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Text messages reduce memory failures in adults with brain injury: A single-case experimental design

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Abstract

Introduction: This study evaluated the efficacy of a low-cost reminder system to support prospective memory after traumatic brain injury and identified factors that contributed to the outcome.

Method: Two single-case experimental designs with multiple baselines across activities are described. Participants presented moderate-to-severe cognitive impairments in one case and post-concussion syndrome in the other. Both reported memory problems in everyday activities. Target activities were selected using the Canadian Occupational Performance Measure. Participants were taught how to send reminders through Google Calendar to their mobile phones.

Results: The Canadian Occupational Performance Measure showed improved self-perception of performance and satisfaction levels. Using non-overlap of all pairs statistical analysis, most, but not all, target activities showed statistically significant improvement, with non-overlap ranging from 47% to 98%. Adjustments in the use of the reminders based on each participant's activities and cognitive abilities were required in order to maximise the benefits.

Conclusion: The reminder system was effective in increasing the frequency of completion of routine activities of daily living. To increase the effectiveness of ubiquitous technology in supporting cognition after brain injury, several factors co-existing with cognitive problems should be taken into account.

Keywords

Prospective memory, traumatic brain injury, reminder messages

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Introduction

The use of technology to support cognitive function is common in daily life. For example, mobile phones and personal digital assistants contain calculators, alarms, calendars and reminders, and can store information such as phone numbers, notes or whole books. The idea underlying the use of technological aids is to extend a person's cognitive ability to help them deal with the complex demands of daily-life activities (LoPestri, 2004). In recent years, technology has been increasingly integrated into clinical settings for different types of cognitive impairment, including memory, attention, time management, organisation and planning skills (Jamieson et al., 2014; Gillespie et al., 2012; Lannin et al., 2014). However, literature in the field of assistive technology for cognition has shown variable outcomes (de Joode et al., 2010; Gillespie et al., 2012), and it is not always clear how the same technology can be applied to different cognitive problems (Lannin et al., 2014). A small randomised control trial demonstrated that receiving text messages sent through Google Calendar to support memory difficulties after brain injury produced varying levels of improvement across participants, probably related to aspects such as the personal meaningfulness of targets, motivation and the number of target behaviours (McDonald et al., 2011). Another study reported on participants who received reminder messages from their mobile phones (Stapleton et al., 2007). Only two of the five participants increased performance in the target behaviours, and the

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authors concluded that this technology may be less suitable for persons with severe brain injury. The influence of non-cognitive aspects on the outcome of using technological aids remains a matter of study (Baldwin et al., 2011). More research is needed to identify clearly the factors that influence efficacy when deciding to use technological aids. Client-centred approaches such as single-case experimental design (SCED) studies provide evidence for the efficacy of an intervention in individual participants and may help us to understand what factors influence outcomes in individuals where these factors can be systematically manipulated (Tate et al., 2013). The Oxford Centre for Evidence Based Medicine (OCEBM) recently updated its classification of 'Levels of Evidence' and places SCED trials at their highest level of evidence for evaluating whether an intervention helps (Howick et al., 2011). Larger group studies also have the potential to examine factors that impact on outcomes, but this is often limited by the fact that studies may be powered to examine efficacy but not powered to examine specific factors that may vary considerably between participants. SCED studies allow a detailed, systematic and controlled examination of the performance of individuals and allow us to generalise to individuals with similar characteristics, particularly when results have been replicated across individuals.

The aims of the present study were to evaluate the uptake of a simple, inexpensive memory aid – SMS notifications sent through Google Calendar – to reduce everyday memory failures in two patients and to identify which factors contributed to the outcome. A central aspect of the research was the use of the Canadian Occupational Performance Measure (COPM; Law et al., 1998), which was used to ensure that only activities that were meaningful to the participants were included. We used a multiple-baseline single-case experimental design to evaluate the effectiveness of the intervention statistically. In addition, we provide a discussion of factors that appeared to affect outcomes during the course of the study, and examine these factors in relation to findings from previous studies. Future SCED studies in different types of patients with brain injury would help to identify new factors that should be considered. Further studies are needed to evaluate how frequently these factors are present in clinical practice.

