**The effect and mechanisms of implementation intentions on prospective memory
in individuals with and without schizotypal personality features**

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Abstract

Prospective memory (PM) refers to remembering to do something at a future time. Studies showed that implementation intention can improve PM performance. The present study aimed to examine the effect and mechanism of implementation intention on PM in individuals prone for schizotypal personality disorder (SPD proneness) in laboratory condition. Fifty-one participants with SPD proneness and 51 controls were administered a PM task. They were further randomly assigned to an implementation intention condition and a typical instruction condition. All participants completed the PM task with low and high cognitive load conditions. The results showed that implementation intention improved PM performances in both SPD proneness and control groups, indicating that implementation intention was an effective strategy for improving PM performance. However, the mechanisms were different for the two groups. For controls, implementation intention did not affect their cognitive resources allocation strategy. Participants with SPD proneness allocated significantly more cognitive resources to PM task in the implementation intention condition.

Keywords: prospective memory; implementation intention; schizotypal personality proneness

Running head: Implementation intention effect on prospective memory

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Forming an intention and realizing it at a later time (i.e., prospective memory, PM) are very important in our daily life (Einstein & McDaniel, 1996). For example, patients have to remember to take medication at the right time; parents have to remember to pick up their children from day care; and managers must remember to attend important meetings. PM failures may cause serious consequences, sometimes life threatening. In PM studies, participants usually have to engage in an ongoing task. Concurrently, they have to monitor the environment and execute the PM task when: a PM cue(s) appears (i.e., event-based PM); a particular time is reached (i.e., time-based PM); an activity has been finished (i.e., activity-based PM) (Einstein & McDaniel, 1990; Kvavilashvili & Ellis, 1996).

Because of the importance of PM, some strategies have been suggested to improve people's PM performance (Chasteen, Park, & Schwarz, 2001; Fish et al., 2007; Hashimoto, Umeda, & Kojima, 2011). One of them is implementation intention, put forward by Gollwitzer (1993, 1996, 1999) to help achieve people's intentions and goals. This technique has been shown to be effective in several domains such as improving performances of inhibition and working memory tasks (Gollwitzer & Sheeran, 2006). Specifically, implementation intention prescribes an encoding in the form "if I encounter X then I will do Y" (Gollwitzer, 1999). It consists of two related components, the first component specifies the exact situation X that the action is to be executed, and the second component specifies the desired action Y. And it also helps to form a strong link between the target cues to the intended task. A number of studies have shown that implementation intention could be used to improve

healthy people's PM performance (Breneiser, 2009; Cohen & Gollwitzer, 2008; Gollwitzer & Sheeran, 2006; McDaniel, Howard, & Butler, 2008; McDaniel & Scullin, 2010; McFarland & Glisky, 2012; McFarland & Glisky, 2009), including older adults who might show some cognitive impairments (McFarland & Glisky, 2011; Zimmermann & Meier, 2009).

Moreover, the technique has been applied to some clinical and subclinical groups. For example, Kardasmenos et al. (2008) found that implementation intention improved PM performance in patients with multiple sclerosis. Empirical findings have shown that schizophrenia patients were impaired in all types of PM (Wang et al., 2009), whereas individuals with subclinical features of schizophrenia such as schizotypal personality disorder proneness (SPD proneness) were impaired in time- and event-based PM (R. C. Chan et al., 2008; Wang et al., 2008). Given that individuals with SPD proneness share similar but a milder form of subclinical symptoms (e.g., ideas of reference, social anxiety) (Raine, 1991) and cognitive deficits (Gooding & Tallent, 2003; Kopp, 2007) with patients with schizophrenia, it would be theoretically interesting to examine if the implementation intention strategy will exert its effect upon the PM performances in individuals with SPD proneness.

For the underlying mechanisms of implementation intention, it remained unclear and controversial. Gollwitzer (1999) contended that implementation intention set up a linkage between intention and specific cues, and made the initiation of the intended action process upon detecting the cues automatic. According to this perspective, implementation intention improves PM performance

by reducing the degree of reliance on cognitive resources. McDaniel and colleagues (2008) reported that ongoing task performance was not influenced by implementation intention. Moreover, when implementation intention was formed, there was no PM performance decline in high cognitive load condition (by adding a random number generation task to the ongoing task) compared with the standard cognitive load condition (without the random number generation task). These results are consistent with the idea that implementation intention initiates an automatic process for PM.

