The Impact of Using Implementation Intentions as Task Instructions on Prospective Memory Performance After Stroke

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Abstract

Prospective Memory (PM), the ability to remember to carry out intentions in the future, is often impaired after stroke. Little is known about rehabilitation of PM post-stroke with literature limited by small sample sizes and reliance on self-reported memory performance. Implementation intentions may make prospective remembering more automatic and follow a simple if-then structure (if X occurs, then I will do Y), focusing on the cue rather than the task. We aimed to investigate the effect of implementation intentions on PM post-stroke. Twenty-eight individuals with stroke and 27 controls were randomly allocated to a standard instruction or implementation intention condition and completed an assessment battery over two sessions. Implementation intention instructions were provided for PM tasks on the Delayed Message Task, Lexical Decision Prospective Memory Task (LDPMT), and the Virtual Reality Prospective Memory Shopping Task. The implementation intention groups performed better on all PM tasks compared to the standard instruction group, but no results reached statistical significance, likely due to the small sample size. In addition, the implementation intentions group monitored the time significantly more on the LDPMT than those in the standard instruction group.

Keywords: Prospective Memory, Stroke, Implementation Intentions, Brain Injury, Rehabilitation

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Introduction

Prospective Memory (PM) is the encoding, retention, and delayed retrieval of intended actions, (i.e., remembering to so something in the future; Shum, Levin, & Chan, 2011). According to the Process Model of Complex PM (Kliegel, Martin, McDaniel, & Einstein, 2002), PM involves an interaction of multiple cognitive processes broken into four phases: intention formation (planning to do something in the future), intention retention (keeping the intention in mind over a delay period), intention initiation (initiating the action at the appropriate time or when the PM cue is present), and intention execution (completing the intended action). PM is required to complete many everyday activities, (e.g., remembering to take medication or turning off the iron after use) and impairments in PM can negatively impact a person's independence (Groot, Wilson, Evans, & Watson, 2002).

Impairments in general memory function are commonly self-reported after stroke and by family (de Haan, Nys, & Van Zandvoort, 2006; Kalashnikova, Zueva, Pugacheva, & Korsakova, 2005). However, most studies have investigated retrospective memory (RM), memory for past events, rather than PM. In a scoping review (Hogan, Fleming, Cornwell, & Shum, 2016), we found that the previous literature is limited and reports mixed results, dependent on the measure used. Nevertheless, the overall findings suggest impairments in PM post-stroke, particularly for time-based PM (i.e., when an action must be completed at a certain time or after a certain amount of time has passed). Rehabilitative intervention can benefit memory, especially when focused on strategy training which compensates for deficits (Elliott & Parente, 2014). The rehabilitation literature on PM also has mixed results, with improvements dependent on time post-stroke and an individual's ability or interest in technology (Hogan et al., 2016).

Improving PM Performance

The use of external memory aids (i.e., paper/electronic diaries, alarm systems, Voice Organisers, palmtop computers) have been found to improve PM performance after stroke and acquired brain injury (ABI). However, it is often dependent on an individual's technological ability, willingness to set up reminders/check diaries, and individual preference (McDonald et al 2011; Van den Broek et al 2000; Kim et al 2000; Waldron et al 2012; Shum, Fleming et al 2011).

Group-based memory interventions are becoming more popular when trying to improve PM after ABI, however, research is often limited by economic resources (Thickpenny-Davis & Barker-Collo, 2007). Miller and Radford (2014) investigated a group-based memory intervention (combination of external and internal compensatory strategies) for PM after stroke (*n* = 27 completed training). While significant others reported significant improvements in participants' PM ability, the individuals with stroke reported no such improvement. Additionally, PM improvement was only trending towards significance (moderate effect size) after the intervention, with a longer time post-stroke resulting in less PM improvement, suggesting that focused PM rehabilitation should begin early after stroke for greatest benefits. A similar study (Withiel, Stolwyk et al., 2019) examined group memory skills training (i.e., psychoeducation, internal and external compensatory memory strategies, lifestyle factor education), on four individuals with stroke. Only one participant reported better PM function during the follow-up period. Lawson et al. (2020) examined the same memory skills training program (Withiel, Wong, et al., 2019) in person (*n* = 18) and via telehealth (videoconferencing; *n* = 28), reporting that both groups showed significant PM improvement (both self-report and objective measure) at post-intervention and follow-up compared to baseline.

