporated into neuropsychological rehabilitation [40]. Smartphone reminding apps, if designed with usable features for people with ABI, can be used to promote this scheduling by sending push notifications and by giving people a usable platform to schedule. This can particularly benefit people receiving care in the community by supplementing the support from rehabilitation staff that may be less frequent than in intensive rehabilitation centres.

User issues and app design

This long-term *in the wild* study of app use allowed us to document the changes in frequency and quality of use over time. The participants who used the app consistently

did sustain their use throughout the study, particularly when receiving the UPs. Over time, they reported being able to set reminders more easily and quickly, and developed expertise with the touchscreen interaction. This expertise development amongst people with ABI and little previous smartphone experience, highlights the potential for smartphone reminder apps as a feasible and effective long-term intervention for memory difficulties. These results are in line with Svoboda *et al.* [34] who followed up participants with ABI that had engaged with the use of a mobile reminder during a trial. These participants continued using the memory aid one year later.

The long-term nature of our study also allowed us to capture issues that may only occur occasionally but are nevertheless important to document. For example, MAC reported a reliance on the technology that resulted in a conflict when her family member lost the phone.

DMs experience setting a reminder for a GPs appointment highlights an important issue for clinicians and designers. The app allowed her to successfully set and received a notification about a GPs appointment that she intended to make. However, there were no other systems in place to ensure she remembered to phone the GP to make this appointment, which she forgot to do. This highlights the complexity of scheduling. From a clinical perspective the experiences of DM and MAC illustrate the need for assistive technology to be embedded into a system of support from family or caregivers. From a technological point of view, DMs issue may indicate the need for a system that not only allows reminders to be set that notify the user at the right time, but one that also guides people through the process of setting different types of reminders. Researchers have investigated guiding technologies that can help people through the sub-steps of a task. A recent randomised controlled trial of such a device (GUIDE), illustrated that this kind of prompting can be just as effective as intensive rehabilitation

for supporting people with ABI to complete their morning routine [27]. A future challenge for technologists may be to develop this kind of guiding technology to help people through the steps of scheduling events of different types, e.g. setting a Doctor's appoint has very different requirements to a medication reminder.

Insight and perceived need

Previous work has highlighted that people with ABI may not have insight into their memory difficulties and so not feel the need to set reminders [13, 15]. Related to this is the perceived need for reminders. A recent study investigating the use of smartwatch prompts in a community ABI setting highlighted the importance of motivation that influences technology use [19]. Central to this motivation is the perceived need for the technology. Our participants did generally see the need for the scheduling system, though some did report not feeling the need for the UPs. This lack of perceived need for the UPs did not impact the use of the app.

Conclusions

We developed ApplTree, a scheduling app designed to be usable by people with cognitive impairments resulting from acquired brain injury. Key features are a narrow/deep user interface design and unsolicited prompting. These findings illustrate the benefit of user-led research into accessible design; the difficulties reported by people with ABI in previous research [15, 22], and limitations with previous research [17] were addressed during the design of our reminding app. The positive impact of these features on app use was demonstrated in this study, and further issues were highlighted by detailing the participant feedback during an *in the wild* mixed methods study. Prospective memory and attention difficulties experienced by this group are also common to older adults experiencing mild cognitive impairment, people with learning

disabilities, people with dementia, and people experiencing mental illnesses such as bipolar disorder and depression. This work can provide the basis for similar user-led research with these groups.

