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Prospective memory training in young adults enhances trained-task but not transfer-task performance

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ABSTRACT
Training and transfer effects of prospective memory training have not been assessed in healthy young adults yet. The present study examined the effects of an 8-day prospective memory training programme using the Virtual Week computer game in 18–24-year-old students. Using the performance of an active control group as comparison, the study revealed a significant short-lived beneficial training-induced effect on a nearest-transfer task consisting of a different version of the trained task. No evidence was obtained for transfer effects to other tasks measuring prospective memory (near transfer), or to tasks measuring various executive functions or general intelligence (far transfer). These results were compared to those from a previous study in which an identical training and testing protocol was used in 13–15-year-old adolescents. This study did reveal some evidence of near and far transfer. The results of the two studies combined suggest a greater potential for prospective memory training to induce beneficial transfer effects in young adolescents than in young adults.

Prospective memory (PM) refers to cognitive processes that are necessary to remember to perform intended actions (Einstein & McDaniel, 1996). PM is crucial for many daily-life tasks and disease- or ageing-induced PM impairments can have serious consequences for one’s ability to live independently (e.g., Hering, Kliegel, Rendell, Craik, & Rose, 2018; Woods et al., 2008). Previous research examined whether PM capacity can be enhanced through targeted process-based, restorative cognitive training (Hering, Rendell, Rose, Schnitzspahn, & Kliegel, 2014; Raskin & Sohlberg, 2009). One training variant consists of direct training on a PM task, rather than training one or more executive functions (EFs) thought to underlie PM performance, such as working memory, response inhibition, and task switching (e.g., Brom & Kliegel, 2014). There are only a few examples of direct restorative PM training studies (Raskin & Sohlberg, 1996, 2009; Rose et al., 2015; Sohlberg, White, Evans, & Mateer, 1992; Zhao, Junjun, Maes, 2019), and, to our knowledge, only two of these used healthy samples. Specifically, Rose et al. (2015) trained older participants using a computerised PM task and found transfer of training gains to real-world PM tasks but not to laboratory-based PM and EF tasks. Zhao et al. (2019) examined the effects of a similar PM training programme in 13–15-year-old adolescents. Relative to adolescents in an active control group, the trained adolescents displayed a training-induced performance improvement on a new version of the trained task (nearest transfer), and on a non-trained PM and working memory (WM) task.

One factor that may modulate training and transfer gains in healthy subjects is the trainee’s age. Performance on PM tasks with features implying a strong involvement of EFs, such as those involving non-salient cues that are not focal to the ongoing task or time-based PM cues (e.g., Einstein et al., 2005; Mäntylä, 1996), show an inverted U-shaped developmental trajectory. Such trajectory also holds for tasks measuring EFs putatively underlying PM (Kliegel, Mackinlay, & Jäger, 2008; Mahy, Moses, & Kliegel, 2014). Given this trajectory, there are two possible lines of reasoning concerning differences in receptivity to cognitive training in general, and to PM training in particular. According to the first account, the compensation account (e.g., see Karbach & Unger, 2014), participants who perform suboptimal (before training), either because being on the increasing (children) or decreasing (older participants) slope of the U-shaped developmental trajectory, will profit more from training than those already performing optimally. This is because there is more room for improvement, also potentially based on a higher degree of neural plasticity, in the former participants. The second view, the magnification account, instead holds that those with strong cognitive abilities, in this case associated

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with young adulthood, will profit most because these individuals have more cognitive resources for learning and applying new abilities. For process-based cognitive training targeting executive functions, the evidence largely seems to support the compensation account (e.g., Karbach & Unger, 2014; Von Bastian & Oberauer, 2014; Zhao, Chen, & Maes, 2018). However, whether this also holds for PM training remains to be investigated.

The aim of the present study was to assess, for the first time, training and transfer effects of PM training in healthy young adults. We employed the same training protocol as was used in the study by Zhao et al. (2019) in a sample of young adolescents and, as a second aim, we also wanted to compare the results of the present and previous study. According to the magnification account, we should expect equal or better training-induced gains in the present adult sample compared to those observed in the adolescents. Instead, the compensation account would predict less benefits for the adults, already having fully-developed PM and underlying EF capacities, than adolescents. In terms of the type of EFs that could benefit from the PM training (if at all), we especially expected WM to profit from the training.