Computerized memory training, which is cost-effective and easy for patients to access, is also becoming popular (Sigmundsdottir, Longley, & Tate, 2016). Withiel et al. (2018) found that Lumosity, a computerised cognitive training program, was not supported as an effective training tool for improving self-reported PM after stroke (*n* = 5). When Lumosity (*n* = 22) was compared against memory skills training (*n* = 24), the memory skills groups showed significantly greater improvements in PM performance between baseline and post-intervention compared to the Lumosity group, however, this improvement was not maintained at follow-up (Withiel, Wong et al., 2019) Lastly, Mitrovic et al. (2016) investigated computer-based visual imagery training on PM after stroke (*n* = 15) where participants were able to practice their newly learnt strategy in a Virtual Reality (VR) environment. PM performance significantly improved over the course of the study and participants performed significantly better on the Cambridge Prospective Memory Test (CAMPROMPT; Wilson et al., 2005), at post intervention compared to baseline, which was maintained at follow-up.

The rehabilitation literature focusing on PM after stroke is limited and the findings are mixed. Single-case experimental designs limit the generalisation of results to wider populations. In addition, research investigating technological devices indicate results are often dependent on an individual's preference and technological experience (Kim et al., 2000). Other approaches like Prospective Memory Training (Sohlberg et al., 1992) and memory skills training (Withiel, Stolwyk et al., 2019) have promising preliminary results. However, training is often intensive and requires a large time commitment from both the client and therapist. While the previous research is limited, it offers a broad direction for future research and outlines that further rehabilitation techniques need to be developed and evaluated with larger samples to determine whether PM can be improved after stroke. In addition, PM should be assessed with objective measures, rather than relying solely on self-report measures. Simple strategies that are easy to learn and can be easily transferred to everyday situations should be examined.

Implementation Intentions

Previous research has found that poor planning or divided attention at the encoding stage (intention formation) can negatively impact PM performance (Einstein, Smith, McDaniel, & Shaw, 1997; Shum, Cahill, Hohaus, O'Gorman, & Chan, 2013). Therefore, it is important that this first stage of PM is given adequate attention and not interrupted. Implementation intentions are believed to improve PM performance (Gollwitzer & Brandstätter, 1997) due to deeper encoding during the initial planning stage. The more emphasis that is placed on intention encoding at the planning stage should result in easier and more automatic retrieval of the intention at a later stage. Strengthening the anticipation of a triggering cue is said to aid in spontaneous retrieval. One way to do so is to use implementation intentions, a simple strategy used in the wider psychological literature (Chen et al., 2015).

Implementation intentions follow a simple if-then structure, *if X occurs, then I will perform behaviour Y* (Gollwitzer & Brandstätter, 1997). For example, if I have eaten my dinner, then I will take my medication. When forming general intentions, most people focus on the intended action. However, implementation intentions place the focus on the triggering event or PM cue (i.e., dinner) rather than the action to be completed (i.e., take medication). By placing more emphasis on the triggering event, it is argued that PM responses become more automatic, alleviating the need for conscious monitoring of PM cues, thus requiring less effort. Studies that utilise implementation intentions commonly include both a verbal and imagery component (Chen et al., 2015). Participants may be required to repeat an implementation intention instruction multiple times (verbal form), followed by a visualisation period where they imagine themselves completing the task (imagery form).

A previous systematic/meta-analytic review found that implementation intentions improve PM in both younger and older healthy adults (Chen et al., 2015). The strategy has also been found to improve PM in clinical populations like Parkinson's disease (Foster, McDaniel, & Rendell, 2017), early psychosis (Khoyratty et al., 2015), and multiple sclerosis (Kardiasmenos, Clawson, Wilken, & Wallin, 2008). Mioni, Rendell, Terret, and Stablum (2015) found that implementation intentions did not improve either time- or event-based PM in a traumatic brain injury (TBI) sample but did improve time-based PM for healthy controls. These researchers concluded that the strategies needed to improve PM after TBI are likely to be more complex than those that benefit healthy adults and may need to target more than just the initial intention formation phase of the PM process. It is important to note that the study utilised only verbal implementation intention instructions, but not visual rehearsals. Grilli and McFarland (2011) reported that self-imagining improved event-based PM in a group with brain injury ($N = 12$; predominately TBI participants, $n = 9$) concluding that the benefits of implementation intentions with imagery may help individuals with brain injury to process the PM task with more self-relevance, therefore, making it more memorable.