Method

Participants

Two participants attending a community brain-injury rehabilitation service took part in the study. The participants were recruited as part of a pilot study exploring the use of Google Calendar as a memory aid after acquired brain injury. Both were identified by the interdisciplinary team and were approached in the first instance by their therapist, who provided brief verbal and written information in addition to the invitation to participate. Informed consent was obtained. Ethical approval was obtained from the National Health Service (NHS) West of Scotland Local Research Ethics Committee.

Experimental design

We used SCED methodology (Tate et al., 2013) with multiple baselines across target activities (Figure 1). For this experimental design, a series of target activities (dependent variables) were identified with each participant using the COPM. A systematic measurement of engagement in target activities was carried out in two phases: baseline and intervention. The intervention phase will be referred to as the reminder phase (independent variable) in this study. The onset of the reminder phase was different for each target activity, and it was randomly established, with the only criterion of having at least five data points during each phase. In multiple-baseline designs, it is expected that the benefit of the intervention (a reminder in the present study) would be specific to the activity targeted and would not be generalised across behaviours. Data points collected during baseline and intervention phases were contrasted using non-overlap of all pairs (NAP) statistical analysis (Parker and Vannest, 2009). This method offers statistical indices that indicate to what extent performance during the intervention phase is different from the baseline.

The reminder system

Participants received SMS text messages sent through Google Calendar. The principle underlying the system is that an organiser (calendar) stores information about

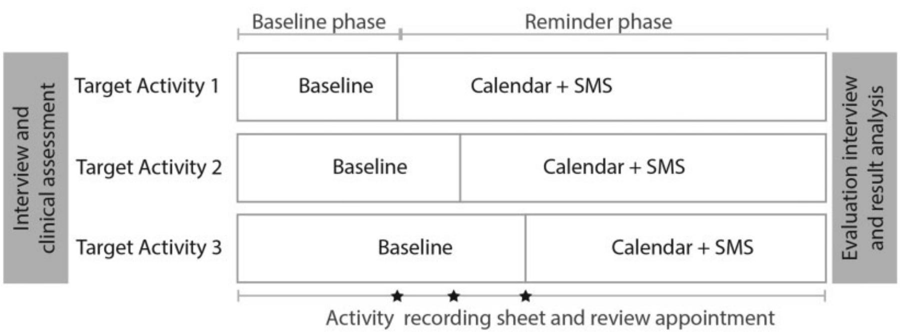

Figure 1. Experimental design. Each target activity has a different baseline length. Review sessions are indicated with a star at the bottom.

what and when something has to be done, and an auditory alarm along with a text message associated with these activities prompts the performance of a specific task. The system can be set up with smart phones or personal digital assistants, with both of these systems being ubiquitous and not designed specifically for rehabilitation.

Assessments

Each participant undertook a semi-structured interview to identify their experience of using computers, the internet and mobile phones, and to review the cognitive strategies that they were using or had previously tried. The COPM was used to evaluate activities of daily living (ADL) and to detect changes in participants' self-perception of occupational performance after the intervention phase. This tool provided a rating of each participant's priorities regarding activities that could be used as target activities. The Patient Competency Rating Scale (PCRS; Prigatano, 1986) was used as a measure of the performance in ADL from the perspective of a significant other pre- and post-intervention. The Hospital Anxiety and Depression Scale (HADS; Zigmond and Snaith, 1983) was used to screen for anxiety or depression before the initiation of the study and on completion of the study. Participants underwent a neuropsychological assessment, including the 3rd Version of the Wechsler Adult Intelligence Scale (WAIS-III) short form to obtain a general index of intelligence; the Rey Complex Figure Test (RCFT) to examine visuospatial impairment; the Cambridge Prospective Memory Test (CAMPROMPT; Wilson et al., 2005) to evaluate event- and time-based prospective memory; the Rivermead Behavioural Memory Test – Third Edition (RBMT-III; Wilson et al., 1985) to evaluate a range of memory functions relevant to everyday remembering demands; and the Modified Six Elements Test from the Behavioural Assessment of the Dysexecutive Syndrome (BADS; Wilson et al., 1996) to evaluate planning, task scheduling and performance monitoring. Information about premorbid IQ was also obtained from clinical records in order to describe the level of impairment post injury.

