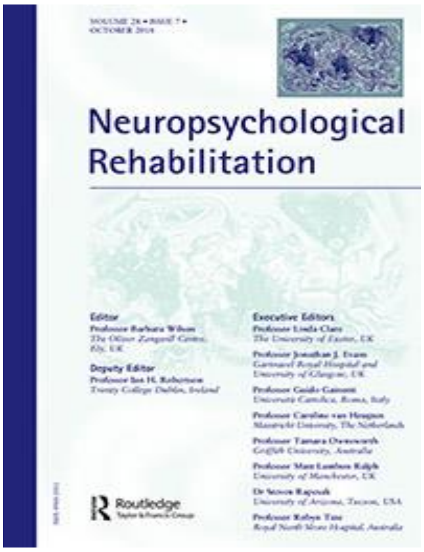

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Article: MindMate: A Single Case Experimental Design Study of a Reminder System for People with Dementia

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Abstract

Prospective memory difficulties are commonly reported in people with dementia. The evidence supporting the use of prospective memory devices among the dementia population remains limited. MindMate is a recently developed smart device application that aims to support individuals with a diagnosis of dementia, improving self-management skills and quality of life.

This study investigated the effectiveness and usability of the reminder tool on the MindMate application as a memory aid.

Three participants with a diagnosis of Alzheimer's disease were recruited to this multiple baseline single case experimental design study. Partners of the participants recorded their performance on everyday tasks on weekly monitoring forms during a baseline phase (between five and seven weeks) and during the intervention phase (five weeks) whilst using MindMate.

Two participants successfully used the app throughout the intervention weeks and gave positive usability ratings. Tau-U analysis showed a significant increase in memory performance between baseline and intervention phase (Tau-U = 1, 0.94, $p<0.01$). A third participant withdrew from the intervention phase following difficulties turning off the reminders and frustrations with the reminder alert sound.

For two of the three participants, use of MindMate was feasible and effective in supporting remembering of everyday tasks compared to practice as usual.

Keywords: Cognitive Rehabilitation, Compensatory Strategy, Dementia, Memory, Prospective Memory, Technology,

Introduction

Background

Prospective memory (PM) refers to the ability to remember to do something in the future (McDaniel and Einstein 2011) and is often impaired in people with dementia. PM tasks include remembering to attend an appointment, take medication, and turn off the oven after cooking. PM relies upon various cognitive functions, including executive functioning, working memory, attention and long-term memory (Einstein and McDaniel 1990); therefore, it is unsurprising that individuals with dementia experience difficulties with PM tasks. Indeed, it has long been established that prospective memory is vulnerable even in the early stages of dementia (Huppert and Beardsall, 1993), and is affected in a range of different forms of dementia including Alzheimer's disease and frontotemporal dementia (Dermody et al., 2016) and vascular dementia (Livner et al., 2009). PM is highly important for maintaining functional independence (Chasteen *et al.* 2001). Failure to complete an intended action can negatively impact activities of daily living and have serious health consequences (Spíndola and Brucki 2011). Furthermore, carers of individuals with dementia report failures in PM as more burdensome than retrospective memory failures (i.e. the ability to recall past events or information) (Smith *et al.* 2000).

Einstein and McDaniel (1990) proposed a distinction between time-based and event-based prospective memory: Time-based PM is remembering to perform an action at a certain time, while event-based PM is remembering to perform an action when some external event occurs, such as remembering to post a letter when driving past the post office. Although both types of PM are impaired in different forms of dementia, Dermody et al., (2016) found time-based PM to be disproportionately affected in an Alzheimer's disease group.

Taking into consideration the impact of prospective memory difficulties on people with dementia, it is important to identify appropriate interventions to address these difficulties. While there is currently no cure available for dementia, there is an increasing emphasis on early diagnosis to enable access to interventions that focus on improving independence and quality of life (BPS, 2016). Appropriate support can have a significant impact on the degree to which someone is able to manage their condition over time and live independently, delaying the need for care home or hospital admission, which adds savings to the health economy (Knapp *et al.* 2013). It also reduces both individual and caregiver distress (Jamieson *et al.* 2017a).

Memory Aids

External memory aids are a widely used and effective intervention for assisting people with memory impairment (Sohlberg et al., 2007). As a compensatory approach, they aim to bypass the deficit area and teach the individual strategies to solve functional problems (Kapur and Wilson, 2009). Mastering these strategies will, it is assumed, help the individual manage in their everyday environment despite the presence of the impairment (Dewar et al., 2016). While paper-based aids, including calendars, to-do lists and diaries, are omnipresent in populations with and without memory impairment, they are limited by being passive reminders - they require individuals themselves to initiate using or checking them which, in itself, is a memory task (Wilson *et al.* 1999). Electronic memory aids offer a means of overcoming this difficulty, as they often include a cueing device that attracts the individual's attention to the task and can include a facility for storing information (Kapur, Glisky, and Wilson, 2004).

