

This is the accepted version of the following article: Mahan, S., Rous, R., and Adlam, A.L.R. (In Press). A Systematic Review of Neuropsychological Rehabilitation for Prospective Memory Deficits as a Consequence of Acquired Brain Injury, to be published in the Journal of the International Neuropsychological Society. This article may be used for non-commercial purposes in accordance with the journal's Terms and Conditions for self-archiving.

**A Systematic Review of Neuropsychological Rehabilitation for Prospective Memory
Deficits as a Consequence of Acquired Brain Injury**

Mahan, S.,¹ Rous, R.,² Adlam, A-L.R.¹

¹Child and Adolescent Neuropsychology Group, Psychology, University of Exeter, Exeter,
EX4 4QG, UK

²Acute Neurological Rehabilitation Unit, The Wellington Hospital, St John's Wood, London,
NW8 6PD

Corresponding author:

Dr Anna Adlam

Child and Adolescent Neuropsychology Group

School of Psychology, College of Life and Environmental Sciences

University of Exeter

Exeter, EX4 4QG

UK

Tel: +44 (0)1392 722209

Fax: +44 (0)1392 724623

Email: a.r.adlam@exeter.ac.uk

Word count for abstract: 243

Word count for manuscript text (excluding title page, abstract, references, tables and figures):

4821

Mahan-Prospective Memory Rehabilitation in ABI

Abstract

Objective: Prospective memory (PM) impairments are common following acquired brain injury (ABI). PM is the ability to keep a goal in mind for future action and interventions have the potential to increase independence. This review aimed to evaluate studies examining PM rehabilitation approaches in adults and children with ABI.

Method: Relevant literature was identified using PsycARTICLES (1894 to present), PsycINFO (1880 to present), the Cochrane Library (1972 to present), MEDLINE PubMed, reference lists from relevant journal articles, and searches of key journals. Literature searches were conducted using variants of the terms *brain injury*, *stroke*, *encephalitis*, *meningitis*, and *tumour*, combined with variants of the terms *rehabilitation* and *prospective memory*.

Results: Of the 435 papers identified, 11 were included in the review. Findings demonstrated a variety of interventions to alleviate PM deficits, including compensatory strategies (e.g., external memory aids) that provide either content-specific or content-free cueing, and remediation strategies (e.g., meta-cognitive training programmes) aimed at improving the self-monitoring of personal goals. Risk of bias for individual studies was considered and the strengths and limitations of each of the included studies and the review itself were discussed.

Conclusions: Interventions utilised with adults can be effective; PM abilities can be improved by utilising simple reminder systems and performance can be generalised to facilitate everyday PM functioning. There is, however, a lack of research of PM interventions conducted with children with ABI, and paediatric interventions need to consider on-going cognitive maturation.

Keywords: Prospective Memory; Acquired Brain Injury; Rehabilitation

Introduction

Acquired brain injury (ABI) is a non-degenerative injury to the brain occurring after birth, and can be caused by traumatic (e.g., road traffic accidents) or non-traumatic (e.g.,

Mahan-Prospective Memory Rehabilitation in ABI

stroke, infection) events. Prevalence rates vary internationally (e.g., 280 children per 100,000 in the UK, Hawley, Ward, Long, Owen, & Magnay, 2003; 500 children per 100,000 in the United States of America (USA), Langlois, Rutland-Brown, & Thomas, 2006; 566 adults per 100,000 in the UK; Headway, 2015; 468 adults per 100,000 in the USA, Corando et al., 2011), however, mild traumatic brain injury (TBI) is consistently found to be the most common type of ABI.

The frontal lobes, specifically the prefrontal cortex (PFC), are thought to be most vulnerable to damage as a consequence of ABI (Ylvisaker, 1998). Accordingly, among the most common and debilitating deficits following ABI are impairments relating to executive functioning (EF), which refers to higher-order cognitive processes thought to be largely localised to the frontal lobes and their networks (Simons, Schölvink, Gilbert, Frith, & Burgess, 2006; Stuss & Alexander, 2000).

EF refers to the integration of cognitive processes that support goal-directed, purposeful behaviour that are vital for the execution of many daily living tasks (McCauley & Levin, 2004). This includes the ability to anticipate the consequences of actions, the ability to formulate plans, and the ability to monitor, adapt and organise behaviour depending upon the task or context (Burgess, Scott, & Frith, 2003; Duncan, Emslie, Williams, Johnson, & Freer, 1996). Prospective memory (PM) is not a distinct construct, but rather the outcome of a series of cognitive processes, primarily memory and EF (Fish, Wilson, & Manly, 2010). It refers to the ability to remember to carry out a planned action in the future (Ellis, 1996); this can refer to an event-based action (e.g., remembering to pass on a message), a time-based action (e.g., remembering an appointment), or an activity-based action (e.g., remembering to charge your phone at the end of the day; Kvavilashvili & Ellis, 1996).

To successfully engage in a PM task, it is theorised that an individual must initially encode and remember the action required. Secondly, an individual is required to recall the

action at the necessary time, which involves a dependence on cognitive abilities such as attention and intact executive functioning. An individual must then execute the action, and finally evaluate the outcome of the action so as to avoid unnecessary repetition of the PM task (Fish et al., 2007).

