Technological Memory Aid Use by People with Acquired Brain Injury

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Abstract

Evans, Wilson, Needham and Brentnall (2003) investigated memory aid use by people with acquired brain injury (ABI) and found little use of technological memory aids. The present study aims to investigate use of technological memory aids and other memory aids and strategies ten years on, and investigate what predicts use. People with ABI and self-reported memory impairments (n = 81) completed a survey containing a memory aid checklist, demographic questions and memory questionnaires. Chi-square analysis showed that ten of 18 memory aids and memory strategies were used by significantly more people in the current sample than in Evans et al. (2003). The most commonly used strategies were leaving things in noticeable places (86%) and mental retracing of steps (77%). The most commonly used memory aids were asking someone to remind you (78%), diaries (77%), lists (78%) and calendars (79%) and the most common technologies used were mobile phone reminders (38%) and alarms/ timers (38%). Younger people who used more technology prior to their injury and who use more non-technological memory aids currently were more likely to use technology. Younger people who used more memory aids and strategies prior to their injury and who rated their memory as poorer were more likely to use all types of memory aids and strategies.

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Introduction

Individuals who have suffered acquired brain injury (ABI) have a high prevalence of memory impairments (Ownsworth, & McFarland 1999). These impairments make it difficult for people with ABI to perform everyday tasks which require memory such as personal care, cooking, or tasks related to health such as remembering appointments, treatment plans and medication. From both an economic and psychological point of view it is beneficial to help those with memory difficulties to live independently at home, rather than in care homes, where possible (Pollack, 2005). ABI is estimated to cost the UK government around £7bn per year (Department of Health, 2005). This is similar in other countries, for example the cost of caring for those who have had a head injury is estimated to be $50 billion annually in the USA (Finkelstein, Corso and Miller, 2006). Many people with ABI who live within the community are cared for by family members or friends who help alleviate the strain on care services. However, caring for people with memory difficulties can lead to psychological stress for those providing the support and care (Brodaty & Donkin, 2009; Caprani,

Greaney & Porter, 2006). Interventions which improve independence can be beneficial socially and economically, by allowing people to stay in their homes for longer and by reducing carer/caregiver strain.

Memory aid use

Pencil and paper memory aids and memory strategies can be useful and are used by many people with ABI. Evans and colleagues (2003) investigated which memory compensation aids and strategies people with ABI (n=94) used and which factors predicted use (Evans et al., 2003). They found that calendars (54% of participants), wallcharts (64%) and notebooks (72%) were commonly used by participants. Strategies such as asking others to remind (49%) and mental retracing (48%) were also commonly used. The use of these compensatory aids and strategies requires effort and time from the client. Clinicians can play a role in encouraging and developing memory aid use and it is important to understand which strategies are most commonly used, what factors predict use and how use changes over time.

Wilson *et al.* (1996) and Evans *et al.* (2003) investigated which factors predicted use of memory aids. They found that people who were younger, had a greater amount of time since injury, used more memory aids prior to injury, had a higher level of independence and better attentional functioning used more memory aids (Wilson et al., 1996; Evans et al., 2003).

Assistive technology

One type of memory aid which Evans and colleagues (2003) found was rarely used was assistive technology for memory compensation. They predicted that use would increase as technology becomes more widely available and more advanced. Technology has an advantage over pencil and paper reminders because it can actively prompt participants about memory tasks. In previous years, portable or wearable Personal Digital Assistants (PDAs) such as Palm PDA or NeuroPage pager have been used, and can be programmed by either the patient or carer to give prompts throughout the day to remind a person with memory problems to attend appointments or take their medication (e.g. Wilson, Emslie, Quirk & Evans, 2001; Svoboda & Richards, 2009). The more recent development of Smartphone and Tablet devices has allowed these functions to be carried out using easily accessible mainstream hardware and software. Other recently developed bespoke systems can guide people through a single task with several sub-steps such as food preparation (Kinempt; Chang, Chen & Chuang, 2011) or hand-washing (COACH; Mihailidis Carmichael & Boger, 2004) or remind people of events which they may have forgotten by playing back a series of photos taken during the day (SenseCam; Hodges et al., 2005).

Efficacy of assistive technology

In a review of assistive technology for cognition, Gillespie, Best and O'Neill (2012) reviewed the application of technology for different cognitive functioning domains using the World Health Organisation International Classification of Functioning (ICF) framework. The domains relevant to everyday activities which involve memory included 'organisation and planning', 'time management', 'memory' and 'attention'. Gillespie and colleagues found that the majority of technologies that were designed to improve ICF 'organisation and planning' were micro-prompting systems which supported step-by-step completion of tasks with sub-steps, such as cooking or washing hands. All of

the technologies which were designed to help with ICF 'time management' were prospective memory reminding systems which prompted to interrupt one task in order to carry out another. A smaller number of storing and displaying and alerting technologies were also investigated in the literature and these aimed to help with the ICF domains of 'memory' and 'attention' respectively.

In a recent systematic review we investigated studies which tested the efficacy of prospective memory reminding systems and micro-prompting systems for improving memory performance on everyday tasks (Jamieson, Cullen, McGee-Lennon, Brewster & Evans, 2013). We found good evidence for the efficacy of both of these types of devices and a meta-analysis of seven group studies testing prospective prompting devices gave a large overall effect size (d = 1.27) (n=147). There is therefore good evidence that technology exists that can improve performance on two ICF domains when compared to practice as usual or a non-technological equivalent.