Assistive Technology

Various electronic technology aids compensating for prospective memory difficulties have been shown to be effective in the acquired brain injury (ABI) population. For example, several studies have explored the use of NeuroPage, a portable pager that sends audio/vibration alerts to remind the person to do something, and have reported a significant improvement in target behaviours relative to baseline (e.g. Evans, Emslie, and Wilson, 1998; Wilson et al., 2001). Similar success has been demonstrated in personal digital assistants (PDAs) (e.g. Gillette and DePompei, 2008; Wright et al., 2001); smart watches (Jamieson *et al.* 2017b); and smart phones (Savage and Svoboda, 2013; Svoboda and Richards, 2009). In their systematic review, Jamieson *et al.* (2014) found good evidence for the efficacy of prospective memory reminding systems; a meta-analysis of seven group studies, of participants with ABI, gave a large overall effect size (d = 1.27) (n = 147).

Smart Phones and Applications

Various reminding applications (apps) can be used with smartphones, such as Google Calendar and Microsoft Office Calendar. In a study of people with an ABI, McDonald *et al.* (2011) conducted a small randomised controlled trial using the Google Calendar application, in which participants recorded completion of prospective memory tasks. After event details are recorded, Google calendar sends timed reminders to the person's mobile phone. In their study, McDonald et al., (2011) found Google Calendar to be significantly more effective than a paper-based diary. Similar positive outcomes were reported with an individual with ABI, who had severe verbal and visual memory difficulties and no prior use of a memory aid (Baldwin and Powell 2015).

Assistive Technology & Dementia

While numerous studies have evaluated the use of technological memory aids among the ABI population, research into their effectiveness among the dementia population remains scarce. Indeed, most research has been confined to micro-prompting devices, which guide people through a single task with several sub-steps. These studies have demonstrated success completing tasks including; hand-washing (COACH; Mihailidis, Carmichael, and Boger, 2004); food preparation (e.g. Kinempt: Chang et., 2013); and table-setting (Giulio E. Lancioni *et al.* 2009). Only one case report was identified investigating the effectiveness of an app

(Google Calendar) with a participant with mild Alzheimer's disease (El Haj *et al.* 2017). This study showed a reduction in forgetting of chosen target behaviours.

In 2015 a dementia specific application called MindMate was launched (https://www.mindmate-app.com/). The app includes features and videos on diet and physical health, as well as games and a tool for storing photographs, with the overall aim of supporting people with dementia to improve their self-management skills, and therefore maintain their independence for as long as possible. It also offers a reminder tool which was the focus of the present study.

Current Study

The present study aimed to examine the use of MindMate as a memory aid for people who have received a diagnosis of dementia, who are considered to be in the early stages, and who are specifically experiencing prospective memory difficulties. A secondary aim of the study was to help understand whether an application synced to a tablet or smartphone is a usable and acceptable off-the-shelf assistive technology.

The main hypotheses were:

- Performance on target memory tasks will improve significantly with the introduction of the MindMate reminding tool.
- The app will be a usable and acceptable form of assistive technology for people with dementia

Reporting follows the guidelines detailed in the Single-Case Reporting Guideline in Behavioural Interventions (SCRIBE) 2016 Checklist (Tate *et al.* 2016).

Method

Participants

Participants were identified and recruited from their community mental health team to the study. Patients who had received a diagnosis of dementia by a psychiatrist using ICD-10 criteria, which the psychiatrist considered to be in the mild stages, and who reported memory difficulties that had been confirmed by a professional or family member, were considered for participation. Participants owned a smart phone or tablet computer with internet access, and had a partner willing to support and monitor memory aid use.

Exclusion criteria were participants who:

- Had a pre-existing neurological or severe psychiatric problem (e.g. bipolar disorder, psychosis).
- Had a diagnosis of dementia considered to be in the moderate to severe stages.
- Had visual or auditory difficulties (which cannot be corrected with the use of glasses or hearing aids) that would prevent use of a smartphone.
- Had a diagnosed or suspected developmental learning disability.
- Those whose first language was not English.
- Those who were currently using online or electronic memory aids. Previous non-electronic memory aid use was documented but did not exclude individuals from participation.

Three participants were recruited to the project, all of whom had a diagnosis of Alzheimer's disease that was considered to be in the mild stages by their psychiatrist. One of these participants, CE, decided to stop using MindMate during the first week of the intervention phase. Initially, difficulties with turning off the reminder alarm were found, due to a bug on the app, and required fixing by the app developers. Following this, CE said she found the alarm sound frustrating and with reduced motivation, decided not to continue using the app. However, both CE and her partner agreed to continue with the baseline phase for another five weeks. The cognitive profile of this participant, as well as the remaining two participants, FD and SI, are reported in Table 1. Participants were assessed using the following neuropsychological tests and questionnaires:

- Test of Pre-Morbid Functioning (TOPF, Wechsler, 2011);
- Rivermead Behavioural Memory Test -3rd version (RBMT-3; Wilson et al., 2008);
- Wechsler Abbreviated Scale of Intelligence – 2nd edition (WASI-II; Wechsler, 1999);
- Trails subtest of the Delis–Kaplan Executive Function System (D-KEFS; Delis, Kaplan, and Kramer, 2001);
- Controlled Oral Word Association Test using letters F-A-S (Spreen and Benton, 1977);
- Prospective and Retrospective Memory Questionnaire (Smith *et al.* 2000).

Many of these tests had already been completed by participants FD and CE prior to participation in the study (within the previous six months), as part of their diagnostic assessment by their neuropsychological team. During the study only tests not completed within the previous six months were administered, to give an overall impression of participants' intellectual functioning, memory and executive functioning. Collateral information on daily functioning in these domains was also gathered from the participants' partners during the clinical interview.

