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Prospective Memory After Stroke: A Scoping Review

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The aim of this paper was to review the limited, but growing, literature on prospective memory (PM) following stroke using a scoping study methodology. Multiple databases were systematically searched and yielded 11 studies that were classified as observational ($n = 7$) or intervention studies ($n = 4$) and reviewed for quality. PM impairment after stroke was more commonly identified using behavioural measures compared to self-report measures. There were mixed findings regarding the extent and nature of PM impairment poststroke; however, more studies reported impairment for time-based PM, compared to both event- and activity-based PM. Studies examining rehabilitative techniques for PM resulted in mixed findings and were limited as most were case studies of poor methodological quality. Overall previous research in this area was limited as most studies were often underpowered due to small sample sizes, or used single-item measures which may not be robust enough to reliably measure PM impairment. Additionally, the methods used to measure PM were varied and many studies did not control for retrospective memory impairment, which could impact the results, as PM has both a retrospective (remembering both the action and when it needs to be completed) and prospective component (remembering to perform the action when appropriate). In conclusion, PM impairment is apparent poststroke, specifically for time-based PM. However, more research is needed to determine why PM impairment occurs, and how it can be improved.

Keywords: Brain injury, stroke, prospective memory, memory, rehabilitation, scoping review

Introduction

Stroke can be broadly defined as the sudden onset of neurological symptoms due to a disruption in blood supply to the brain, often resulting in tissue death (Australian Institue of Health and Welfare, 2013; Kolb & Whishaw, 2009). According to the World Health Organisation (2004), 15 million people worldwide suffer a stroke each year. Of these, 5 million do not survive and another 5 million are left permanently disabled. Dependent on the size and location of infarction or haemorrhage, stroke often causes impairments in a range of physical, communication, behavioural and cognitive functions, which can impact on an individual's daily functioning and ability to live independently (Caplan, 2006; Lincoln, Kneebone, & Macniven, 2012).

Individuals who have had a stroke are often left with apparent physical and language

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impairments, and rehabilitation in general aims at using restorative and/or compensatory strategies to treat these. Cognitive impairments are also common after stroke and can influence daily functioning (Caplan, 2006). These include impairment of attention and executive functioning, specifically in the areas of planning, integration of actions, judgement and the performance of complex behaviours (i.e., integrating behaviours together to cook a complex meal; Andrews, Halford, Chappell, Maujean, & Shum, 2014; Ownsworth & Shum, 2008). People with stroke and their families also commonly report impairments in general memory function post-stroke (Andrews, Halford, Shum et al., 2014; De Haan, Nys, & Van Zandvoort, 2006; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005). The previous literature has often focused on *Retrospective Memory* (RM) or the recall of previously learnt information, rather than another type termed *Prospective Memory* (PM).

Research focusing on PM is relatively new compared to other forms of memory (i.e., retrospective and working memory), only gaining interest in the experimental and clinical literature in the last 20 to 30 years (Kliegel, McDaniel, & Einstein, 2008). PM is defined as the encoding, storage and delayed retrieval of intended actions (Shum, Levin, & Chan, 2011). Furthermore, PM encapsulates an interaction of multiple cognitive processes, broken down into five stages: (a) intention formation; (b) intention retention; (c) intention initiation; (d) intention execution; and (e) evaluation of outcomes (Ellis & Milne, 1996). If any of these stages are compromised, PM failure could occur.

PM is considered to have both a retrospective and prospective component (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995). The retrospective component is remembering both the action and the time that the action needs to be performed, whereas the prospective component is remembering to perform the action when it is either the appropriate time or when an appropriate event has occurred. Thus, retrospective memory is important for PM performance because if an individual can remember that they had to do something (prospective component) but not remember what it was (retrospective component), a PM failure could still occur.

Three types of PM task have been outlined within the literature: time-, event- and activity-based. Time-based tasks include those that require an action to be completed at a certain time, or after a certain amount of time has elapsed (i.e., making a phone call at a specific pre-determined time, or turning the oven off after 30 minutes), whereas event-based tasks require an action to be completed when a specific target event occurs in the individual's environment (i.e., completing an ongoing daily task and when you see your colleague, stopping the ongoing task and relaying a message to them; Smith, 2008). Activity-based tasks are similar to event-based in that they require a cue from the environment; however, the action is to be completed after or during an activity (e.g., turning off the oven after cooking; Kvavilashvili & Ellis, 1996). Each PM type (event-, time- and activity-based) requires different levels of cognitive demand, dependent on the monitoring strategies used.

Many models of PM have been developed, including the Multiprocess Framework of PM (McDaniel & Einstein, 2000), which posits that prospective remembering can occur due to either monitoring (keeping the PM task in mind and searching the environment for PM cues while completing an ongoing task) or spontaneous retrieval (spontaneously remembering to complete a PM action, as if the intention popped into mind). The more recent Dynamic Multiprocess Framework (Scullin, McDaniel, & Shelton, 2013), on the other hand, proposes that both monitoring and spontaneous retrieval are inter-connected and work together to support PM performance. This model suggests that individuals utilise strategic monitoring when environmental PM cues are expected, in time-based PM for instance, and this requires higher levels of cognitive resources for PM task completion. However, when environmental cues are not expected, generally in event- and activity-based PM tasks, individuals disengage from monitoring and instead rely on spontaneous retrieval mechanisms to support PM performance.

Intact PM skills are required to complete many everyday activities (e.g., remembering to pick up milk on the way home from work, or remembering to take medication at a certain time), thus impairments in PM functioning can have detrimental effects on the individual and those surrounding them, as well impacting the ability to live independently (Groot, Wilson, Evans, & Watson, 2002). Individuals with stroke have previously been included in many studies assessing PM, when the focus has been on the broader acquired brain-injury (ABI) group (Fish, Manly, Emslie, Evans, & Wilson, 2008; Fish, Wilson, & Manly, 2010; Groot et al., 2002; Lemoncello, Sohlberg, Fickas, & Prideaux, 2011), as opposed to examining the stroke population specifically. PM failure has also been identified and reviewed in other clinical and neurological populations such as schizophrenia (Ordemann, Opper, & Davalos, 2014; Shum, Ungvari, Tang, & Leung, 2004), traumatic brain injury (Banville & Nolin, 2012; Canty et al., 2014; Clune-Ryberg

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et al., 2011; Shum, Fleming, & Neulinger, 2002; Shum et al., 2011), mild cognitive impairment and dementia (Costa, Caltagirone, & Carlesimo, 2011; Costa, Carlesimo, & Caltagirone, 2012; van den Berg, Kant, & Postma, 2006), and Parkinson's disease (Costa et al., 2012; Kliegel, Altgassen, Hering, & Rose, 2011; Pirogovsky, Woods, Filoteo, & Gilbert, 2012). Of the seven reviews conducted with diverse clinical populations (outlined above), four focused on only observational measures of PM, and three reviewed both observational and intervention studies. The body of literature focusing on rehabilitative techniques to help improve PM in these populations is growing.