Prevalence of assistive technology use

While it seems that the need for memory rehabilitation is great and that technology can improve everyday memory performance, it is less clear whether or not technological memory aids are actually used by people with memory difficulties after ABI. Evans *et al.* 2003 found that only 3.2% of people with ABI (n=94) were using a mobile phone to help their memory. At present there is little provision for assistive technology within the National Health Service (NHS) in the UK and use is likely to be driven by the person with memory difficulties, their family members or suggested by a caregiver. It is likely that the situation is similar in countries with a similar infrastructure to the UK. Use of assistive technology is likely to require support from clinicians and caregivers who may themselves lack confidence with technology. A study by Hart and colleagues (2003) found that clinicians of people with traumatic brain injury believed that technology could help with cognitive difficulties memory, planning, organization and task initiation. However participants reported low confidence in their abilities to guide clients in using technology, especially if their experience with technology was limited. In the last decade, personal technology has become highly advanced and available, in particular with the popularisation of mobile phones and smartphones. In 2015 almost 5 billion people use a mobile phone and 1.75 billion use smartphones (Statista, 2015). In 2013 it was reported that 7 out of 10 people in Britain used smartphones (Styles, 2013). These devices are now so widespread that they are likely to already be used by many people with ABI and their caregivers. Mobiles, smartphones and other widely available and accessible technology such as alarms, timers, tablets, personal computers and cameras have the ability to provide reminders to help with prospective memory, provide pictures and videos to help with retrospective memory and can provide prompts to guide people through everyday tasks.

The aim of this study was to investigate the use of memory aids and strategies by people with ABI. We also wished to investigate if the increase in the availability of mobile and Smartphone devices with memory aid capabilities has been accompanied by an increase in the use of digital memory aids by people with memory impairment, and to quantify and describe that use. Any technologies which can help compensate for various types of memory difficulties during everyday activities were included. If there is an increase in use of memory aid technology then it will be interesting to investigate whether this use is predicted by the same or different factors that predict non-technological memory aid use.

Study aims

1) To compare prevalence of memory aid use between 2003 (results from Evans et al. (2003) and 2014.

2) To investigate the prevalence of technological and non-technological memory aid use, and memory aid strategy use amongst people with ABI, and to find out which types of technology are most commonly used and in what way.

3) To investigate which factors are associated with use of technological and non-technological memory aids, and memory aid strategies.

Method

Participants

Participants were recruited between November 2013 and June 2014 and were identified through NHS services in Scotland: Community Treatment Centre for Brain Injury (CTCBI) within the United Kingdom National Health Service Greater Glasgow and Clyde (NHS GG&C), and NHS Grampian. Recruitment was also undertaken through the UK brain injury charity Headway, via meetings in Scottish localities (Glasgow, Falkirk, Lothian, Dumfries and Aberdeen). Inclusion criteria were a diagnosis of ABI and memory difficulties as reported by self or other. For participants recruited through Headway, memory impairment was self-reported during initial discussion with the researcher. Participants recruited through the NHS were only approached if improving memory had been established as a rehabilitation aim after self-report of memory difficulties and / or a formal assessment from clinicians within the service. Only people aged 18 and over who were able to give informed consent to participate in the study were approached.

Materials

In the following order the survey consisted of:

1) Demographic questions (age, gender, work status and education level)
2) A memory aid use checklist adapted from Evans et al. (2003)
3) A self reported memory questionnaire (the Prospective and Retrospective Memory Questionnaire - PRMQ (Crawford, Smith, Maylor, Della Sala, & Logie, 2003)).

Details about how the injury was acquired and time since injury were obtained from the recruiting NHS service where available. Participants who were recruited through Headway were asked to provide information about their injury on the first page of the survey below the demographic information section.

The memory aid checklist was taken from Evans et al. (2003). Because this checklist questionnaire was administered during face-to-face interviews in the original study, it was adapted for the present study so that it could be easily understood in a postal survey format. Types of memory aid were split into three categories – non-technological memory aids (such as paper diaries or calendars), technological memory aids (such as mobile phone or alarm based reminders) and strategies (such as leaving objects in noticeable or unusual places) (see appendix for full list of items). In the technological reminders checklist the item 'a mobile phone to remind you' and the item 'asking someone to text you' were both included to separate those using a mobile phone calendar,

reminding app or alarm from those simply using a mobile phone to receive texts from a carer or family member to remind them about tasks. For each item participants were asked whether they used it before their brain injury, whether they use it now, how often they use it (daily, weekly or monthly) and how useful it is (helps a lot, helps a little or does not help). After the technology reminders checklist there was a space for people to write what they used tech memory aids for.

Procedure

This study took the form of a cross-sectional postal survey. Three hundred and eight people with ABI were sent the survey with the expectation of a 1 in 3 response rate. The target sample size of 100 was similar to the number of participants recruited by Evans et al. (2003) (94 people with ABI). People with ABI were approached via the CTCBI in Glasgow and brain injury services in NHS Grampian, with questionnaires being passed on to participants either in person or through the post. Participants with ABI recruited through Headway were given the forms by the researcher, Headway staff or volunteers at support group meetings. All participants returned the survey to the researchers using a free-post envelope provided. The study methods and the survey were approved by the University of Glasgow research ethics committee on 14th October 2013.

Statistical analysis

Survey responses were only included in the analysis if both the memory aid checklist and the PRMQ were fully completed. Five of the 86 returned surveys did not have both sections completed, or had sections partially completed. These were removed from the analysis leaving 81 fully completed surveys.