Data acquisition

Activity recording sheets were completed for all target activities across baseline and reminder phases. Participant 1 completed the recording sheet by himself, whereas a significant other completed the recording sheet for Participant 2. Each row in the recording sheet corresponded to a target activity; the columns contained the days of the week. Participants had to indicate whether the activity was performed by ticking the corresponding box. The exact time when the activity was performed was required only for timed events (for example, taking medication).

Experimental procedure

The study was carried out over a period of approximately 3 months for each participant. They attended an initial and final session that consisted of assessment and interview. During the baseline phase, participants completed the recording sheets without receiving reminders. Three review sessions were carried out across the study (Figure 1). Participants were taught how to set reminders through Google Calendar in the first review session; new reminders were activated in the following review sessions. The activation of the reminders was carried out by the participants in the rehabilitation centre with the support of an occupational therapist, who explained that reminders would be activated gradually for the different target activities. The target activities selected were the highest rated on the COPM. They were asked not to add activities independently until finishing the study. Both participants had experience of using computers and the internet. Therefore, they did not experience major difficulties learning how to use the calendar. A manual was developed for this research, which demonstrated step by step how to create an account and set the reminders. At the end of the intervention phase, the COPM was re-administrated in order to assess participants' self-perception of performance and satisfaction level of their target activities. At this point, recording sheets were also collected and the significant other repeated the PCRS. The participants received detailed feedback on their performance at a later date.

Results: Description of participants, including cognitive functioning prior to intervention

Participant 1 (P1)

P1 was 22 years old when he was assaulted. He sustained a severe diffuse traumatic brain injury, frontal contusions, extra-axial haematomas and an anterior cranial fossa fracture. P1 does not remember the assault. He has no previous history of brain injury or any medical/psychiatric condition. He had obtained a Higher National Diploma, and was working before the accident. At the time of the study, he had not been able to return to work and lived with his family (parents and sibling). He participated in the study 3 years post injury. P1 made a very good physical recovery. However, cognitive and emotional problems remained. The main difficulties after the assault were poor sleep patterns, fatigue and slowed information processing. His premorbid IQ was estimated at the top end of the average range. He showed a significant decrease in his general intellectual functioning after the assault, although remaining in the average range. This decrease is primarily explained by a significantly low processing speed index that reduced to the low-average range (see WAIS-III results in Table 1). The RCFT indicated a normal visual-spatial functioning. In terms of memory, the RBMT showed an average memory index, and his performance in the CAMPROMPT fell in the average range. Despite having average scores on memory tests, P1 reported daily-life prospective memory problems. On the PCRS, P1's mother reported his main difficulties as cognitive (for example, understanding new instructions, scheduling activities and memory). She reported emotional

Table 1. Test scores.

Test	P1 scores	P2 scores
WTAR	108	117
WAIS-III (Short Form)		
Full Scale IQ	97	109
VCI	98	114
POI	93	107
WMI	102	109
PSI	81	91
RCFT (Copy)	33/36 (11–16th percentile)	34/36 (>16th percentile)
CAMPROMPT	36	32
RBMT 3 – General Memory Index	106	120
BADS (Modified 6 Elements)	4/4	4/4
PCRS	Pre: 105 Post: N/A	Pre: 115 Post: 109
HADS	Pre: A = 11/D = 8 Post: N/A	Pre: A = 7/D = 9 Post: A = 7D = 6

WTAR: Wechsler Test of Adult Reading; WAIS-III: 3rd Version of the Wechsler Adult Intelligence Scale; VCI: Verbal Comprehension Index; POI: Perceptual Organisation Index; WMI: Working Memory Index; PSI: Processing Speed Index; RCFT: Rey Complex Figure Text; CAMPROMPT: Cambridge Prospective Memory Test; BADS: Behavioural Assessment of the Dysexecutive Syndrome; PCRS: Patient Competency Rating Scale; HADS: Hospital Anxiety and Depression Scale.

dysregulation, which affected his performance in instrumental ADL. He was independent in basic ADL. On the HADS, he scored moderate for anxiety and mild for depression.