Another viewpoint suggested that implementation intention makes people more conscious about the PM task and perceive it as more important (Kliegel, Martin, McDaniel, & Einstein, 2004). Based on this viewpoint, implementation intention improves PM performance by changing participants' cognitive resources allocation strategies, that is, making them pay more attention to monitor the PM cues to improve their PM performance. In line with this viewpoint, Zimmermann and Meier (2009), Meeks and Marsh (2010) found implementation intention increased PM accuracy but decreased ongoing task performance (longer reaction time) at the same time.

Recently, McDaniel and Scullin (2010) reported that although there was no decline in ongoing task performance when implementation intention was formed, the technique did not benefit PM when cognitive resources were challenged by adding a more difficult secondary task. They suggested that implementation intention was effective because they formed a robust associative encoding between

the PM cues and the intentions which may stimulate spontaneous retrieval of the intended actions (McDaniel, Guynn, Einstein, & Breneiser, 2004; Scullin, McDaniel, & Einstein, 2010). However, the retrieval of the action does not guarantee participants accomplish the PM task. Because participants still have to execute the action besides the retrieval of the intend action. The execution of the action needs cognitive resources. Thus, even with implementation intention, cognitive resources are still needed to execute the PM task by competing with ongoing task, particularly when the cognitive resources are limited. This study would further examine the mechanisms of implementation intention.

Given the above, the aims of the present study were (1) to examine the effects of implementation intention on PM performance in SPD proneness individuals and controls. (2) to explore the mechanisms of implementation intention on PM in SPD proneness individuals and controls as well as their differences. In the study we used the typical prospective paradigms developed by Einstein and McDaniel (1990). The participants had to execute the PM task when the PM cues appeared while they were busily engaged in an ongoing task (N-back task in this study). Since the effect of implementation intention on PM was supported by studies in both healthy and clinical populations, we expected that implementation intention would also be effective in improving PM performance in participants with SPD proneness.

In addition, we varied the cognitive load of ongoing task to explore the mechanism of implementation intention. The cognitive load was manipulated by the level of N-back task (1-back vs. 2-back. From pilot study, we found that 2-back as a

high cognitive load condition was strong enough to differentiate from 1-back as a low cognitive load condition). Given the above mentioned mechanisms of implementation intention and cognitive impairments such as working memory deficits in SPD proneness population (Gooding & Tallent, 2003; Kopp, 2007), we predicted that the mechanism of implementation intention may be different between participants with SPD proneness and the controls. Specifically, they might behave similarly with the controls when the cognitive load was low, but differently when the cognitive load was high. For the controls, we expected that if the task in high cognitive load condition was demanding enough, implementation intention would not automatize PM responding as shown by McDaniel and Scullin (2010). We would like to further examine the mechanism of implementation intention by using a demanding task in the high cognitive load condition. We predicted that for healthy controls implementation intention might initiate a spontaneous retrieval of the PM task, but extra resources were still needed to accomplish the PM task. Therefore implementation intention could improve their PM performance in low cognitive load condition, but not if the cognitive resources were challenged in high cognitive load condition.

For the participants with SPD proneness, because of their limited cognitive ability (Gooding & Tallent, 2003; Kopp, 2007), implementation intention might alter their cognitive resources allocation strategy, such as paying more attention to the PM task. Thus we predicted that in the low cognitive load condition implementation intention would improve their PM performance without reducing ongoing task

performance. However, in the high cognitive load condition, implementation intention would improve their PM performance but reduce the corresponding ongoing task performance.

Method

Ethics Statement. This study was approved by the ethical committee of Institute of Psychology, Chinese Academy of Sciences. All participants provided written informed consent after they were given a brief introduction to the study and a chance to ask questions relating to the study. Participants in this study were recruited from university students from Beijing and they were paid for their participation.