Localisation of PM functions within the brain has been undertaken in recent times using functional neuroimaging. These interventions have included both healthy individuals and those with brain injury (Burgess, Gonen-Yaacovi, & Volle, 2011). The review identified the brain regions commonly involved in PM were the rostral prefrontal cortex (Rostral PFC), otherwise known as the frontal pole or Brodmann area 10 (BA10). This brain region is commonly activated during PM performance with co-activation of BA7 (precuneus) and BA40 (parietal cortex). Another region often associated with PM performance was the anterior cingulate cortex (ACC, BA32), however, the relation of the ACC with PM performance was not as strong as the rostral PFC or parietal regions, and therefore more research has been recommended to determine its specific role in PM functioning.

Volle, Gonen-Yaacovi, de Lacy Costello, Gilbert, and Burgess (2011) conducted a voxel-based lesion study to examine both event- and time-based PM. Lesions were the result of either brain tumour or stroke and it was found that those with lesions in the BA10 showed impairments in time-based PM, but not event-based PM. Given that the frontal and parietal areas of the brain are heavily involved in PM functioning, it would be expected that those with stroke, especially occurring in the anterior part of the brain would show a higher prevalence of PM deficits than those with damage to posterior regions.

Purpose and Objectives

Few studies have been conducted examining PM after stroke compared to studies related to RM and other cognitive functions. This is surprising, considering PM ability is often related to daily functioning and independent living, however, given the relative infancy of research on this topic, this is understandable. The primary aim of the current paper was to summarise and critically review the limited, yet growing literature on PM following stroke to determine if PM is impaired after stroke, and whether PM interventions can improve prospective remembering poststroke.

Methods

A scoping methodological framework (Levac, Colquhoun, & O'Brien, 2010) was used to identify, categorise and summarise the findings of relevant studies, as well as analyse the methodological quality of each study. The following review consisted of five steps: (1) identifying the research question; (2) identifying relevant studies; (3) study selection; (4) charting the data; and (5) collating, summarizing and reporting the results. In order to guide the structure of the review strategy, a research question was formulated, 'what does existing research literature present about PM performance after a stroke?' Following the practice of more contemporary reviews, the current review will also provide an analysis of methodological quality for each study. Given the limited amount of literature and varied methodological approaches assessing PM after stroke, a scoping review was considered more appropriate than a systematic review given that the aim was to broadly examine the literature on the topic. A scoping study methodology allows for the summary of previous findings, identification of gaps in the literature and directions for future research.

Identifying Relevant Studies

The second step involved identification of relevant studies for the current review and followed two steps. First, SCOPUS, PsycINFO and Web of Science were searched using specific terms and with the time period set from the earliest year available to *April 2015* in all databases. Multiple terms for both PM (prospective memory OR memory for future intention∗) and stroke (stroke OR cerebrovascular accident OR ischemia OR haemorrhage) were combined in the search to ensure no articles of relevance were missed. Second, the reference lists of the resulting articles were perused for relevant additional articles. As PM is a relatively new area of interest, one research dissertation was also included for review.

Study Selection

Potentially relevant studies were identified in the initial search. After the removal of duplicates, abstracts were reviewed using the following criteria. Studies were excluded if (i) PM was only briefly mentioned and not directly measured or researched in studies; (ii) the samples consisted of participants with mixed aetiologies without

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reporting the stroke group results separately; (iii) they were either review articles or conference abstracts that examined PM in individuals with stroke; and (iv) they were written in languages other than English.

Data Extraction, Review and Rating of Articles

The studies that met criteria for review were then categorized into either observational or intervention studies. The observational studies were further categorised by methodology, either self-report, behavioural or a combination of both. The studies were entered into a spreadsheet according to data including author(s), publication year, aims, research question(s), sample, measures, procedure, main findings and limitations. Finally, analysis was performed to identify recurrent themes as well as gaps in the literature. Studies were reviewed and rated by a single rater using the STROBE statement (a 22-item scale reviewing observational studies; von Elm et al., 2007), SCED scale (an 11-item scale reviewing single-case experimental designs; Tate et al., 2008) and the PEDro-P Scale (an 11-item scale reviewing clinical trials; Murray et al., 2013), dependent on the design of the study being reviewed. These scales were chosen as they are recommended for ensuring high quality of research in populations with brain impairment (Tate & Douglas, 2011). Effect sizes were either extracted from the studies or calculated, where appropriate. Effect sizes were calculated manually and checked for accuracy, using either Cohen's d, phi (φ) or partial-eta squared (η_p^2) dependent on the statistical analysis of each study.

Results

Of the 71 articles found, 11 studies met criteria for inclusion in the current review. Figure 1 outlines the flow of study selection. After studies were identified they were grouped into two broad categories: observational studies ($n = 7$) and intervention studies ($n = 4$).

Observational Studies

All seven studies in this category utilised observational methods to measure PM performance after stroke, and were further categorised into self-report and behavioural observations (some studies utilised multiple methods of assessment and are included in both self-report and behavioural subcategories). The methods of assessment varied, with measures used representing the different types of PM (e.g., event-, time- and activity-based PM) and different methods for evaluating PM (e.g., self-report, behavioural, clinical, experimental measures, virtual reality [VR]). The methodological quality of these studies was rated as reasonably high (i.e., ratings of 17–18 out of 22) according to the STROBE checklist. The assessment used and corresponding findings, effect sizes and quality analysis can be found in Table 1.