This is because of the hypothesised strong involvement of this specific component of executive functioning in at least three of the different stages of PM, the formation, retention, and initiation of the intention (e.g., Mahy, Moses, & Klügel, 2014). Moreover also empirically, specifically this component showed significant training-induced benefits of the computerised PM training task used in the adolescent sample in Zhao et al. (2019), next to benefitting performance on a non-trained, time-based PM transfer task.

Method

Participants

The participants were 70 college students from Lanzhou city, China. Most students (90.0%) were from the Han population; the others were from minority groups, such as Chinese Hui Muslims. The sample size was based on a power analysis using a conservative estimate of the expected effect size. This effect size was based on the difference in mean score for the trained and non-trained groups on those post-training tasks that revealed a significant transfer effect in the study by Zhao et al. (2019; Cohen’s effect sizes ≥0.68). Using $d = 0.68$, $\alpha=0.05$, and 1-$\beta=0.80$, the power analysis revealed a sample size of 28 for each group. All participants signed an informed consent form and participated voluntarily. Two students dropped out during pre-testing and the remaining participants were randomly assigned to equal-sized training and active control groups. One participant did not complete the entire training programme. The mean age of the remaining participants from the training group ($n = 34$; 14 men) was $M = 21.3$ (SD = 1.2) years; for the control group ($n = 33$; 14 men), $M = 20.7$ (SD = 1.2) years. All participants were right handed and had normal or corrected-to-normal vision. None of the participants was colour blind and had a history of psychiatric or neurological disease. All participants received a small financial remuneration upon completion of the tasks. The study was approved by the Ethics Committee of Psychological Experiments of Northwest Normal University.

Pre-training, post-training, and follow-up tests

All participants first performed a test battery (pre-training assessment). This battery was repeated immediately after the training and control groups had completed their respective treatments (post-training assessment) and, for one task, also 3- and 6-months thereafter. The tests included in the battery, and corresponding dependent measures, were as described in Zhao et al. (2019). Briefly, the PM task used to measure nearest-transfer effects consisted of a variant of the Virtual Week (VW) task (Rendell & Henry, 2009; Rose et al., 2015) that was also used for training (see below) but with different to-be- performed activities. Task difficulty was the same as that on Virtual Week training Day 7 (see below). Near transfer was measured using an event-based PM (hereafter: EBPM-focal 1) task based on a dual-task paradigm (Bisiacchi, Schiff, Ciccola, & Klügel, 2009), and a time-based PM (TBPM) task originally developed by Cona, Arcara, Tarantino, and Bisiacchi (2012). In addition to these PM tasks, the present study also included a task measuring EBPM with cues that were either focal (hereafter: EBPM-focal 2) or non-focal (hereafter: EBPM-non focal). This task consisted of remembering to respond to target letters (focal trials), or the colour of the frame surrounding target letters (non-focal trials), while the participant was engaged in an ongoing 2-back memory updating task involving letters (see Zuber, Klügel, & Ihle, 2016). We also included various WM measures. The first was based on the 2-back WM updating task that was used during the first test block of the EBPM-2 task. The other WM measures were derived from a running working memory (RWM) task with a long (easy task) and short (difficult task) inter-stimulus interval. Response inhibition was assessed using a go/no-go (GNG) task with letters, and interference control by means of standard Stroop colour-word and flanker tasks. Task-switching ability was assessed using a task involving switching between a parity and magnitude judgement about single digits. General intelligence was measured using Raven’s Standard Progressive Matrices (RSPM) and Raven’s Advanced Progressive Matrices (RAPM) tests.