Participants and Design. A total of 700 undergraduate students completed the Schizotypal Personality Questionnaire (SPQ) (Chen, Hsiao, & Lin, 1997; Raine, 1991). These participants were then classified into those with and without SPD proneness. According to the manual of SPQ (Raine, 1991), individuals who scored at the top 10 percent of the total sample were selected as SPD proneness group (mean SPQ score = 42.39, $SD = 5.98$), and the participants who scored at the bottom 10 percent were selected as participants without SPD features (control group, mean SPQ score = 8.88, $SD = 4.75$). A total of 105 participants participated in this study. Data of 3 participants were excluded in the analyses because their SPQ scores fluctuated significantly from questionnaire survey to experiment study (see procedure section). This resulted in a total of 102 participants (51 SPD proneness and 51 controls). Before the experiment, all participants were asked to complete a questionnaire about their

demographical information and they also undertook an IQ test. IQ was estimated using the short form (information, arithmetic, similarity, and digit span) of the Chinese version of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) (Gong, 1992). This method has been used to estimate intellectual functioning before (Blyler, Gold, Iannone, & Buchanan, 2000; E. Chan, Chen, & Chan, 2005). The SPD proneness group and the control group did not differ significantly in gender ratio, age, education and IQ, all $p > .05$ (SPD proneness group: 23 males, 28 females; age: $M = 20.24$, $SD = 1.62$; years of education: $M = 13.65$, $SD = 1.52$; IQ: $M = 120.76$, $SD = 8.60$; control group: 28 males, 23 females; age: $M = 20.39$, $SD = 1.76$; education years: $M = 13.51$, $SD = 1.55$; IQ: $M = 121.69$, $SD = 8.37$). Participants in the SPD proneness group and control group were further randomly assigned to an implementation intention condition and a typical instruction condition. The demographical variables were not significantly different between participants in the implementation intention condition and typical instruction condition.

A 2 (PM instructions: implementation intention, typical instruction) $\times$ 2 (group: SPD proneness, control) $\times$ 2 (cognitive load: high, low) mixed design was used in this study. PM instructions and group were between-group variables, and cognitive load was a within-subject variable.

We adopted a typical dual-task PM paradigm in this study (Einstein & McDaniel, 1990). The implementation intention was manipulated by “if...then...” instructions. An N-back task with varying levels of cognitive load (1back, 2back) was used as the ongoing task. The dependent variables were accuracy and

reaction times of PM and ongoing tasks.

Procedure. The flow of the study was: instruction of N-back task (Callicott et al., 1998), practice of N-back task, formal N-back task (without PM), instruction of PM task, questionnaire filling as a delay task, and then formal experiment tasks (N-back task with PM task). At first, the participants learned the instructions of the N-back task. They were told that two-character words in two categories would be presented on the center of the screen: animals (e.g., monkey, dog) and non-animals (e.g., table, computer). They were instructed to judge whether the current word was in the same category as the one presented just before (1-back) or the word 2 positions back in the sequence (2-back). The participants were further instructed to do the N-back task as quickly and accurately as possible by pressing the "J" key when the two words were in the same category, or "F" key when the two words were in different categories. The participants performed the 1-back and 2-back tasks in sequence. Such an arrangement might make it easier for them to understand the requirement of the task and complete it. Similar procedure has been adopted in prior study of cognitive load task manipulation (Callicott, et al., 1998). Then the participants were given 20 practice trials for each 1-back and 2-back tasks to ensure they understood the task. After the practice, the participants undertook 1-back task and 2-back task with one block for each, without mentioning PM task. After finishing the N-back task, participants were given instructions for the PM task. They were told that there was an additional task that they needed to do, that is, to press the spacebar if they ever saw any one of four target words (viz., butterfly, peafowl, towel,

and curtain). The participants were told that their primary goal was still to respond to the N-back task.

After reading the PM task instructions, the participants were asked to explain the instructions and recall the four target words to the experimenter, and imagine performing the task for 30 seconds (Chasteen, et al., 2001; McDaniel, et al., 2008). For the implementation intention group, the participants were asked to repeat “When (if) I see butterfly, peafowl, towel, or curtain during the N-back task, then I will press the spacebar” three times out loud (Cohen & Gollwitzer, 2008). And then they were asked to imagine (for 30 sec) seeing butterfly, peafowl, towel, or curtain appear on the computer screen and pressing the spacebar. For the typical-instruction group, the instruction of PM did not ask the participants to form a link between the cues and targets and avoided the format “when (if)…, then…”. They just read the instructions and explained them back to the experimenter and then imagined performing the N-back task for 30 sec.