Self-report PM Performance

Five of the studies utilised self-report methods, wherein participants completed questionnaires about their everyday memory functioning. The methodological quality of these studies was rated as reasonably high (i.e., ratings of 17–18 out of 22) according to the STROBE checklist. These questionnaires resulted in a total PM score which was then compared, in some studies ($n = 4$), to scores from a control group without stroke to determine if individuals with stroke experienced more frequent PM failures. In other studies ($n = 2$), the self-reports of participants with stroke were compared with significant-others' reports.

Three of the studies that compared participants with stroke to controls reported that self-reported PM failures were not significantly different between the two groups (Barr, 2011; Brooks, Rose, Potter, Jayawardena, & Morling, 2004; Kim, Craik, Luo, & Ween, 2009). One study, however, reported differing results, concluding that individuals with stroke reported significantly more PM failures than controls (Man, Yip, Lee, Fleming & Shum, 2015). However, this finding was dependent on age, with older individuals with stroke, reporting more frequent PM failure than the younger control and older control groups. Specifically, the older stroke group reported significantly more frequent PM failure for Basic Activities of Daily Living (BADL) than the younger control group only and more frequent PM failure for Instrumental Activities of Daily Living (IADL) than both younger and older controls.

Two studies compared self-reported PM failure of individuals with stroke to a significant-others' report (Barr, 2011; Man, Yip et al., 2015). Both found no significant differences between the report of significant-others and participants with stroke for total PM. However, when one of the studies (Man, Yip et al., 2015) examined the BADL and IADL subscales separately for both old- and young-stroke groups combined, a significant difference was found between scores for IADL PM, with significant-others reporting significantly more frequent PM failures for IADL (i.e., more

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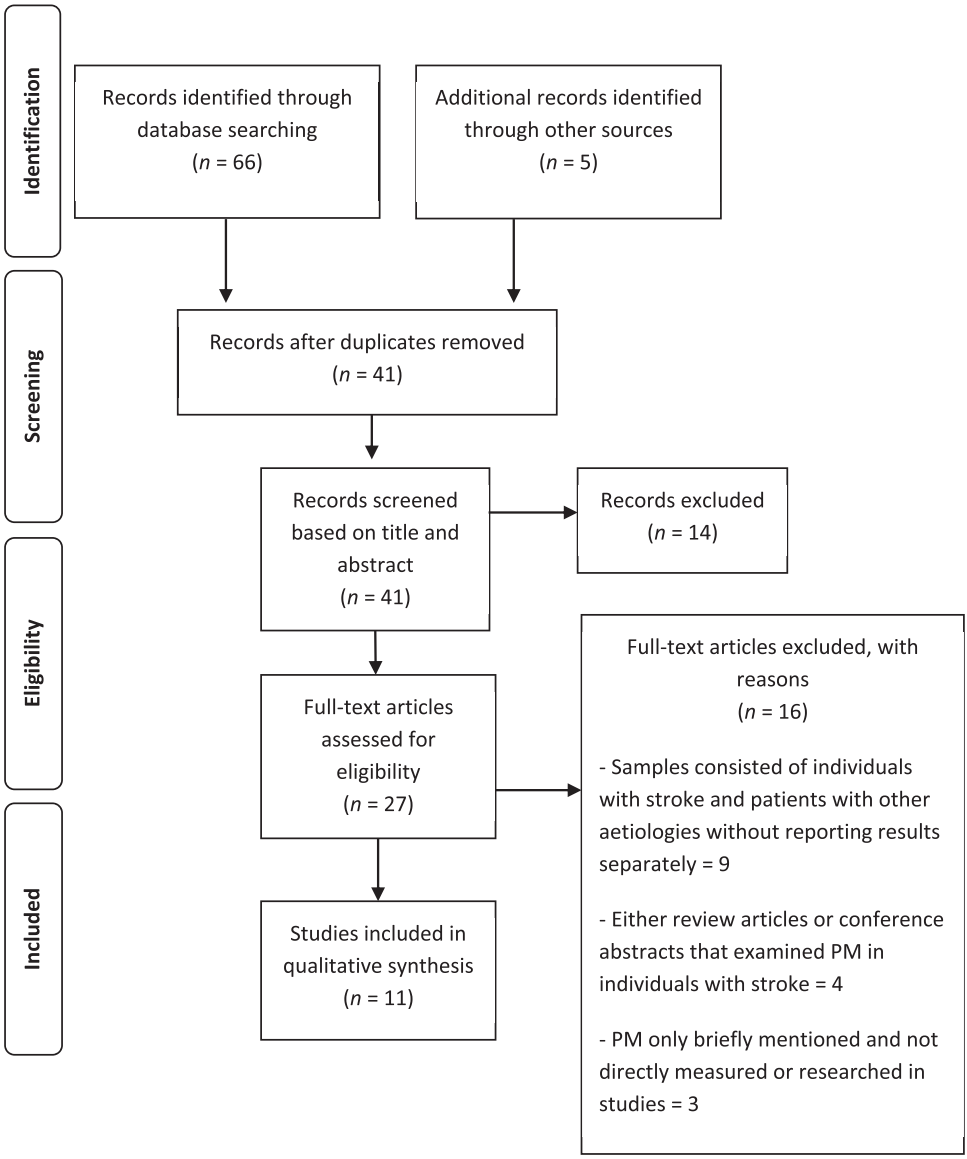


FIGURE 1

PRISMA flow-chart of study selection for current review.

non-routine) activities than the individuals with stroke.

Behavioural Measurement of PM

Performance

Six of the studies utilised behavioural measures of PM. These studies either used experimental paradigms ($n = 3$), VR platforms ($n = 1$), standardised clinical measures ($n = 3$) or naturalistic measures of PM ($n = 3$) to examine impairments in PM poststroke, often comparing the performance of individuals with stroke to non-stroke control groups. The methodological quality of these studies was rated as reasonably high (i.e., ratings of 17–18 out of 22) according to the STROBE

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TABLE 1
Observational Studies

