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The assessment and rehabilitation of prospective memory problems in people with neurological disorders: A review

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People with neurological disorders often report difficulty with prospective memory (PM), that is, remembering to do things they had intended to do. This paper briefly reviews the literature regarding the neuropsychology of PM function, concluding that from the clinical perspective, PM is best considered in terms of its separable but interacting mnemonic and executive components. Next, the strengths and limitations in the current clinical assessment of PM, including the assessment of component processes, desktop analogues of PM tasks, and naturalistic PM tasks, are outlined. The evidence base for the rehabilitation of PM is then considered, focusing on retraining PM, using retrospective memory strategies, problem-solving training, and finally, electronic memory aids. It is proposed that further research should focus on establishing the predictive validity of PM assessment, and refining promising rehabilitation techniques.

Keywords: Brain injury; Assessment; Rehabilitation; Everyday memory.

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INTRODUCTION: THEORETICAL PERSPECTIVES ON PROSPECTIVE MEMORY

To achieve a goal, we often develop intentions that cannot be executed immediately and which must be retained for action at a particular time or in a particular context. This “realisation of delayed intentions” (Ellis, 1996), such as remembering to post a letter or attend an appointment, has been termed prospective memory (PM). Failures of PM are common within the general population, and it has been argued that when people talk of having a “poor memory”, they often mean poor PM (Baddeley, 1997). There is also evidence that PM performance has a stronger correlation with self-rated memory problems than retrospective memory performance, both in people with traumatic brain injury (TBI) and neurologically healthy controls (Kinsella et al., 1996).

Ellis (1996) summarised the stages involved in PM. Unless the intention can be acted upon immediately, one must either actively rehearse the intention, or encode it in such a way that it is likely to come to mind when enactment is possible (e.g., by association with a particular context). Given that over long delays one would want to engage in other tasks, encoding is ideally such that the intention retains a special status in relation to other remembered material (“ongoing/incomplete”) but does not unduly interfere with concurrent activity. The intention must then be retrieved and the action performed at the appropriate time or in response to the appropriate event. Finally, the intention should be tagged as “achieved”, thus avoiding unnecessary repetition.

Various schemes for classifying PM tasks have been proposed. A common distinction (e.g., Einstein & McDaniel, 1996) is between event-based tasks (e.g., post a letter when you see a postbox), time-based tasks (e.g., phone the bank at 4.00 p.m.) and activity-based tasks, in which the trigger is one’s own preceding behaviour (e.g., take medication after breakfast). Ellis (1988) also distinguished between pulse intentions, which need to be performed at a specific time, and step intentions, which have a less tightly-specified window for completion (e.g., I need to call the bank at some time today). These distinctions are mirrored to a degree in clinical assessments (see below).

As discussed, PM refers to a series of processes involved in forming, storing and appropriately retrieving an intention. An important question for clinical assessment is the degree to which these processes are specific to PM or required in many sorts of tasks. Is it the case, for example, that intentions are stored in a different way to other memory content (in which case PM difficulties may not be predicted from standard information recall tests) or that the requirements for monitoring or initiating activity for PM are distinct (in which case PM difficulties may not be well predicted by standard

measures of attention and executive function)? This issue can be considered in a number of ways including examining neural and cognitive correlates of PM in the healthy population and associations/dissociations between PM and other impairments in people with brain injuries.

An early functional imaging study with healthy volunteers produced results that were consistent with PM requiring general resources but with some potential specificity. Okuda et al. (1998) used positron emission tomography (PET) to compare a baseline of repeating word lists with a PM task of tapping their hand in response to occasional PM targets. Increases in regional cerebral blood flow (rCBF) associated with PM were reported in several areas of prefrontal cortex, the anterior cingulate and a parahippocampal region – areas frequently active in many attentionally demanding tasks. In addition, increased activation was seen in frontopolar cortex (BA 10) in the PM condition. As this area was not typically activated by standard attentional tasks, it was argued to be specific to PM. While Okuda et al.'s design did not allow differentiation between holding and *acting* on an intention, a more stringently controlled study by Burgess, Quayle, and Frith (2001) reported results that were consistent with a particular role for BA 10 in maintaining a PM, even, when the opportunity to execute it did not arise. Rather than this being associated specifically with intention storage, however, they have elaborated an argument in which it reflects switching attention between external events and internal content (e.g., thoughts, memories, etc; Burgess, Gilbert, & Dumontheil, 2007; Christoff, Ream, Geddes, & Gabrieli, 2003; den Ouden, Frith, Frith, & Blakemore, 2005). It seems therefore that this region is important for PM (which involves monitoring of the environment in relation to stored intentions) but is not exclusive to it.