The rehabilitation of prospective memory. Compensatory interventions are commonly utilised in brain injury rehabilitation to alleviate the impact of cognitive deficits on an individual's daily life (Wilson, 2004). They often involve the use of external, prompting memory aids to alleviate the experience of PM deficits, and thus, an individual's dependence on others to remember daily tasks. These memory aids are often considered as either being passive or active aids (Herrman, Brubaker, Yoder, Sheets, & Tio, 1999; Schaffer & Geva, 2015). Passive aids are methods of recording the content of a PM task (for example, a 'to-do' list). Although passive aids can be useful, individuals who experience memory complaints may struggle to successfully employ these aids. For example, users of passive aids need to be able to independently remember to self-monitor and amend the content within the aid as necessary, which can impact upon the successful completion of the PM task (Thöne-Otto & Walther, 2008). Conversely, the advantages of utilising active memory aids are that they prompt the user about a PM task or goal, by either alerting the individual using a content-specific cue (e.g., an audio-visual message alert on a smartphone) or alerting the individual about a task using a content-free cue (e.g., an alarm tone). The advantage of content-free cues, where no specific detail of the PM task is provided, is that the individual needs to only set a standard reminder, rather than input content-specific reminders. Numerous content-specific reminders have the potential to be overwhelming for the recipient, in addition to being laborious for the user to set multiple content-specific reminders every day. Conversely, a disadvantage of content-free memory aids may be that an alarm sounds and the user may forget what it was for. Within rehabilitation, other approaches, such as skill

training, aim to remediate (rather than compensate for) a lost or, in the case of children, a potentially under-developed skill in the context of an injury (Krasny-Pacini Chevignard, & Evans, 2014). In the context of rehabilitation for PM, the remediation of PM as a skill per se has not been reported; underpinning skills such as metacognition to improve awareness and self-monitoring, however, have been incorporated in to interventions.

Rationale and objective. Evidence is available to suggest that memory and EF systems rarely fully recover following an ABI sustained in childhood or adulthood (Middleton, 2001; Roozenbeek, Maas, & Menon, 2013). In context of paediatric ABI (pABI), it is often considered that higher-level cognitive deficits, such as PM, may only become apparent over time when these abilities are expected to develop and mature in a typically developing child. Moreover, PM difficulties will potentially become more noticeable as the child matures, due to children and adolescents being expected to become more independent at home and at school with increasing age (Gamino & Chapman, 2007; Ross et al., 2011). Consequently, interventions supporting PM following ABI in both adults and children have the potential to increase independence and enhance social participation.

The objective of this systematic literature review was to examine the rehabilitation approaches for PM impairments as a consequence of ABI in both adults and children. If evidence for interventions for children was lacking, this review also aimed to identify interventions from the adult literature that could be adapted to support children with these deficits. To achieve this, the review aims to answer the following questions: What are effective rehabilitation approaches for PM difficulties in individuals with ABIs? Can these interventions be applied to a paediatric population?

Method

Mahan-Prospective Memory Rehabilitation in ABI

The study received a favourable opinion from the NRES ethics committee (IRAS 150366) and the University of Exeter ethics committee (Reference Number 2015/639). This systematic review was conducted using the PRISMA reporting protocol (Moher, Liberati, Tetzlaff, Altman, & the PRISMA Group, 2009) as this allows for a standardised non-biased approach to the review.

Eligibility criteria. Peer-reviewed journal articles, both group and single-case designs, were included. These journal articles investigated interventions and rehabilitation programmes addressing PM outcomes with adult (aged 18-65 years) and/or child and adolescent participants (aged 0-17 years) with a primary diagnosis of ABI. Eligibility criteria for the systematic review are detailed in Figure 1.

[INSERT FIGURE 1 HERE]

Information sources. Studies were identified by searching electronic databases, visually scanning reference lists of relevant articles, and searching key journals. The electronic databases PsycARTICLES (1894 to present), PsycINFO (1880 to present), the Cochrane Library (1972 to present), and MEDLINE PubMed (1966 to present) were searched between November 2013 and May 2016. In addition, searches were conducted on selected references from relevant journal articles and from key journals, including ‘Neuropsychologia’, the ‘Journal of the International Neuropsychological Society’, ‘Developmental Medicine and Child Neurology’, ‘Brain Injury’, ‘Brain Impairment’, and ‘Child Neuropsychology and Developmental Neurorehabilitation’, until May 2016.

Search terms. The following search-terms were used for the systematic review: (1) (“acquired brain injur*” or “acquired head injur*” or “traumatic brain injur*” or “traumatic head injur*” or “brain injur*” or “head injur*” or “stroke” or “cerebral vascular accident*” or “cerebral vascular incident*” or “encephalitis” or “meningitis” or “tumour*” or “tumor*”); (2) (“intervention*” or “rehabilitat*” or “train*” or “therap*” or “strateg*” or “treatment*”);

(3) (“prospective memory”). The symbol * relates to database operators, which permit the search of possible extra letters in the term to be included within the search (for example, searching “head injur*” will permit the search of the terms “head injury” and “head injuries”). The three searches were then combined with the database operator ‘AND’.

Study selection and data collection process. The selection for screening eligible records was conducted by the systematic review author alone. A data extraction sheet was developed based on Cochrane Consumers and Communication Review Group’s data extraction template, so that each report could be critiqued, presented and summarised in a clear and concise manner.