Independent t-tests were used to compare the current sample with the 2003 sample on demographic variables. Chi squared tests were used to analyse the difference in proportion of participants indicating they used each piece of technology between the two study samples.

The outcome variables for the regression analyses were number of technological reminders used after injury, and number of all types of memory aids used after injury. The 'technological reminders used' variable was highly skewed – a large number of participants used zero or one technological memory aid only (59%). For this reason negative binomial regression was used to investigate which factors predicted technological reminder use.

For negative binomial regression analysis, incidence rate ratio (IRR) was reported, with 95% confidence interval (CI). IRR indicates the estimated relative change in the dependent variable for each unit increase in the independent variable. For example, within a negative binomial regression model predicting technological memory aid use, an IRR for age of 0.97 indicates that for every one-year increase in age, the number of technological memory aids used would reduce by 3%.

A linear regression analysis was used to investigate the factors which predicted the number of aids used (all types) as this variable was normally distributed. Predictors were added to each model in a set order based on the findings reported by Evans et al. (2003). For the models predicting technology use, age, pre-morbid technology use and current non-technology use were added to the model first in a hierarchical manner followed by the other factors. For models predicting all memory aid use, age and pre-morbid all memory aid use were added to the model first in a hierarchical manner

followed by the other factors. As each factor was added to the model, an ANOVA analysis was performed to test whether the model was significantly improved when the new factor was added.

Pearson's correlations were used to investigate the relationship between memory ability and memory aid use. The technological memory aid use variables (for both before and after injury) were highly positively skewed and the 'all memory aid use before injury' variable was also moderately positively skewed. These variables could not be assumed to be normally distributed. For this reason non-parametric methods (Spearman's rank for correlations) were used when analysing these variables.

Participants' comments about what they used technological memory aids for were grouped according to the kinds of memory being supported. For example if a participant wrote 'for appointments' then this would be coded as using technology to help with prospective memory (future intentions). Three of the authors coded this written feedback independently and then came to a consensus about any disagreement.

Results

Most participants (total n = 81) were recruited through CTCBI NHS GG&C (n=40, 49%) and Headway (n=33, 41%) with a small number from NHS Grampian (n=8, 10%). Participants' mean age was 51.2 years (range = 27 – 76, SD = 10.34) and 32 (40%) were female. The most common aetiology of injury was traumatic brain injury (n=48, 59%) followed by subarachnoid haemorrhage (n=9, 11%), stroke (n=5, 6%), aneurysm (n=4, 5%), encephalitis (n=4, 5%), infection (n=4, 5%) and other (n=7, 9%). Median time since injury was 3.56 years (range = 0.44 – 61, SD = 9.77, median reported due to a participant with a long time since injury) and (n=20, 25%) were employed at the time of the survey. Mean number of years in education was 12.74 (range 10 – 18, SD = 2.47).Table 1 shows participants' PRMQ overall and sub-scores, number of all memory aids used, technological aids, strategies and non-technological aids.

Mean self-reported memory problems score, measured on the PRMQ, was around 1.5 to 2 standard deviations higher than the mean score for the general population (38.88, range = 17 - 67). This score was calculated in a large sample (n = 551) of healthy people between the ages of 17 and 94 (Crawford et al., 2003). Crawford et al. found that age and gender did not influence PRMQ scores so comparison to an age and gender matched sample is not necessary. One third of the participants (33%) were within 1 standard deviation of the mean PRMQ score for the general population.

 [Table 1 about here]

Aim 1 – To compare prevalence of memory aid use between 2003 and 2014.

The participants in the current study were significantly older than the participants in the 2003 study, who had a mean age of 39.53 (SD = 13.38) (t = 6.38, df = 173, p = 0.00001). The mean years since injury in the 2003 sample (5.89, SD = 4.79) was lower than the current sample but this difference was not significant (t = 1.0006, df = 173, p = 0.318). The current sample spent significantly longer in education compared to the 2003 sample (2003 mean = 11.95 years, SD = 2.13) (t = 2.272, df = 173, p = 0.0243).

Table 2 compares the proportion of participants in the 2003 and 2014 samples who indicated that they used each memory aid. Only the items which could be directly compared between 2003 and 2014 were included in this analysis. Chi-square analysis was used to examine which aids and strategies were used by significantly different proportions of participants in each study. For the technological memory aids, mobile phones and alarms/ timers were used by a significantly higher proportion of people in the current study. Among the non-technological aids, a significantly higher proportion of participants stated that they asked someone to remind them, used lists on paper and used diaries. Five strategies were used by a significantly greater proportion of participants in the current study compared to the participants in the 2003 study. These strategies were mental retracing, repetitive practice, objects in noticeable places, rhymes or phrases and alphabetic searching.

[Table 2 about here]

Aim 2 – To investigate the prevalence of technological and non-technological memory aid use, and memory aid strategy use amongst people with ABI, and to find out which types of technology are most commonly used and in what way.

The proportion of people using each technology-based reminder, with participants' perceived helpfulness ratings, are shown in Figure 1.

 [Figure 1 about here]

The prevalence of use of each non-technological strategy or aid, with participants' perceived helpfulness ratings, are shown in Figure 2.