While some previous research has investigated the positive impact implementation intentions have on real-life PM examples post-stroke (i.e., medication adherence post-stroke; O'Carroll, Chambers, Dennis, Sudlow, & Johnston, 2013), there is a lack of research that evaluates the impact implementation intentions have on PM performance post-stroke. PM may be impaired after stroke due to poor monitoring abilities (Hogan, Cornwell, Fleming, Man et al., 2021). By increasing the level of planning through implementation intentions in the intention formation stage of PM, it is suggested that fewer cognitive resources would be needed to monitor for PM cues, as it should be more automatic.

Aims and hypotheses

The current study aimed to investigate the effect of implementation intentions on PM performance post-stroke using implementation intention instructions that feature both a verbal and imagery component. It was hypothesised that implementation intentions would increase overall PM performance for both individuals with stroke and neurologically healthy controls on all PM measures.

Method

Design

Participants completed an assessment battery as part of a larger PM study. The current study focuses on three PM measures. A between-subjects single blind pseudo-randomised controlled design was used. Participants were allocated to two groups determined by pre-existing group membership (stroke vs. control), and then, they were randomly allocated to an instruction condition (standard instructions vs. implementation intentions). The four groups received the same assessment battery with the only difference being the instructions provided on three of the PM measures (Delayed Message Task [DMT], Lexical Decision Prospective Memory Task [LDPMT], and Virtual Reality Prospective Memory Shopping Task [VRPMST]). The CAMPROMPT was used as a standardised control PM measure to ensure that the groups performed similarly prior to the introduction of implementation intentions.

Participants

Twenty-eight individuals with stroke (14 standard instruction, 14 implementation intentions) and 27 neurologically healthy controls (13 standard instruction, 14 implementation intentions) took part in the current study. Individuals with stroke were recruited through multiple stroke organisations and health facilities in Queensland, Australia. Inclusion criteria included: aged 18-85 years; diagnosis of cerebrovascular accident within the last five years; and living in the community post-stroke for at least one month. Exclusion criteria included: stroke located in brainstem/cerebellum; history of other brain injury/neurological illness; diagnosis of dementia/neurodegenerative illness; significant psychiatric disorder; insufficient communicative ability (i.e., diagnosis of severe aphasia); significant visual, hearing, or hand function impairment that would impact participation ability; or current alcohol/substance abuse. If recruited through health facilities, stroke was confirmed based on medical reports and allocation to stroke rehabilitation services. If participants were recruited through support groups/stroke organisations, stroke was self-reported and confirmed through medical reports. Controls were recruited through Griffith University and community groups and were required to be aged 18-85 years old, with no history of neurological illness, brain injury, or stroke. Exclusion criteria included: significant psychiatric illness, current alcohol/substance abuse, significant visual/hearing impairment, or insufficient communicative ability.

Measures

Delayed Message Task

Participants completed a Delayed Message Task (DMT) to examine PM performance after a 24 hr delay wherein they created a message that they would pass onto the researcher via text, phone or email. Participants were given a correct message score out of 1 (did not pass correct message = 0, passed correct message = 1) and a time-based PM score out of 5 with higher scores indicating better performance (i.e., 5 points = +/-10 min of target time, 4 points = +/- 11-30 min, 3 points = +/- 31-60 min, 2 points = +/- 61-120 min, 1 = +/-121 min, 0 = did not relay message). A standard instruction version and an implementation intention version were created. Participants were required to fill in the blanks to create their own implementation intention instruction which differed between participants dependent on the time/day, method of contact, and unique message (i.e., 'If it is [time], then I will [contact method] [*researchers name*] telling them [message].') An example of an implementation intention instruction would be: *if it is 2:30pm Tuesday, then I will contact Christy telling her I had cereal for breakfast*.

Lexical Decision Prospective Memory Task

Participants completed the Lexical Decision Prospective Memory Task outlined in Hogan et al. (2021). The LDPMT is a standard laboratory task that utilises a dual-task paradigm, consisting of an ongoing Lexical Decision Task (LDT) and two PM tasks, namely event- (press the button on the right when an animal word appears) and time-based PM tasks (press the button on the right every 60 seconds) over two sessions. Time monitoring is also measured as the number of clock-checks during the time-based section. Detailed information on the design and LDPMT scoring can be found in Hogan et al. (2021). Event-based PM is scored out of 6 and time-based PM out of 18, with higher scores indicating better PM performance. Participants are given either standard instructions or additional implementation intention PM instructions (i.e., if I see an animal word, then I will press the button on the right).