Data items. Information was extracted from each record based on: (1) characteristics of study participants (including age and primary diagnosis); (2) the description of the intervention or rehabilitation programme; (3) the outcome measures employed to assess the efficacy of the intervention for alleviating PM difficulties, and; (4) the effect sizes of the intervention, where possible; where it was not possible to determine effect sizes (if mean and standard deviation were not reported), results were provided in the way they were reported in the record. If possible, a meta-analysis will be conducted to synthesise the data extracted across multiple studies.

Risk of bias in individual studies and across studies. To ascertain the validity of eligible records, an appraisal criteria (illustrated in Figure 2) was developed based on Consolidated Standards of Reporting Trials (CONSORT) guidelines, with items added that are specific to ABI (consistent with Ross et al., 2011) and cognitive rehabilitation (consistent with Krasny-Pacini et al., 2014). As this systematic review also included single-case studies, the six CONSORT items that only related to group studies were substituted with items from the SCED rating scale (www.psycbite.com). The SCED scale is used for the evaluation of articles reporting single-case interventions, or intervention studies with small sample sizes

(Krasny-Pacini et al., 2014). Each of the 27 items was awarded a score of 1 (if the criterion was met) or 0 (if not met or if was not possible ascertain from information within the article).

In line with Ross et al. (2011) and Krasny-Pacini et al. (2014), articles that met 75% of the criteria specified were considered to be of ‘high’ quality. Articles that were rated between 50% and 74% were deemed to have ‘moderate’ quality, and those achieving less than 50% were ‘lower’ quality (Krasny-Pacini et al., 2014; Ross et al., 2011). The authors of these articles reported that this quality rating was created following a faculty research meeting, due to the lack of available guidance about precise methods of determining the quality and consequent risk of bias in journal articles. Moher et al. (2009) state that it is important to assess the risk of bias within journal articles, and thus, papers with ‘high’ quality ratings (consistent with Krasny-Pacini et al., 2014; Ross et al., 2011), were deemed to have a reduced risk of bias and, consequently, the findings more empirically sound. Results from records were also examined for information that suggested there may be missing data (publication bias) or missing data from included records (selective recording bias). To determine the reliability of this tool, a second reviewer rated three (27%) of the reports independently. Ratings were identical across all papers (100%).

[INSERT FIGURE 2 HERE]

Summary measures and planned method of analysis. A reduction in PM memory failures was the primary outcome measure of interest in this systematic review. Where possible, Cohen’s *g* (Cohen, 1988) effect sizes (ES) of pre- and post-intervention PM memory failures were calculated as a standard difference between means, using Hedges *g* (Hedges & Vevea, 1998), which was adapted by Morris and DeShon (2002). This approach has been utilised (or recommended) in prominent review articles (Cicerone et al., 2005; Krasny-Pacini et al., 2014; Rohling, Faust, Beverly, & Demakis, 2009; Ross et al., 2011) that investigated the efficacy of cognitive intervention, and thus it was deemed appropriate for

employment within the current systematic review. Calculating effect size enables researchers to analyse the magnitude of effects that exist between experimental groups; significance levels simply state if an experimental effect is present rather than the magnitude of effects (Gravetter & Forzano, 2006). ES is separated into boundaries as being a small ($0 < g < 0.2$), medium ($0.2 < g < 0.5$) or large effect ($g > 0.8$). Figure 3 illustrates the formulas for calculating ES. If it was not possible to calculate ES, the record would be analysed based on the results reported within the paper.

[INSERT FIGURE 3 HERE]

Results

Study selection. Figure 4 provides a flow diagram of the search strategy and study selection. The study selection took place in stages, with articles initially being screened by reading the title alone, then by reading the abstract, and then by reading the full-text article. Hiroyoshi et al. (2013) is an example of a paper screened by title alone; the title clearly demonstrated that the sample within the study had a diagnosis of dementia. Clune-Ryberg et al. (2011) is an example of a paper screened by abstract, which demonstrated no evidence of rehabilitation approaches in the abstract.

[INSERT FIGURE 4 HERE]

Study characteristics. Table 1 summarises and describes the main findings of the studies included in this systematic review pertaining to content-specific compensatory strategies. Table 2 summaries and describes the main findings of the studies included in the review pertaining to content-free and metacognitive strategies. Eight studies (studies 1, 2, 4, 5, 6, 7, and 10) included in the review recruited adult participants (aged 18 to 65 years), two studies (studies 9 and 11) recruited paediatric and adolescent participants (aged 8 to 17 years), and two studies (studies 3 and 8) recruited child, adolescent and adult participants (aged 8 to 65 years). Of these 11 studies, seven studies (studies 1, 2, 6, 8, 9, 10 and 11)

employed a single-case design and four studies (studies 3, 4, 5, and 7) employed a group-design. Studies 1 to 9 (six studies with adult participants aged 18 to 65 years, and three with child, adolescent, and adult participants aged 8 to 65 years) included in the qualitative synthesis pertained to compensatory interventions *only* to alleviate PM difficulties in individuals with ABI. Studies 10 and 11 (one study with adult participants aged 19 to 60 years, and one with paediatric participants aged 8 to 14 years) utilised a hybrid approach; both studies employed a meta-cognitive, remediation training strategy (Goal Management Training; GMT; Duncan, 1986; Levine et al., 2007) *and* a compensatory strategy (content-free cueing) aimed at facilitating the self-monitoring, evaluation and regulation of personal goals. Ten studies achieved a ‘high quality’ rating (77% to 93%); one study (Fish et al., 2007) achieved a ‘moderate quality’ rating (64%).

