Behavioural Science Section / Original Paper

Gerontology

Gerontology
DOI: 10.1159/000485796

Received: July 4, 2017
Accepted: November 28, 2017
Published online: January 19, 2018

Four-Week Strategy-Based Training to Enhance Prospective Memory in Older Adults: Targeting Intention Retention Is More Beneficial than Targeting Intention Formation

Andreas Ihle[a, b] Rafal Albiński[c] Kamila Gurynowicz[c] Matthias Kliegel[a, b]

[a]Department of Psychology, University of Geneva, Geneva, Switzerland; [b]Center for the Interdisciplinary Study of Gerontology and Vulnerability (CIGEV), University of Geneva, Geneva, Switzerland; [c]Department of Psychology, SWPS University of Social Sciences and Humanities, Warsaw, Poland

Keywords
Prospective memory · Strategy-based training · Rehearsal · Imagery · Old age

Abstract
Background: So far, training of prospective memory (PM) focused on very short instances (single sessions) and targeted the intention-formation phase only. ***Objective:*** We aimed to compare the effectiveness of 2 different 4-week strategy-based PM training types, namely imagery training (targeting the encoding of the PM intention in the intention-formation phase) versus rehearsal training (targeting the maintenance of the PM intention in the intention-retention phase) in older adults. ***Methods:*** We used a 4-week training protocol (8 sessions in total, 2 sessions per week). From the 44 participants, 21 were randomly assigned to the imagery training (vividly imagining a mental picture to memorize the connection between the PM cue words and related actions during intention formation) and 23 to the rehearsal training (rehearsing the PM cue words during intention retention). The criterion PM task was assessed before and after the training. ***Results:*** Comparing the effectiveness of both training types, we found a significant time by training type interaction on PM accuracy in terms of PM cue detection, $F(1, 42) = 6.07$, $p = 0.018$, $\eta^2_p = 0.13$. Subsequent analyses revealed that the rehearsal training was more effective in enhancing PM accuracy in terms of PM cue detection than the imagery training. ***Conclusion:*** Strategy-based PM training in older adults targeting the maintenance of the PM intention in the intention-retention phase may be more effective in enhancing PM accuracy in terms of PM cue detection than the strategy targeting the encoding of the PM intention in the intention-formation phase. This suggests that for successful prospective remembering, older adults may need more support to keep the PM cues active in memory while working on the ongoing task than to initially encode the PM intention.

Introduction

Prospective memory (PM) is defined as remembering to carry out an intended action at an appropriate time in the future [1], either after a certain amount of time has elapsed (*time-based PM*) or in reaction to external cues (*event-based PM*). In both types, PM tasks are embedded in other *ongoing activities* that need to be interrupted in order to properly complete the PM action. PM is especially important in old age as it crucially determines the

KARGER

E-Mail karger@karger.com
www.karger.com/ger

Andreas Ihle
CIGEV, University of Geneva
route des Acacias 54
CH–1227 Carouge (Switzerland)
E-Mail Andreas.Ihle@unige.ch

ability to maintain an independent functioning in everyday life [2]. Yet, several meta-analyses indicated that PM performance is substantially lower in older age [3, 4]. Therefore, research recently started to investigate possibilities to improve PM performance in older adults [5].

Recent work on this important topic focused on 2 approaches for training PM, namely a strategy-based approach and a process-based approach. The latter usually aims at improving a specific cognitive ability (e.g., working memory), which in turn should result in improved PM accuracy. This approach *aims to augment or to restore the underlying processes* of PM [5, 6]. In contrast, the strategy-based approach (on which we focus in the present paper) usually entails providing participants with a mnemonic strategy that can be used when completing a PM task. Thereby, strategy training *aims to compensate or circumvent limitations in underlying processes* [6]. Strategies presented to participants may include (among others) imagery or implementation intentions strategies targeting the encoding phase of PM (see below for a more detailed description of these approaches).

Thus, a key aspect of PM training concerns the specific PM phase that is targeted by the intervention. As conceptualized by Ellis [7] and Kliegel et al. [8], PM consists of several phases: First, an *intention-formation* phase, in which the intention is formed and encoded (including details regarding where and when an intention has to be executed). This is followed by an *intention-retention* phase, in which the intention needs to be held active in memory, awaiting to be initiated as soon as the PM cue appears. Finally, the intention has to be carried out in the intention-execution phase.

Two major gaps in the current PM training literature can be identified. First, PM-enhancing strategies have so far been used in settings in which an experimental group was presented only once with a strategy and later compared to a nonstrategy control condition [9]. Yet, repeating training sessions and successively increasing difficulty level may perhaps be crucial for reaching maximum PM training gains. Second, and conceptually possibly even more important, to our knowledge all published studies focused on exploring strategies targeting the intention-formation phase, but not on strategies targeting the intention-retention phase. The present study set out to address these two open issues.