Behavioural studies with healthy volunteers have addressed questions regarding whether holding an intention for delayed action interferes with ongoing activity and whether PM tasks correlate with executive and other measures (both of which would suggest a requirement for general attentional resources). While results have varied somewhat with the nature of the tasks, there is certainly evidence that, if participants have an intention in mind with the expectation that it will need to be executed at some stage during the current task, this exerts a detrimental effect on performance of that current task even if the expected cue for the PM action is never presented (Einstein & McDaniel, 1996; Einstein et al., 2005; Smith, 2003; Smith, Hunt, McVay, & McConnell, 2007). Similarly, positive correlations have been reported between performance on PM tasks and executive tests in healthy volunteers, although these are most apparent in complex, multi-tasking PM situations (Martin, Kliegel, & McDaniel, 2003).

While these results are consistent with PM requiring general attentional resources, it is important however to keep in mind the nature of the PM tasks commonly used in these studies. In a typical task (e.g., Einstein &

McDaniel, 1990), participants are asked to encode an intention (e.g., press button x when the word LORRY appears on screen). They will then complete an “ongoing task”, such as rating words for their pleasantness or concreteness, during which LORRY will occasionally appear. Aside from noting that these are typically event-based (rather than time- or activity-based) PM tasks, two features may emphasise relationships with other attentional measures. Firstly, by making adequate encoding of the instructions a condition of beginning the test, performance variance due to retrospective memory failure, which may be common in real-world situations, is reduced. Secondly, to acquire sufficient data these paradigms are often fast paced, contain frequent PM cues and are of limited duration. In this, the paradigms are not obviously different from, for example, vigilance tasks (in which the participants wait for a cue to produce the instructed response) or dual-task measures (in which engagement with one task must be tempered by the need to remember the other) – indeed whether they are termed a “PM”, “attention” or “executive” measure may be simply terminological preference. This does not, of course, mean that performance would not predict PM difficulties over longer intervals in daily life, but this should be tested rather than assumed.

Turning to potential distinctions between processes required in PM and other forms of memory, it seems that current evidence is a little mixed. For example, Goschke and Kuhl (1993) gave participants instructions upon which either the participant or the examiner would later need to act. Reaction times in a subsequent word recognition task were significantly faster for words related to the participant’s actions than the examiner’s actions – a finding termed the “intention superiority effect” (ISE). Marsh, Hicks, and Bink (1998) further reported that the ISE was only observed for pending intentions (whereas responses to words referring to actions already completed by participants were actually slowed). However, it has been questioned whether these differences specifically relate to the maintenance of an intention or whether they might arise as an artefact of the more elaborate encoding given to the motor intentions used in these studies. Freeman and Ellis (2003), for example, found that to-be-enacted material was only more accessible than to-be-observed material when the content was encoded verbally, not when motor encoding strategies were used. Further, the ISE was abolished if participants’ ability to imagine themselves performing the PM task at encoding was reduced by performing a concurrent motor activity. While there is evidence from electroencephalography (EEG) studies showing that event-related potentials (ERPs) to PM cues, retrospective memory cues and items in an ongoing task can be differentiated (e.g., West & Krompinger, 2005) it is currently unclear whether these differences relate to the memory processes *per se* or the different actions that the cues trigger.

The best test of whether PM should be conceived as a product of many processes common to other tasks rather than having a distinct neural basis comes