Virtual Reality Prospective Memory Shopping Task

Participants completed the Virtual Reality Prospective Memory Shopping Task. Detailed design and scoring information can be found in Hogan et al. (2021). The VRPMST features an ongoing shopping task (scored out of 12), two event-based PM tasks (collect a receipt after purchasing a food item and asking the security guard if they have found your lost glasses scored out of 8), a time-based PM task (check heart rate every three minutes and scored out of 12), and time monitoring measured as the number of clock checks. Participants are given either standard instructions or implementation intention instructions (e.g., If I buy an item of food, then I will get a receipt).

Procedure

Ethical clearance was obtained from the relevant hospital and university ethics committees and written consent was obtained from all participants prior to study commencement. The neuropsychological test battery was conducted over two sessions (approximately 1.5 - 2hrs) with breaks to avoid fatigue. The implementation intention groups received implementation intention instructions in the form of, *if X occurs, then I will do Y*, for the PM components of the DMT, LDPMT, and VRPMST. Participants were instructed to read the implementation intention sentence out loud three times, then visualise themselves completing the task for 30 seconds.

Data Analysis

Data were analysed using IBM SPSS statistics for Windows (Version 25; IBM Corporation, 2017). Descriptive statistics for demographic data were obtained and groups were compared on demographic variables using ANOVAs, t-tests, and chi-square analyses. The data were screened for accuracy, missing values, outliers, and normality. Comparisons of the DMT, LDPMT, and VRPMST scores were made using factorial between-groups ANOVA (stroke vs control and standard instruction vs. implementation intention instruction). Effect sizes were determined using η_p^2 and interpreted as: small = 0.01; moderate = 0.09; or large = 0.25 (Cohen, 1998). If the interaction of the ANOVA was significant, post-hoc analyses were run for the DMT, LDPMT, and VRPMST between the stroke and control groups to see if implementation intentions resulted in better PM performance.

Results

No significant differences in age, education, estimated IQ, gender ratio, or specific stroke information were found between groups (see Table 1). According to the Modified Rankin Scale (Rankin, 1957), 8 individuals with stroke had no significant level of disability, 11 slight, 7 moderate, and 2 moderately severe. On the Nottingham Extended Activities of Daily Living scale (Nouri & Lincoln, 1987), both individuals with stroke and their significant-others reported that they completed most daily activities on their own or on their own with difficulty (stroke: M = 52.68, SD = 14.37; significant-other: M = 53.92, SD = 13.48; $t(51) = -0.28$, $p = .78$).

[INSERT TABLE 1]

Data screening showed that 8 data points were missing (1 event-based LDPMT, 2 time-based LDPMT, 2 event-based VRPMST, 2 time-based VRPMST, and 1 time-based DMT) due to technical failure, fatigue, and lack of familiarity with technology. DMT time-based PM and LDPMT event-based PM were significantly skewed. Untransformed scores are reported, as transformations did not change the significance of the results. Analyses are reported with two outliers on LDPMT event-based PM, as removal did not change the significance of the results. Table 2 outlines the means and standard deviations for each group on the DMT, LDPMT, and VRPMST. Each participant group performed similarly to their respective group (i.e., stroke standard vs implementation intention $p = .110$; control standard vs implementation intention $p = 1.00$) on the CAMPROMPT suggesting equal PM performance before the introduction of implementation intentions.

[INSERT TABLE 2]

Delayed Message Task

Most participants (76.36%) correctly passed the message along to researchers (Table 2) and no significant differences were found between the groups on either instruction (χ^2 = 1.06, p = .30) or group (χ^2 = 2.29, p = .13). The ANOVA revealed no significant main effects for group, F(1, 50) = 3.42, p = .07, η_p^2 = .064 (95% CI stroke [2.23, 3.99], control [3.44, 4.86]), or instruction, F(1, 50) = 1.02, p = .32, η_p^2 = .020 (95% CI standard instruction [2.46, 4.20], implementation intentions [3.17, 4.69]), and no interaction was found, F(1, 50) = 1.60, p = .31, η_p^2 = .021.