In terms of PM strategies targeting PM encoding in the intention-formation phase, implementation intentions have been studied most often [9–11]. This approach is based on goal-directed verbalization of intentions in a "If x arises, then I will perform y" manner [12, 13]. Evidence showed that the implementation intentions strategy is effective in improving PM performance. For example, Brom and Kliegel [5] found that using an *implementation intentions* strategy significantly increased participants' tendency to remember checking their blood pressure. The effectiveness of this approach was significantly higher than the effectiveness of a process-based task-switching training approach (note that even here the strategy was presented to participants only once and was not trained in several sessions during a longer amount of time). With a similar strategy approach, Burkard et al. [14] reported significant improvements in PM. In their recent meta-analysis, Chen et al. [15] supported the generally beneficial effect of implementation intentions on PM with a medium effect size (d = 0.45) for younger adults, and a larger effect size (d = 0.68) for older adults.

Another encoding strategy that has been studied in PM training research is imagery-based episodic future thinking (EFT). EFT is an approach of vividly imagining experiencing future situations and during which complex mental scenes are created. Due to this complexity, EFT relies on a wide range of cognitive processes such as executive control, semantic memory, and self-projection [16]. Evidence suggests that EFT can successfully support PM performance. In a study by Griffiths et al. [17], imagining future events increased social drinkers' time-based PM performance in a Virtual Week task (but did not improve PM performance of alcohol dependent participants). McFarland and Glisky [18] reported a significant increase in PM performance for an imagery-based EFT strategy and an implementation intentions strategy. Interestingly, combining the imagery with the implementation intentions strategy did not improve PM performance over either strategy applied alone (i.e., there was no incremental effect of combining both strategies). They concluded that implementation intentions may not require imagery to be effective in improving PM performance and that the imagery strategy alone may be able to improve PM performance. Altgassen et al. [19] compared younger and older adults in the Dresden Breakfast task in which participants had to prepare breakfast according to a set of rules and time restrictions including several PM tasks. All of the participants had to make a plan, but only half of them were asked to imagine themselves completing the task. Results showed that both younger and older adults significantly benefited from that future thinking imagination. Finally, in a study by Schmidt et al. [20], participants were instructed to imagine themselves performing the planned action in reaction to salient cues in the environment. Results showed a significant training effect that could not, however, be fully attributed to imagery/EFT strategy, as in this study participants were also taught a strategy that allows transforming event-based tasks into time-based tasks. Therefore, the specific effects of the 2 strategies could not be disentangled in that study.

In sum, both implementation intentions and imagery-based future thinking were proved to be beneficial in terms of improving PM performance. Yet, both strategies target the intention-formation phase by improving the encoding of the PM intention at the beginning of the task. To extend the literature, we contrasted 2 different strategy-based training types that targeted different PM phases and their inherent cognitive processes. The first one targeted the encoding of the PM intention in the *intention-formation* phase and entailed a form of imagery training (this strategy will be further referred to as *imagery training)*. Note that this method was inspired by previous work on mental imagery in episodic memory research [21] and differed from the future thinking approach outlined above with respect to the fact that in our study participants did not imagine themselves performing the intention, but instead as vividly as possible imagined a mental picture linking a PM cue word and a paired action (e.g., PM cue word = "street" and paired action = "buy bread") as vividly as possible. In the PM task that was presented afterwards, participants were asked to react to the PM cue word (e.g., "street") by pressing the Q key and then to type in the paired action (e.g., "buy bread"; participants were not asked to perform those paired actions, but to image as vividly as possible the PM cue word-action pairs; see the Imagery Training section in the Methods for further details). Albiński et al. [22] used this imagery strategy in a PM study, in which participants encoded PM cue word-action pairs and were later tested on PM performance. They manipulated the strength of the association between PM cue words and the related actions (i.e., low- vs. high-association pairs) and found higher PM performance for low-association, compared to high-association pairs. At first glance, this finding may seem counter-intuitive. Interestingly, they also found longer encoding times for low-association, compared to high-association pairs and that longer encoding times were functionally related to later PM performance. They argued that participants may perceive the low-association pairs as more difficult and therefore devoted more time to encode. Although Albiński et al. [22] assessed PM performance only after but not before the strategy intervention (and thus were not able to examine pretest-posttest training effects), they pointed out that the imagery strategy used in their study may be a potentially promising training approach to enhance PM performance by prolonged encoding of PM cue word-action pairs as it may allow to create associations even for difficult or unusual PM cue-action pairs (as shown with the low-association pairs in their study).

In contrast, the second training (further referred to as rehearsal training) targeted the maintenance of the PM intention in the *intention-retention* phase. For this approach, participants were provided with breaks during the PM task, in which a message that appeared on the computer screen prompted them to think about what they were supposed to do in the task and to rehearse the PM cue words (see the Rehearsal Training section in the Methods for further details). Thus, with the rehearsal training strategy, we aimed at refreshing the level of activation of PM cues during intention retention.

Our major goal was to compare the effectiveness of the 2 training types (imagery vs. rehearsal training) in enhancing prospective remembering using a 4-week training protocol (8 sessions in total, 2 sessions per week). One additional goal was to disentangle possible differential strategy effects on 2 key components of prospective remembering, namely PM cue detection (i.e., the detection of the PM cue in order to initiate the PM intention) and PM intention retrieval (i.e., the retrieval of the intended action in order to complete the PM intention) [1, 8, 23] (see also West [24], for an overview of the different neurophysiological correlates of these distinct PM components). This will allow clarifying which PM processes, in terms of encoding the PM intention or retaining the PM intention active in memory, and which PM component, in terms of PM cue detection or PM intention retrieval, may most strongly benefit from strategy-based interventions to support successful prospective remembering in old age. In terms of hypotheses, we predicted a general training effect on both PM components. With respect to differential training effects, given the lack of evidence, we had no a priori hypotheses of one strategy being more effective than the other.