from the neuropsychological literature. There are, to our knowledge, no convincing reported cases of a pure PM deficit (i.e., in the context of demonstrably intact retrospective memory and other functions). The converse, that PM difficulties commonly arise in the context of more general mnemonic, attentional and executive problems, is however, clear (indeed it is the requirement for adequate function across a number of cognitive processing domains that almost certainly accounts for the ubiquity of the complaint). With due caveats for the adequacy with which it is assessed (see below), PM impairments have been reported in a wide range of disorders known to impede a range of cognitive functions including early dementia (Huppert, Johnson, & Nickson, 2000), acquired traumatic and non-traumatic brain injury (Brooks, Rose, Potter, Jayawardena, & Morling, 2004; Groot, Wilson, Evans, & Watson, 2002; Knight, Harnett, & Titov, 2005; Schmitter-Edgecombe & Wright, 2004; Shum, Valentine, & Cutmore, 1999), Parkinson's disease (Katai, Maruyama, Hashimoto, & Ikeda, 2003; Kliegel, Phillips, Lemke, & Kopp, 2005), depression (Rude, Hertel, Jarrold, Covich, & Hedlund, 1999), and schizophrenia (Elvevag, Maylor, & Gilbert, 2003; Kondel, 2002; Shum, Ungvari, Tang, & Leung, 2004). Accordingly the focus in a number of studies has been not on whether PM has distinct features but rather the relative contributions of memory and other deficits to PM function. Groot et al. (2002), for example, administered standard clinical tests of retrospective memory, intellectual ability, attention, executive function and working memory to a sample of people with brain injury of mixed aetiology, along with a PM test (later adapted to form the Cambridge Prospective Memory Test, CAMPROMPT, Wilson et al., 2005). The strongest predictors of PM function were memory performance (as measured by prose recall) and two measures of set switching (Wisconsin Card Sorting Test and Trails B), each accounting for between 15 and 27% of the variance in PM. Kopp and Thöne-Otto (2003) took as read that people with TBI with severe amnesia would perform poorly on PM tasks. Having excluded such patients, they found that executive task performance (as defined by performance on the Behavioural Assessment of the Dysexecutive Syndrome test battery; Wilson, Evans, Alderman, Burgess, & Emslie, 1996), rather than memory performance formed the better predictor of PM in the remaining sample.

From the preceding review, it is possible to sketch out a straightforward hierarchical model of PM function: memory problems (as assessed on standard recall tasks) will lead to PM problems because individuals will tend to forget the content of their intentions. Where memory is adequate, other forms of capacity limitation (attention, monitoring, etc.) will be the primary reasons for PM error. There is also the potential for interaction between these levels with, for example, distractibility interfering with the encoding of an intention, and relatively weak memory traces increasing the

onus on strategic monitoring. With these considerations from the PM literature in mind, we now turn to the assessment of PM function in clinical practice.

CLINICAL ASSESSMENT OF PROSPECTIVE MEMORY

Assessing component processes

For assessment purposes, the crucial processes contributing to PM performance are intention formation, storage, and timely retrieval. Intention formation is difficult to assess formally and is probably best considered in an interview – does the person have tasks they are not completing? Are PM tasks self-generated or at the request of others? Is the person motivated? Each of these areas may have quite different implications for apparent PM problems.

In terms of intention storage, there are many standard tests of memory capacity that may be informative for these purposes. The most useful tests are likely to be those including a delay between learning and recall, during which completion of other activities prevents active rehearsal (and which assess both visual and verbal memory, e.g., Rey-Osterreith Complex Figure, Corwin & Bylsma, 1993; logical memory subtest of the Wechsler Memory Scales, Wechsler, 1997). However, while evidence of forgetting over these intervals would suggest poor memory over longer intervals, adequate performance would not necessarily mean that no information would be lost over greater durations. Similarly, it is difficult to equate the encoding processes and motivational aspects of everyday intentions with those in formal tests. Finally, in everyday life, patients adopt strategies that are not available in formal testing. For these reasons, memory measures alone may make rather weak predictors of everyday PM performance.

The abilities associated with the timely retrieval of a stored intention also need consideration. It is possible that a person would periodically activate their intention but have difficulty maintaining it between retrieval and execution, for example, thinking “I must remember to take my memory stick out of the computer” but failing to maintain the goal for the relatively short time it takes the computer to shut down. To access these types of capacity, measures of sustained attention, distractibility and dual tasking (e.g., the Sustained Attention to Response Test; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997; the Test of Everyday Attention; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994) may form good indicators of performance. The merit of examining component processes in detail is that it may allow rehabilitation to be targeted at a crucial limiting stage within the PM process. However, while poor performance on tests of memory, attention,

etc. may be associated with poor PM, adequate performance would not ensure PM success if the synthesis of these different abilities was impaired. We now turn to measures that attempt to capture the entirety of the PM process, from encoding through to execution.