Table 1. *Characteristics and Cognitive Profile for Participants FD, SI&CE*

	FD	SI	CE
Age (gender)	74 (male)	71 (male)	59 (female)
Diagnosis (severity)	Alzheimer's disease (mild)	Alzheimer's disease (mild)	Alzheimer's disease (mild)
Test			
WASI-II perceptual reasoning score	*	Average	Average
WASI-II verbal comprehension score	Low Average	Low Average	Low Average
WASI-II Full-Scale - 4	Low Average	Low Average	Low Average
TOPF estimated full-scale pre-morbid IQ	Average	High Average	Average
RBMT score (percentile rank)	Impaired (0.1)	Impaired (0.2)	Impaired (0.4)
Trails A score (percentile rank)	Average (*)	Low Average (20^{th})	High Average (90^{th})
Trails B score (percentile rank)	Average (*)	Impaired (<10^{th})	Average (40^{th})
Verbal Fluency score (percentile rank)	Impaired (*)	Average (30^{th})	Average (40^{th})
PRMQ – self-rating(t-score)	Impaired (7)	Borderline Impaired (34)	Average (56)
PRMQ – carer (t-score)	Impaired (27)	Average (49)	Borderline Impaired (33)

Key: WASI-II = Wechsler Abbreviated Scale of Intelligence – Second Edition; TOPF – Test of Pre-morbid Functioning; RBMT = Rivermead Behavioural Memory Test; PRMQ – Prospective and Retrospective Memory Questionnaire; * = not reported in the neuropsychological assessment report for participant

Recruitment Procedures

Potential participants were given written information about the study via a member of the Older People Community Mental Health Team (OPCMHT) or post diagnostic service they were known to, within NHS Greater Glasgow and Clyde (See Workflow diagram, figure 1). Following expression of interest, they were provided with further written information and they completed an opt-in slip, consenting to be contacted, which was sent to the researcher. The researcher contacted the potential participants who were provided with the opportunity to discuss the study further and ask questions. Once participants and their partners agreed to participate, they were asked to sign a consent form.