Materials and Methods

Participants

In total, 44 community-dwelling older adults (M_{age} = 67.93 years; SD_{age} = 3.48; age range: 62–76 years; 37 women) participated in the present study. All of them achieved 28 points or more when completing Mini-Mental State Examination. All participants were volunteers recruited in University of Third Age facilities in Warsaw, Słupsk, and Sopot. From the 44 participants, 21 were randomly assigned to the imagery training and 23 to the rehearsal training (using a random number generation procedure in Microsoft Excel). There were no pretraining differences between the 2

Table 1. Baseline participant characteristics prior to training

Variable	Imagery training (n = 21)	Rehearsal training (n = 23)	Difference statistic	
			t or χ^2	p
Age, years	67.62 (3.58)	68.22 (3.44)	$t(42) = 0.57$	0.575
Sex (sample proportions)				
Women	19 (90.5%)	18 (78.3%)	$\chi^2(1) = 0.48$	0.488
Men	2 (9.5%)	5 (21.7%)		
PM accuracy in terms of PM cue detection, proportion score	0.32 (0.28)	0.28 (0.33)	$t(42) = 0.42$	0.678
Accuracy of PM intention retrieval, proportion score	0.17 (0.23)	0.17 (0.23)	$t(42) = 0.09$	0.933
Ongoing task accuracy , proportion score	0.91 (0.14)	0.86 (0.18)	$t(42) = 0.98$	0.333
Ongoing task reaction times, ms	2,093 (642)	2,604 (1274)	$t(42) = 1.66$	0.105
Digit-span forward score	4.10 (1.14)	3.57 (1.34)	$t(42) = 1.41$	0.167
Operation span score	21.38 (20.40)	18.91 (11.68)	$t(42) = 0.50$	0.621
PRMQ PM dimension score	17.81 (4.29)	19.43 (4.32)	$t(42) = 1.25$	0.218
PRMQ RM dimension score	17.19 (4.31)	18.96 (4.63)	$t(42) = 1.31$	0.198

Data are presented as mean (SD) or as stated. Baseline participant characteristics prior to training, separately for the imagery and the rehearsal training group as well as difference test statistics to evaluate pre-training differences between the two training groups. Digit-span forward, subtest from the Wechsler Adult Intelligence Scale-Revised [25, 26]; operation span, score represents the overall number of letters across all correctly recalled sets [27, 28]; PRMQ, Prospective and Retrospective Memory Questionnaire [29], assessing the PM and retrospective memory (RM) dimensions of memory functioning in everyday life.

training groups (see Table 1 for baseline participant characteristics prior to training). All assessments and training sessions were conducted at the University of the Third Age facilities.

Criterion PM Task

The criterion PM task (assessed at pre- and posttest) was embedded in a lexical decision task (LDT) ongoing task. Participants were asked to decide whether a string of letters was a word or not by pressing the "M" key for words and the "V" key for nonwords. For the embedded PM task, PM cue word-action pairs were used (e.g., PM cue word = "street" and paired action = "buy bread"). Participants were asked to remember to press the "Q" key whenever they noticed a PM cue word (e.g., "street") during the LDT (i.e., PM cue detection). After a correct Q press, a box showed up on the screen and participants were asked to type in the action associated with that PM cue word (e.g., "buy bread"; i.e., PM intention retrieval). In the LDT plus PM block, there were 54 words, 54 nonwords, and 12 PM cue words. Among all 120 stimuli, PM cue words were placed on trials 10, 11, 20, 35, 55, 70, 72, 88, 94, 109, 111, and 115. Prior to the LDT plus PM block participants completed also a 30-trial warm-up LDT-only block and a 100-trial LDT-only block for baseline purposes (50 words/50 nonwords). PM criterion measures were taken in 2 separate sessions at pretest (no more than 7 days before the first training session) and posttest (no more than 7 days after the last training session).

Training Types

Both training types lasted about 4 weeks and consisted of 8 sessions (2 sessions per week).

Imagery Training

The *imagery training* targeted the encoding of the PM intention in the intention-formation phase. Each imagery training session consisted of 2 parts (i.e., noncomputer training in the first part as well as computer training in the second part of each training session). In the first part of each imagery training session, without the use of the computer, participants trained the mental imagery strategy as such. Specifically, they were asked to vividly imagine and write down a mental picture that they created in their mind and that in their opinion would be helpful for them to remember the association between a word and a paired action. For example, if the word was "desk" and the action that should be linked to that word was "write," they could for example vividly imagine a letter-writing situation and write down for example "I sit at my desk with a pencil in my hand. I look down at a sheet of paper and I write a letter." Thus, participants should as vividly as possible imagine a mental picture linking a word and a paired action and describe this image by writing it down. The number of such pairs that should be imagined and written down increased each week, with 2 imagined and written down pairs in the first week, 3 in the second, 4 in the third, and 5 in the fourth week.