Clinical tests of PM

The first point to make is that the type of computerised paradigms, outlined above and pervasive in the normal experimental literature, have rarely been employed with clinical populations. Instead, PM has been assessed with “real” actions performed in the testing room. The Rivermead Behavioural Memory Test (RBMT; Wilson, Cockburn, & Baddeley, 1985) includes some PM items (remembering to deliver a message, to ask for the return of a belonging and the date of an appointment), embedded within other memory tasks. It has good ecological and excellent predictive validity, but may include too few PM tasks to generate much range in performance. Accordingly, these subtests were expanded to form the Cambridge Prospective Memory Test (CAMPROMPT; Wilson et al., 2005). This test comprises three time- and three event-based PM tasks for enactment during a 30-minute period. Despite sharing a modest correlation with the RBMT, convincing evidence that CAMPROMPT predicts everyday PM performance is to date lacking (which may of course be related to the difficulty in measuring such everyday performance). The Memory for Intentions Screening Test (MIST; Raskin, 2004) is also reported to have good validity and a comprehensive normative dataset. However it is not (to our knowledge) commercially available, and although some published studies have used the MIST (Carey et al., 2006; Woods et al., 2009), reports on the test itself have not yet been published other than in conference proceedings.

There are also studies examining the use of virtual reality in the clinical assessment of PM (Brooks et al., 2004; Knight et al., 2005). While there is clearly the potential for exciting developments here, currently the degree of “immersion” (feeling genuinely *in* the environment) is questionable. For example, due to the difficulty in mastering navigation, in current reports, the assessor frequently has to navigate around the environment, following the patient’s instructions.

Aside from the lack of demonstrated validity, the downside of examining the holistic synthesis of processes required for PM is the difficulty in specifying the locus of any problem that is detected (e.g., whether it stems from amnesia for the intention, distraction, poor initiation, or other executive aspects of the task). Addressing this, Kliegel, McDaniel, and Einstein (2000) asked participants, in addition to executing the actions, to recall their plans at different task phases. This allowed separate scores for planning, memory and execution to be formed (although this measure is not

commercially available, it can be recreated and cautiously interpreted with reference to 62 young and old healthy volunteers from the 2000 paper). Similar strategies have been applied to a range of multitasking measures, often characterised as “executive” tests, which have a strong PM component. In the modified Six Elements Test (in Wilson et al., 1996), for example, participants are asked to complete some of six tasks over 10-minute period. This requires participants to keep this goal in mind and periodically switch between tasks without any external cue. The key PM error is, despite being able to state the overall goal, to get so caught up in one task that the goal of switching is neglected. While this basic form of the test also emphasises comprehension, strategy development and rule breaking, subsequent elaborations (Burgess, Veitch, de Lacy Costello, & Shallice, 2000) have produced separate component scores. An inherent problem, however, when using a single measure, lies in the interdependence between components (e.g., failure of the memory component precludes success on the executive component).

Naturalistic PM tasks

So far we have focused on the issue of how likely test scores are to predict patients’ PM performance in everyday life, and found that evidence regarding this is often lacking. One solution is to measure everyday PM performance directly. Early studies of PM employed a variety of naturalistic tasks such as making a telephone call at a set time (Moscovitch, 1982), or sending a postcard on a particular day (Meacham & Singer, 1977). Maylor (1990) investigated the effects of spontaneous strategy use on PM by asking participants to make a telephone call once a day for five days, finding that the most effective strategy was to associate the task with a routine activity. Infra-red technology was used by Sellen, Louie, Harris, and Wilkins (1997) to record the location of participants within a workplace, who had been asked to perform the PM tasks of pressing a button on a special badge every time a particular location was passed. More recently, Fish et al. (2007) asked participants with PM problems resulting from brain injury to make telephone calls at four set times every day for three weeks (see below for details). The likely predictive advantage of the phone call approach, in using an ecologically valid task over ecologically valid time-scales against the “ongoing task” of everyday life, is of course accompanied by a number of limitations. Firstly, it may be perceived as intrusive and onerous in comparison with a one-off assessment. Secondly, it is not possible to establish the validity of reasons given for missed PM targets, or whether patients are using the assistance of others or electronic aids to facilitate their performance (although the level of performance is probably more clinically informative than how it was achieved). Finally, the day-to-day structure and time commitments of people’s lives vary considerably, so it may be difficult to establish a sound normative basis against which to

judge individual performance. Using such techniques to compare individual performance before and after an intervention, however, where many of these moderating factors are constant, has considerable appeal (see Fish et al., 2007).