Computerised training programme

We used Virtual Week for training. The training programme was based on that described by Rose et al. (2015). Briefly, Virtual Week concerns a board game in which the participant moves around with the roll of a dice, which is part of the ongoing task. The times of day at which people are usually awake are indicated on the board. Each circuit of the board represents one virtual day. Another aspect
of the ongoing task is the requirement to make choices about daily activities, such as what to eat for breakfast. The PM tasks entail the requirement to perform lifelike activities, that is, select a specific item from a list containing distractor items, upon encountering specific cues or events (EBPM task), or at specific times (TBPM task). Some of these activities concern regular tasks, to be performed on each virtual day of a given virtual week. Other activities involve irregular tasks that only must be performed on the current virtual day. In addition, there are also time-check tasks requiring the participant to monitor real time on a clock. The clock is either permanently visible or hidden. Task difficulty can be manipulated by changing the number of regular, irregular and/or time-check tasks, by hiding or not hiding the clock, and by changing the number of lure options on the list of the to-be selected item. During training, the participant performed three virtual days on each of eight training days. Each virtual day was repeated until the percentage of correctly performed PM tasks was larger than 70%. The difficulty level was mostly increased across training by increasing the total number of irregular and time-check tasks, the number of lure options, and/or by hiding the clock. This increase was pre-specified, that is, not based on the participant’s performance (see Appendix A). The main dependent measures were the percentage of correctly completed tasks and the number of repetitions required to achieve the minimum accuracy level.

**Procedure**

All participants completed the pre-training tasks in two days in a fixed order: RSPM and RAPM (even items), GNG, flanker, Stroop, RWM-easy, RWM-difficult, switching, EBPM-1, TBPM, VW, and EBPM-2 tasks. The students in the training condition then completed the 8-day VW-task training. During the time that the students in the training group were working on the VW tasks, the participants from the control group made sand paintings in the same campus setting. All participants then completed the same post-training test sessions in the same order as described for the pre-training sessions except for using the odd items of the RSPM and RAPM. A 3- and 6-month follow-up assessment session (hereafter: F3 and F6 session, respectively) was performed for the VW task.

**Data analysis**

The training data were analysed using repeated measures analysis of variance (RM-ANOVA), with Virtual Day (24) as within-subject factor. RM-ANOVAs were performed on the main dependent variable from each assessment task, with Group (training vs. control) as between-subjects factor, and Session as within-subject factor (either pre-training vs. post-training, pre-training vs. F3, or pre-training vs. F6, if applicable). Critical significant Group × Session interactions were further evaluated using simple main effect analyses, while correcting for family-wise Type 1 error inflation by adjusting the α level. Partial eta-squared ($\eta_p^2$) was used as effect-size estimate.

**Results**

The mean accuracy level across the 24 VW training levels (for each level taking the final repetition) is displayed in the left panel of Figure 1. ANOVA revealed a strong quadratic trend, $F(1, 32) = 115.38, p < .001, \eta_p^2 = .78$. A similar trend was observed for the average number of repetitions that were required for achieving >70% accuracy (Figure 1, right panel), $F(1, 32) = 25.07, p < .001, \eta_p^2 = .44$. The peaks in the latter panel reflect the introduction of new regular tasks on Virtual Day 9, and usage of a combination of 4 regular, irregular, and time-based tasks, and 3 lure options for the first time on Virtual Day Day 14. Overall, these results are indicative of training-induced performance improvements because task difficulty was mostly gradually increased across virtual days, except on the last three training days. Specifically, task difficulty on each of Virtual Days 19–21 was repeated on Virtual Days 22–24. The strong increase in accuracy on the last three virtual days reflects a strong repetition/training-induced task performance benefit.

**Figure 1.** Left panel: Mean (±standard error of the mean; SEM) percentage of trials with a correct response, pooled across trial types, for each of the virtual days. Right panel: Mean (±SEM) number of repetitions required to achieve >70% response accuracy on each of the virtual days.
A temporary training benefit was also visible in VW transfer-task performance (see Figure 2 for the groups’ performance on each of the assessment tasks and sessions).

ANOVA on the pre- and post-training VW data revealed a significant effect of group, $F(1, 65) = 10.86, p < .002, \eta^2_p = .14$, session, $F(1, 65) = 16.70, p < .001, \eta^2_p = .20$, and their interaction, $F(1, 65) = 18.85, p < .001, \eta^2_p = .23$. The session effect was significant for the trained students, $F(1, 32) = 46.16, p < .001, \eta^2_p = .58$, reflecting more accurate responding on the post- compared to pre-training session, but not for the students in the control group, $F < 1$. The trained students performed significantly more accurate than the control participants during the post-training session, $F(1, 65) = 36.78, p < .001, \eta^2_p = .36$, but not the pre-training session, $F < 1$. This training-induced beneficial effect was no longer present on the F3 and F6 sessions, as reflected in Figure 2.
in the absence of a Group × Session interaction effect in the corresponding ANOVAs, \( ps > .09 \). These results provide evidence for a short-lived training-induced beneficial effects on the VW assessment task.