[Figure 2 about here]

How memory aids were used

When coding the answers to the comment box question, 'If you use any of these technological memory aids, what do you use them to remind you about?', there was reasonable level of agreement between the three raters with 80% of the comments coded in the same category by each rater. Thirty five participants (43.2%) gave relevant answers to this question in the space provided. Some of the participants' comments contained information about more than one different use of technology and so there were 46 separate comments analysed. The majority (n=30, 65%) of answers referred to reminders about future intentions. These included using phone calendars, text messaging and alarms to alert about appointments, household tasks, social events and medications. The second most common use of technology was to wake up in the morning or after a nap (n=11, 24% of comments mentioned using technology in this way). Three comments (6.5%) mentioned using technology to help orient to time and date. One comment talked about using a mobile phone to store information (e.g. who they had called) to prevent them doing the same thing twice. There was also a single comment about using technology to help with emotional regulation. Mobile phone use or texting was mentioned in 34.3% (n=16) of the comments and all of these comments mentioned it in reference to setting and receiving reminders for future intentions.

Aim 3 – To investigate which factors are associated with use of technological and non-technological memory aids, and memory aid strategies.

Memory aid technology:

Greater use of technological reminders post-ABI was associated with younger age (IRR = 0.97, CI = 0.956 to 0.987, p < 0.001), higher premorbid technological memory aid use (IRR = 1.23, CI = 1.15 to 1.32, p < 0.001), and higher current use of non-technological memory aids/strategies (IRR = 1.09, CI = 1.04 to 1.15, p < 0.001). These variables explained 75.8% (Nagelkerke $R^{2=}$ 0.758) of variance in technological memory aid use.

All memory aids:

Greater use of all reminders and strategies post-ABI was associated with younger age (estimate = -0.11, CI = -0.19 to -0.04, p < 0.01), higher use of all memory aids before injury (estimate = 0.53, CI = 0.34 to 0.71, p < 0.001) and higher PRMQ scores (estimate = 0.2, CI = 0.097 to 0.304, p < 0.001). These variables explained 38.5% (R^2 = 0.385) of the variance in memory aid use.

Discussion

A postal survey was used to examine the types of memory aids currently used by people with acquired brain injury living in the community. The proportions of different memory aids used were compared to the proportions reported in a 2003 survey, and the factors which influence memory aid use were examined.

Memory Aid Use

Ten of the 18 memory aids compared were used by a significantly greater proportion of people in the current study compared to the participants in Evans et al. (2003). These included many different types of aids including technological aids such as mobile phones and alarms/ timers, and non-technological aids and strategies such as asking others to remind, lists on paper diaries, mental retracing, repetitive practice, objects in noticeable places, rhymes or phrases and alphabetic searching. It is possible this increase represents a general increase in memory aid and strategy use for people with ABI. The increase could also be explained by other differences between the two study samples. The studies were carried out in Cambridgeshire (2003) and Scotland (current) and so participant overlap is unlikely. The current study participants were, on average, older by around ten years. It seems unlikely that this would account for the difference in memory aid use, as both studies found that younger age predicted use of all types of memory aids. The participants in the current study reported significantly more years in education than the 2003 participants. Education level was not a significant predictor of memory aid use in the current study. However, higher education level could indicate higher socio-economic status (SES) and factors related to higher SES such as better social/family support may contribute to greater use of memory aids. While Evans and colleagues (2003) did not test the impact of level of education on memory aid use, they did investigate pre-morbid intelligence using the National Adult Reading Test – revised (NART; Nelson and Willison, 1991). They found that the NART was not significantly associated with memory aid use.

Greater time since injury was found to be related to increased memory aid use in Evans et al. (2003). The current sample had, on average, just over one year more since their injury, although this difference was not significant. Differences in recruitment method mean that severity of injury could be different for the two groups. Eighty-one of the 94 participants in Evans et al. (2003) had a history consistent with a period of coma and posttraumatic amnesia (PTA). Mean coma time was 7 days and mean PTA time was longer than 4 weeks. Therefore many of the participants in the study fell into the PTA category of 'very severe'. Methodological limitations prevented such detailed information about participants' injuries being collected in the current study, but it is possible that the Evans et al. (2003) study included participants who had more severe difficulties compared with the current study sample and this may have impacted on their ability to use memory aids effectively.

People with ABI who were younger, used more memory aids prior to injury and who had poorer self-rated memory were found to use more of all types of memory aid in the present study. Age and pre-morbid memory aid use were also found to be influential in Evans et al. (2003). They did not find objective memory ability (Rivermead Behavioural memory test – RBMT (Wilson, Cockburn & Baddeley, 1999)) to be a significant predictor of memory aid use in a regression analysis (self-reported memory ability data were not gathered). However, Wilson and colleagues (1996) did find that RBMT score influenced memory aid use and, using a bi-variate analysis, Evans et al. (2003)

found that a RBMT screening score above 3 was related to use of six or more memory aids. Therefore it does seem that previous studies have found that better objective memory ability is associated with higher use of aids. These findings contrast the current findings that poorer self-reported memory leads to greater use of strategies in this group. An explanation for this could be that better objective memory is related to higher cognitive functioning which may lead to greater insight into memory difficulties. This could lead to low memory self-evaluation and to increased use of memory aid strategies. Alternatively somebody with very poor memory might lack insight into their difficulties and be unaware of their need for memory aids. In the absence of objective memory data in the present study sample, it is difficult to clarify the relationship between objective memory ability, self-reported memory ability and memory aid use.

Technological aid use

Comparing the results of this study to those of Evans et al. 2003, use of some technological memory aids does appear to have increased. Use of mobile phones as memory aids has increased from around 3% to 38% amongst people with ABI in the last 10 years. Alarm/timer use has also seen a large increase from 9% to 38%. This could reflect the general trend of greater memory aid use in the current sample compared to the 2003 sample. It could also be due to the advancement in and greater availability of mobile phone technology for personal use. Two of the most commonly used technological memory aids were mobile phones, and asking someone to text them. Use of other technologies studied in both papers has not increased and this is likely because pagers, dictaphones and electronic organisers have become obsolete in the last 10 years and their functions are now performed on smartphones.