Participant 2 (P2)

P2 was assaulted when he was 32 years old. He scored 15/15 on the Glasgow Coma Scale on admission. However, he and his wife reported significant changes after the accident related to his cognitive and emotional state. His medical history shows no previous head injury but he reported about six or seven depressive episodes since he was 15 years old, for which he was prescribed antidepressant medication. P2 self-referred to the rehabilitation centre, where he was diagnosed with post-concussion syndrome (PCS). He participated in the study two years after the assault. He was working and lived with his wife and child at the time of this study. P2's premorbid IQ was estimated at the high-average range. His general intellectual functioning decreased significantly after the assault, falling in the average range (Table 1). His processing speed index was significantly slow relative to the other indices, which were closer to his premorbid IQ. His visual-spatial functioning was normal (performance above the 16th percentile in the RCFT). P2 performed in the high-average range in the memory test (RBMT-3) and in the average range in the prospective memory test (CAMPROMPT). There was no evidence from the neuropsychological assessment of memory or executive function impairment. However, P2 showed a significantly low processing speed. Additionally, he reported fatigue, sleep disturbance, irritability and anxiety, all of which are indicators of a PCS (King, 2003). Despite not showing memory problems on the table top assessments, P2 reported experiencing daily-life memory problems, probably due to low processing speed and non-cognitive problems. He scored in the normal range for anxiety and borderline for depression on the HADS. On the PCRS, P2's wife reported that his main difficulties were related to his emotional regulation. She also reported that P2 had problems remembering to do things and staying involved in work activities, which affected his performance in daily-life activities and in meeting daily-life responsibilities.

Results: Participants' use of cognitive strategies and technological aids prior to intervention

Participant 1

P1 used his mobile phone to set alarms for medications. He considered the alarms to be effective but annoying (sometimes the alarm went off in situations in which he wanted his phone to be silent, such as in the cinema). Another problem he identified was that if he did not take the medication shortly after an alarm went off, he was likely to forget about it. Sometimes he wrote lists for the things he had to do, but he forgot to check them. He mentioned that one of his main cognitive difficulties was forgetting activities when he was doing something else, in particular when using the computer. Passive memory aids did not seem to be effective in his case. P1 was familiar with the use of mobile phones and computers, as his previous studies and work involved the use of these devices.

Participant 2

P2 was familiar with the use of a diary to remember to do activities at work. After the injury, he started to use special features in his mobile phone to recall the activities he had to perform, but he often forgot to look at them. His wife often sent him text messages as reminders, although P2 suggested that this system was not very effective because he generally did not perform the activity immediately after receiving the message and he was likely to forget about it. On the other hand, he depended on his wife to send him the messages. Sometimes he also wrote notes on his hands as reminders. Pre-study, P2 was familiar with the use of mobile phones and computers.

Results: Performance on target activities

Participant 1

Target activities selected by P1 were: (1) taking medication, (2) getting ready for next day, (3) preparing to leave home and (4) eating pattern (Figure 2).