Before beginning the PM task, the participants were asked to finish a series of questionnaires (lasting about 15 minutes) including the SPQ as a delay task. The SPQ was retested to see whether the SPQ scores of the participants were stable. Three participants showed a large fluctuation on SPQ score and were excluded in subsequent analyses. Then the formal experiment began. A total of 4 blocks of PM task were conducted, 2 blocks with low cognitive load (1-back) and 2 blocks with high cognitive load (2-back). The 2 high cognitive load blocks and the 2 low cognitive load blocks were counterbalanced with the low cognitive load blocks conducted first. Each

block had 120 trials including 4 PM target trials. The four target words randomly appeared at the 23th or 24th trial, 50th or 51st trial, 83th or 84th trial, and 110th or 111th trial (McDaniel, et al., 2008; McDaniel & Scullin, 2010). The participants were given a short break every 60 trials. After the experiment, the participants were asked to recall the four PM target words and the PM task requirements.

Results

Ongoing task trials with reaction times outside the range of ± 2.5 standard deviations from each participant's means were excluded for analysis.

The effect of cognitive load and the PM performance of SPD proneness

We calculated the proportion of correct PM responses and the reaction times on correct trials in each experimental condition, and these means are displayed in Table 1. The data were submitted to a mixed 2×2×2 ANOVA to examine the difference of PM performance between the SPD proneness participants and the controls. The main effect of cognitive load was also tested to ensure the manipulation of cognitive load was effective. The alpha level for concluding significance was set at .05. The main effect of cognitive load was significant for ongoing task [accuracy: $F(1,94) = 135.40, p < .001$; reaction time: $F(1,94) = 58.42, p < .001$], indicating that the manipulation of cognitive load was effective. The main effect of cognitive load was also significant for PM accuracy [$F(1,94) = 16.98, p < .001$], the PM accuracy was lower in the high cognitive load condition than in the low cognitive load condition.

With regard to the main effect of group on PM accuracy, there was no significant difference found between SPD proneness and control groups [$F(1,98) =$

TABLE 1

Performance of PM task in each group and condition

		<i>SPD proneness</i>		<i>Control</i>	
		<i>Low cognitive load</i>	<i>High cognitive load</i>	<i>Low cognitive load</i>	<i>High cognitive load</i>
		<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Implementation intention	Accuracy	0.71 (0.20)	0.57 (0.24)	0.73 (0.24)	0.60 (0.34)
	Reaction time (ms)	972.0 (230.1)	936.8 (313.2)	1013.6 (338.6)	1104.5 (401.9)
Typical instruction	Accuracy	0.46 (0.32)	0.33 (0.33)	0.54 (0.33)	0.47 (0.31)
	Reaction time (ms)	996.9 (275.1)	1116.6 (298.2)	1036.3 (276.8)	1118.7 (332.0)

1.60, $p = .210$]. In order to exclude the potential influence of retrospective memory on PM performance, we conducted an additional analysis and only analyzed the data of the participants who could correctly recall all four PM target cues (butterfly, peafowl, towel, and curtain) at the end of the task, this resulted in 84 participants in total (41 SPD proneness [25 in implementation intention condition and 16 in typical instruction condition, and 43 controls [20 in implementation intention condition and 23 in typical instruction condition). Participants in SPD proneness group ($M = .54$) showed significantly poorer PM performance compared with participants in the control group ($M = .65$) [$F(1,80) = 4.91, p = .030$]. This was consistent with previous studies that SPD proneness individuals showed impairments in PM (R. C. Chan, et al., 2008; Wang, et al., 2008). Moreover, under the low cognitive load condition, there were no significant differences found between participants with SPD proneness ($M = .63$) and controls ($M = .68$) [$F(1,80) = 2.4, p = .130$]. However, under the high cognitive load condition, performance of participants in the control group ($M = .61$) was significantly better than that of participants in the SPD proneness group ($M = .50$) [$F(1,80) = 5.19, p = .025$]. These results indicated that a possible reason for the poorer performance of SPD proneness participants might be due to that their cognitive resources were reduced and did not have enough cognitive resources to accomplish the PM task when the ongoing task was difficult. However, in order to ensure the statistical power of our results, the following analyses were based on the data of all 102 participants. None of the main effects or interactions on PM reaction time was significant, thus PM reaction time was not analyzed further.