It is difficult to put these results into context through comparison with the general population as few statistics on the general use of memory aid technologies are available. A comparison can be made by using smartphone use as a proxy for being familiar and comfortable with technology. Although statistics vary, it has been reported that around 50% of people between the ages of 45 and 55 (the average age of the participants in the study) use a smartphone in countries where smartphone penetration is high such as the UK and USA (Nerea, 2013). This is higher than 41% of people who, in our survey, used 3 or more pieces of technology and higher than 38% of people who commonly used mobile phone reminders. These statistics allow the tentative suggestion that while technology use has increased markedly over the last decade for people with ABI, this group is behind the general population in terms of the uptake and use of smart technologies and mobile phone reminding technologies.

The most commonly used memory aids or strategies reported in the survey were leaving items in noticeable or regular places, developing habits after repetitive practice, making lists on paper, using wall calendars and asking other people to remind them about things. Diaries and notebooks were also quite popular. These findings are useful when thinking about how technology could be designed around people's existing habits. Many reminding technologies have been developed from non-technological strategies which people commonly use. For example calendar and notes applications come as standard on modern smartphones. Turning these memory aids into memory aid technology is useful because it allows active prompting from the device at relevant times. However technological versions of some of the most popular strategies have not become so widespread. For example, a technological version of the strategy 'placing items in regular places' could be a system

displaying reminders which is placed in a highly visible regular place in the home. A tablet based system which performed this function was developed by McGee-Lennon and colleagues after several co-design sessions with older users (McGee-Lennon, Smeaton & Brewster, 2012). These results offer more evidence that this type of technology may be useful for people with memory impairment after ABI.

In this study, people with ABI who were younger, used more technological memory aids prior to their injury and who used more non-technological aids and strategies after their injury tended to use a higher number of technological memory aids. When investigating which factors predicted all memory aid use, Evans et al. (2003) found that age, time since injury, previous use of memory aids, level of independence and attentional functioning were the most important predictors. Therefore there is a similarity between the factors which predicted all memory aid use in 2003 and the factors which predict technological memory aid use in 2014. It is interesting to note that the most commonly reported use for memory aid technology was to remind about future intentions, with a small number of references to waking up and orienting to time and date. There is growing interest in technologies which can support autobiographical memory (Hodges et al., 2005) and working memory during performance of tasks with several sub-steps (Mihailidis Carmichael & Boger, 2004). However the current results suggest that prompting technologies which help organisation and prospective memory and, to a lesser extent, alerting technologies which support orientation are the types of assistive technologies currently being used by people with ABI to support memory.

Implications

This study highlights factors which are associated with memory aid use and which explain quite a large proportion of the variance in all memory aid use for people with ABI. These factors are fairly easy to establish within a few minutes in a clinical setting and have potential to be a good indication of the likelihood that somebody will make use of memory aids or not. This information is useful when developing individual rehabilitation plans for patients and when considering the use of technological and non-technological memory aids.

Methodological Considerations

The comparison between this study and Evans et al., 2003 is limited by their differing methodologies. Variables such as independence, everyday attention and severity of head injury cannot be compared as they were not possible to ascertain in a postal survey. The methodology also meant it was not possible to distinguish how much help each participant received from caregivers to complete the survey.

Although there was a wide range of self-reported memory ability, the PRMQ results show that most participants reported some level of memory impairment and all participants in this study self-reported impaired memory and/or had memory functioning as a rehabilitation goal. However, objective assessment of memory performance was not carried out. The PRMQ does correlate with global measures of memory in the general population (Rönnlund, Mäntylä and Nilsson, 2008) and it has been found that prospective memory performance is predicted by prospective memory complaints in older adults (Zeintl, Kliegel, Rast and Zimprich (2006). However, people often have difficulty with insight and self-awareness after ABI (Fleming and Strong, 1995. A number of participants were within one standard deviation of the mean PRMQ score for the general population

and it is difficult to tell whether this reflects a weakness in the recruitment method or a lack of awareness from participants about their memory difficulties.Acquired brain injury can often lead to memory impairment, apathy and cognitive, sensory and motor difficulties. It could be claimed that a self-reported survey administered without researcher supervision might fail to elicit many responses (due to the difficulty of the task). Additionally, any responses which are obtained may not be accurate (due to the difficulty of remembering or processing answers, or perseveration in responses). Various steps were carried out when designing the survey in order to overcome these potential hurdles. It was made clear on the instructions on the front of the survey that while the survey was addressed to the person with ABI, it was recommended that a family member or caregiver help with the completion of the survey. For the memory aid items it was made clear, both in the description of the task and the individual items, that the participants should only select the technologies, aids or strategies which they used for reminding. The aim of this was to prevent participants from selecting items which they use for other purposes (e.g. a mobile phone to stay in contact with people or a computer to play games). Other steps such as making the questionnaire as short as possible so that it only took 30 minutes to complete and splitting the questionnaire into two parts with the suggestion that people take a break between the sections were designed to improve the likelihood of accurate completion. A draft questionnaire was also altered after consultation with an acquired brain injury expert at the charity Headway and several changes were made including the layout of the checklist (making the font larger and easier to read and grouping each checklist item in its own box to hold people's attention) and the wording of the introduction to the different sections (making it as clear as possible and giving examples to illustrate the points).