Study (year)	Sample	Age in years M (SD)	Stroke type/location	Time since onset	Measure	Findings and effect sizes	STROBE quality analysis
Brooks et al. (2004)	42 Stroke (inpatient; 23 m, 19 f) (17 excluded due to RM deficit, thus analyses based on 25 individuals with stroke)	71.8 (9.40)	21 RH, 20 LH, 1 BL	1 week–2 months	Self-report questionnaire: examining real-life PM tasks. Questions included "How often do you forget to take medication?" Each item was answered on a seven-point Likert scale from Never to Always.	Self-report PM: No significant difference between stroke and matched controls ($p = .57$, $d = .17$).	17/22
	25 age-matched controls	68.44 (7.11)			Virtual Reality: Moving House Task. EBPM, TBPM and ABPM tasks, were embedded in an ongoing activity, wherein participants helped someone move house.	TBPM: no significant difference between stroke and controls ($p = .05$, $d = -.57$; trend towards significance). EBPM: Controls performed significantly better than stroke ($p = .004$, $d = -.88$) ABPM: Controls performed significantly better than stroke ($p < .001$, $d = -1.06$).	
					Naturalistic Task: Remembering a Belonging task (EBPM). From the RBMT (Wilson, Cockburn, & Baddeley, 1991): participants are instructed to give a personal item (i.e., a watch) to the experimenter and told to remember to ask for the item back at the end of the study, and to recall, where the item was hidden.	EBPM: No significant difference between stroke and controls ($p = 1.00$, $\varphi = .004$).	

TABLE 1
Continued

Study (year)	Sample	Age in years M (SD)	Stroke type/location	Time since onset	Measure	Findings and effect sizes	STROBE quality analysis
					Naturalistic Task: Written explanation task (EBPM). Participants instructed to ask the experimenter for a written explanation of the study when they finished the VR task.	EBPM: Control group performed significantly better than stroke group ($p = .03$, $\varphi = .31$).	
Kim et al. (2009)	12 stroke (outpatient)	69.33 (7.02)	5 RH, 5 LH, 2 BL	4.8 months–108 months	Self-report questionnaire: PRMQ (G. Smith et al., 2000). 16-item self-report questionnaire (eight items for each domain, PM and RM). Participants rate how often each type of memory failure occurs in everyday life on a five-point Likert scale ranging from Never to Very often.	Total score: No significant difference for both PM and RM between controls and stroke (p = ns, $d = -.47$).	18/22
	12 age- and education-matched controls	69.08 (4.94)			Clinical Measure: Virtual Week (EBPM - regular and irregular tasks; and TBPM).	EBPM Regular Correct-responses: No significant difference between stroke and control ($p = .44$, $d = -.35$) EBPM Irregular-Correct responses: No significant difference between stroke and control ($p = .076$, $d = -.78$) TBPM Correct-responses: Stroke significantly poorer than controls ($p = .007$, $d = -1.28$). EBPM Regular Miss-responses: No significant difference between stroke and control $p = .099$, $d = .70$) EBPM Irregular Miss-responses: No significant difference between stroke and control ($p = .183$, $d = .57$) TBPM Miss-responses: Stroke had significantly more misses than controls ($p = .001$, $d = 1.87$).	

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TABLE 1
Continued

Study (year)	Sample	Age in years M (SD)	Stroke type/location	Time since onset	Measure	Findings and effect sizes	STROBE quality analysis
					Experimental Measure: Memory for Intentions (RM and Total PM). Assesses both retrospective and prospective components of PM through a process of associating real-life intentions to pictures and having participants recall the correct cues and intentions in a later recall condition.	RM: No significant differences between stroke and controls PM: Stroke had significantly poorer performance on the prospective component ($p < .001$, $\eta_p^2 = .491$), even after controlling for their lower performance on the paired-associate task ($p = .004$, $\eta_p^2 = .332$).	
					Naturalistic Task: Remembering a Belonging task (EBPM).	EBPM: No significant difference found between stroke and controls ($p = .67$, $\varphi = .19$).	
Cheng et al. (2010)	18 Stroke (inpatient; 12 m, 6 f)	65 (Range = 45–85)	18 Thalamic stroke 8 RH, 8 LH, 2 BL	2 weeks–2 months	Experimental Task: TBPM. Participants instructed to tap desk at 5 minute intervals from the starting time (PM task) while completing an ongoing task.	TBPM: Stroke performed significantly poorer than controls ($p < .01$, $d = -2.25$).	17/22
	18 (11 m, 7 f) age- and education-matched controls		14 infarct, 4 haemorrhage		Experimental Task: EBPM. Participants instructed to tap desk when they saw an animal word during an ongoing task. Also requested to tell the experiment their phone number when the ongoing task was completed.	EBPM: No significant difference between stroke and controls ($p > .05$, $d = -.46$).	

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TABLE 1
Continued

Study (year)	Sample	Age in years M (SD)	Stroke type/location	Time since onset	Measure	Findings and effect sizes	STROBE quality analysis
Barr (2011)	22 Stroke (community-dwelling; 9 f, 13 m)	65 (15.12)	6 haemorrhage, 7 cerebral infarction, 9 unspecified as haemorrhage or infarction	6 months–72 months	Self-report questionnaire: PRMQ.	Total PM: No significant difference between control and stroke ($p = .16$, $d = -.54$). Total PM: No significant differences between stroke and significant-other ($p = .55$, $d = .10$).	17/22
	20 significant-others				Clinical Measure: CAMPROMPT (Wilson, 2005; EBPM and TBPM). Participants complete distractor puzzles as the ongoing task and are required to complete three EBPM tasks and three TBPM tasks either throughout or after the session has ended.	Total PM: Stroke significantly more PM failure than controls ($p < .05$, $\eta p^2 = .12$).	
	22 controls (18 f, 4 m)	53.77 (13.67)				EBPM: No Significant difference between stroke and control ($p > .05$, $d = -1.53$) TBPM: No Significant difference between stroke and control ($p > .05$, $d = -1.45$). Higher levels of depression related to significantly poorer TBPM performance.	