The effect of implementation intention on PM performance

For the 2×2×2 ANOVA, there was a significant main effect of implementation intention on PM accuracy [$F(1,98) = 15.31, p < .001$], and implementation intention significantly improved PM performance. In order to test our hypothesis that implementation intention would improve PM performance in SPD proneness individuals. We conducted a 2×2 ANOVA for SPD proneness group, results showed there was a significant main effect of implementation intention, implementation intention significantly improved their PM performance ($M = .64$) compared with typical instruction condition ($M = .39$) [$F(1,49) = 13.31, p = .01$].

Comparison of the mechanisms of implementation intention on PM between controls and SPD proneness

In order to examine the mechanism of implementation intention, and to examine our hypothesis that SPD proneness participants and controls might have different mechanisms, a set of planned comparisons was conducted and the data of SPD proneness and control participants were analyzed separately. Such analyses were more direct to examine our research purposes discussed in the introduction (Callender & McDaniel, 2007; McDaniel, et al., 2008; McDaniel & Scullin, 2010).

The key to test our hypotheses was to evaluate whether implementation intention effects were influenced by cognitive load. We compared the low and high cognitive load conditions in implementation intention group. If the implementation intention was affected by cognitive load, we would contrast whether implementation intention would benefit PM performance under high or low cognitive load conditions

respectively.

Control group. Performance of PM task. High cognitive load produced significant decline in PM performance relative to low cognitive load condition [$F(1,49) = 7.36, p = .009$]. Moreover, even with implementation intention, PM performance of participants declined significantly under high cognitive load condition ($M = .60$) compared with low cognitive load condition ($M = .73$) [$F(1,49) = 6.72, p = .016$]. More importantly, under low cognitive load condition, implementation intention significantly produced an increase in PM performance [$F(1, 49) = 5.44, p = .024$]. While under high cognitive load condition, there was no significant difference between implementation intention group and typical instruction group [$F(1,49) = 1.86, p = .179$]. These results were consistent with those of McDaniel and Scullin's (2010) study that implementation intention produced a significant better PM performance than that with typical instruction. However, implementation intention did not confer benefits (relative to typical instructions) to PM in the high cognitive load condition. Such results may indicate that implementation intention was affected by cognitive resources.

Control group. Performance of ongoing (N-back) task. We calculated the proportion of correct N-back task responses and the reaction times of correct responses in each experimental condition, and these means are displayed in Table 2. Cognitive load had a significant main effect on N-back task accuracy [$F(1,47) = 77.62, p < .001$]. The accuracy of N-back task under high cognitive load condition ($M = .79$) was significantly lower than that under low cognitive load condition ($M = .89$). In

addition, the cognitive load also had a significant main effect on reaction time [$F(1,47) = 25.83, p < .001$], with the reaction time of N-back task under high cognitive load condition ($M = 1230.7$) longer than that under low cognitive load condition ($M = 1066.5$). The main effects of implementation intention were not significant for both accuracy and reaction times of the ongoing task. These results indicated that implementation intention did not affect the performance of N-back task which meant that the cognitive resources for the ongoing task were not sacrificed for the PM task. The interaction between implementation intention and cognitive load was significant for reaction time [$F(1,47) = 4.43, p = .041$] but not for accuracy. Simple effect tests showed that for the typical instruction group, reaction time in the high cognitive load condition ($M = 1326.8$) was longer than that in the low cognitive load condition ($M = 1065.6$) [$F(1,47) = 26.37, p < .001$]. For the implementation intention group, reaction time in the high cognitive load condition ($M = 1164.0$) was also longer than that in low cognitive load condition ($M = 1067.8$) [$F(1,47) = 4.34, p = .043$], but to a smaller degree. And no matter in which level of cognitive load condition, there were no significant differences in reaction time between the implementation intention and the typical instruction groups. These results were consistent with previous studies (McDaniel, et al., 2008; McDaniel & Scullin, 2010). It could be caused by the manipulation of cognitive load.

SPD proneness group. Performance of PM task. Cognitive load had a significant main effect [$F(1,47) = 77.60, p < .001$]. The accuracy under high cognitive load ($M = .45$) was lower than that under low cognitive load condition ($M = .53$).