The postal survey method of this study may have lead to a selection bias. It is possible that the 81 people who returned the survey were different from the 227 people who did not respond. For example, completion might be more common from those who are motivated in their rehabilitation. This may be particularly true of people who were approached through Headway because these participants were voluntarily attending rehabilitation in the community. Successfully responding to a postal survey may also reflect a high level of functioning, organisation and insight into memory problems. The invitation in the survey for caregivers to help participants to respond may have tempered selection bias by allowing carers to scaffold the cognition required for survey completion for participants who may otherwise have failed to complete and return the survey. Furthermore, although the PRMQ data are difficult to interpret because of the issues with insight described above, it does provide some evidence that this sample is representative of people with increased memory difficulty after mild to moderate ABI.

Future research

Future studies might benefit from asking about extra technologies which were not included in this survey, for example day/date clocks for orientation or smartwatches as an orientation or memory support. It might also be interesting to survey caregivers separately to investigate whether there is a difference between carer and self-report of memory aid use. Mobile phones were one of the most commonly used memory aid technologies and they have many potential uses for cognition. While the survey responses indicated that phones (and all technology) were mostly used to aid prospective memory, future work could investigate in greater detail how people are using mobile phones to support memory.

Rehabilitation

One potentially important predictor of memory aid use which was not investigated in this study was level of neuropsychological rehabilitation each participant received. Evans et al., 2003 looked at the influence that acute inpatient and post acute specialist rehabilitation had on memory aid use. No association was found between memory aid use and rehabilitation received. It was concluded that rehabilitation was either ineffective in teaching people to use aids or it was not encouraging the use of aids. While the recruitment method of the present study guaranteed that all participants had received some rehabilitation or input either through the NHS or Headway, further details about rehabilitation were not investigated in this study because of the limitations of the survey design. It was decided that questions about rehabilitation services would be difficult for people with ABI to accurately report. There were also concerns that the survey should not be too long as this would lower the response rate. Future studies could investigate the impact that rehabilitation currently has on use of technological and non-technological memory aids.

Design

This study found a large increase in use of technological memory aids amongst people with ABI compared to previous research. However, in the sample as a whole, 23.5% did not report using any technological memory aid and 59% used two or fewer pieces of technology. Therefore there is great potential to increase the use of technology amongst people with ABI. While we accept the possibility that more technological memory aid use may not equate to better rehabilitation (and that using one or two memory aids effectively and often may be better for some people), the evidence suggests that use of memory aid technology in general can be an effective intervention for compensating for memory difficulties (Jamieson et al., 2013; Gillespie et al., 2012). Designing technology which is appropriate for people with cognitive impairment is one way in which to improve uptake and effectiveness of memory aid technology, and future research could investigate how different designs influence people's perception and use of technology. The participants in the current study were using more non-tech aids and strategies than technology. More appropriate design and improved accessibility of technology may be necessary for it to become as prevalent as pencil and paper methods. The psychological and practical barriers which impact upon uptake are also important issues to investigate.

Conclusion

This study has highlighted a substantial increase in use of reminding technology by people with ABI in the last ten years, showing that alarms, texting and mobile phone reminding are the most commonly used technologies. It was also clear that people with ABI used more of all types of memory aids than ten years ago. Technological memory aid use was best predicted by age, pre-morbid technological memory aid use and amount of non-technological strategies and aids used. While methodological limitations must be considered, the results of this study give some important insights into which memory aids and strategies people with ABI are using and who is making good use of them.

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Appendix

Non-technological reminders - instructions
Below is a list of memory aids, devices and strategies that are sometimes used for remembering things such as birthdays, doctor's appointments, names or everyday tasks such as shopping.
For each one, please indicate;

1. Tick a box to indicate if you used the memory aid before your brain injury.	2. Tick a box to indicate if you use the memory aid now.	3. Tick one box to indicate how often you use it (monthly, weekly or daily).	4. Tick one box to indicate how useful the aid or strategy is for you.

First we want to know about simple pencil and paper or verbal reminders which you use:
items
Asking others to remind you in person
A diary to help you remember things coming up in future (e.g. appointments or things to do)
A diary/journal to help you remember what you have done
Wall calendars
Whiteboard or wall chart
Making a list of things to do on a piece of paper (e.g. a things to do list or a shopping list)
Making notes of what you need to remember in a notebook.
Post-it notes

Technological reminders - instructions
Next, tell us about any technology (e.g. a mobile phone or computer) which you use to remind yourself about things. For example, do you use technology to help you remember to go to appointments, to remember social events such as birthdays, or to help you perform everyday tasks such as shopping, cooking or cleaning?
Please only tick the boxes if you have used or currently use this technology to help you remember things – many people will use a mobile phone as a phone but only tick the box if you use it to help you remember things.
Items
Mobile phone to remind you
Laptop computer or tablet computer (e.g. iPad) to remind you
Desktop computer to remind you
Television (e.g. automatic prompting about or recording of favourite shows)
Using a camera to take pictures of a holiday or special occasion to help you remember it afterwards.*
Using a digital camera to take pictures of everyday events to remind you of what you have done.
A pager to remind you
Electronic personal organiser
Dictaphone/ voice recorder to remind you
Alarm clock to wake up*
Alarm clock/ timer to remind you to do something
An internet based calendar to remind you (such as Google calendar)
Asking someone to send you a text message you to remind you about something
A watch with a date/timer to remind you
If you use any of these technological memory aids, what do you use them to remind you about?
*These items were not included in analysis as the function of reminding was not prompted. These items were added to prevent people from reporting that they used camera or alarm to remind them, when they really only used them to take pictures on holiday or wake up.