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TABLE 1
Continued

Study (year)	Sample	Age in years M (SD)	Stroke type/location	Time since onset	Measure	Findings and effect sizes	STROBE quality analysis
Kant et al. (2014)	39 Stroke (community-dwelling; 69% male)	58.2 (14.2)	31% haemorrhage	$M = 17$ months ($SD = 8.3$)	Experimental measure: dual-task paradigm (EBPM and TBPM). Participants performed an ongoing task pen and paper task (Bourdon-Wiersma task: marking arrays of four dots among arrays of 3–5 dots) and were required to complete both EBPM (saying 'regel' – the Dutch word for line, when whenever the last configuration in a line contained three dots) and TBPM (insert a coin in a designated contained after each minute had passed).	EBPM: No significant differences between stroke and control ($p = .075$, $d = -.50$). TBPM: Stroke significantly poorer than controls ($p = .002$, $d = -.88$).	17/22
	53 age-, education- and IQ-matched controls (38% male)	51.7 (17.4)			Naturalistic Task: Remembering a Belonging task (EBPM).	EBPM: No significant difference found between stroke and controls ($p = .879$, $d = -.13$)	
					Naturalistic Task: Phone call (TBPM). Participants had to make a phone call after 30 minutes.	TBPM: No significant difference between stroke and controls ($p = .452$, $d = -.23$).	
Man, Chan & Yip (2015)	40 Stroke (outpatient; 25 m, 15 f) 44 (8 m, 36 f) controls	50.13 (10.30) 41.86 (9.32)	19 ischemia 21 haemorrhage		Clinical Measure: CAMPROMPT – HKCV (EBPM and TBPM). Hong Kong Chinese Version of the CAMPROMPT.	EBPM: Stroke significantly poorer than controls ($p = .001$, $d = -1.34$). TBPM: Stroke significantly poorer than control ($p = .001$, $d = -1.88$).	17/22

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TABLE 1
Continued

Study (year)	Sample	Age in years M (SD)	Stroke type/location	Time since onset	Measure	Findings and effect sizes	STROBE quality analysis
Man, Yip et al. (2015)	29 younger stroke group (community-dwelling; 14 m, 12 f) 46 older stroke group (community-dwelling; 54 m, 22 f) 46 younger controls (15 m, 31 f) 66 older controls (46 m, 20 f) 65 significant-others	49.29 (5.11) 67.07 (6.92) 45.48 (3.37) 68.68 (5.24)		1 month–more than 24 months	Self-report questionnaire: BAPM (Man et al., 2011). A shortened version of the CAPM. Measures PM failure, wherein PM is broken into prospective remembering for BADL and IADL, with eight items for each, rated on a five-point Likert scale.	PM Total Whole-group: No significant difference between stroke and significant-others ratings ($p = .06$, $d = -.33$; trend towards significance). PM Total: When divided into age groups of young and old, the older stroke group reported significantly more frequent PM failure than the young-control group ($p < .001$, $d = .83$) and the older control ($p = .01$, $d = .60$), but not the younger stroke group ($p =$ ns, $d = .37$). IADL PM Whole-group: Significant-others reported significantly more PM failures than stroke ($p = .01$, $d = -.46$). BADL PM Whole-group: No significant difference between stroke and significant-other ($p = .43$, $d = -.46$). IADL PM Young: No significant difference between stroke and significant-others ($p = .38$, $d = -.59$) BADL PM Young: No significant difference between stroke and significant-others ($p = .55$, $d = -.42$). IADL PM Old: No significant difference between stroke and significant-others ($p = .05$, $d = .53$; trend towards significance) IADL PM Old: Older stroke significantly poorer than young-control ($p = .029$, $d = .89$), old-control ($p < .001$, $d = .42$) and young-stroke ($p < .001$, $d = .25$). BADL PM Old: No significant difference between stroke and significant-others ($p = .39$, $d = .16$). BADL PM Old: Older-stroke significantly poorer than younger-control, ($p < .001$, $d = .72$). No significant difference between old stroke and old control ($p =$ ns, $d = .36$) or old-stroke and young-stroke ($p =$ ns, $d = .23$).	17/22

m = male; f = female; LH = left hemisphere; RH = right hemisphere; BL = bilateral damage; PRMQ = Prospective and Retrospective Memory Questionnaire; CAMPROMPT = Cambridge Prospective Memory Test; CAMPROMPT – HKCV = Cambridge Prospective Memory Test – Hong Kong Chinese Version; RPA-ProMem = Royal Prince Alfred Prospective Memory Test; BAPM = Brief Assessment of Prospective Memory. TBPM = Time-based PM; EBPM = event-based PM; ABPM = activity-based PM. Effect sizes (Hu, 2010) measured using Cohen's *d* are interpreted using the following criteria: .2; medium = .5; or large = .8. Cohen (1988) suggested effect sizes be interpreted in term of small (.1), medium (.3) and large (.5) when calculated using phi (φ), and small (.01), medium (.09) and large (.25) when calculated using partial-eta squared (ηp^2).

checklist. The behavioural measures targeted different types of PM including time-, event- or activity-based PM, or a combination reflected in a total PM score (e.g., Kim et al., 2009).

While one study measured activity-based PM (Brooks et al., 2004) finding that individuals with stroke performed significantly worse than controls, the majority focused on event- and time-based PM performance. The studies examining event-based PM resulted in mixed findings, with two of the studies reporting significantly poorer event-based PM performance for participants with stroke compared to controls (Brooks et al., 2004; Man, Chan & Yip, 2015), and the other four reporting no significant differences between the individuals with stroke and controls (Barr, 2011; Cheng, Tian, Hu, Wang, & Wang, 2010; Kant et al., 2014; Kim et al., 2009). Results seemed to be dependent on the type of measure used. Significant findings were found when utilising a VR paradigm (Brooks et al., 2004), a naturalistic task (remembering to ask for a written explanation at the end; Brooks et al., 2004) and the Cambridge Prospective Memory Task – Hong Kong Chinese Version (CAMPROMPT – HKCV; Man, Chan & Yip, 2015). No significant differences were found when using another naturalistic task (remembering to ask for a belonging back; Brooks et al., 2004; Kant et al., 2014; Kim et al., 2009), the Virtual Week (Kim et al., 2009), the original version of the CAMPROMPT (Barr, 2011) or experimental/laboratory measures (Cheng et al., 2010; Kant et al., 2014).

Three studies examining time-based PM reported significantly poorer performance for individuals with stroke compared to controls (Cheng et al., 2010; Kim et al., 2009; Man, Chan & Yip, 2015). Another two studies reported no significant differences between the groups' PM performances (Barr, 2011; Brooks et al., 2004), and one reported mixed findings dependent on the measure used (Kant et al., 2014). As with the event-based PM, findings were dependent on the type of measure utilised. Significant differences were found when using the CAMPROMPT – HKCV (Man, Chan & Yip, 2015), Virtual Week (Kim et al., 2009) and experimental/laboratory measures PM (Cheng et al., 2010; Kant et al., 2014), however, no significant differences were found when utilising a VR platform (Brooks et al., 2004), the original version of the CAMPROMPT (Barr, 2011) and a naturalistic task (making a phone call after 30 minutes; Kant et al., 2014).