TABLE 2

Performance of ongoing task in each group and condition

		<i>SPD proneness</i>		<i>Control</i>	
		<i>Low cognitive load</i>	<i>High cognitive load</i>	<i>Low cognitive load</i>	<i>High cognitive load</i>
		<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Implementation intention	Accuracy	0.90 (0.07)	0.82 (0.09)	0.89 (0.05)	0.79 (0.10)
	Reaction time (ms)	1059.9 (196.8)	1241.9 (294.3)	1067.8 (243.0)	1164.0 (353.1)
Typical instruction	Accuracy	0.90 (0.07)	0.79 (0.11)	0.88 (0.09)	0.79 (0.12)
	Reaction time (ms)	938.8 (164.9)	1040.6 (211.2)	1065.6 (219.6)	1326.8 (362.6)

Under the low cognitive load condition, implementation intention significantly produced an increase in PM performance [$F(1,49) = 6.31, p = .015$]. Under the high cognitive load condition, their PM performance was also significantly better in the implementation intention than that in the typical instruction condition [$F(1,49) = 8.62, p = .005$]. Such results are different from those in the control group. These results indicated that cognitive resources could play an important role in implementation intention. Implementation intention may influence the PM performance by reallocating the cognitive resources during executing the PM task, i.e., by allocating more cognitive resources to PM task and less cognitive resources to ongoing task.

SPD proneness group. Performance of ongoing (N-back) task. Cognitive load had a significant main effect on N-back task performances. The accuracy of N-back task under high cognitive load condition ($M = .80$) was significantly lower than that under low cognitive load condition ($M = .90$) [$F(1,47) = 59.27, p < .001$]. And the reaction time of the N-back task under high cognitive load condition ($M = 1129.47$) was longer than that under low cognitive load condition ($M = 999.32$) [$F(1,47) = 38.67, p < .001$]. The main effect of implementation intention was not significant for accuracy [$F(1,49) = .74, p = .400$]. The accuracy for those in the implementation intention condition was .86 and for those in the typical instruction group was .84. However, the main effect of implementation intention was significant for reaction time [$F(1,49) = 6.55, p = .014$]. Reaction time for those in the implementation intention condition ($M = 1139.1$) was significantly longer than that in the typical

instruction condition ($M = 989.7$). Although the interaction between implementation intention and cognitive load was not significant, we still compared the cost of ongoing task (difference in reaction time between implementation intention group and typical instruction group) in low and high cognitive load conditions in order to see whether the cost of ongoing task only happened in low cognitive load condition or in both levels of the cognitive load conditions. The results showed that, in the low cognitive load condition, reaction time in the implementation intention condition was not significantly different from that in the typical instruction condition [$F(1,49) = 3.29, p = .076$]. However, in the high cognitive load condition, reaction time in the implementation intention condition ($M = 1241.9$) was significantly longer than that in the typical instruction condition ($M = 1040.6$) [$F(1,49) = 4.41, p = .041$]. These results indicated that the cognitive resources assigned to ongoing task decreased in the implementation intention group and mainly in the high cognitive load condition. It is possible that for SPD proneness participants, when their cognitive resources were sufficient, implementation intention improved their PM without decline in ongoing task. However, when their cognitive resources were challenged, implementation intention improved their PM performance by changing their cognitive resources allocation strategy, which is, they assigned some cognitive resources from ongoing task to PM task.

Discussion

In the present study, we found that participants in the SPD proneness group had poorer PM performance than those in the control group. In addition,

implementation intention was effective in improving participants' PM performance including individuals with SPD proneness, consistent with our hypothesis. Moreover, the mechanisms of implementation intention were different for individuals with SPD proneness and the controls, also consistent with our hypothesis. To our knowledge, this is the first study to show that implementation intention is an effective technique for improving PM performance in participants with subclinical schizophrenia features.