Content-specific cues. Studies 1 to 9 investigated the efficacy of devices that deliver content-specific cues to alleviate PM task errors in individuals with ABI (six studies with adult participants aged 18 to 65 years, and three studies with child, adolescent, and adult participants aged 8 to 65 years). These included prompts delivered by a pager, a personal digital assistant (PDA), a Television Assistive Prompting (TAP) device, the use of Google Calendar, the calendar function on a smartphone, and a device to record voice memos.

Three papers demonstrated that a paging system could be utilised to reduce PM deficits in individuals with TBI. Emslie, Wilson, Quirk, Evans, & Watson (2007) demonstrated this with adult participants (aged 30 to 49 years). Wilson, Emslie, Quirk, Evans, & Watson (2005) and Wilson et al. (2009) demonstrated this with child, adolescent and adult participants (aged 8 to 65 years). All three studies showed evidence to suggest that PM task performance improved when receiving content-specific pager prompts.

An increase in PM task success has also been demonstrated in studies with adolescent and adult participants (aged 17 to 65 years) utilising PDA devices as external memory aids

(Lannin et al., 2014; Waldron, Grimson, Carton, & Blanco-Campal, 2012). Lannin et al. demonstrated that PDA devices with an alerting function facilitate memory functioning better than non-electronic memory aids. A Televised Assisted Prompting (TAP) system has also been shown to be a unique compensatory strategy for PM failures in adult participants aged 18 to 60 years (Lemoncello, Sohlberg, Fickas, & Prideaux, 2011). This study demonstrated some task-novelty effects with higher task completion with TAP prompting for research-assigned experimental tasks, compared to self-selected preferred or non-preferred tasks.

The use of digital calendars on smartphones has provided a novel method of recording PM tasks and enabling the user to set alerts to deliver content-specific prompts at the appropriate times for everyday memory tasks (Ferguson, Friedland, & Woodberry, 2015; McDonald et al., 2011). Ferguson et al. demonstrated a significant increase in task completion and task punctuality when prompts were received (participants were adults aged 24 to 55 years). Furthermore, thematic analysis revealed that reminders improved participants' sense of independence, their confidence in coping with PM difficulties, and their general mood. Research conducted by McDonald et al. with adult participants (aged 19 to 65 years) provides further evidence that digital calendar prompts provide an effective tool for compensating for PM difficulties; Google Calendar was shown to be more effective than a standard diary, and was preferred by the participants.

The use of a voice-recording device as an external memory aid has also been investigated with adult participants (aged 30 to 57 years). Van Den Broek, Downes, Johnson, Dayus, and Hilton (2000) demonstrated that all participants showed improvements on a message-passing task, and four participants showed improvements on a domestic task when they utilised voice organiser prompts.

Content-free cues and metacognitive methods. Two studies investigated the efficacy of content-free cueing and metacognitive GMT to alleviate PM task errors. Fish et al. (2007)

and Krasny-Pacini et al. (2013) examined the effects of GMT and external content-free cueing (in the form of text messages) on PM task performance. Fish et al. found a significant effect of content-free cueing with adults with ABI (aged 19 to 60 years) with a greater number, and more accurate, calls on days when content-free “STOP” cues were received by participants. Krasny-Pacini et al. (2013) investigated the efficacy of an adapted version of GMT that was tailored to a paediatric population and external content free cueing (in the form of alerts reading “Look into your mental notebook”). Participants demonstrated a significant improvement on the PM task following the GMT intervention and receiving content-free cues.

Evidence for the possible remediation of prospective memory functioning. The majority of interventions included in this review surround external memory aids that were employed to prompt and consequently offer compensatory methods (either by content-specific or content-free cueing) for reducing PM failures. These studies provide evidence to suggest that various interventions can be used to compensate for PM failures. Three of these studies, however, demonstrated a remediation of PM functioning with participants continuing to demonstrate improvements (when compared to their baseline performance) in their PM function even after their compensatory aid had been removed (Emslie et al., 2007; Wilson et al., 2005, 2009). Furthermore, Lannin et al. (2014) found that the use of a PDA device resulted in an improvement on the psychometric measure, the General Frequency of Forgetting (GFF; Gilewski, Zelinski, & Shaie, 1990) in comparison to standard rehabilitation using passive memory aids. This suggests a general subjective memory improvement separate to the PM tasks. Krasny-Pacini et al. (2013) also demonstrated that metacognitive GMT training and content-free cueing facilitated the improvement of everyday PM functioning for goals separate to the training task.