Intervention Studies

Four studies aimed to assess the efficacy of treatment on PM impairments in individuals with stroke. Details of the intervention studies are summarised in Table 2. A combination of external and internal compensatory strategy training was used by Miller and Radford (2014) to evaluate the impact of a group-based memory intervention on PM performance. While significant-others reported a significant improvement in PM after training using self-report methods, no such differences were reported by individuals with stroke. This was the only group studied, examining an intervention on PM; however, the methodical quality rated by the PEDro-P Scale (Murray et al., 2013) was moderate (5/11). The study was limited by the high drop-out rate, and the use of pseudo-random allocation rather than true random allocation of participants to intervention groups. It was also not clear whether both participants and assessors were blind to the condition that participants had been placed in.

Three studies used a single-case design. Sohlberg, White, Evans and Mateer (1992b) examined Prospective Memory Training (PMT; Sohlberg, White, Evans, & Mateer, 1992a) as a remedial technique for PM impairment in one participant poststroke. It was found that the participant's PM ability gradually increased over the course of the intervention. The methodological quality rated by the SCED scale (Tate et al., 2008) was moderate (6/11). Using external compensatory rehabilitation strategies, van den Broek, Downs, Johnson, Dayus, and Hilton (2000) evaluated an electronic memory aid for PM performance poststroke. It was concluded that a Voice organiser (VO) device could improve PM ability after stroke; however, results were highly dependent on individual differences in the two participants. The methodological quality rated by the SCED scale was moderate (7/11). Kim, Burke, Dowds, Robinson Boone, and Park (2000) conducted a questionnaire which assessed participants' satisfaction with a palmtop computer which aimed at improving PM performance. One single stroke participant reported that the palmtop computer was not beneficial, primarily due to a lack of interest and prior technological experience; however, the methodology of this study was rated as poor (3/11).

Other Features of the Studies ($n = 11$)

Other features which were addressed in the previous studies included time poststroke, the study setting, depression, the prevalence and neuropathology of PM impairment poststroke and the effect sizes. The studies included in the current review assessed the PM abilities of individuals with stroke from one week poststroke to 47 years poststroke; however, only one study (Miller & Radford, 2014) explored the relationship of time poststroke to PM

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TABLE 2
Intervention Studies

Study (year)	Stroke Sample	Age in years M (SD)	Stroke type	Time since stroke	Design	Intervention	PM measure	Findings	Quality Analysis
Sohlberg et al. (1992b)	1 m stroke; outpatient	51	SAH	15 months	Single case ABAB	Prospective memory training (PMT). Therapist systematically extends the length of time between PM tasks, aiming to increase the length of time between intention formation and intention execution.	Time between forming an intention and correctly remembering to execute the intention.	PM ability increased from 5 minutes at baseline to 12 minutes at study completion, with a gradual increase throughout the study.	6/11[a]
van den Broek et al. (2000)	1 f, 1 m stroke; outpatient	56, 48	SAH	19–47 months	Single case ABA	Electronic memory aid: Voice Organiser (VO) stores voice messages, along with the day and time when the reminder is needed. When the reminder is due, the device sounds an alarm. The message can then be played by pressing a button on the device.	Experimental measure: Message-passing task (EBPM). Relatives needed to convey four messages (experimenter created) to participants before 9:00 am on pseudo-random days. Participant required to report the message back after 6:00 pm (9 hour delay). E.g., 'Collect the coat from the dry cleaners.'	Both participants benefited from the introduction of the VO on the message-passing task, as remembering was higher in the device condition than both no device conditions.	7/11[a]
							Experimental Measure: Domestic task (TBPM). At weekly session, experimenter gave participants four tasks to recall to their relatives on pseudo-random days and predetermined times. E.g., 'Hoover the lounge at 10:00 am on Tuesday.'	Only one participant had improved performance in the domestic task, with the other showing deteriorated performance with the device (which may have been due to their reliance on a written memory aid which might have been interrupted by VO use).	
Kim et al. (2000)	1 f stroke; outpatient	48	BL thalamic stroke due to venous sinus thrombosis	10 months	Self-report follow-up	Electronic memory aid – Palmtop computer (PSION). Palmtop computer programmed with schedule-management software, used as an external memory aid.	Self-report: phone survey. Questions discussed if the device was useful, how often they used it, whether they still use the device or other memory aids, their prior computer experience, and whether they would recommend the device to other brain injured patients.	The participant did not consider the device to be useful, did not purchase the device, and yet would recommend the use of the device to other brain-injured individuals. She decided not to use the device because it was not similar to her personal computer and thought that training would take too long.	3/11[a]

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TABLE 2
Continued

Study (year)	Stroke Sample	Age in years M (SD)	Stroke type	Time since stroke	Design	Intervention	PM measure	Findings	Quality Analysis
Miller and Radford (2014)	21 m, 19 f stroke (outpatient; only 27 individuals completed training)	53.8 (12.3)	24 infarction 16 haemorrhage 12 temporal lobe 18 frontal lobe 23 LH, 10 RH, 7 BL		Wait-list crossover design	Group memory training program. Two hour group-based sessions (8–12 participants per session) conducted weekly, for six weeks. Each session involved education about memory and training in the use of external and internal compensatory strategies.	Clinical Measure: RPA-ProMem (Radford, Lah, Say, & Miller, 2011; EBPM and TBPM). PM measured over both long- and short-term retention intervals.	Baseline Total PM: Individuals with stroke performed lower than the normative means of the RPA-ProMem. No significant difference ($p = .06$) in PM performance after intervention. However, there was a trend towards significance, and the moderate effect size ($d = -.42$) suggests that the small sample size might have been a limiting factor. After controlling for baseline memory performance, the amount of improvement post-training was associated with time since onset, with a longer time since onset associated with less PM improvement ($r = -.47$, $p = .019$). Those who completed the training closer to their onset of stroke benefited more.	5/11[b]
	19 significant-others						Self-report measure: CAPM Part A (Roche et al., 2002). Subjective questionnaire pertaining to everyday PM performance, wherein PM is broken into prospective remembering for BADL and IADL, rated on a five-point Likert scale.	Baseline: Both individuals with stroke and their significant-others reported PM ability to be in normal range (according to normative test data; Shum & Fleming, 2014; $d = -.31$). Significant-others reported a significant improvement in PM after training ($d = .94$). Stroke participants reported no significant difference between pre and post-training.	