In the second part of each imagery training session, participants completed a computer PM task (similar to the LDT/PM paradigm used in pre- and posttest measures, see above). We asked participants to use the previously learned mental imagery strategy from the first part of the training session also in the PM task in this second part of the training session (i.e., vividly imagining a mental picture to remember the association between the PM cue words and the paired actions during PM encoding in the intention-formation phase; e.g., for the PM cue word-action pair of "street" – "buy bread" that we outlined in the description of the criterion PM task, participants could for example imagine "I walk along a street. I approach a shop. I stop to enter the shop and buy bread."). In the first week, 6 PM cue word-action pairs were used, and this number increased by 2 each week (to increase difficulty level), resulting in 12 PM cue word-action pairs in the fourth week of training.

Rehearsal Training

The *rehearsal training* targeted the maintenance of the PM intention in the intention-retention phase. In each rehearsal training session, participants completed a computer PM task (similar to the LDT/PM paradigm used in pre- and posttest measures, see above). Three evenly spaced breaks were introduced during the task in the intention-retention phase. During those breaks, a message appeared on the screen (participants were informed about this before the onset of the task): "Think for a moment about what you are supposed to do in this task. Try to rehearse the cue words you were supposed to react to[1]. If you are ready, press SPACE to continue the task." The duration of the breaks was self-paced. As in the imagery training, during the first week, 6 PM cue word-action pairs were used, with 2 more added each week (to increase difficulty level), resulting in 12 PM cue word-action pairs during the fourth week of training.

Statistical Analyses

First, we investigated training effects on PM accuracy in terms of PM cue detection. A 2 (time: pretest vs. posttest) × 2 (training type: imagery vs. rehearsal) mixed ANOVA was conducted. PM accuracy in terms of the proportion of correctly pressing the Q key in reaction to the PM cue words (i.e., PM cue detection; 12 PM cue words in pretest and 12 in posttest) served as dependent variable.

Second, we examined training effects on the accuracy of PM intention retrieval. A 2 (time: pretest vs. posttest) × 2 (training type: imagery vs. rehearsal) mixed ANOVA was conducted. The accuracy of PM intention retrieval in terms of the proportion of correctly recalled actions (that were paired with the respective PM cue words) served as dependent variable [22, 23].

Third, we examined training effects on ongoing task accuracy and reaction times in order to control for possible tradeoff effects between the ongoing and the PM task. A 2 (time: pretest vs. posttest) × 2 (training type: imagery vs. rehearsal) mixed ANOVA was conducted. Ongoing task accuracy in terms of the proportion of correct word/nonword decisions served as dependent variable. A similar analysis was conducted on reaction times (for correct ongoing task responses).

Fourth, we investigated PM gains across training sessions to explore the successive training progress over time. As during the training participants encountered each difficulty level of the training task twice (e.g., 2 training sessions with 6 PM cue word-action pairs in the first week), we conducted a series of dependent samples *t* tests in order to compare PM accuracy in terms of PM cue detection between the first and the second training of each week (thus comparing training sessions with equal difficulty level). We also compared mean PM accuracy in terms of PM cue detection (collapsed across the 2 sessions of the same week with equal difficulty level) across the 4 weeks, for which the difficulty level (i.e., the number of PM cue word-action pairs) increased progressively each week from 6 PM cue word-action pairs during the first week to 12 during the fourth week (thus comparing training sessions across increasing difficulty level). We acknowledge that these analyses are merely explorative. To take possible problems of multiple testing (cumulative alpha-error) into account, we applied Bonferroni post hoc tests. For these analyses, PM accuracy in terms of the proportion of correctly pressing the Q key in reaction to the PM cue words (i.e., PM cue detection; 6 PM cue words during week 1, 8 during week 2, 10 during week 3, and 12 during week 4) served as dependent variable.

[1] Here, "to react" means to remember to press the "Q" key whenever participants noticed a PM cue word and to type in the action associated with that PM cue word.

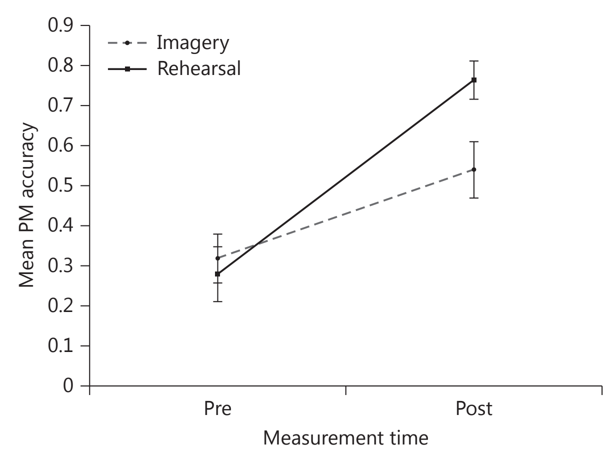

Fig. 1. Mean PM accuracy in terms of PM cue detection at pre- and posttest as a function of training type (imagery vs. rehearsal). Bars represent standard errors.

Results

Training Effects on PM Accuracy in Terms of PM Cue Detection

For PM accuracy in terms of PM cue detection, there was a significant time by training type interaction, $F(1, 42) = 6.07$, $p = 0.018$, $\eta^2_p = 0.13$. The main effect of time was also statistically significant, showing an increase in overall PM accuracy in terms of PM cue detection across both measurements, $F(1, 42) = 43.87$, $p < 0.001$, $\eta^2_p = 0.51$. Participants were less accurate in detecting the PM cues in the PM task at pretest (M = 0.30, SD = 0.30) compared to posttest (M = 0.66, SD = 0.30).