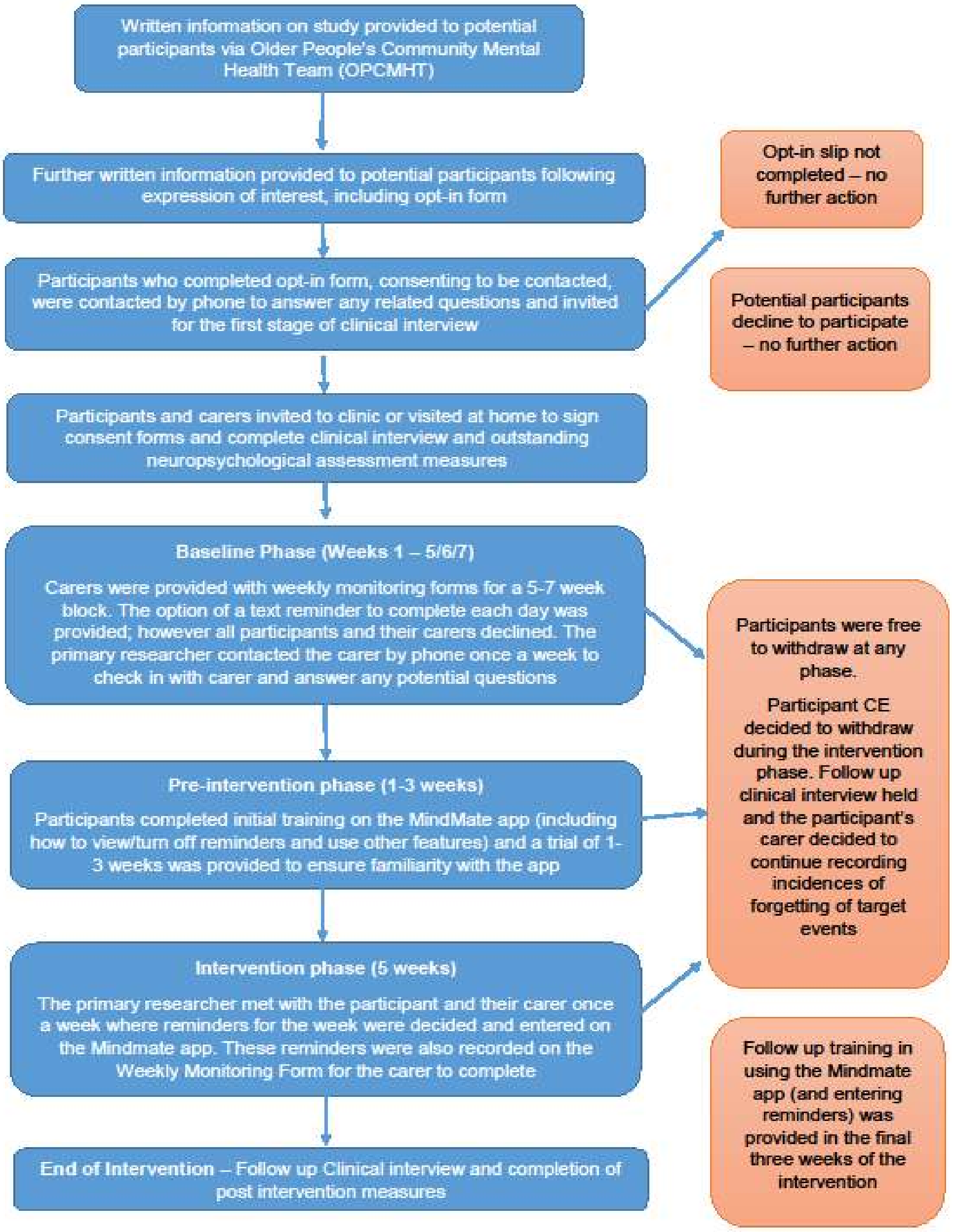


Fig.1. Workflow Diagram

Materials

MindMate is a free to download and use dementia application for tablets, iPhone and android devices (http://www.mindmate-app.com/). It includes a "Reminder" tool which allows events to be entered for a specific time and date, then sends reminder alerts about the event, thus acting as a memory prompt. Each participant used their own phone/tablet as it was assumed they would already be familiar with its use.

A weekly monitoring form listing individual prospective memory targets and the times they need to be completed by was provided to the partner. Baldwin and Powell (2014) highlighted the importance of picking memory targets that were personally meaningful for the individual, therefore memory targets were constructed in conjunction with the participant and the partner. This approach was also used in the NeuroPage studies (Wilson *et al.* 2001). On days where no targets could be identified, the researcher set a reminder for the participant to send a text message or make a phone call to the researcher. The weekly monitoring form was used daily by an identified partner to record whether or not activities were remembered and completed at an appropriate time, during both the baseline and intervention phases. They were asked to tick targets achieved without prompting from other people, and cross targets that were either forgotten, remembered but not completed, completed at the wrong time, or only completed following prompting from partner.

Design

A randomised single case experimental design (SCED) multiple baseline across participants study was used, staggering the onset of the intervention. The Medical Research Council (MRC) Framework for Complex Interventions (MRC, 2008) supports the use of SCED studies in the feasibility, piloting and evaluation stages of complex interventions (Craig et al., 2008). The present study focused on both the usability and effectiveness of the app.

Withdrawing intervention might raise ethical issues, therefore a multiple baseline, as opposed to a withdrawal (e.g. ABA) design was deemed most appropriate. The three participants were randomly allocated to a five, six or seven-week baseline using the Research Randomizer programme provided by the Social Psychology Network (http://www.randomizer.org). MindMate was then introduced for participants for a five-week period.

The study was developed with reference to the methodological quality criteria for single case experimental design studies (Risk of Bias in N of 1 trials – RoBiN-T, Tate et al., 2013).

Ethics

Ethical approval was obtained from the West of Scotland Research Ethics Committee 3 (16/WS/0219) and Specific Site Approval (16/WS/0219) granted from NHS Greater Glasgow and Clyde. Informed consent was obtained from all three participants and their partners.

Setting, Sessions, and Data Recording

An initial interview with the participant and their partner identified target behaviours as well as previous memory aid use (see Table 2 for example target events). Baseline data was gathered over 5-7 weeks, during which time, all target events that were forgotten and instances of reminding were recorded. Prior to the start of the intervention phase, each participant completed training in using the MindMate app. This involved a demonstration of the reminder tool on their smart phone or tablet; participants were sent reminders asking them to undertake a number of tasks (e.g. call the researcher) to ensure they could read the message and respond appropriately (i.e. press the correct button). The intervention phase then lasted five weeks.

Table 2 *Sample Target Events for Participants FD & SI*

Initials	Sample Target Events
FD	- Call a family member - Attend an appointment - Gardening - Go to the shop
SI	- Go to choir - Attend a meeting - Bring/collect granddaughter from ballet - Make soup

At the beginning of each week of the intervention, the researcher met with the partner and participant in their local OPCMHT office or in their home. They were asked about upcoming events for the week which were entered into MindMate by the researcher. The participant was asked how far in advance they would like to receive the reminder. Reminders were delivered at various times across the day, and so participants were encouraged to have their tablet or smartphone on them at all times. Similar to baseline, the partner recorded all target events that were forgotten as well as instances of reminding. The partner also recorded instances where the MindMate reminder failed to come through on the correct day or time, or any other technical difficulties noted with the application.

Towards the end of the intervention phase, participants received 2-3 further training sessions on how to use MindMate. This included the provision of a step-by-step guide, alongside illustrated instructions on how to locate, enter, and navigate the app and its Reminder tool (Appendix 7). This included inputting and deleting reminder events. The acquisition of this skill did not form part of the aims of this study; however qualitative information was gathered upon completion of the training.

Following completion of the intervention block, qualitative information was gathered to evaluate the usefulness of MindMate, to identify its strengths and limitations and to ascertain whether the participant would use the aid in the future. Participants were asked to complete a pre- and post-study questionnaire on eight domains, adapted from the Unified Theory of Acceptance and Use of Technology (UTAUT) questionnaire (Venkatesh et al., 2003). These were administered at the initial clinical interview and the follow up clinical interview. The UTAUT includes groups of items concerning: performance expectancy (expectancy that the technology will be useful for its purpose); effort expectancy (perception of effort needed to use it); attitude towards the technology; social influence (the influence of others on the use of the technology); facilitating conditions (the extent to which their environment facilitates use of the technology); self-efficacy (estimations of their own ability to use the technology); anxiety (levels of anxiety felt when using the technology) and behavioural intention (an indication of whether the participant is intending to use the technology in the next 6 months). Scores for each item (on a scale of 1 to 5) within each domain can be pooled to give overall scores for each domain at each time point.