Strategies – instructions
Finally, tell us about other tricks, habits or strategies do you use to remind yourself of things

Mental retracing of your steps - to find misplaced items (e.g. 'where did I last see the keys?'…)

Repetitive practice- repeating tasks until they become a habit

Leaving objects in places you will notice them to remind you to use them or take them with you.

Leaving objects in the same place so you know where to find them

Rhymes or phrases to remember important information (e.g. 'remember remember the 5th of November')

Changing passwords or PIN numbers to combinations you use regularly

Writing on your hand (or elsewhere)

Alphabetic searching- Considering if a name or object begins with the letter A, B , C.....etc.

Please give details here of any other memory aids or strategies which you use that were not in the checklist and tell us what you use them to help you remember.

Table 1: Descriptive statistics for survey responses

Variables	Descriptive statistics (people with ABI, n = 81)
Mean PRMQ score (range, SD)	
Overall	52.98 (17 – 78, 15.87)
Prospective	27.53 (8 - 40, 8.38)
Retrospective	25.44 (8 - 39, 8)
Short term	26.49 (8 - 40, 8.2)
Long term	26.48 (9 - 40, 8)
Self-cued	28.17 (8 - 40, 8.2)
Environmentally cued	24.8 (9 - 38, 8.2)
Mean number of all types of memory aids used (range, SD)	
BEFORE injury	6.14 (0 - 18, 4.52)
AFTER injury	11.47 (2 – 26, 4.46)
Technological memory aid use prevalence (after injury) n (%)	
One or more used	61 (75)
3 or more used	37 (41)
6 or more used	8 (10)
Non-technological memory aid use prevalence (after injury) n (%)	
One or more used	78 (96)
3 or more used	68 (84)
6 or more used	37 (46)
Strategy use prevalence (after injury) n (%)	
One or more used	79 (97)
3 or more used	71 (88)
6 or more used	17 (21)

PRMQ = Prospective and Retrospective Memory Questionnaire; ABI = acquired brain injury; SD = standard deviation

Table 2 – Prevalence of memory aid use reported in 2003 and 2014. The types of aid or strategy are grouped in the following order; technological memory aids, non-technological memory aids and memory strategies.