A subsequent simple effects analysis revealed a significant increase in PM accuracy in terms of PM cue detection across time for the imagery training ($M_{pretest} = 0.32$, $SD_{pretest} = 0.28$; $M_{posttest} = 0.54$, $SD_{posttest} = 0.32$; $p < 0.001$) and for the rehearsal training ($M_{pretest} = 0.28$, $SD_{pretest} = 0.33$; $M_{posttest} = 0.76$, $SD_{posttest} = 0.23$; $p < 0.001$). Notably, this pretest-posttest difference (in terms of means of difference scores) was larger for the *rehearsal* training (M = 0.48, SD = 0.44) than for the *imagery* training (M = 0.22, SD = 0.23). Together with the aforementioned significant time

DOI: 10.1159/000485796

by training type interaction, this pattern indicated that the training-related effects on PM accuracy in terms of PM cue detection were significantly larger for the rehearsal than for the imagery training (see Fig. 1 for an illustration).

Training Effects on Accuracy of PM Intention Retrieval

For accuracy of PM intention retrieval, there was a significant main effect of time, showing an increase of overall accuracy of PM intention retrieval across both measurements, $F(1, 42) = 37.80$, $p < 0.001$, $\eta^2_p = 0.47$. Participants were less accurate in PM intention retrieval at pretest (M = 0.17, SD = 0.23) compared to posttest (M = 0.48, SD = 0.31). Yet, there was no main effect of training type and no time by training type interaction on the accuracy of PM intention retrieval (*p*s > 0.124).

Training Effects on Ongoing Task Accuracy and Reaction Times

For ongoing task *accuracy,* no significant effects were found (*p*s > 0.265). For ongoing task reaction times, there was a significant main effect of training type, $F(1, 42) = 7.76$, $p = 0.008$, $\eta^2_p = 0.16$, with participants from the imagery training being significantly faster (M = 2,066 ms, SD = 648 ms) than participants from the rehearsal training (M = 2,699 ms, SD = 1,115 ms). Yet, there was no main effect of time and no time by training type interaction on ongoing task reaction times (*p*s > 0.464).

PM Gains across Training Sessions

Imagery Training

For the imagery training, a series of dependent *t* tests showed a significant within-difficulty-level difference in PM accuracy in terms of PM cue detection between the 2 training sessions that took place in the first week (i.e., an increase in PM accuracy from the first to the second training session in week 1; see Table 2). There were no other significant within-difficulty-level differences in the other 3 weeks (*p*s > 0.05). A within-subjects ANOVA exploring overall PM accuracy in terms of PM cue detection (collapsed across the 2 sessions of the same week with equal difficulty level) regarding training progress across the 4 weeks showed a significant effect of week, $F(3, 18) = 6.02$, $p = 0.005$, $\eta^2_p = 0.50$. Bonferroni post hoc tests showed that overall PM accuracy in terms of PM cue detection significantly increased from the second to the fourth week (with no significant difference between the first and the second week; $M_{1st\ week} = 0.37$; $M_{2nd\ week} = 0.48$; $M_{3rd\ week} = 0.56$; $M_{4th\ week} = 0.66$). Notably, this increase was observed despite the fact that the PM task got progressively more difficult each week.

Table 2. Means, standard deviations, and *t* test statistics for PM gains across training sessions

	M_{1st} training	SD_{1st} training	M_{2nd} training	SD_{2nd} training	*t* test (1st vs. 2nd training within each week)		
					t	*p*	*d*
Imagery training							
Week 1	0.23	0.33	0.52	0.37	$t(20) = 3.47$	0.002	0.78
Week 2	0.55	0.40	0.41	0.35	$t(20) = 1.41$	0.174	0.31
Week 3	0.52	0.32	0.61	0.33	$t(20) = 1.34$	0.196	0.28
Week 4	0.63	0.32	0.68	0.31	$t(20) = 1.10$	0.285	0.23
Rehearsal training							
Week 1	0.40	0.27	0.73	0.35	$t(22) = 4.64$	<0.001	0.97
Week 2	0.72	0.29	0.80	0.15	$t(22) = 1.45$	0.162	0.30
Week 3	0.81	0.15	0.87	0.16	$t(22) = 1.54$	0.137	0.32
Week 4	0.89	0.14	0.89	0.14	$t(22) = 0.19$	0.855	0.04

Rehearsal Training

For the rehearsal training, a series of dependent *t* tests showed a similar pattern of results as for imagery training: the only significant within-difficulty-level difference in PM accuracy in terms of PM cue detection was observed between the first and the second training during the first week (i.e., an increase in PM accuracy from the first to the second training session in week 1; see Table 2). A within-subjects ANOVA exploring overall PM accuracy in terms of PM cue detection (collapsed across the 2 sessions of the same week with equal difficulty level) regarding training progress across the 4 weeks showed a significant effect of week, $F(3, 20) = 19.60$, $p < 0.001$, $\eta^2_p = 0.75$. Bonferroni post hoc tests showed that overall PM accuracy in terms of PM cue detection significantly increased from the first to the fourth week ($M_{1st\ week} = 0.57$; $M_{2nd\ week} = 0.76$; $M_{3rd\ week} = 0.84$; $M_{4th\ week} = 0.89$), despite the fact that the PM task got progressively more difficult each week.