Lexical Decision Prospective Memory Task

All four groups scored above 91% correct on all ongoing LDT tasks (ongoing LDT 1: F[3, 50] = 1.56, p = .21, η_p^2 = .086; ongoing LDT 2: F[3,49] = .89, p = .45, η_p^2 = .052). For event-based PM, no significant group, F(1, 50) = .70, p = .41, η_p^2 = .014 (95% CI stroke [3.78, 5.22], control [4.38, 5.31]), or instruction, F(1, 50) = 2.51, p = .12, η_p^2 = .048, (95% CI standard instruction [3.63, 4.98]; implementation intentions [4.46, 5.54]) main effects or interaction, F(1, 50) = 2.33, p = .13, η_p^2 = .045, was found. For time-based PM, a significant main effect was found for group, F(1, 49) = 7.53, p = .008, η_p^2 = .133, with controls scoring significantly higher (95% CI control [11.47, 16.22]) than individuals with stroke (95% CI stroke [6.19, 11.73]). No significant instruction main effect, F(1, 49) = .81, p = .37, η_p^2 = .016 (95% CI standard instruction [7.39, 13.49], implementation intentions [9.70, 14.66]), or interaction was found, F(1, 49) = .51, p = .48, η_p^2 = .010, for time-based PM. For monitoring, a significant main effect was found for group, F(1, 49) = 13.37, p = .001, η_p^2 = .214, with controls (95% CI control [19.20, 28.65]) monitoring significantly more than individuals with stroke (95% CI stroke [6.42, 16.91]). Additionally, a significant instruction main effect was found, F(1, 49) = 4.23, p = .045, η_p^2 = .079, wherein the implementation intention groups (95% CI implementation intentions [15.61, 26.98]) monitored significantly more than the standard instruction groups (95% CI standard instruction [9.24, 18.52]), however, no interaction was found, $F(1, 49) = .58$, $p = .45$, $\eta_p^2 = .012$.

Virtual Reality Prospective Memory Task

The four groups scored similarly on the VRPMST ongoing task, indicating that it was not too difficult, $F(3, 49)= 1.71$, $p = .18$, $\eta_p^2 = .095$. For event-based PM, the ANOVA revealed no significant main effect for group, $F(1,49) = .72$, $p = .40$, $\eta_p^2 = .014$, or instruction, $F(1,49) = 1.40$, $p = .24$, $\eta_p^2 = .028$, and no significant interaction was found, $F(1,49) = .72$, $p = .40$, $\eta_p^2 = .014$. For time-based PM no significant main effects were found for group, $F(1, 49) = 2.76$, $p = .10$, $\eta_p^2 = .053$ (95% CI stroke [2.53, 6.24], control [4.63, 8.04]), or instruction, $F(1, 49) = 1.27$, $p = .27$, $\eta_p^2 = .025$ (95% CI standard instructions [2.77, 6.59], implementation intentions [4.29, 7.71]), and no significant interaction was found, $F(1, 49) = .72$, $p = .40$, $\eta_p^2 = .014$. A significant main effect of group, $F(1, 49) = 7.58$, $p = .008$, $\eta_p^2 = .134$, was found for monitoring with controls (95% CI control [11.57, 21.47]) monitoring significantly more than individuals with stroke (95% CI stroke [5.32, 11.99]). No significant main effect for instruction, $F(1, 49) = .036$, $p = .85$, $\eta_p^2 = .001$ (95% CI standard instruction [8.06, 18.10], implementation intentions [8.17, 16.40]), or interaction was found for monitoring, $F(1, 49) = 1.80$, $p = .19$, $\eta_p^2 = .035$.

Discussion

The current study aimed to assess the effect of implementation intentions on PM after stroke. It was hypothesised that implementation intentions would result in better overall PM performance for both individuals with stroke and controls. The hypothesis was not supported. Individuals with stroke showed impairments in time-based PM compared to controls but only on the LDPMT. This is in line with previous research that has found that individuals with stroke have impaired PM compared to healthy controls (Barr, 2011; Brooks et al., 2004;

Hogan et al., 2016; Man, Chan, et al., 2015), particularly time-based PM (Cheng et al., 2010; Hoganet al., 2021; Hogan, Cornwell, Fleming, & Shum., 2020; Kant et al., 2014).