| Memory aid or strategy	Number (%) of whole sample using the aid or strategy (Evans et al., 2003, n = 94)	Number (%) of whole sample using the aid or strategy (this study, n = 81)	Significant on X^2 test? (p value)
Mobile phone	3 (3)	31(38)	YES (p < 0.001)
Pager	5(5)	2(2)	NO
Electronic personal organiser	7 (7)	4(5)	NO
Dictaphone	2(2)	2(2)	NO
Alarm / timer	9(10)	31(38)	YES (p < 0.001)
Watch with date / timer	17(18)	12(15)	NO
Asking someone to remind you	46(49)	63(78)	YES (p < 0.001)
Diary	51(54)	61(77)	YES (p < 0.01)
Wall calendar	68(72)	55(69)	NO
Lists on paper	59(63)	62(78)	YES (p < 0.05)
Notebook	60(64)	49(62)	NO
Post-it notes	32(34)	32(41)	NO
Mental retracing	45(48)	61(77)	YES (p < 0.001)
Repetitive practice	28(30)	36(46)	YES (p < 0.05)
Objects in noticeable places	33(35)	69(86)	YES (p < 0.001)
Rhymes or phrases	2(2)	25(31)	YES (p < 0.001)
Writing on your hand	23(25)	25(31)	NO
Alphabetic searching	7(7.4)	28(36)	YES (p < 0.001)
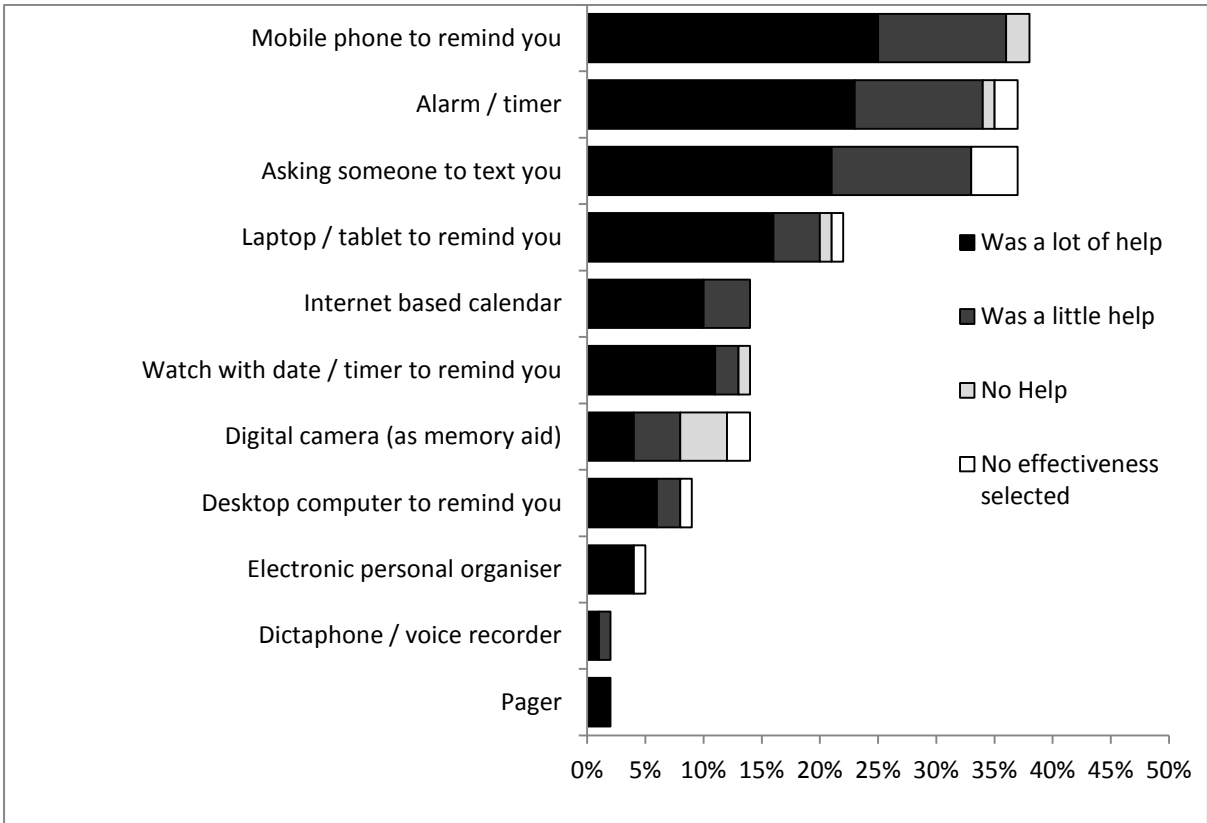
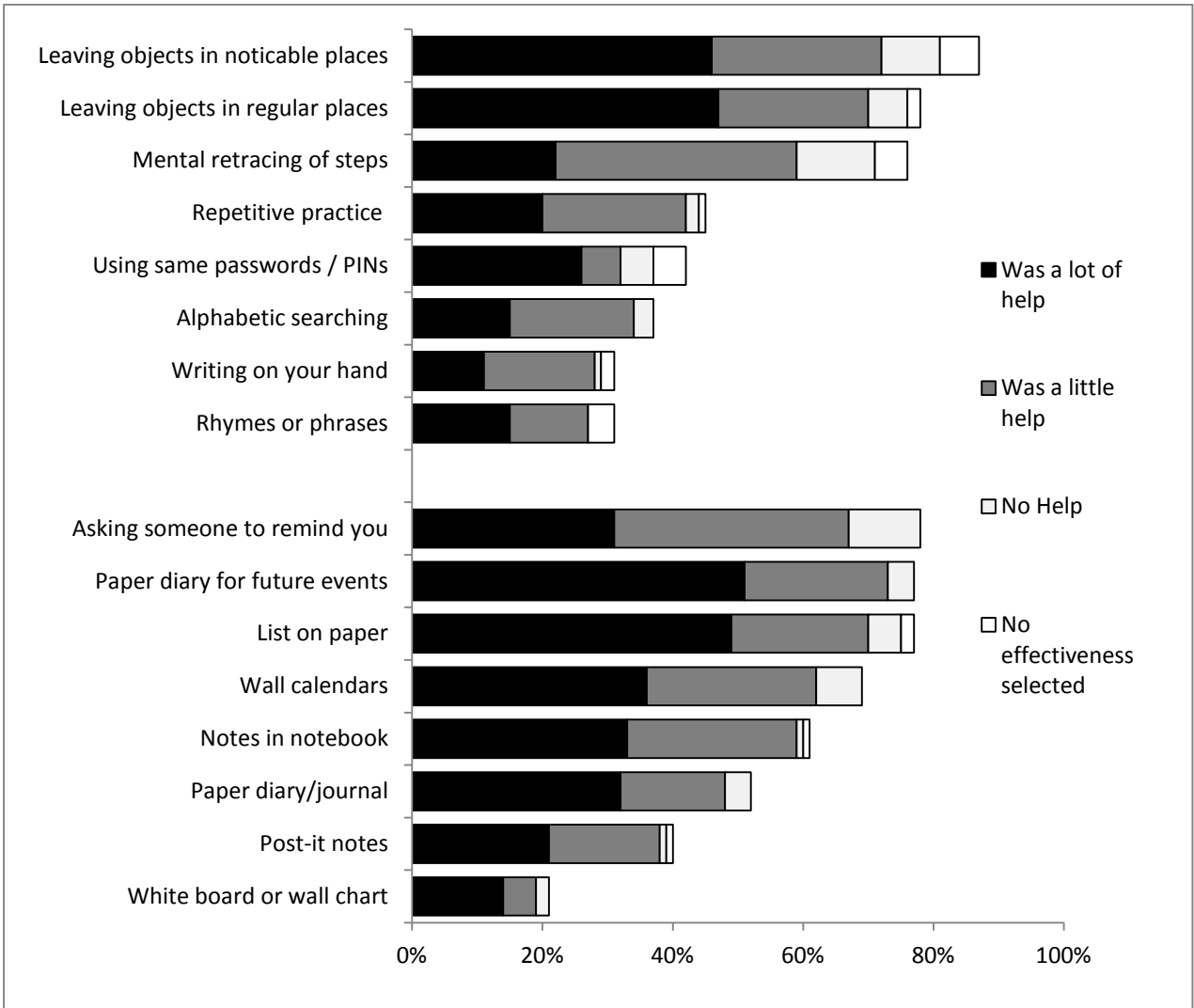**Figure 1: Survey respondents' use of assistive technology, with usefulness evaluation.**

Figure 2: Survey respondents' use of strategies and non-technological memory aids, with usefulness evaluation.