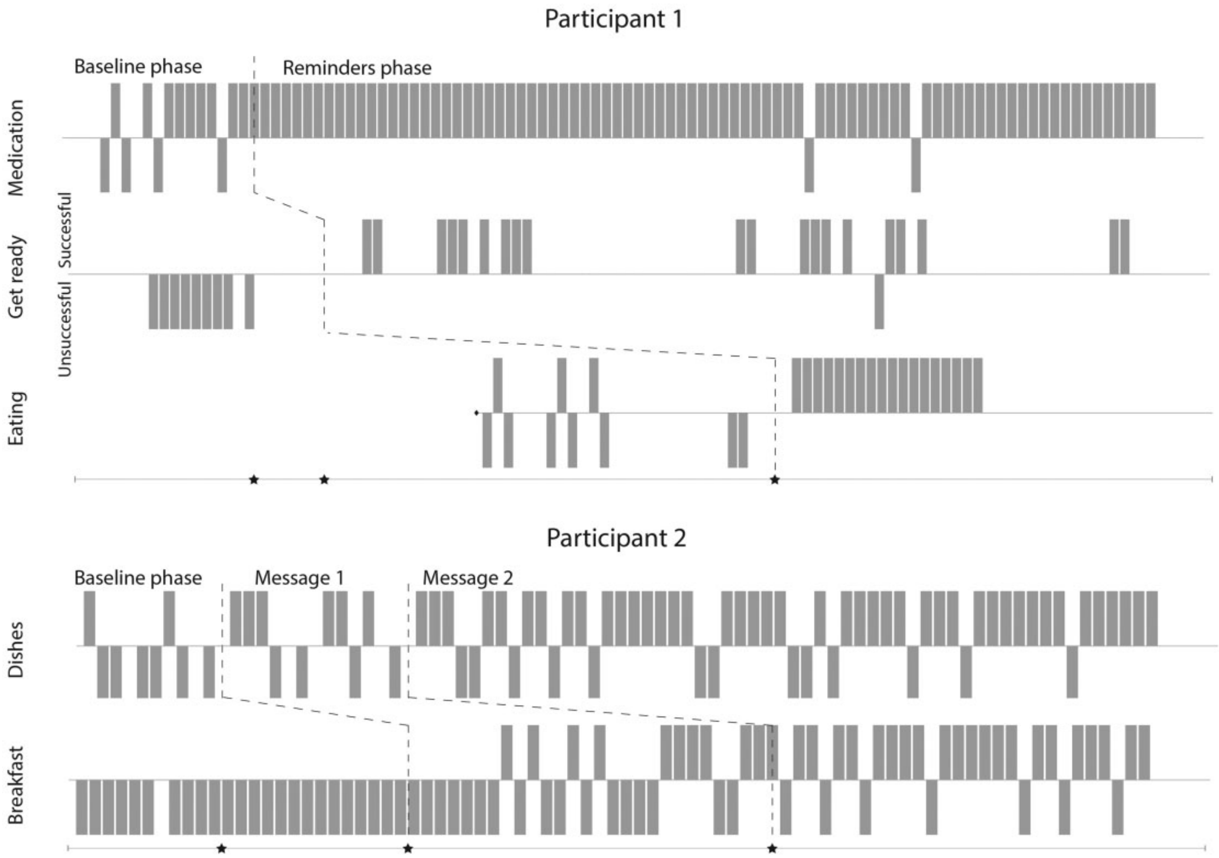

Figure 2. Performance on target activities. The bars indicate success and failure for each of the target activities. The dashed line indicates the multiple baseline periods and the stars at the bottom indicate the three review sessions carried out for each participant. Empty spaces correspond to missing days. For Participant 1, no data were obtained for the activity 'Preparing to leave home'.

Table 2. COPM results.

		Pre		Post	
	Importance	Performance	Satisfaction	Performance	Satisfaction
Participant 1					
Medication	10	10	5	8	7
Get ready	7	4	2	10	10
Eat pattern	–	–	–	–	–
Participant 2					
Breakfast	10	1	1	8	10
Dishes	10	3	1	7	7

Taking medication. This was the most important area for improvement identified by P1. He had to take medications three times a day. A failure was defined as missing one or more medications a day. At baseline, P1 was using his mobile phone to set alarms to remind him to take his medication, and he rated his performance at maximum (Table 2), even though sometimes he turned off the alarm without taking the medication, forgetting about it afterwards, as shown in Figure 2. P1 rated this activity with satisfaction level 5 (out of 10), despite having rated his performance as optimum. He continued with his existing strategy during the baseline phase. NAP data analysis showed 63% improvement during the reminder phase. However, this value was not significant ($p > 0.05$). After the reminder phase, P1 rated his performance as 8 (2 points decrease from initial assessment) because on two occasions the reminder did not come through and he felt the system was not always reliable. Independently, P1 developed two strategies to support the use of the reminders. First, he reinforced the text messages with email reminders, both from Google Calendar. Second, if he did not take the medication right away, he left the message unread, using the unread message as a prompt. P1 reported being pleased with the improvement in his performance – he felt that the use of text messages represented an advantage over the use of alarms.