[INSERT TABLE 1 HERE]

[INSERT TABLE 2 HERE]

Discussion

The studies outlined in this systematic review demonstrate that a number of varying rehabilitation methods are available to alleviate PM deficits following ABI, and support a patient's EF skills for planning and organising. These include compensatory strategies in the form of external memory aids, which provide either content-specific or content-free cueing, and training programmes aimed at facilitating meta-cognitive skills (e.g., self-monitoring and self-evaluating personal goals). This review has also highlighted that there is a greater availability of research pertaining to adult rehabilitation and only two studies involving paediatric participants. This limited evidence-base for paediatric rehabilitation has also been highlighted in previously published reviews (Fish et al., 2010; Laatsch et al., 2007; Limond & Leeke, 2005; Ross et al., 2011). Overall, research in the field of PM interventions following ABI is, however, arguably limited relative to other disorders.

Critique of research included in the review. 10 of the 11 studies achieved a high quality rating and one received a moderate quality rating, according to the appraisal criteria utilised in the review (see Figure 2). This suggests that the risk of bias in individual studies and across studies was low, and the eligible records in the review were largely valid. They were deemed to have appropriate research methods, an adequate description of the intervention, and employed appropriate statistical analysis, for example.

Although all literature included in this review demonstrated promising findings in favour of a variety of PM interventions, it was only possible to report the ES for four of the studies included in the review (studies 2, 3, 10, and 11). It was not possible to calculate the ES for the remaining studies, because the means and standard deviations were not reported. Consequently, for seven of the studies (studies 1, 4, 5, 6, 7, 8, and 9), it is only possible to state that the interventions resulted in a significant improvement in PM performance, and not the magnitude of the effect of the intervention. Although this does not mean that a large

effect size for the intervention was not present in these studies, it is not possible to reliably state this.

Five of the studies (studies 3, 4, 5, 6, and 7) included in the review did not examine the effects of removing the content-specific strategies on PM task performance. It is, therefore, possible that the improved PM performance reflect the cumulative effect of the ongoing, novel intervention rather than the specific strategy (e.g., pager, PDA) itself. An alternative research design, therefore, may have been to employ an A-B-A-B approach. Future studies, however, would need to carefully consider the ethical dilemma of withdrawing a compensatory strategy that is proving helpful to participants.

A further limitation of seven of the studies (studies 2, 3, 4, 6, 7, 8 and 10) employed in this review is that they did not compare contrasting compensatory external memory strategies for PM task performance. Consequently, knowledge surrounding the *superiority* of one strategy over another is limited which, therefore, limits the evidence-base regarding the efficacy of a certain compensatory strategy for a certain presentation or age group. Each of the studies included in this review employed different outcome measures, which further limits comparison between the efficacies of contrasting external memory strategies. Future research could focus on comparing multiple compensatory strategies using the same, standardised PM outcome measures.

Critique of review. Although Fish et al. (2010) conducted a review looking at the assessment and rehabilitation of PM deficits in people with neurological disorders, to the author's knowledge, this is the first systematic review looking solely at PM interventions following ABI. This review, therefore, offers a unique opportunity to consider the theoretical and clinical implications of the available literature for this patient group.

A further advantage of this review is that both single-case and group studies were included. It has, however, been argued that single-case studies are less valid than group

studies due to external validity limitations (Cicerone, Azulay, & Trott, 2009). Tate et al. (2008), conversely, report that single-case methods are readily applicable to clinical practice, in addition to providing a unique method of documenting individualised outcomes and thus providing empirical evidence in support of rehabilitation approaches. Nonetheless, a possible direction for future research could be to conduct randomised control trials using interventions that have proof-of-principle (based on findings from single-case designs) to further explore the effectiveness of the interventions and establish the generalisability to large sample sizes.

A limitation of the current review is that 16 records were excluded due to inadequate description of rehabilitation programmes. It was, therefore, not possible to critique the efficacy of these programmes for rehabilitating PM functioning.

Three of the studies (studies 1, 8, and 9) included in this systematic review contained overlapping samples. They cannot, therefore, be considered as three independent studies when evaluating the strengths and limitations of the evidence and drawing conclusions across the literature.

Implications for clinical practice. This review has highlighted a variety of contrasting methods of rehabilitating PM deficits; however, clinicians should remain mindful that eight of the 11 studies included in the review investigated the efficacy of PM interventions with adult participants only. Given the limited availability of research evidence to support the efficacy of PM interventions in a paediatric population, it is imperative that future research focuses on contributing to this evidence-base. Although very few studies exist for the paediatric population, it could be argued that all of the interventions shown to be effective in adults could be adapted for a paediatric population, providing that the age and developmental level of the child is considered when designing the intervention (Limond, Adlam, & Cormack, 2014). Wilson et al. (2009) successfully utilised a paging system in both adults and children, and demonstrated PM improvements. Krasny-Pacini et al. (2013)

demonstrated the efficacy of a memory rehabilitation programme and content-free cueing for improving PM deficits in children with ABI, which utilised an adapted GMT intervention previously employed with adults (Fish et al., 2007). This suggests that interventions utilised with adults can be effective; however important adaptations may be necessary, as evidenced by Krasny-Pacini et al. (2013). Paediatric rehabilitation needs to consider cognitive function in the context of on-going maturation (rather than the loss of function, as is often the case in adult interventions).

Limond et al. (2014) suggest a sequential approach to intervention and they state that lower-level cognitive processes “must be optimised to facilitate rehabilitation of higher-order specific processes” (p. 183). They have proposed a theoretical model to help guide paediatric interventions, which consider the cognitive maturation of the child/adolescent. The model proposes a hierarchy for different rehabilitation approaches dependent upon the cognitive capabilities necessary for the intervention to be effective. Clinicians must, therefore, be mindful of this model when adapting interventions from an adult population.