Data Analysis

Frequencies were calculated for percentage of target events remembered out of all events each week. It was anticipated that the frequency of events to be remembered would differ on a weekly basis, so percentage of events remembered were calculated each week. As well as visual inspection, statistical analysis was also undertaken.

Visual inspection includes the calculation and transformation of each participant's performance to a graph for the purpose of visually analysing (a) trend (progress over time), (b) level (magnitude of the data), and (c) stability (variability or "bounce" of the data) (Gast, 2005). The procedure for visual inspection follows steps as outlined by Lane and Gast (2014) using the graphic display and divided into (a) within-condition and (b) between-conditions analysis of data. Stability was defined as 80% of data points being within an envelope of ±25% of the phase median.

Tau-U analyses were conducted to investigate whether significant improvements in performance of memory tasks were found between the different phases. Tau-U is a method for measuring data non-overlap between two phases (A and B) (Tau-U; Parker et al., 2011b). Non-overlap methods do not rely on means, medians, or modes but rather consider individual values of all data points in pairwise comparisons across phases (Parker et al., 2011b). Non-overlapping data as an indicator of performance difference between phases is included in standards for evaluating SCED's (Horner et al., 2005). Tau-U is a distribution free non-parametric technique, with an index well-suited for small datasets, and is useful in aggregating data across phases to provide an overall effect size. Analysis was run, and reported, with and without adjustment for baseline trend. Depending on the data, it possesses statistical power of 91-115 percent of parametric tests (Vannest, Parker and Gonen, 2011). All calculations were performed via the website: http://singlecaseresearch.org/ (Vannest, Parker, and Gonen, 2011).

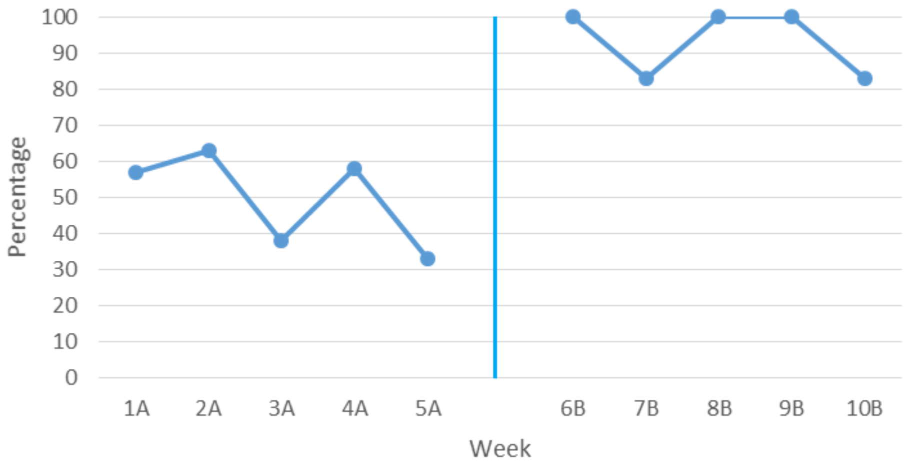
The UTAUT scores were reported descriptively.

Results

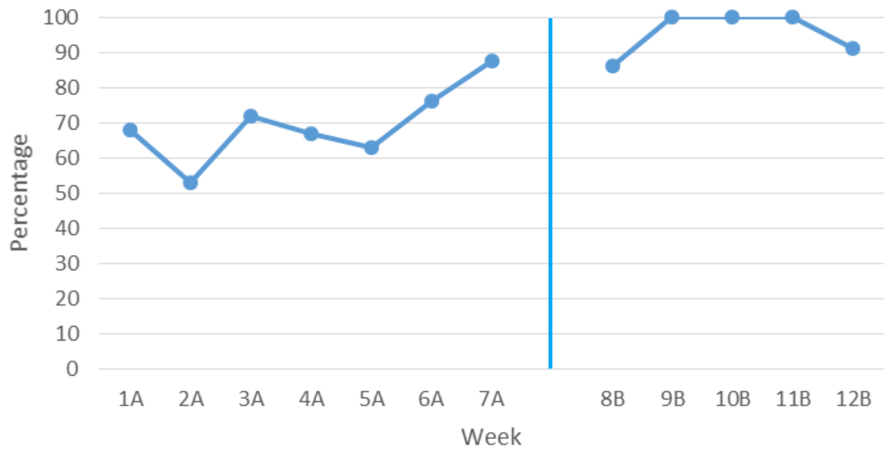
Quantitative Summary of Results

Data were collected between February and June 2017. The three graphs in figure 1 summarise the data of the three participants, FD, SI and CE, respectively. The data points represent the percentage of completed target events during baseline and intervention phases. No adverse events were recorded for any participant during the study. Participant FD completed 49% (41/83) of tasks during baseline phase, and 93% (31/33) of tasks during intervention phase, without partner prompting. Participant SI completed 69% (84/121) of tasks during baseline phase, and 95% (35/37) of tasks during the intervention phase. Participant CE completed 51% (71/137) across eleven weeks of baseline phase.