Discussion

The present study set out to compare the effectiveness of 2 different 4-week strategy-based PM training types (imagery vs. rehearsal training) in older adults. For both strategy-based PM training types, we observed a significant increase in PM accuracy in terms of PM cue detection as well as in accuracy of PM intention retrieval from pretest to posttest. For imagery training, this is in line with prior single-session PM training studies targeting PM intention encoding that showed training-related enhancements in PM accuracy in terms of PM cue detection [5, 15, 17–19] (there are no prior PM training studies targeting the intention-retention phase). Notably, our study is the first in comparing 2 strategies targeting different PM phases and their inherent cognitive processes. Our data suggest that a strategy targeting the maintenance of the PM intention in the intention-retention phase may be more beneficial in enhancing PM accuracy in terms of PM cue detection than a strategy targeting the encoding of the PM intention in the intention-formation phase.

From a conceptual perspective, the rehearsal training provided participants with time during the intention-retention phase to rehearse the PM cue words and paired actions, strengthening the maintenance of the PM intention. In contrast, in the *imagery* training, participants were asked during the PM intention-formation phase to imagine potential links between a PM cue word and the paired action, strengthening the encoding of the PM intention. Comparing both training types suggests that the strategy targeting the maintenance of the PM intention in the intention-retention phase seemed to be more effective in enhancing PM accuracy in terms of PM cue detection than the strategy targeting the encoding of the PM intention in the intention-formation phase. This indicates that for successful prospective remembering, older adults may need more support to keep the PM cues active in memory while working on the ongoing task than to initially encode the PM intention. This dovetails with prior findings and the conceptual view that intention retention is a crucial process for successful prospective remembering [7, 8]. This is because besides the need to continuously keep the PM cues active in memory, the intention-retention phase also requires the continuous processing of the background activity and the monitoring for those PM cues, which places particular demand on working memory updating [8, 30]. This is especially crucial in older adults given the age-related decline in continuous updating of working memory [31] and thereby less available cognitive resources to maintain the PM cues active in memory [8]. Hence, in the rehearsal training, the breaks during the intention-retention phase (that allowed participants to rehearse the PM cue words) may help to continuously keep them active in memory, which later may support detection of these PM cues.

With respect to our additional goal to disentangle possible differential strategy effects on the different PM components, we observed greater PM accuracy in terms of PM cue detection as well as greater accuracy of PM intention retrieval (from pretest to posttest) after both the rehearsal and the imagery training. Yet, contrasting the 2 training strategies we found differential training effects only on PM accuracy in terms of PM cue detection (but not on PM intention retrieval). Notably, this dovetails with the findings of Zimmermann and Meier [11] suggesting that effects of an implementation-intention strategy (targeting PM encoding in the intention-formation phase) on prospective remembering were mainly related to enhancements of PM cue detection (but not to enhancements of PM intention retrieval). More generally, this is also in line with observations that mainly problems of PM cue detection (and in contrast much less problems of PM intention retrieval) account for most PM failures in old age [1, 8], which is also linked to the different neurophysiological correlates of these distinct PM components [24, 32, 33]. This further corroborates our conclusion that for successful prospective remembering for older adults it seems more difficult to keep the PM cues active in memory while working on the ongoing task than to initially encode or to later retrieve the PM intention.

From an intervention perspective, our 4-week training study suggests that repeated exposition to a strategy and active training of that strategy across several weeks may be beneficial, as PM accuracy in terms of PM cue detection increased week after week in case of both training types (with the exception from the first to the second week for imagery training). This observation is remarkable since the PM task got progressively more difficult each week (6 PM cue words during week 1, 8 during week 2, 10 during week 3, and 12 during week 4). One may argue that changing the number of PM cues might be somewhat blurring this analysis. However, increasing difficulty across training is a hallmark of cognitive training and important to keep participants' motivation and avoid ceiling effects [34, 35]. Another interesting observation was that for both training types there was a significant increase in PM accuracy in terms of PM cue detection from the first to the second training during the first training week (within the same difficulty level). After that first training week, there were no further significant within-difficulty-level-related PM accuracy increases, but only significant between-difficulty-level-related PM accuracy increases. Specifically, in the second to the fourth week, participants were already in the first of the 2 training sessions within a certain difficulty level able to show a relatively high PM accuracy in terms of PM cue detection for that difficulty level (and their PM accuracy did not further increase with the second training of that same difficulty level). PM accuracy increases were only observed when increasing the difficulty level in the following week (compared to the preceding difficulty level). This may suggest that (at least for strategy-based PM training) it seems crucial to allow participants sufficient time to practice the strategy at the very beginning of an intervention. After that, the difficulty level of the training could be relatively quickly increased to reach further performance gains. Notably, following the present results, this seems to concern both intention formation and intention retention targeting strategies.