Implications for theory and research. A number of studies in this review have shown evidence of the strategies having transfer effects; Wilson et al. (2005, 2009) and Emslie et al. (2007) found that, even after a pager system was removed, participants continued to achieve more of their PM tasks in comparison to their baseline performance; Krasny-Pacini et al. (2013) also demonstrated that a hybrid approach of metacognitive GMT training and content-free cueing can facilitate the improvement of everyday PM functioning for goals separate to the training, and; Lannin et al. (2014) found that participants reported a general subjective memory improvement separate to the PM tasks. These findings, therefore, raise an interesting theoretical question: can external memory strategies designed to compensate for PM deficits facilitate the remediation of PM functioning? Unfortunately, these findings were not discussed in detail within these papers. It is, therefore, unclear if the

participant internalised a memory strategy to support PM, developed a habit or routine and thus minimised the PM demands, or developed PM skills, as a result of the repeated use of an external memory aid. Although it may not be possible to definitively answer these queries within this review, the findings are, nonetheless, interesting towards the debate of whether PM is a skill that can be taught or whether it can only be facilitated through external strategies. Regardless, this review highlights that external strategies aimed to improve PM task performance can be generalised to facilitate everyday PM functioning for participants. This, therefore, offers the potential for prompting memory aids to alleviate the experience of PM deficits, and thus, reduces an individual's dependence on others to remember daily tasks. This in turn may increase an individual's sense of independence and increase social participation.

Conclusions. This review has summarised and critiqued the findings of studies that investigate the efficacy of PM interventions in individuals with ABI. The literature demonstrated the efficacy of varying rehabilitation methods to alleviate PM deficits following ABI; more PM tasks were completed when participants received either content-free or content-specific cues or took part in a metacognitive training programme. This suggests that PM abilities can be improved following ABI by utilising simple reminder systems. The review has also highlighted that interventions utilised with adults can be effective; however, paediatric rehabilitation might benefit from considering the influence of on-going cognitive maturation when contemplating which adult interventions might be effective with children. Limond et al.'s (2014) theoretical model might provide a useful framework to guide future research in this area. The review has also highlighted that external strategies aimed to facilitate PM task performance can be generalised to facilitate everyday PM functioning. A major finding of this review is that there is an extreme lack of research of PM interventions conducted in children with ABI, and future research is needed to improve this evidence base.

Acknowledgements

No conflict of interest to report. This critical review received no funding or financial support.

Mahan-Pro prospective Memory Rehabilitation in ABI

References

- Anderson, V. A., & Yeates, K. O. (2010). Introduction. In V. A. Anderson & K. O. Yeates (Eds.), *Pediatric traumatic brain injury: New frontiers in clinical and translational research* (pp. 1-6). Cambridge, UK: Cambridge University Press.
- Appleton, R. (1998). Epidemiology, incidence, causes, severity and outcome. In R. Appleton & T. Baldwin (Eds.), *Management of brain injured children* (pp. 1-20). Oxford, UK: Oxford University Press Inc.
- Bodack, M. I. (2010). Paediatric acquired brain injury. *Optometry*, *81*, 516-527.
- Burgess, P. W., Scott, S. K., & Frith, C. D. (2003). The role of the rostral frontal cortex (area 10) in prospective memory: a lateral versus medial dissociation. *Neuropsychologia*, *41*, 906-918.
- Cicerone, K. D., Dahlberg, C., Malec, J. F., Langenbahn, D. M., Felicetti, T., Kneipp, S.,...Catanese, J. (2005). Evidence-based cognitive rehabilitation: Updated review of the literature from 1998 through 2002. *Archives in Physical and Medical Rehabilitation*, *86*, 1681-1692.
- Cicerone, K. D., Azulay, J., & Trott, C. (2009). Methodological quality of research on cognitive rehabilitation after traumatic brain injury. *Archives of Physical and Medical Rehabilitation*, *90*, 52-59.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates Publishers.
- Clune-Ryberg, M., Blanco-Campal, A., Carton, S., Pender, N., O'Brien, D., Phillips, J., Delargy, M., & Burke T. (2011). The contribution of retrospective memory, attention and executive functions to the prospective and retrospective components of prospective memory following TBI. *Brain Injury*, *25(9)*, 819-831.