m = male; f = female; SAH = subarachnoid haemorrhage; LH = left hemisphere; RH = right hemisphere; BL = bilateral damage; [a] = SCED; [b] = PEDro-P Scale.

performance, finding that individuals who had a longer time since stroke onset showed less improvement after an intervention when PM was measured using the RPA-ProMem. The study settings also varied with two studies recruiting inpatients, six studies recruiting outpatients and three studies recruiting community-dwelling individuals with stroke. Level of depression was only investigated by Barr (2011), who found that higher levels of depression were related to significantly poorer performance on time-based tasks.

Little is known about the prevalence of PM impairment poststroke. One study (Kant et al., 2014) reported the prevalence of PM failure in the stroke group to be 41%. This percentage suggests that PM failure is a problem for a substantial proportion of people with stroke. No other studies reported data relating the prevalence of PM impairment in the stroke samples.

The effect sizes varied from small to large, dependent on the type of study. Majority of the effect sizes calculated for self-reported PM were small (63.2%, $n = 12$; medium = 26.3%, $n = 5$; and large = 10.5%, $n = 2$). However, when calculated for observational measures of PM, the majority were large (50%, $n = 12$; medium = 25%, $n = 6$; and small = 25%, $n = 6$). Only two effect sizes were calculated for the intervention studies because the studies did not report enough information for them to be calculated. The effect sizes that were calculated were small and large.

Kant et al. (2014) also explored the impact of lesion location on PM performance poststroke. It was found that lesions in the right superior temporal gyrus (STG) were more prevalent in individuals with selective PM failure (time-based or event-based, not both) in comparison to those without PM impairment. These findings, however, warrant further investigation as the methods used in the study to explore anatomical correlates were somewhat coarse. One observational study previously mentioned examined the impact of thalamic lesions on PM impairment poststroke (Cheng et al., 2010). Cheng et al. (2010) concluded that individuals with thalamic lesions due to stroke had impaired time-based PM ($p < .01$) but not event-based PM when compared to non-stroke controls, with no differences being found between right and left thalamic lesions. Additionally, it was found that the volume of thalamic lesion was negatively correlated with time-based PM performance ($r = -.86$, $p = .000$). Other than Kant et al. (2014) and Cheng et al. (2010), no other observational studies examined the patterns of neuropathology associated with PM impairment following stroke.

Discussion

It is apparent that the literature is limited when examining the impact stroke has on PM functioning. The investigation of PM abilities in stroke populations is a relatively new area of memory research, and more research is needed within this growing area. The literature reviewed here, while narrow, suggests that stroke has a significant impact on PM performance, specifically time-based PM, in that when measured using behavioural measures of PM, individuals with stroke often show impairments in their PM abilities compared to control groups. The majority of the effect sizes are large, suggesting a significant impairment after stroke; however, it must be noted that results are mixed and variables which impact on PM and limitations of the reviewed studies need to be considered when interpreting the results.

While the rehabilitative research is limited, and three out of the four studies used single-case experimental designs, it provides avenues and directions for future PM rehabilitation. PMT training (Sohlberg, 1992a), while offering promising results for the improvement of PM poststroke, is intensive and requires a lot of time commitment from both the client and therapist. Additionally, single-case experimental designs limit the generalisation of results to wider populations and can have carry-over and order effects. While Miller and Radford's (2014) group intervention study reported a trend towards significance, no significant difference was found in PM performance after the intervention. This trend towards significance accompanied by the moderate effect size suggests that the small sample size might have been a limiting factor. The studies examining technological devices to better PM performance (Kim et al., 2000; van den Broek et al., 2000), found improvements to be highly dependent on the individuals' preference and experience with technology. Limitations aside, these studies offer broad direction for future research. More rehabilitative techniques and interventions need to be developed, conducted and assessed with larger stroke samples, wherein PM is assessed using reliable, standardised measures to provide more evidence for rehabilitative interventions and tools.

There are a number of possible reasons for the varied findings regarding whether PM impairment is a problem after stroke. First, different types of PM measures have different strengths and limitations. While many studies used reliable and validated self-report measurements, such as the Prospective and Retrospective Memory Questionnaire (PRMQ; G. Smith, Del Sala, Logie, & Maylor, 2000), Comprehensive Assessment of Prospective Memory (CAPM; Roche, Fleming, &

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Shum, 2002) and the Brief Assessment of Prospective Memory (BAPM; Man, Fleming, Hohaus, & Shum, 2011), results from self-report measures which have not been evaluated for reliability or validity may result in unreliable findings (i.e., the 10-item questionnaire used by Brooks et al., 2004). Additionally, when using validated measures it is helpful if the results for each subscale are reported separately. For example, Barr (2011), using the PRMQ, summed the retrospective and prospective components to form a measure of everyday memory function total. Thus, when interpreting the results in relation to PM function, there is no delineation of PM from RM failure limiting conclusions about self-reported PM poststroke.

One possible reason as to why PM impairment was not found in individuals with stroke when using self-report methods is the sample size. While Barr (2011), Brooks et al. (2004) and Kim et al. (2009) found no such impairment, Man, Yip et al. (2015) did. These contrasting findings to previous research may have been due to the larger sample size ($n = 75$) and hence greater power, as compared to the other studies with smaller sample sizes (range = 12–25). Furthermore, while self-report methods are easy to administer in both clinical and experimental settings, impairments in self-awareness following neurological injury can impact the reliability of the results (Roche et al., 2002). So while majority of the studies found no significant differences between the self-rating of PM for participants with stroke and controls (Barr, 2011; Brooks et al., 2004; Kim et al., 2009), this does not necessarily mean that PM is not impaired poststroke. In fact, this method of assessment may be measuring self-awareness of PM failure rather than PM failure itself. As suggested by Barr (2011), Brooks et al. (2004), Kim et al. (2009) and Man, Yip et al. (2015), self-reports should be interpreted with caution as impairments in self-awareness are highly probable and participants with stroke may be reporting their pre rather than poststroke abilities.