We examined training effects on ongoing task accuracy and reaction times in order to control for possible tradeoff effects between the ongoing and the PM task. Results showed no effects on ongoing task accuracy and only a significant effect of training type on ongoing task reaction times, with participants from the rehearsal training being slower than participants from the imagery training. However, there were no differences in ongoing task response times between the 2 training groups prior to training. Most importantly, there was no main effect of time and no time by training type interaction on ongoing task reaction times. This suggests that the observed greater training effects on PM accuracy in terms of PM cue detection in the rehearsal compared to the imagery training are not attributable to differential effects on the processing of the ongoing task in which the PM task was embedded.

One may argue that the different strategies targeting different PM phases may have introduced a confound between type of training and phase of PM and that it may be something about the neuropsychological basis of the strategy that is important, rather than the PM phase targeted. We acknowledge that the 2 strategies clearly differed with regard to the respective PM phase they targeted and the cognitive processes linked to that respective PM phase (i.e., imagery as a classical strategy for memory encoding in the intention-formation phase and rehearsal for memory maintenance in the intention-retention phase). We further acknowledge that there may be different neuropsychological underpinnings for each strategy, but we would argue that they are inherent features of the cognitive architecture of each PM phase [8]. Future PM studies might for example vary the load of those inherent cognitive processes involved in the respective PM phases, such as the number of PM cues and/or the number of related PM actions that need to be encoded as well as ongoing task and working memory load during intention retention to investigate whether this differentially affects the outcome of imagery and rehearsal PM training. Additional recall tests of the content of the intention after the intention-formation and after the intention-retention phase may help to evaluate whether PM training effects are due to enhanced intention encoding and/or enhanced intention maintenance to gain further insights into the neuropsychological processes involved in the 2 PM training types.

One may also argue that the dosages in the 2 training types may have been different because in the rehearsal training participants were interrupted several times during the ongoing task to rehearse the intention, while this was not the case in the imagery training. However, the overall dosage of both training types was comparable because the intention-encoding training in the imagery condition was of similar length as the 3 breaks taken together in the rehearsal training for intention maintenance. Thus, we argue that the observed greater training effects on PM accuracy in terms of PM cue detection in the rehearsal compared to the imagery training are not due to a higher dosage or intensity of training. Yet, future PM research might vary the time and dosage for the different training types to evaluate whether this affects PM training outcomes. Likewise, future PM studies might compare a 4-week training protocol (as used in the present study) with a single training session (as used in prior PM training studies targeting PM intention encoding [5, 9–11, 14–20], in which the encoding strategy was presented to participants only once and was not trained in several sessions during a longer amount of time as in our study). Another possible target for future PM studies might be the investigation of other populations by, e.g., comparing healthy individuals with those with cognitive impairments regarding the effectiveness of imagery and rehearsal PM training.

To sum up, our study showed a significant increase in PM accuracy in terms of PM cue detection and in accuracy of PM intention retrieval from pretest to posttest as a result of 2 different 4-week strategy-based PM training types targeting the intention-formation and the intention-retention phase in older adults. Comparing both training types, the strategy targeting the maintenance of the PM intention in the intention-retention phase seemed to be more effective in enhancing PM accuracy in terms of PM cue detection than the strategy targeting the encoding of the PM intention in the intention-formation phase. This suggests that for successful prospective remembering, older adults may need more support to keep the PM cues active in memory while working on the ongoing task than to initially encode the PM intention.

Acknowledgements

We thank Nicola Ballhausen for helpful discussions on the study topic. The project was financed from the funds of the National Science Center, decision No. DEC-2012/07/D/HS6/02533. A. Ihle and M. Kliegel belong to the Swiss National Center of Competences in Research LIVES – Overcoming Vulnerability: Life

Course Perspectives, which is financed by the Swiss National Science Foundation (grant number: 51NF40-160590). The authors are grateful to the Polish National Science Centre and the Swiss National Science Foundation for their financial assistance.

Disclosure Statement

The authors declare that they have no conflicts of interest.