Getting ready for next day. P1 identified one of his problems as forgetting to take everything he needed for his daily activities. For example, he regularly forgot his towel when he went to the gym. During the baseline phase, P1 was asked to check the activities for the next day and prepare his bag every evening before going to bed (Figure 2). During the intervention phase, P1 showed a 97% improvement, statistically significant at $p < 0.001$, relative to the baseline. P1 reported that the reminders for getting ready were very helpful, as they made him think about the activities he had to do next day. In the final assessment, P1 reported that after receiving the reminder for two months, the new activity was part of his routine and he did not need reminders anymore. His satisfaction and performance improved considerably (see Table 2).

Preparing to leave home. The reminders were not successful for this activity. P1 reported that he was not able to identify properly how much time in advance he needed to set up a reminder to leave home. It was suggested to P1 to break down activities into specific steps, so the time required to get ready to leave could be calculated, with the main variable being the distance to the place and transportation mode. P1 could do this with assistance, but he was not able to implement this strategy independently, and he did not complete the recording sheet for this activity.

Eating pattern. Halfway through the study, P1 identified this new target activity. He reported that he frequently went from breakfast to dinner without eating much in between. Although this target activity was not identified during the COPM assessment, it was included after completing a baseline period, recording how many meals he had per day. P1 was very motivated to include this new target activity, as he had identified the goal to 'start a new diet to have more energy', which would assist with fatigue management. P1's aim was to have three meals a day – having only one or two meals a day was recorded as a failure. During the intervention phase, P1 improved by 85%, statistically significant at $p < 0.01$. For this activity, he also developed a complementary strategy: he complemented the text messages with reminders that popped up on the screen of his computer. This was particularly useful for him, since one of the problems he reported was that when he is doing something, usually working on his computer, he struggles to disengage and change activity. Overall, he noticed the biggest improvement in his eating pattern. He felt he had more energy because he ate more regularly. Neither the repeat HADS nor PCRS were returned for P1.

Participant 2

Target activities selected by P2 were: (1) having breakfast and (2) doing the dishes (Figure 2). During the review sessions, P2 stated that he did not feel much improvement with the reminder messages. Additionally, in the assessment, P2 indicated that he had previous experience using reminders sent to his mobile phone and they did not work. For this reason, we decided to try modifying the content of the message in order to obtain stronger prompts. The intervention phase was divided in two sub-phases: 'Message1' and 'Message2'.

Having breakfast. P2 identified having breakfast as an important activity for improvement. He rated his performance and satisfaction at the minimum score and attributed his poor physical state and fatigue to the fact he did not have breakfast. The content of the message during the 'Message1' phase was 'Bruce Lee ate breakfast', as P2 was a martial arts enthusiast and he recognised the importance of having breakfast in relation to better cognitive performance and better general health. Data showed a 51% improvement at $p < 0.05$. However, change in performance did not match the onset of the reminders. Thus, we cannot definitely assign the improvement in the performance with the reminder system. During the third review session, P2 reported that he felt that the reminders were not very helpful. He stated that he struggled to get up in the morning and sometimes received the messages while he was still in bed, and that he did not have enough time in the morning due to other activities such as ironing clothes for work and his desire for a morning cigarette. P2 also stated that he felt frustrated at not being able to improve because breakfast time was an opportunity to spend more time with his child. Thus, the content of the message was modified to 'Spend time with [child's name]. Have breakfast with her!', and we proposed reorganising his activities in order to have more time in the morning (e.g. ironing his clothes the night before). His performance showed a significant 47% improvement over the previous reminder phase ($p < 0.01$). These results were reflected in the COPM (Table 2).