For event-based PM, no significant differences were found for either control or individuals with stroke on either the LDPMT or VRPMST. This finding is inconsistent with those of Grilli and McFarland (2011) who reported improvements in event-based PM when using implementation intentions in a TBI population and contrast to those of Zimmerman and Meier (2010) who reported improvements in PM when implementation intentions were introduced in older adults. While individuals with stroke in the implementation intention condition performed higher on time-based PM than individuals with stroke in the standard condition on all three PM tasks, no significant differences were found. Additionally, no significant increases in time-based PM performance were found for the control group using implementation intentions on the DMT, LDPMT, or VRPMST. The findings of the current study are consistent with those of Mioni et al. (2015) who found that implementation intentions did not improve time-based PM in a TBI population. Mioni et al. found significant improvements in time-based PM for controls, whereas the current study did not. It is likely that the current study was underpowered to find significant results. An adequately powered study may find significant effects, however, whether this would translate to clinical significance is unknown.

Implementation Intentions and Monitoring

Impairments in PM after stroke may be due to deficits in monitoring ability, but it is possible that the monitoring strategies used for event- and time-based PM tasks are different (Hogan et al., 2021). Event-based PM would use a spontaneous response strategy whereas time-based PM would require a more strategic monitoring approach. While monitoring is difficult to measure in event-based PM tasks, it can be easily assessed in time-based PM by measuring time monitoring or clock checking.

Individuals with stroke in the standard condition checked the time significantly less than controls in the standard condition on both the LDPMT and VRPMST. This lack of monitoring may be why PM impairment exists after stroke. The introduction of implementation intentions saw monitoring increase significantly for both groups on the LDPMT but not the VRPMST. This finding is counterintuitive to the implementation intention literature that claims that they serve to automatise the retrieval process by increasing the level of planning in the initial intention formation stage of PM, making the retrieval process more automatic (Chen et al., 2015). While this increase in time checking is theoretically counterintuitive, it suggests that implementation intentions may help to aid in the use of other strategies which help PM performance (i.e., monitoring). A previous study by the research team (Hogan et al., 2021) highlighted that increased monitoring significantly increased time-based PM performance after stroke.

Implications

Implementation intentions were not found to significantly increase PM performance post-stroke for event-based PM or time-based PM on any PM measure. However, the study was underpowered to find significant results and further research with larger samples should be conducted to evaluate the impact that implementation intentions have on PM after stroke and whether PM improvements can translate to clinical significance. Perhaps implementation intentions are suitable for simpler well-controlled PM tasks, like the LDPMT, rather than more complex ecologically valid tasks like the VRPMST. Implementation intentions are believed to make the prospective remembering process more automatic, as a stronger connection between the task and the PM cue is made in the intention formation stage. When implementation intentions were introduced to the individuals with stroke, monitoring significantly increased to the same levels as healthy controls. While this increase is counterintuitive to the theoretical literature, this finding suggests that implementation intentions may help to aid in the use of other strategies which help PM performance. As the current research is only preliminary, more research with larger samples is needed to clarify what impact implementation intentions have on PM after stroke. The current findings suggest similar conclusions to Mioni et al. (2015) who suggested that for improvements in PM in brain injured populations, more complex strategies are needed that target more than one phase of the PM process. While it is great that we can address the intention formation stage using implementation intentions, perhaps more strategies need to be included to enhance the other stages of the PM process to see more significant improvements.

This study tried to address some of the limitations of the previous stroke and PM rehabilitative literature (i.e., single-case experimental design, lack of objective PM assessment, focus on both types of PM separately, and reliance on unfamiliar technologies as rehabilitation tools), however, limitations are still apparent. Firstly, the sample size is small, and therefore underpowered to find significant results. A few technical errors on both the LDPMT and VRPMST also resulted in missing data. Within the VRPMST participants were required to perform three PM tasks and an ongoing task simultaneously, therefore, the cognitive load may have been too high. The tasks could be separated into different sections; however, this may then be too simple and result in ceiling effects. Given the benefits of VR in the assessment of PM in terms of increased participant motivation and ability to assess multiple constructs simultaneously (Canty et al., 2014; Knight & Titov, 2009) it is recommended that research continue to develop and improve VR PM paradigms for use in both measurement and rehabilitation settings in stroke and other clinical populations.