References

1 Kliegel M, Ballhausen N, Hering A, Ihle A, Schnitzspahn KM, Zuber S: Prospective memory in older adults: where we are now and what is next. Gerontology 2016;62:459–466.
2 Woods SP, Dawson MS, Weber E, Gibson S, Grant I, Atkinson JH: Timing is everything: antiretroviral nonadherence is associated with impairment in time-based prospective memory. J Int Neuropsychol Soc 2009;15:42–52.
3 Henry JD, MacLeod MS, Phillips LH, Crawford JR: A meta-analytic review of prospective memory and aging. Psychol Aging 2004;19:27–39.
4 Ihle A, Hering A, Mahy CEV, Bisiacchi PS, Kliegel M: Adult age differences, response management, and cue focality in event-based prospective memory: a meta-analysis on the role of task order specificity. Psychol Aging 2013;28:714–720.
5 Brom SS, Kliegel M: Improving everyday prospective memory performance in older adults: comparing cognitive process and strategy training. Psychol Aging 2014;29:744–755.
6 Hering A, Rendell PG, Rose NS, Schnitzspahn KM, Kliegel M: Prospective memory training in older adults and its relevance for successful aging. Psychol Res 2014;78:892–904.
7 Ellis J: Prospective memory or the realization of delayed intentions: A conceptual framework for research; in Brandimonte M, Einstein GO, McDaniel MA (eds): Prospective Memory: Theory and Applications. Mahwah, Erlbaum, 1996, pp 1–22.
8 Kliegel M, Altgassen M, Hering A, Rose NS: A process-model based approach to prospective memory impairment in Parkinson's disease. Neuropsychologia 2011;49:2166–2177.
9 Meeks JT, Marsh RL: Implementation intentions about nonfocal event-based prospective memory tasks. Psychol Res 2010;74:82–89.
10 Chasteen AL, Park DC, Schwarz N: Implementation intentions and facilitation of prospective memory. Psychol Sci 2001;12:457–461.
11 Zimmermann TD, Meier B: The effect of implementation intentions on prospective memory performance across the lifespan. Appl Cogn Psychol 2010;24:645–658.
12 Gollwitzer PM: Goal achievement: the role of intentions. Eur Rev Soc Psychol 1993;4:141–185.
13 Gollwitzer PM: Implementation intentions – strong effects of simple plans. Am Psychol 1999;54:493–503.
14 Burkard C, Rochat L, Blum A, Emmenegger J, Juillerat Van der Linden A-C, Van der Linden M: A daily-life-oriented intervention to improve prospective memory and goal-directed behaviour in ageing: a pilot study. Neuropsychol Rehabil 2014;24:266–295.
15 Chen X, Wang Y, Liu L-L, Cui JF, Gan MY, Shum DHK, Chan RCK: The effect of implementation intentions on prospective memory: a systematic and meta-analytic review. Psychiatry Res 2015;226:14–22.
16 Terret G, Rose NS, Henry JD, Bailey PE, Altgassen M, Philips LH, Kliegel M, Rendell PG: The relationship between prospective memory and episodic future thinking in younger and older adulthood. Q J Exp Psychol 2015;69:310–323.
17 Griffiths A, Hill R, Morgan C, Rendell PG, Karimi K, Wanageratne S, Curran HV: Prospective memory and future event simulation in individuals with alcohol dependence. Addiction 2012;107:1809–1816.
18 McFarland C, Glisky E: Implementation intentions and imagery: individual and combined effects on prospective memory among young adults. Mem Cogn 2012;40:62–69.
19 Altgassen M, Rendell PG, Bernhard A, Henry JD, Bailey PE, Phillips LH, Kliegel M: Future thinking improves prospective memory performance and plan enactment in older adults. Q J Exp Psychol 2014;68:192–204.
20 Schmidt IW, Berg IJ, Deelman BG: Prospective memory training in older adults. Educ Gerontol 2001;27:455–478.
21 Rhodes SM, Donaldson DI: Electrophysiological evidence for the effect of interactive imagery on episodic memory: encouraging familiarity for non-unitized stimuli during associative recognition. Neuroimage 2008;39:873–884.
22 Albiński R, Kliegel M, Gurynowicz K: The influence of high and low cue-action association on prospective memory performance. J Cogn Psychol 2016;28:707–717.
23 Schnitzspahn KM, Zeintl M, Jäger T, Kliegel M: Metacognition in prospective memory: are performance predictions accurate? Can J Exp Psychol 2011;65:19–26.
24 West R: The temporal dynamics of prospective memory: a review of the ERP and prospective memory literature. Neuropsychologia 2011;49:2233–2245.
25 Wechsler D: Manual for the Wechsler Adult Intelligence Scale-Revised. New York, Psychological Corporation, 1981.
26 Hornowska E: Skale Inteligencji dla Dorosłych Davida Wechslera WAIS-R oraz WAIS-III. Warsaw, Scholar, 2004.
27 Unsworth N, Heitz RP, Schrock JC, Engle RW: An automated version of the operation span task. Behav Res Methods 2005;37:498–505.
28 Jasielska A, Kaczmarek L, Brońska A, Dominiak M, Niemier K, Patalas D, Sokołowski A, Tomczak M: Związek pamięci roboczej ze strategiami regulacji emocji. Ann Psychol 2015;XVIII:553–565.
29 Crawford JR, Smith G, Maylor EA, Della Sala S, Logie RH: The Prospective and Retrospective Memory Questionnaire (PRMQ): normative data and latent structure in a large non-clinical sample. Memory 2003;11:261–275.
30 Smith RE, Bayen UJ: A multinomial model of event-based prospective memory. J Exp Psychol Learn Mem Cogn 2004;30:756–777.
31 Luo L, Craik FIM: Aging and memory: a cognitive approach. Can J Psychiatry 2008;53:346–353.
32 West R, Herndon RW, Covell E: Neural correlates of age-related declines in the formation and realization of delayed intentions. Psychol Aging 2003;18:461–473.
33 Zöllig J, West R, Martin M, Altgassen M, Lemke U, Kliegel M: Neural correlates of prospective memory across the lifespan. Neuropsychologia 2007;45:3299–3314.
34 Cuenen A, Jongen EMM, Brijs T, Brijs K, Houben K, Wets G: Effect of a working memory training on aspects of cognitive ability and driving ability of older drivers: merits of an adaptive training over a non-adaptive training. Transp Res Part F Traffic Psychol Behav 2016;42:15–27.
35 Dunning DL, Holmes J: Does working memory training promote the use of strategies on untrained working memory tasks? Mem Cogn 2014;42:854–862.