Doing the dishes. P2 identified that doing the dishes was a very important activity for him to improve on. He stated that performing better at home was very important for him, as the relationship with his wife and child had deteriorated after the injury. During the intervention phase 'Message1', P2 first received a reminder saying 'Do the dishes'. P2 showed an improvement of 40%. However, this result is not significant ($p = 0.15$). During the second review session, P2 redefined the content of the message to 'Mrs P2 cooked dinner. Do the dishes! It makes her happy', taking into account that he observed a good response from his wife when he performed this activity, contributing towards a better relationship with her. During the phase 'Message2', the performance improved by 36% over the improvement showed in the previous phase 'Message1', reaching a borderline significant level (exact $p = 0.08$). Note that only adjacent phases should be subjected to statistical analysis (Parker et al., 2011), being 'Baseline versus Message1' and 'Message1 versus Message2'. The re-assessment of the COPM demonstrated that P2's perception of performance and satisfaction improved considerably for this activity, and this change is clinically significant.

After the last review session, P2 stated that he realised he was able to link general goals with specific activities and to use the text messages to be reminded about those general aims. P2 reported feeling more in control of his routine and less anxious in general. His score on the repeat HADS reduced to normal for depression and remained normal for anxiety. No significant change was observed on the repeat PCRS.

Discussion

Participant 1

The reminder system was successful, particularly for those activities that P1 engaged in on a regular basis, such as taking medication, getting ready for the next day and having meals. SMS reminders for taking medication and eating pattern were supported by adjustment to the implementation of the reminders: leaving messages unread to use them as prompts, and setting up emails and pop-up messages from Google Calendar to support text messages. P1 is likely to require support to set reminders for ad hoc appointments. He was not able to set reminders to prompt him to get ready to leave home, probably because it occurred at different times across the week, unlike the other reminders that were set at a particular time and repeated regularly over a period of time. His experience using computers was evident when creating activities on Google calendar and setting reminders.

Participant 2

P2's improvement of his target activities was greater when the reminders were directed not just at the activity but the importance of performing the activity. The content of the messages was defined in order to strengthen the link between the text message and the initiation of the action – the relevance of this strategy is that P2 can identify the reasons for improving performance but did not typically think about it when he actually had to perform the action. For example, when P2 received the first reminders 'Do the dishes', it was easy to ignore because he reported that doing dishes was an activity that he did not enjoy. However, when the message reminded him of how this contributed to a better relationship with his wife, he was more likely to do it. A clear improvement was observed when the reminders contained a motivational message directly associated with his role as husband and father, increasing the frequency of completion of the target activities.

Factors influencing participants' performance and clinical considerations

In order to evaluate the uptake of text messages to improve performance, we used a SCED study with multiple baselines across behaviours, under the assumption that the effect produced by the reminder would be observable only in the activity that is being targeted. This is clearly depicted in Figure 2, particularly for P1. The improvement in the performance matches with the implementation of the reminder across the three target activities. One difficulty we had in the study was the consistency of the participants completing the recording sheets. There were time periods with no information about what happened. We have no reason to assume any systematic bias in outcome measures for missing days in baseline or intervention phases. Enough data points were obtained to characterise the performance of the participants. Results of the COPM support the outcomes: both participants showed improvement in meeting their target activities. However, adjustment of the strategy was needed. A series of factors that influenced our results have been identified.

Use of personally meaningful activities. Participants in the study selected the target activities based on their self-perception of relevance, performance and satisfaction with the activity. This approach represents an advantage in terms of targeting practical issues affecting everyday functioning relevant for the participants and also in terms of the motivation towards the target activity. As far as we know, this issue has not been directly addressed in the assistive technology literature, despite the relevance of participant's motivation to successful interventions (Trombly, 1995). A relevant drawback in the use of personal meaningful target activities for research is the reliability of registering performance. To deal with this, some studies have used less meaningful but more reliable outcome measures, for example text or call a number at specific times (Fish et al., 2007). One can argue that an activity such as making a phone call is equivalent to a prospective memory task in real life. However, it lacks the motivational component that a self-selected activity may have.