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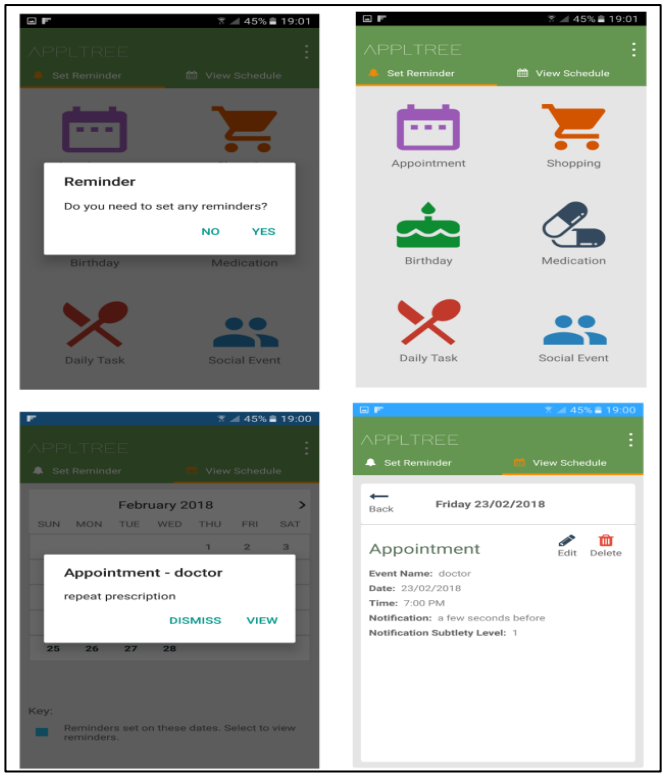

Figure 1. ApplTree UP (top left), opening screen (top right), a reminder notification (bottom left) and reminder information (bottom right).