Another method of assessing real-life PM functioning is to use diaries. Patients may record PM successes, strategies used, PM failures and reasons behind them. Sohlberg and Mateer (2001) advocate this method particularly for attentional problems, arguing that it adds to clients' understanding and sense of control. Because remembering to record PM lapses is itself a PM task (whether done on-the-fly or at the end of the day) which also carries a heavy retrospective memory demand, the reliability of such methods may be questionable. In terms of questionnaires, there are a number that specifically focus upon PM (see Crawford, Smith, Maylor, Della Sala, & Logie, 2003; Hannon, Adams, Harrington, Fries-Dias, & Gipson, 1995; Roche, Fleming, & Shum, 2002) as well as more general measures that include PM items (see Broadbent, Cooper, Fitzgerald, & Parkes, 1982; Burgess, Alderman, Evans, Emslie, & Wilson, 1998). The usual caveats relating to self- or informant-report (e.g., insight, recall, positive and negative halo effects, etc.) apply.

In conclusion, tasks developed for the experimental analysis of PM in healthy participant groups may have clinical use, but this has not been established. There are some merits in taking a componential approach and inferring likely barriers to successful PM functioning, although if the PM problem comes from difficulty combining component skills, this approach may be insensitive. Giving participants "actual" PM tasks to complete is potentially an informative exercise, although, depending on the specific properties of the paradigm, the reasons for PM failure may not be adequately specified.

REHABILITATION OF PROSPECTIVE MEMORY

Neuropsychological rehabilitation is concerned with the achievement of individual goals rather than improvement in specific cognitive functions, and within a holistic framework (e.g., Prigatano, 1999; Wilson, 2003), improvement in PM functioning would form only a component of a wider programme. However, given the ubiquity of PM complaints following brain injury, it is likely that change in this area would feature in many clients' goals.

Retraining approaches

Sohlberg, White, Evans, and Mateer (1992a) used repeated practice of simple PM tasks (e.g., raise your hand when the timer rings) over increasing delay periods in the rehabilitation of two patients with acquired brain injury (ABI).

Patient one, who received 58 hours training over 4.5 months, progressed from being unable to complete a PM task (even without an ongoing task) following a 60-second delay, to being able to complete a PM task following an 8-minute delay with a success rate of 40–80%. Patient two, who received 32 hours training over 3.5 months, showed an increase in such PM “span” from 4 to 8 minutes. In a further case report, Sohlberg, White, Evans, and Mateer (1992b), measured generalisation of PM training. The patient’s PM span increased as before, however, only limited generalisation to retrospective memory tasks and naturalistic PM tasks was seen. Raskin and Sohlberg (1996) investigated this training in a further two cases, contrasting PM training with a control retrospective memory drill (performing simple actions on instruction, then recalling the action over increasing delays). Improvements in PM coincided with the onset of PM training only, were of similar magnitude to those previously reported, and there was also evidence of carry-over to subsequent RM drilling phases. Fleming, Shum, Strong, and Lightbody (2005) have also reported pre–post benefits of PM training, in three cases following training directed at increasing awareness and promoting compensatory strategy use. While these studies show gains plausibly related to PM training, their interpretation is limited by a lack of adequate experimental controls. The positive results do however provide grounds for the more rigorously controlled research needed to justify patients and therapists committing so much time to these programmes.

Supporting the retrospective component of PM tasks

Impairments of retrospective memory are clearly very likely to interfere with PM. An interesting question is whether interventions that strengthen the memory trace are associated with improved execution of that intention. Camp, Foss, Stevens, and O’Hanlon (1996) used spaced retrieval (SR, an established technique for enhancing learning), in training people with Alzheimer’s disease (AD) to perform a daily PM task displayed on a wall calendar. The training involved weekly sessions in which participants were repeatedly asked how they would remember the task. If the response was correct (“by checking the calendar”), the delay before the next iteration was progressively increased. Of 23 participants, 20 were able to report what they should do within 3–7 sessions. Crucially, of those 20, 15 were also successfully *using* the calendar. Kixmiller (2002) reported a pilot study of PM training in a small group of people with AD, which combined principles of SR and errorless learning (EL). EL is typically achieved by discouraging participants from guessing if they are at all uncertain of a response (memory impaired people may be as likely to remember the error as the correct information; Baddeley & Wilson, 1994). EL is frequently combined with other memory rehabilitation techniques, such as SR, or vanishing cues (Glisky, Schacter, & Tulving,