None of the ANOVAs on the data of the remaining tasks revealed a significant interaction effect, \( Fs(1, 65) < 3.62, ps > .06, \eta^2_p < .05 \). The main effect of group was significant for the TBPM and 2-back WM tasks, \( ps < .04 \), reflecting overall better performance for the trained group. The main effect of session was significant for the focal EBPM-2, TBPM, WM-easy, WM-difficult, RSPM, and RAPM tasks, \( ps < .02 \). These results suggest no specific, training-induced benefits for the non-trained tasks, and a general test-retest practise effect for some of the transfer tasks.

**Discussion**

The present group of healthy adult participants completed a PM training programme using the Virtual Week task and showed beneficial practice effects on the trained task. This was most clearly visible when comparing performance on a version of the training task before and immediately after training for the trained group and an active control group. This comparison revealed significantly better post-training performance in the trained than control group. However, this training benefit was no longer present at 3-month follow-up, which is indicative of a short-lived nearest transfer effect. The training did not seem to benefit performance on any of the other near- and far-transfer tasks measuring executive functions or general intelligence.

These results can be compared to those obtained with an identical training programme employed in a sample of young adolescents, as described in Zhao et al. (2019). Performance changes observed across training were similar in the two studies, although overall performance was at a higher level in the present adult sample. However, both training groups started with similar initial levels of performance accuracy and number of required task repetitions. This, combined with the general decreasing trend in performance accuracy in the first 20 training sessions in both studies and the relatively minor absolute between-study differences in required number of task repetitions, suggests that the observed differences in transfer results between the two studies were not likely due to large differences in the extent to which the PM task was challenging in the two age groups. The differences in transfer results concern the facts that the trained adolescents, but not corresponding adults, displayed a maintained nearest transfer effect at 3-month follow-up, showed a short-lived beneficial near-transfer effect to a non-trained time-based PM task, and demonstrated a short-lived far-transfer effect to one of the working memory tasks. In both studies, there was a significant general test-retest improvement for both groups, at least for a number of transfer tasks. The latter observation, together with the accuracy levels displayed in Figure 2, suggest that the transfer differences between the two studies were not likely due to ceiling effects in the present study. For the TBPM and difficult WM tasks, the tasks for which the adolescents showed significant transfer, there seemed to be still sufficient room for (differential) performance improvement in the adults, despite their overall better performance accuracy on these tasks.

Although based on between-study comparisons, the combined results from the two studies suggest somewhat stronger near and far-transfer effects of PM training in young adolescents than in young adults (see also Zhao, Chen, & Maes, 2018, for similar results in a response inhibition training study). The combined data might suggest that the training affected different processes in the two age groups. For example, for the adults the training might have promoted their use of a relatively task-specific strategy, while the executive functions (potentially) demanded in performing the task, particularly working memory (see Mahy et al., 2014) were already optimal. Instead, the same training in the adolescents might have enhanced their initially sub-optimally functioning cognitive processes that were also conducive to performing the TBPM and RWM tasks, thereby demonstrating greater cognitive plasticity than the adults. Such interpretation would be in line with a compensation account of cognitive training. However, an alternative account is that the between-study, age-related transfer-effect differences are entirely due to differences at the level of the use of low cognitive resource-demanding task strategies, rather than at the level of executive functions. Accordingly, for the adolescents, training enhanced the use of more general task strategies, which were transferable to at least some other, non-trained tasks, compared to the task-specific strategies developed by the adults. Future research is necessary to test the validity of these different theoretical accounts. Such research should also incorporate more ecologically valid measures of PM performance, to further test age-related transfer differences of computer-based PM training protocols. Based on the compensation account and the present results, one could expect PM training to have stronger beneficial effects on ecologically valid, daily-life PM transfer tasks in children, young adolescents, and older adults (e.g., see Rose et al., 2015) than in young adults.

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