Participant FD



Participant SI



Participant CE

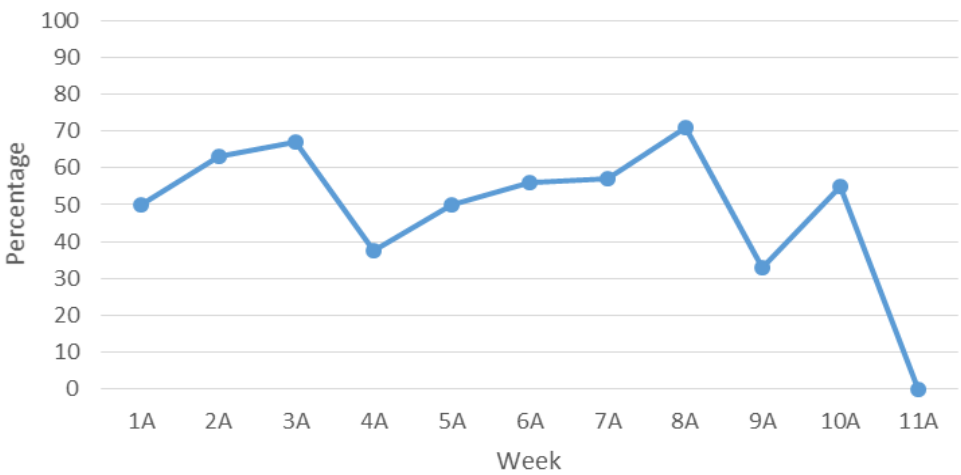


Fig.2. The three graphs summarise the data of the three participants, respectively. The data points represent the percentage of target memory tasks completed each week in each study phase (A = baseline, B = intervention). The Y axis shows percent performance and X axis shows study week.

Participant FD

Evaluation of phases A and B for participant FD indicated data were variable during baseline and intervention. Split-middle method of trend estimation was conducted and indicated there was a decreasing contra-therapeutic trend during baseline and zero-celerating trend during intervention. Data were considered variable in the baseline phase, and stable in the intervention phase, following application of a stability envelope to trend lines. Mean, median and relative level change measures indicated a positive (improving) change from phase A to B.

Tau-U analysis was used to determine performance change between baseline (phase A) and intervention (phase B), and revealed a significant improvement in performance of tasks between baseline and intervention phases (1, $p<0.01$) for participant FD. According to (Parker *et al.* 2011a) this indicates a large effect size. As the baseline trend was downward (declining performance) adjustment for baseline trend was not applied.

Participant SI

Evaluation of each phase for participant SI indicated data were stable during baseline and intervention. Split-middle method of trend estimation was conducted and indicated there was an increasing trend in a therapeutic direction during both phases. Data were considered stable following application of a stability envelope to trend lines. Mean, median and relative level change measures indicated a positive (improving) change across conditions.

Tau-U analyses revealed a significant improvement in performance of tasks between baseline and intervention phases (0.94, $p<0.01$). According to Parker *et al.* (2011a) this indicates a large effect size. When adjusted for baseline trend, the Tau-U was reduced (0.69, $p=0.05$).

Participant CE

Evaluation of the baseline phase for participant CE indicated data were variable, and remained variable following application of a stability envelope to trend lines. A split middle method of trend estimation was conducted and indicated there was a marginally increasing trend in a therapeutic direction over the whole period of data collection, though there was a large decline in the last week, with no tasks remembered that week.

Usability and User Experience

We investigated whether or not the participants found the app acceptable. FD completed three weeks of training prior to beginning the intervention phase, and SI completed one week of training. Problems with the app were reported for all three participants (Table 3). These included occasions where the reminder did not come through at the specified time/day and when the reminder alarm failed to stop despite the participant clicking into the app. The developers recognised a bug on the app with regards to the latter problem and updated the app to remove it.

Table 3 *Number of App Errors Reported by Each Participant*

Participant	Number of App Errors Reported
FD	3
SI	5
CE	3

App errors included: reminder not coming through at right time/day; recurring alarm sound; reminder not appearing under correct day;

Table 4 shows mean scores for each individual UTAUT category for participants FD and SI. Lower scores represent a more positive user experience. The results indicate that FD had a better experience using the technology than SI, but both appeared to score quite low overall. There was an overall decrease in FD's scores between pre- and post- intervention, however the mean score for the anxiety domain increased from 1 (strongly agree) to 2 (agree). SI's scores increased on performance expectancy, effort expectancy, social influence, and self-efficacy. While SI expressed intention to continue using the app following completion of the study, he expressed uncertainty about the usefulness and helpfulness of the app as he was still learning to enter reminders independently. Further training sessions were offered, and accepted, to ease any anxiety using the app.

Table 4. *UTAUT Mean Scores on Each Category for FD and SI*

	FD		SI	
	Pre	*Post*	*Pre*	*Post*
Performance Expectancy	1.67	1	2	2.67
Effort Expectancy	1.75	1.75	2.25	2.5
Attitude	1.67	1.67	1.67	2.33
Social Influence	1	1	2	4
Facilitating Conditions	3	1	2	2
Self-efficacy	3	1	2	4
Anxiety	1	2	2	2
Behavioural Intervention	1	1	2	1
Total Score	28	25	36	42

Lower scores in the UTAUT indicate a better user experience. UTAUT item responses are out of 5, with responses ranging from Strongly Agree to Strongly Disagree. The total is out of 85.

Follow up questions to the questionnaire provided some qualitative information.