1986), in which initially strong cues to the correct response are progressively reduced if accuracy is maintained. In Kixmiller's study, training consisted of six sessions over two weeks. One training task involved making a telephone call to report information. Initially, the five participants observed the trainer performing the task, before performing the task with verbal prompts, then independently with feedback, and so on. Enhanced performance on PM tasks relative to untrained control participants was apparent as long as seven weeks after training. Related methods have recently been investigated by Kinsella, Ong, Storey, Wallace, and Hester (2007). Sixteen patients with mild AD performed an ongoing task (reading a story aloud) and a PM task (substituting a designated word appearing infrequently in the text), under two conditions. Here, SR involved recalling an intention over delay periods increasing from 5 seconds to 3 minutes. Elaborated encoding (EE) and SR consisted of practising a similar PM task without any delay until it could be completed successfully, followed by the SR procedure. SR+EE produced the best PM performance, although performance in the SR-only condition was still superior to that seen in a separate study of comparable patients using no strategy at all. Although the study was not designed to address this matter, it is interesting to consider how the EE-derived benefit relates to the previously described findings regarding the heightened accessibility of action-related material in memory. To our knowledge there are no studies examining whether such motor imagery encoding strategies facilitate PM performance in people with neurological disorders, but this is certainly a topic that warrants investigation.

Supporting the executive component of PM tasks

As we have seen, PM has a strong conceptual overlap with so-called "executive functions". In general, approaches to the rehabilitation of executive deficits have focused on training patients to apply systematic, step-by-step approaches to problem solving (define the problem, generate potential solutions, consider pros and cons, etc.). One study (von Cramon, Matthes-von Cramon, & Mai, 1991) found that, as a group, patients receiving 25 sessions of problem-solving training over 6 weeks performed better on untrained tasks than those given a control training of similar duration. However, as mental flexibility and the capacity to abstract from the particular to the general are often compromised in such patients, generalisation of training effects is an inherent problem.

Another approach is goal management training (GMT; Levine, Robertson, & Manly, 2009; Levine et al., 2000), which uses structured group exercises highlighting common executive difficulties, encouraging participants to think about their own (and each others') experiences, and to discover which strategies (e.g., pausing activities to stop and think, breaking down

goals into sub-goals, using mental imagery, generating and consulting to-do lists) work best for them. Attempts to promote generalisation include homework exercises, recording everyday errors and successes, and identifying factors associated with better or worse performance (e.g., realistic planning, time-pressure, distractions, low mood). Levine et al. (2000) reported advantages for one-session GMT over a control motor-training condition in patients' ability to solve lifelike problems (e.g., arranging seating plans for business meetings). A recent randomised controlled trial examined the effects of 12×3-hour weekly sessions of GMT, combined with memory skills and psychosocial training, in healthy older adults. Positive results were again reported on lifelike problem-solving tasks as well as on self-rated goal management (Levine et al., 2007).

Despite efforts to foster generalisation and maintenance, the everyday benefits of such training still largely depend on strategies spontaneously "coming to mind" in everyday life. Recent studies have examined whether the frequency of such moments can be enhanced by automated cueing systems. Manly, Hawkins, Evans, Woldt, and Robertson (2002) studied the multitasking abilities of people with ABI, finding that when a tone was associated with the instruction to "think about what you are doing", and occasional tones were then presented during multitasking, performance was equivalent to that of healthy controls. Because the cues carried no information about the task ("content-free cues"), the results suggested that the intentions had been formed and retained but were inadequately monitored. Fish et al. (2007) examined the potential application of this effect to PM rehabilitation. Participants with organisational problems following ABI were given brief GMT, emphasising the strategy of periodically pausing ongoing activity to consider one's intentions. PM performance was measured by asking participants to make four phone calls at set times every day to a voicemail service, and content-free cueing was implemented by sending randomly-timed text messages to participants' mobile phones. The texts read simply "STOP" (a mnemonic from training, standing for "Stop, Think, Organise, Plan"), and were not sent near the time when a phone call was due, to prevent the receipt of a text directly triggering the action of making the call. The effect of cueing was measured by sending texts only on five randomly-selected days from the 10-day study period, and PM performance was found to be strongly superior on days with, compared to days without, cues. This illustrates that automated reminders can help to generalise benefits from strategies learned in training over a period of at least 2 weeks.