- Coronado, V. G., Xu, L., Basavaraju, S. V., McGuire, L. C., Wald, M. M., Faul, M.,...Hemphill, J. D. (2011). Surveillance for Traumatic Brain Injury--Related Deaths - United States, 1997-2007. *Surveillance Summaries*, 60(SS05), 1-32.
- Duncan, J. (1986). Disorganisation of behaviour after frontal lobe damage. *Cognitive Neuropsychology*, 3, 271-290.
- Duncan, J., Emslie, H., Williams, P., Johnson, R., & Freer, C. (1996). Intelligence and the frontal lobe: The organization of goal-directed behaviour. *Cognitive Psychology*, 30, 257-303.
- Ellis, J. A. (1996). Prospective memory or the realization of delayed intentions: a conceptual framework for research. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective Memory: Theory and Applications* (pp. 1–22). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Emslie, H., Wilson, B. A., Quirk, K., Evans, J. J., & Watson, P. (2007). Using a paging system in the rehabilitation of encephalitic patients. *Neuropsychological Rehabilitation*, 17(4/5), 567-581.
- Ferguson, S., Friedland, D., & Woodberry, E. (2015). Smartphone technology: Gentle reminders of everyday tasks for those with prospective memory difficulties post-brain injury. *Brain Injury, Early Online*, 1-9.
- Fish, J., Evans, J. J., Nimmo, M., Martin, E., Kersel, D., Bateman, A.,...Manly, T. (2007). Rehabilitation of executive dysfunction following brain injury: “Content-free” cueing improves everyday prospective memory performance. *Neuropsychologia*, 45, 1318-1330.
- Fish, J., Wilson, B., & Manly, T. (2010). The assessment and rehabilitation of prospective memory problems in people with neurological disorders. *Neuropsychological Rehabilitation*, 20(2), 161–179.

- Gamino, J. F., & Chapman, S. (2007). Strategic learning in youth with traumatic brain injury: Evidence for stall in higher-order cognition. *Topics in Language Disorders, 29*(3), 224-235.
- Gilewski, M., Zelinski, E., & Shaie, K. W. (1990). The Memory Functioning Questionnaire for assessment of memory complaints in adulthood and old age. *Psychology of Ageing, 5*, 482-490.
- Gravetter, F. J., & Forzano, L-A. B. (2006). *Research methods for the behavioral sciences* (2nd ed.). Belmont, CA: Thomson Wadsworth.
- Hawley, C. A., Ward, A. B. Long, Owen, D. W., & Magnay, A. R. (2003). Prevalence of traumatic brain injury amongst children admitted to hospital in one health district: a population-based study. *Injury, 34*(4), 256-260.
- Headway. (2015). Acquired Brain Injury: The numbers behind the hidden disability. Retrieved from <https://www.headway.org.uk/media/2883/acquired-brain-injury-the-numbers-behind-the-hidden-disability.pdf>
- Hedges, L., V., & Vevea, J., L. (1998). Fixed- and random-effects models in meta-analysis. *Psychological Methods, 3*, 486–504.
- Herrman, D., Brubaker, B., Yoder, C., Sheets, V., & Tio, A. (1999). Devices that remind. In F. T. Durso (Ed.), *Handbook of applied cognition* (pp. 377-407). New York, NY; John Wiley & Sons, Ltd.
- Hiroyoshi, A., Shinagawa, S., Komori, K., Toyota, Y., Mori, T... Ikeda, M. (2013). Comparison of the utility of everyday memory test and the Alzheimer's Disease Assessment Scale-Cognitive part for evaluation of mild cognitive impairment and very mild Alzheimer's disease. *Psychiatry & Clinical Neurosciences, 67*(3), 148-153.

- Krasny-Pacini, A., Limond, J., Evans, J., Hiebel, J., Bendjelida, K., & Chevgnard, M. (2013). Context-sensitive Goal Management Training for everyday executive dysfunction in children after severe traumatic brain injury. *Journal of Head Trauma Rehabilitation, 1-16*.
- Krasny-Pacini, A., Chevignard, M., & Evans, J. (2014). Goal management training for rehabilitation of executive functions: a systematic review of effectiveness in patients with acquired brain injury. *Disability & Rehabilitation, 36(2)*, 105-116.
- Kvavilashvili, L., & Ellis, J. (1996). Varieties of intention: Some distinctions and classifications. In M. Brandimonte, G.O. Einstein & M.A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 23-52). Mahwah, NJ: Lawrence Erlbaum.
- Laatsch, L., Harrington, D., Hotz, G., Marcantuono, J., Mozzoni, M. P., Walsh, V., & Pike-Hersey, K. (2007). An evidence-based review of cognitive and behavioural rehabilitation treatment studies in children with acquired brain injury. *Journal of Head Trauma Rehabilitation, 22(4)*, 248-256.
- Langlois, J. A., Rutland-Brown, W., & Thomas, K. E. (2006). Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations, and Deaths 2002 - 2006. Retrieved from http://www.cdc.gov/traumaticbraininjury/pdf/blue_book.pdf
- Lannin, N., Carr, B., Allaous, J., Mackenzie, B., Falcon, A., & Tate, R. (2014). A randomised control trial of the effectiveness of handled computers of improving everyday memory functioning in patients with memory impairments after acquired brain injury. *Clinical Rehabilitation, 28(5)*, 470-481.