Within the stroke sample there was a large range of time post-stroke which may have impacted on the rehabilitative benefits of the implementation intentions. Miller and Radford (2014) found that those who accessed rehabilitation closer to their stroke onset benefited more and showed greater PM improvement. It is therefore suggested that future research examine how time post-stroke impacts on the effectiveness of implementation intentions in improving PM after stroke. While the CAMPROMPT was used as a control measure in the current study, future research should examine the impact of previously learnt implementation intentions on PM tasks with standard instructions to examine its utility as a potential simple rehabilitation strategy. Finally, perhaps, more complex strategies that target more than one PM stage are needed to have a greater treatment effect on PM performance after stroke (Mioni et al., 2015). It is suggested that future research explore different strategies that target each stage of the PM process to see if PM can be improved post-stroke.

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Table 1

Demographic Variables and Specific Stroke Information Between Groups

	Stroke Standard (*n* = 14)		Control Standard (*n* = 13)		Stroke II (*n* = 14)		Control II (*n* = 14)				
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F/t*	*df*	*p*
Age (years)	65.57	11.99	54.54	9.93	60.14	13.93	58.14	11.42	2.02	3, 51	.12
Education (years)	13.93	5.24	14.65	2.49	14.25	4.45	13.89	4.00	0.10	3, 51	.96
TOPF	102.79	15.48	108.00	12.30	104.71	10.32	102.93	10.22	0.52	3, 51	.67
Time since stroke (months)	14.64	13.73			17.61	14.26			-0.56	26	.58
Range	2 – 45				2 - 53						
Living in Community (months)	13.00	12.32			16.61	13.73			-0.73	26	.47
Range	1 – 37				2 – 52						
Gender									χ^2		*p*
Male	7		4		4		3		2.84		.42
Female	7		9		10		11				
First time stroke											
Yes(*n*)	10				8				0.62		.43
No (*n*)	4				6						
Type of stroke											
Ischaemic (*n*)	11				8				2.62		.46
Haemorrhagic (*n*)	3				4						
Both (*n*)	-				2						
Stroke Lateralisation											
Left (*n*)	4				7				3.26		.20
Right (*n*)	8				3						
Bilateral (*n*)	2				3						
Unknown (*n*)	-				1						

Note. II = Implementation intention condition; TOPF = Test of Premorbid Function (Wechsler, 2011)

Table 2

Means and Standard Deviations for Each Group on the DMT, LDPMT, and VRPMST

		Stroke				Control			
		Standard (n = 14)		II (n = 14)		Standard (n = 13)		II (n = 14)	
Measure	Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
DMT	Time-based PM	2.57	2.28	3.69	2.10	4.15	1.86	4.14	1.79
	Message Passed Correctly	No = 6	Yes = 8	No = 3	Yes = 11	No = 2	Yes = 11	No = 2	Yes = 12
LDPMT	Section 1 Ongoing task	91.70	6.42	94.88	3.95	95.20	3.26	93.00	4.88
	Event-based PM	3.86	2.11	5.14	1.35	4.83	0.72	4.86	1.46
	Section 2 Ongoing task	91.28	7.46	93.37	5.36	94.75	3.79	93.48	4.23
	Time-based PM	7.46	7.56	10.36	6.40	13.67	5.93	14.00	6.05
	Monitoring	6.77	7.11	16.21	16.10	21.58	9.83	25.93	13.12
VRPMST	Ongoing task	10.92	1.38	11.57	0.65	11.85	0.38	11.36	1.45
	Time-based PM	3.08	4.46	5.50	4.55	6.15	4.41	6.50	4.36
	Monitoring	6.83	8.22	10.21	8.25	18.85	12.59	14.36	12.51
	Event-based PM	3.50	2.75	4.93	2.43	4.69	1.97	4.93	2.95

Note. LDPMT = Lexical Decision Prospective Memory Task, Section 1 maximum possible ongoing task score = 100, Maximum possible event-based PM score = 6, Section 2 Maximum possible ongoing task score = 100, Maximum possible time-based PM score = 18; II = implementation intentions; PM = prospective memory; VRPMST = Virtual Reality Prospective Memory Shopping Task, Maximum possible ongoing task score = 12, Maximum possible time-based PM score = 12, Maximum possible event-based PM score = 8; DMT = Delayed Message Task, Maximum possible time-based PM score = 5.