Supporting mnemonic and executive aspects of PM tasks

Memory aids are widely available, can be inexpensive, and have the potential to be highly effective in compensating for PM problems in mild to moderately

impaired patients (Kapur, Glisky, & Wilson, 2004). Although patients can find it difficult to learn, and remember, to use such aids, it is possible to implement an effective system even in profound amnesia. For example, Kime, Lamb, and Wilson (1996) taught a patient to check her diary by associating this activity with the hourly chime of a watch alarm. There is a substantial body of evidence supporting the use of electronic memory aids in PM rehabilitation, which have the clear benefit of not merely telling you what you intended to do, but also drawing your attention to this information at the appropriate time. The largest such studies are those examining the NeuroPage system (Wilson, Emslie, Quirk, & Evans, 2001; Wilson, Evans, Emslie, & Malinek, 1997), which involves sending text-based reminder messages to a simple pager worn by the user. The 143 patients in the 2001 study increased their attainment of everyday goals by an average of 30% when using the pager relative to baseline performance. There was additional evidence that for some patients, benefits persisted even once the pager was no longer in use, suggesting the pager served a training function (e.g., consolidating intentions into a routine). For others, however, performance declined significantly with the cessation of paging, indicating that long-term use would be necessary (particularly for those with greater executive impairment, see Fish, Manly, Emslie, Evans, & Wilson, 2008).

The effectiveness of NeuroPage is likely to be related to its simple method of providing specific cues for specific actions. However, it does have limitations. Firstly, sufficient time is needed for the service to input new messages onto the system, so intentions formulated for action within the next day or two cannot usually be accommodated. Secondly, there is no return-channel from the device to the administration system. Had someone spontaneously remembered to take his/her medication, for example, there is no way of cancelling the subsequent message. For many patients the benefits outweigh the drawbacks, but more recently, interest has turned to more flexible self-programmed devices. For example, Kim, Burke, Dowds, Boone, and Park (2000) found that seven out of nine patients continued to use a palmtop computer following a trial period of supervised use. There are also encouraging results from studies examining the efficacy of devices with more unusual capabilities, such as voice output, in supporting PM function (van den Broek, Downes, Johnson, Dayus, & Hilton, 2000; Yasuda et al., 2002). A major issue, however, has been the difficulty both patients and carers experience in learning to use these aids. To this end, the MemoJog system was developed to combine user-input with external administration. Two studies reported by Szymkowiak et al. (2005) reported that both elderly and brain-injured participants were able to learn to use the device, although at present, evidence of its efficacy in supporting PM performance is absent. Another major issue in this area for clinicians and researchers, if not for patients, is how quickly the consumer market moves. It is entirely possible

that considerable time and energy spent on developing appropriate systems would be wasted as new commercial products render them, or the platforms they run on, obsolete.

SUMMARY AND CONCLUSIONS

From the clinical perspective, PM seems better viewed as a type of functional goal that makes demands upon many capacities, rather than an isolated form of memory. As PM failures can occur for a variety of reasons, PM problems are likely to be experienced by a wide variety of people with neurological disorders. PM impairments are likely to compromise independence in daily living, both directly through forgetting important tasks, and indirectly through limiting capacity to strategically adapt to deficits. It can also be concluded that there is a surprising lack of evidence regarding effective clinical assessment of PM: although there is convergence from the neuropsychological and functional neuroimaging literatures regarding the importance of executive functions in the performance of PM tasks, the relationship between these measures and everyday performance remains under-investigated. The few existing clinical tests of PM also lack convincing evidence of their ability to detect, within constrained paradigms, impairments that cause problems over extended time periods and with the myriad distractions of everyday life. Further, although the experimental literature on normal PM grew out of a desire to investigate the practical applications of memory research, the majority of research in this area uses brief computerised assessments that are difficult to distinguish conceptually from vigilance and/or dual task paradigms.

An important aim of neuropsychological assessment is to inform the selection and implementation of rehabilitation strategies. For this aim to be realised, interventions that target particular functions need to be identified and evaluated. There is some evidence that, within the PM literature, the particular source of the PM impairment has been considered in formulating rehabilitation strategies (e.g., Camp et al., 1996; Fish et al., 2007; Kinsella et al., 2007). Generalisation of these benefits (e.g., whether patients/carers can learn and successfully apply these techniques to new goals) has yet to be fully examined. The most compelling evidence regarding rehabilitation of PM comes from studies of the use of automated reminders for specific activities (Wilson et al., 2001).

While there are many remaining questions, this is clearly an area in which functional rehabilitation gains are eminently possible. The challenge is to develop and refine these techniques, to help people with PM problems and their carers to use these strategies, and to improve clinical assessment to allow better targeting of interventions.

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