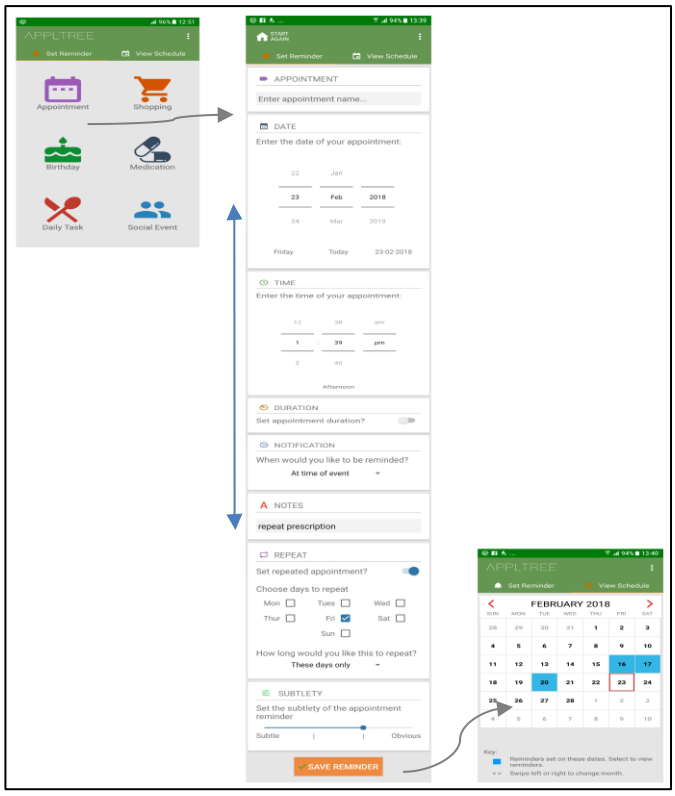

Figure 2. Broad/Shallow UI in ApplTree

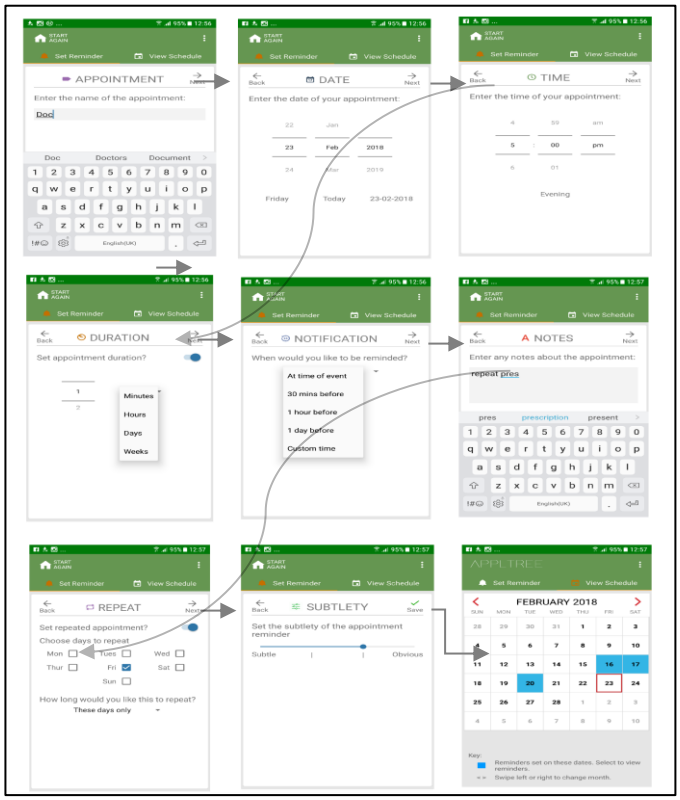

Figure 3. Narrow/Deep UI in ApplTree

Test	DM	WS	NS	MAC	AL
PRMQ total (description)	64 **(high)**	30 **(low average)**	41.5 **(average)**	62 **(high)**	N/A
RBMT percentile rank (description)	5th **(impaired)**	13th **(low average)**	25th **(low average)**	42nd **(average)**	10th **(low average)**
DKEFS switching scaled score (description)	11 **(average range)**	1 **(impaired)**	10 **(average range)**	6 **(low average)**	9 **(average)**

PRMQ = Prospective Retrospective Memory Questionnaire [2]

RBMT = Rivermead Behavioural Memory Test [30]

DKEFS = Delis-Kaplan Executive Function System [6]

Table 1. Cognitive profile on tests of intelligence, memory and executive function for the study participants.

Phase	**1**	**2**	**3**	**4**
Meeting	***1 2***	***3***	***4***	***5***
DM reminders set (phase duration) *Allocation = BABA*	68 (in 31 days)	24 (in 31 days)	50 (in 60 days)	0 (in 30 days)
UP/no UP	UP	noUP	UP	noUP
WS reminders set (duration) *Allocation = ABBA*	45 (in 28 days)	31 (in 28 days)	49 (in 58 days)	68 (in 150 days)^
UP/no UP	noUP	UP	UP	noUP
NS reminders set (duration) *Allocation = AABB*	17 (in 32 days)	0 (in 31 days)	10 (in 29 days)	4 (in 29 days)
UP/no UP	noUP	noUP	UP	UP
MAC reminders set (duration) *Allocation = BABA*	15 (in 30 days)	0* (in 29 days)	14 (in 30 days)	6 (in 31 days)
UP/no UP	UP	noUP	UP	noUP
AL reminders set (duration) *Allocation = BBAA*	13 (in 32 days)	0** (in 30 days)	22 (in 85 days)	11 (in 46 days)
UP/no UP	UP	UP	noUP	noUP

^ The participant had a relapse of an illness related to her ABI that delayed the research meeting.

Table 2. The phase orders for each participant, number of reminders they set and number of days in each phase.

Phase	Mean daily reminders set					
	DM	MAC	NS	WS	AL	Total Daily Mean
UPs	1.29	0.48	0.24	0.93	0.21**	0.63
noUPs	0.39	0.1*	0.27	0.64	0.25	0.33

* For MAC the phone provided for the study was lost during the first month without UPs. The mean daily number of reminders set in the next month-long non-UP phase was 0.2 (6 reminders set in 30 days).

** For AL the UPs did not work during the second allocated UP month.

Table 3. Mean number of reminders set when receiving UPs and not receiving them .