Use the content of the reminder message to support the person's motivation to perform the target activity. The exact wording used in a reminder message may be irrelevant for the outcome in cases where the main difficulties are associated to executive problems, where a sound alert may be enough to improve planning skills. Non-specific content messages have successfully been used to this end (Fish et al., 2007; Manly et al., 2002). For memory problems, the use of systems such as the Neuropage (Wilson et al., 1997) or mobile phones (Stapleton et al., 2007) can effectively remind people of what activity they are supposed to perform using short cues. However, in the present report, we have highlighted the relevance of considering the exact wording of the message when there are emotional/motivational problems involved. For P2, simple reminders were not as useful as the ones that reminded him about the relevance of the activity to his husband/father role. The more detailed reminders also served to remind P2 what he is aspiring to be post injury. The view of his future identity as a good father/husband can act as a powerful motivator of goal-directed behaviour (Christiansen, 1999; Gracey et al., 2009). Previous studies have used prompts based on users' rehabilitation goals (Wilson et al., 2003) or have used SMS to remind participants of their rehabilitation goals (Culley and Evans, 2010). However, neither of these studies considered the exact wording of the message in relation to the participants' motivations, views of their 'future selves' or life roles. More research is needed to explore this further.

Interactive reminder system that checks on unperformed activities. One difficulty with using SMS reminders to recall activities was that if they did not perform the activity right away, they were likely to forget about it. P1 solved this issue by leaving messages unread, so they would prompt the action next time he checked the messages. One feature that most mobile phone reminder applications have is that they require the alarm to be 'accepted' or 'snoozed'. This system represents an advantage over the use of SMS reminders. This issue raises the need of interactive monitoring systems that are able to detect whether the person has performed the activity, such as the Memojog (Morrison et al., 2004), a system developed at the University of Dundee that could deliver messages through the internet to a PDA and could monitor the user's response, contacting a caregiver if there has not been acknowledgement of the message.

Using of different modalities for the reminders. Reminders can be delivered through different systems, for example, paging systems, emails – computer screen pop-up messages, mobile phone alarms and so on. As far as we know, the relative effectiveness of the different modalities has not been evaluated. However, we can say that the most effective or appropriate modality will depend on the particular difficulties of the users. For P1, the effective use of the reminders was supported by the use of emails and pop-up messages, as these were more likely to interrupt P1's activities and were therefore more appropriate for the type of difficulties with which P1 presented.

Combined behavioural strategies and technological aids. People commonly use behavioural strategies to cope with memory difficulties after brain injury (Evans et al., 2003). However, whether the use of behavioural strategies used in conjunction with technological aids increases the effectiveness of the interventions has not been directly investigated. In the present research, we provide preliminary evidence of this; for example, showing that an adjustment in participant P2's routine allowed more time for the performance of the intended action 'having breakfast' in the morning. Another strategy we implemented was to simplify target activities: for example, to support P1's performance on arriving at his daily activities with all the elements required, we suggested a new regular activity 'get ready for tomorrow' instead of setting different reminders for *ad hoc* activities.

Previous experience of using technology. Both participants had previous experience using computers and mobile phones. This factor supports the implementation of these strategies, as previously reported by Evans et al. (2003). There are many other personal factors associated with the uptake of memory compensations (Baldwin et al., 2011) that we have not mentioned in this report, such as emotional barriers (for example, feeling embarrassed about using a memory aid), factors that impact negatively on motivation (for example, receiving too many reminders) or beliefs about memory (for example, using compensations may deteriorate memory).

Conclusion

Both participants showed different cognitive and daily-life memory difficulties, and in both cases, they showed improved performance and increased perception of performance and satisfaction following a text message-based intervention. However, adjustment of the reminding system was required to obtain successful performance, and not all activities selected by the participants benefitted from the system. We conclude that the described reminder system can be used to compensate for different problems, taking into account a careful analysis of the target activities and the person's interest, motivation, cognitive abilities and emotional factors when planning to use this technology.

Key findings

- Reminders adjusted to the individual maximise their benefit.
- Reminder messages linked to occupational roles can be more effective than cue only messages.
- Reminder messages sent through different modalities can be more effective.

What the study has added

Technology that is ubiquitous to our daily life can be effectively integrated into cognitive rehabilitation for people with traumatic brain injury to increase participation in daily activities.

Research ethics

Ethics approval was obtained from the West of Scotland Research Ethics Service on 21 December 2011. Reference number: 11/WS/0102.

Declaration of conflicting interests

The authors confirm that there is no conflict of interest

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