- Lemoncello, R., Sohlberg, M. M., Fickas, S., & Prideaux, J. (2011). A randomised controlled crossover trial evaluating Television Assisted Prompting (TAP) for adults with acquired brain injury. *Neuropsychological Rehabilitation: An International Journal*, 21(6), 825-846.
- Levine, B., Robertson, I. H., Clare, L., Carter, G., Hong, J., ... Wilson, B. A. (2007). Rehabilitation of executive functioning: An experimental-clinical validation of goal management training. *Journal of the International Neuropsychological Society*, 6(3), 299-312.
- Levine, B., Schweizer, T., O'Connor, C., Turner, G., Gillingham, S., Stuss, D. T., ... Robertson, I. H. (2011). Rehabilitation of executive functioning in patients with frontal lobe brain damage with Goal Management Training. *Frontiers in Human Neurosciences*, 5(9), 1-9.
- Limond, J., & Leeke, R. (2005). Practitioner review: Cognitive rehabilitation for children with acquired brain injury. *Journal of Child Psychology and Psychiatry*, 46(4), 339-352.
- Limond, J., Adlam, A-L. R., & Cormack, M. (2014). A model for pediatric neurocognitive interventions: Considering the role of development and maturation in rehabilitation planning. *The Clinical Neuropsychologist*, 28(2), 181-198.
- McCauley, S. R., & Levin, H. B. (2004). Prospective memory in paediatric traumatic brain injury: A preliminary study. *Developmental Neuropsychology*, 25, 5-20.
- McDonald, A., Haslam, C., Yates, P., Gurr, B., Leeder, G., & Sayers, A. (2011). Google Calendar: A new memory aid to compensate for prospective memory deficits following acquired brain injury. *Neuropsychological Rehabilitation*, 21(6), 784-807.

- Middleton, J. A. (2001). Brain injury in children and adolescents. *Advances in Psychiatric Treatment, 7*, 257-265.
- Moher D, Liberati A, Tetzlaff J, Altman DG, & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. *PLoS Med, 6*(7). doi:10.1371/journal.pmed.1000097
- Morris, S., B., & DeShon, R., P. (2002). Combining effect size estimates in meta-analysis with repeated measures and independent-groups designs. *Psychological Methods, 7*, 105–25.
- Rohling, M., L., Faust, M., E., Beverly, B., & Demakis, G. (2009) Effectiveness of cognitive rehabilitation following acquired brain injury: a meta-analytic re-examination of Cicerone et al.'s (2000, 2005) systematic reviews. *Neuropsychology, 23*, 20–39.
- Roozenbeek, B, Maas, A. I. R., & Menon, D. K. (2013). Changing patterns in the epidemiology of traumatic brain injury. *Nature Reviews Neurology, 9*, 231-236.
- Ross, K. A., Dorris, L., & McMillan, T. (2011). A systematic review of psychological interventions to alleviate cognitive and psychosocial problems in children with acquired brain injury. *Developmental Medicine & Child Neurology, 53*(8), 692-701.
- Schaffer, Y., & Geva, R. (2016). Memory outcomes following cognitive interventions in children with neurological deficits: A review with a focus on under-studied populations, *Neuropsychological Rehabilitation, 26*(2), 286-317.
- Simons, J. S., Schölvinc, M. L., Gilbert, S. J., Frith, C. D., & Burgess, P. W. (2006). Differential components of prospective memory? Evidence from fMRI. *Neuropsychologia, 44*, 1388-1397.
- Stuss, D. T., & Alexander, M. P. (2000). Executive functions and the frontal lobes: A conceptual view. *Psychological Research, 63*(3-4), 289-98.

- Tagliaferri, F., Compagnone, C., Korsic, M., Servadei, F., & Kraus, J. (2006). A systematic review of brain injury epidemiology in Europe. *Acta Neurochirurgica, 148*(3), 255-268.
- Tate, R. L., McDonald, S., Perdices, M., Togher, L., Schultz, R., & Savage, S. (2008). Rating the methodological quality of single-subject designs and n-of-1 trials: Introducing the Single-Case Experimental Design (SCED) Scale. *Neuropsychological Rehabilitation: An International Journal, 18*(4), 385-401.
- Thöne-Otto, A. I. T., & Walther, K. (2008). Assessment and treatment of prospective memory disorders. In M. Kliegel, M. A. McDaniel, & G. O. Einstein (Eds.), *Prospective memory. Cognitive, neuroscience, developmental and applied perspectives* (pp. 321-341). New York, NY: Lawrence Erlbaum Associates Taylor Francis Group.
- Van Den Broek, M. D., Downes, J. Johnson, Z., Dayus, B., & Hilton, N. (2000). Evaluation of an electric memory aid in the neuropsychological rehabilitation of prospective memory deficits. *Brain Injury, 14*(5), 455-462.
- Waldron, B., Grimson, J., Carton, S., & Blanco-Campal, A. (2012). Effectiveness of an unmodified personal digital assistant as a compensatory strategy for prospective memory failures in adults with an ABI. *The Irish Journal of Psychology, 33*(1), 29-42.
- Wilson, B. A., Emslie, H., Quirk, K., Evans, J., & Watson, P. (2005). A randomised control trial to evaluate a paging system for people with traumatic brain injury. *Brain Injury, 19*(11), 891-894.
- Wilson, B. A. (2004). Theoretical approaches to cognitive rehabilitation. In L. H. Goldstein & J. E. McNeil (Eds.), *Clinical Neuropsychology: A practical guide to assessment and management for clinicians* (pp. 345-366). London, UK: John Wiley & Sons, Ltd.

Mahan-Prospective Memory Rehabilitation in ABI

Wilson, B. A., Emslie, H., Evans, J. J., Quirk, K., Watson, P., & Fish, J. (2009). The NeuroPage system for children and adolescents with neurological deficits.

Developmental Neurorehabilitation, 12(6), 421-426.

Ylvisaker, M. (1998). *Traumatic brain injury rehabilitation: Children and adolescents*

(2nd ed). Newton, MA: Butterworth-Heinemann.