As PM performance is reliant on a multitude of cognitive functions, it is important to examine and control for any cognitive impairments participants may have to ensure a true measure of PM performance is attained. One such function is RM, where RM performance has been found to be a significant predictor of experimental event-based PM (Kant et al., 2014; Kinch & McDonald, 2001). When comparing PM to other cognitive functions, Kant et al. (2014) found that PM failure occurred in 41% of individuals with stroke and was significantly higher than the prevalence of impairments in processing speed, and attention/executive functioning, but not significantly different from the frequencies of RM failure. A significant limitation of this study, as well as previous studies (Man, Chan & Yip, 2015) was not screening for RM impairment before running the experiment. Prospective remembering has both a prospective and retrospective component, and if a person cannot remember what the task is, he or she cannot be expected to perform it.

Another cognitive function which has been said to impact on PM performance is monitoring ability, specifically time-based. While the laboratory measures of PM reviewed consistently found significant deficits in time-based PM, it is concluded that this finding may not be due to monitoring abilities, as the difference in the amount of clock checks, between participants with stroke and controls was not significant (Cheng et al., 2010; Kant et al., 2014; Kim et al., 2009). If monitoring ability is not significantly impaired after stroke, further research is needed to examine why individuals with stroke have specific difficulties with time-based tasks. It may simply be due to the belief that time-based PM tasks are believed to require more cognitive resources for completion than event-based tasks, as performance relies on higher levels of initiation, monitoring and executive control (McDaniel & Einstein, 2007), and often these cognitive functions are left impaired after stroke.

Many additional factors pertaining to the participants themselves, could have impacted PM performance and were not necessarily controlled for or addressed by all the studies. There was considerable heterogeneity in the stroke populations studied, in terms of time since stroke onset, stroke severity and lesion location, and these factors are likely to impact on the presence and extent of PM impairment.

The studies included in the current review assessed the PM abilities of individuals with stroke from one week poststroke to 47 years poststroke. The large variation in time from one week to many decades poststroke could have an impact on PM abilities in multiple ways. Neurological function starts to recover within the first few days after stroke, with rapid gains realised in the first three months, followed by slower gains in the following six to twelve months, with some individuals still showing gains one to two years poststroke (Hankey, 2007). Thus, time since onset of stroke can greatly impact on the level of impairment, especially when recovery patterns differ for each individual patient (Langhorne, Bernhardt, & Kwakkel, 2011). Not just in terms of natural recovery, but those in different stages of rehabilitation could be expected to show different results, as found by Miller and Radford (2014), who reported greater PM improvement for those who accessed rehabilitation closer to the onset of stroke. This finding is

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promising for researchers and clinicians working with people who have had a stroke and PM.

Study settings and an individual's opportunity to experience PM failure can also play a role in how individuals with stroke report PM impairment, particularly on self-report measures. This is because level of independence and different testing environments may see significant-others or nurses/carer completing daily PM tasks for individuals with stroke. This could impact how participants and their significant-others self-report PM failures which focus on BADL and IADL PM.

Additionally, factors such as damage location and level of depression were not always addressed. While most studies outline the type of stroke and lateralisation, only Kim et al. (2009) reported which lobes were damaged, providing a clear outline of the location of damage to the brain. This is important as individuals with damage to brain regions not related to PM function would not be expected to show PM impairment. Level of depression was only investigated by Barr (2011), who found that higher levels of depression were related to significantly poorer performance on time-based tasks. As depression has been found to negatively impact on PM performance, it is also imperative to control for, especially as depression is quite common poststroke (Hoffmann, Ownsworth, Eames, & Shum, 2015).

The methodological quality of the studies ranged from high to low, dependent on the study and measure used. Observational studies, rated using the STROBE statement resulted in a narrow range of scores. While this may suggest that the methodological quality of the observational studies was high, it is not necessarily the case. Rather, the narrow range of scores outlines the limitations of the STROBE as a quality analysis tool. This is most likely because it was primarily designed to be used more as a reporting guideline, rather than an evaluation tool (von Elm et al., 2007). The main reasons why studies were rated moderate to low in quality when using the SCED scale was because observer bias, independence of assessors, statistical analysis and evidence for generalisation were not addressed. These studies could be improved by addressing these simple factors. Additionally, the group intervention study received a moderate quality rating when assessed with the PEDro-P scale because pseudo-random allocation was used rather than random allocation. It was also not mentioned whether allocation was concealed; whether blinding of participants, therapists and assessors took place; and there was a high level of drop out meaning that the measures of at least one key outcome were not obtained from more than 85% of the subjects initially allocated to groups. Study quality could be improved by addressing these factors and improving the rate of drop out.

Limitations of the Study

This review would have been strengthened by using two raters instead of one and incorporating inter-rater reliability tests into the procedure. The evaluation of studies was also limited by the tools chosen to rate methodology. The STROBE statement was used for the purposes of evaluating methodological quality; however, it generated a narrow range of scores. Thus, it is recommended that future reviews utilise a tool which has been designed to rate the methodological quality of observational studies such as a Risk of Bias measure.

Recommendations for Future Research

Overall, future research should focus on using reliable and valid PM measures, control for or stratify individuals of stroke into groups based on factors which have previously been found to impact PM performance (i.e., RM performance, monitoring ability, time-since stroke onset, location of testing, location of damage to the brain, level of depression and level of self-awareness) and develop and evaluate rehabilitative techniques to help improve PM performance poststroke. Future research could be conducted to examine the utility of other external (e.g., smart phone applications) and internal compensatory rehabilitative strategies. It is suggested that training programs take into consideration the personal preferences of individuals with stroke, specifically in relation to any technology that is introduced.

Implementation intentions (a simple goal-setting strategy) have been used previously to improve PM performance in non-stroke adult populations (Chen et al., 2015), as well as other clinical populations like early psychosis (Khoyratty et al., 2015). It is suggested that future rehabilitation research can consider utilising this simple, yet effective internal strategy to assess the effect on PM functioning poststroke.

Overall, PM impairment exists after stroke, particularly when examined using behavioural measures. As PM is linked with abilities in everyday functioning, it is imperative that future research is conducted to help examine both the extent and nature of PM impairment after stroke.

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Conflict of Interest

None.

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