FD said, "Wish I had it earlier" when asked about overall impression of the app. His partner said she enjoyed the "principle of it". She described how she usually does everything for FD and tells him everything that he needs to do whereas the app "gives him something for himself…a sense of independence".

SI said the alarm "sound was good for catching my attention" when otherwise engaged. He found it helpful "to some extent", although reported frustration with ongoing memory difficulties. The partner of SI also reported frustration with the errors associated with the app, reported earlier. Specifically, the times when the reminders did not come through as specified. She described how the reminder app does not capture the other, perhaps unexpected, memory difficulties that SI was experiencing, such as remembering to collect luggage from airport carousel or remembering to check he has all necessary items (e.g. keys, wallet) when leaving the house. SI's partner also reported increased incidences of confusion in SI, since commencing the study, which she attributed to the app and when the reminders did not come through as intended.

When asked about the main difficulties associated with using the App, prior to withdrawal, the partner of CE said that CE was “either in denial of memory difficulties…or lacked insight into them”. CE reported her memory to be “fine” and described the noise from the alarm as “annoying”. CE’s partner reported that usually CE would be very motivated to participate in research studies, however she was struggling to use other parts of the iPhone and so wondered whether her difficulties operating the app made her want to withdraw from the intervention phase. He noted increased apathy in CE and wondered if this was possibly a result of her dementia diagnosis. He said he wished the study had taken place a year ago, when CE exhibited fewer difficulties with memory and completing tasks.

Discussion

Efficacy

Baseline data confirmed that all participants often forgot to carry out target behaviours or only carried them out if reminded by their partners. The results of the efficacy analysis show that introduction of the reminder app for FD and SI led to a statistically significant change in prospective memory performance for both participants, with a large effect size reported for both. Although CE withdrew at the intervention phase, the extended baseline period provided very important experimental control in relation to the possibility of improvement in performance unrelated to the intervention (i.e. controlling for any potential effect of regular monitoring/recording of remembering performance). This is further discussed later in relation to the issue of the improving baseline trend observed in SI.

With increasing emphasis on early detection and intervention for people with dementia, this study adds to the limited, but growing, body of literature suggesting the effectiveness of electronic memory aids for people with dementia. While this was the first piece of research evaluating the effectiveness of the MindMate app as a reminder tool, similar positive results have been reported with the Google Calendar app with both the ABI and dementia population (McDonald et al, 2011; Baldwin and Powell, 2014; El Haj et al., 2017).

Usability

There are an increasing number of older people using smart phones and tablet devices; they are relatively easy to use, socially acceptable and cost-effective. In a recent survey of memory aid use among people with brain injury, Jamieson et al., (2017a) noted that other technologies, including pagers, dictaphones, and electronic organisers have become obsolete, as many of their functions can now be performed on smartphones. This has facilitated the introduction of more sophisticated, cheaper and user-friendly aids, such as the MindMate app.

Smartphones and tablet devices also offer a solution for overcoming any potential stigma that might be associated with using an aid. Baldwin et al., (2011) found that a key factor leading to avoidance of memory aids among people with brain injury was that they were a threat to the individual’s pre-injury identity. The same could be considered for those with a diagnosis of dementia. The importance of offering memory compensatory strategies that reflect an individual’s sense of self, lifestyle and values has been highlighted previously (Baldwin et al., 2011). Smartphones and tablet devices address this issue, due to their omnipresence in today’s society.

The secondary aim of this research was to evaluate the usability and acceptability of this app as an assistive technology device for people with dementia. The UTAUT scores were overall positive; both participants expressed a favourable opinion of the app, and expressed intention to use the app following completion of the study. However, frustrations were noted when the app did not function as intended, and this influenced both SI's self-efficacy and his partner's beliefs around the potential benefits of the app.

Apps on smart devices are continually developing and upgrading; this is in response to both growing consumer demand, and to updates on the devices' operating systems, which can impact the app's functioning. For example, problems with turning off the alarm for CE were a result of a bug developing on the app, following an upgrade of the smartphone's mobile operating system (iOS for Apple). As a result, an update of the MindMate app was required to remove this bug. These changes are difficult to control for and present a challenge in terms of a person with dementia's ability to adapt to these changes and upgrades. The impact of upgrades and changes to an app on the individual with dementia is an important consideration for the developers of apps that target this population as well as researchers.

For example, future studies evaluating apps should be transparent with potential participants about the possibility of technical difficulties at the point of recruitment. The current researcher was in regular contact with both participants and app developers, therefore the difficulties were addressed in a relatively short space of time. However, if this regular access is not available, contact details for accessing technical support should be made available to participants at the outset.

The results of the UTAUT questionnaire should be interpreted with caution as it is not a standardised measure and it only reflects the views of two participants. Indeed, the third participant withdrew from the study following reported frustration with the alarm sound and difficulties turning off the reminder. This would suggest that she found it neither acceptable nor usable. The partner of CE believed that CE's dementia was too far advanced for her to learn to operate a new app; this suggests it may be important to consider the role of insight as inclusion criterion for future research. While CE expressed enthusiasm to participate at the outset of the present study, results of her PRMQ would suggest that she did not believe her memory difficulties were at the level of impairment. Indeed, at follow-up interview, CE described her memory as "fine" and "good". While lack of insight is a common clinical feature of people with dementia, it is possible that this might impact participation in research to support a difficulty that they might not believe they have.

Methodological Limitations

The study followed RoBiNT recommendations for both external and internal validity in SCED studies (Tate et al., 2013). While these were mostly met, certain scale items were more difficult to achieve.

It was not expected that that the reminder strategy would have any long-term effects on memory ability following completion of the study; therefore, no generalisation measures were undertaken. A description of setting was also not provided; as the reminders were delivered across the day; the participants may have been in their home or elsewhere in the community at the time of receiving them.

Tate *et al.* (2013) recommend the demonstration of at least three repetitions of treatment effect. Due to time constraints, the present study could only demonstrate two repetitions, following withdrawal of participant CE. This also impacted the score for design with control, as only four phases were recorded. It was also not possible to blind the participant or therapist to the study conditions because training had to be provided on using the app prior to commencing intervention phase. The lack of blinding of the experimenter was unlikely to cause bias, as it was the app that was delivering the reminders to the participant.

It was often difficult to identify memory targets for the week ahead for participants; therefore proxy experimental memory tasks were created (e.g. send researcher a text message at a certain time). The researcher met with each participant and their partners at the beginning of each week, during the intervention phase, and they often did not have clearly defined schedules for the week ahead. The majority of people who receive a diagnosis of dementia are in the older adult population, and are therefore more likely to be retired and may have fewer fixed events in their week. This highlights the importance of baseline and intervention phases being long enough to capture events for which a reminding device is likely to be helpful. In the present study baselines of up to seven weeks were used, which was feasible but does place demands on participants (including carers) to continue to record everyday difficulties whilst waiting for them to use a device that may be of benefit to them.

The partner of SI also noted that less anticipated events (e.g. leaving luggage at airport) were most distressing for SI, and these events were difficult to capture using the MindMate app. This difficulty in predicting, measuring and controlling for unexpected or unusual events that might catch people out was also reported by Jamieson et al., (2017) in their study evaluating smartwatches.

Wolery and Harris (1982) advised on the continuation of the baseline phase condition if behaviours were changing in a therapeutic direction. This did not happen for participant SI, despite an increasing trend being observed, for a couple of reasons. First, the participant was very eager to begin using the MindMate app and, having initially informed him and his partner of the 7-week time frame for baseline data collection, the researcher was concerned about patient engagement should baseline have to continue indefinitely. Second, dementia, unlike ABI, is a degenerative condition, and with focus on early intervention, it would seem unethical to make the participant continue with baseline for an unknown period of time. It does however limit the conclusions that may be drawn with regard to the multiple baseline design. SI showed an increase in performance around week six of the baseline phase. FD also showed an increase in performance at week six, attributed to the introduction of the MindMate app. In relation to multiple baseline methodology this raises the possibility that both participants were showing improvement in performance that was not related (in the case of FD) to the onset of the intervention, but rather was a result of some other factor. It seems unlikely that some form of spontaneous improvement in memory functioning (in the context of dementia). Another option could be that the practice of regular monitoring/recording of performance was acting to raise awareness of remembering tasks and so improve performance. If this was the case then one might have expected CE to show a similar increase in performance after a similar amount of time, but as reported, CE's performance was stable throughout the baseline period (and possibly declining in the final few weeks). Furthermore, FD was also showing a decreasing performance over the baseline period, with a very marked increase immediately upon introduction of the MindMate.

Recruitment took place across three community mental health teams over a five-month period. However, only four participants were initially identified, and two completed the study. One possible reason for this could be the lack of people being diagnosed with mild dementia within the teams. Indeed, many health professionals and post-diagnostic support workers from the teams noted the dearth of patients with a diagnosis of mild dementia on their caseload; most, if not all, were in the moderate to severe stages of their illness. Jamieson et al., (2014) suggested that memory aids may support learning of associations (e.g. taking medication and mealtimes). For this reason, they highlight the added advantage of training participants to learn to use an aid while the cognitive impairment is relatively mild; the knowledge is more likely to be retained as a person's memory deteriorates. However, other studies have shown positive effects evaluating electronic memory aids with participants with both moderate and severe dementia (e.g. Oriani et al., 2003;Mihailidis et al., 2004; 2008). For example, (Mihailidis et al., 2004) reported increased performance at handwashing using their computerised device (COACH) in participants with moderate to severe dementia. It would be interesting to expand inclusion criteria for future similar research to include those with a dementia considered to be in the moderate or severe stages, and evaluate differences.

Staff also reported a low number of patients on their caseload who owned a smart phone or tablet. According to Ofcom (2016), smartphones are the most widely-owned internet-enabled device. Although 66% of adults own a smartphone, and 54% of households own a tablet, the 65+ population are reported to be the slowest in terms of uptake of smart devices. However, the number of users is projected to increase year on year (Statista, 2017).

Conclusion

The findings from this study provide evidence supporting the effectiveness of the intervention. While user experience was mostly positive, some concerns were raised in relation to the nature of the reminder offered and the frustration experienced when the reminder, very occasionally, did not deliver, as intended. It is possible that the lack of research looking at the efficacy of memory aids with this population is a result of the many challenges experienced in this study. Nonetheless, both participants indicated overall favourability with the app, with intention expressed to continue using it to support their memory difficulties. Therefore, the MindMate app could serve as a feasible intervention for prospective memory difficulties in people with dementia in clinical practice.

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