The SPD proneness group showed a trend of PM impairment. When we excluded those participants who did not remember the four PM cues and the PM task, SPD proneness individuals performed significantly worse than the controls. These results were consistent with Chan et al. (2008) and Wang et al. (2008) that schizotypal subjects performed worse than healthy individuals on event-based PM. Moreover, many previous studies have shown the usefulness of implementation intention in improving PM performance (Breneiser, 2009; Cohen & Gollwitzer, 2008; Gollwitzer & Sheeran, 2006; McDaniel, et al., 2008; McDaniel & Scullin, 2010; McFarland & Glisky, 2009, 2011). Implementation intention could also help to improve PM performance of individuals with SPD proneness effectively. Thus it might be a useful technique to help them to achieve the future intentions.

The mechanisms of implementation intention in benefiting PM performance were found in our study to be different for individuals with SPD proneness and controls. For the controls, the results did not suggest that implementation intention created an entirely automatic PM responding (Gollwitzer, 1999). This is because

under the high cognitive demand condition, implementation intention did not benefit PM performance which meant implementation intention was affected by the cognitive resources, and it did not meet the definition of automatic processing (Bargh, 1989; Bargh & Chartrand, 1999; Cohen & Gollwitzer, 2008). Previous studies have reported that implementation intention was not affected by the challenge of cognitive resources (Brandstätter, Lengfelder, & Gollwitzer, 2001; McDaniel, et al., 2008). However, their cognitive load manipulations may not be successful and participants still had extra resources to accomplish PM task for those in the implementation intention condition under high cognitive load demand (McDaniel & Scullin, 2010). McDaniel and Scullin (2010) made the ongoing task more difficult by making the task more speeded and objective, and the results showed that when participants' cognitive resources were challenged, implementation intention could not benefit PM any more. Similarly, in the present study, the performance of the 2-back task declined dramatically from 1-back task which indicated the 2-back task was difficult enough to challenge the cognitive resources for PM task. The results of the control group in the present study were consistent with McDaniel and Scullin's study. Although in implementation intention condition, the ongoing task performance did not decline in the high cognitive load condition, the PM performance did not increase. Thus implementation intention was influenced by the cognitive resources and the process of implementation intention was not completely automatic.

Rummel, Einstein and Rampey (2012) indicated that implementation

intention enhanced spontaneous retrieval of intentions without costing more additional cognitive resources to ongoing task. However, successful retrieval of the intentions itself was not enough for executing a PM intention. The PM task was still competing for the limited cognitive resources with ongoing task to shift from the ongoing task to the PM task even with the implementation intention encoding (Einstein, Smith, McDaniel, & Shaw, 1997; Marsh, Hicks, & Watson, 2002; McDaniel, Robinson-Riegler, & Einstein, 1998). Perhaps, in the low cognitive condition, the ongoing task was comparatively easier. So was the competition of cognitive resources for PM task from ongoing task. Therefore, implementation intention was effective in improving PM performance. However, in the high cognitive load condition, the ongoing task was more difficult and required more cognitive resources. It was difficult for the PM task to compete for cognitive resources even with implementation intention, thus implementation intention did not increase PM performance.

There were some studies on implementation intention in individuals with PM impairments such as older adults (McFarland & Glisky, 2011) and multiple sclerosis (Kardasmenos, et al., 2008). In their studies, implementation intention benefited PM of people who suffered cognitive declines by making the PM retrieval more automatic (Kardasmenos, et al., 2008; McFarland & Glisky, 2011). But in our study, the results suggested that the effect of implementation intention on PM was affected by cognitive resources. Although we should be cautious by directly comparing our results to these studies (Kardasmenos, et al., 2008; McFarland & Glisky, 2011) since

we studied different population, we still found our study had an improvement in the experimental design: we included cognitive load as an independent factor in our design and could examine the mechanism of implementation intention more clearly. The results indicated that in the low cognitive load condition, the improvement of PM was not at cost of ongoing task which was consistent with previous studies, while in high cognitive load condition, the improvement of PM was at cost of ongoing task. Such ongoing task performance decline indicated that implementation intention encoding may lead them to focus their attentions on monitoring PM cues. And studies have shown that SPD proneness participants were impaired in working memory (Gooding & Tallent, 2003; Kopp, 2007). Therefore, one explanation for the effect of implementation intention on SPD proneness group might be that their reduced cognitive resources forced them to allocate the resources for ongoing task to PM task in the high cognitive demand condition when they encoded PM task by implementation intention.

Limitations and future directions

There are several limitations in our study. First, our sample was limited to the undergraduate college students. The current results could not be generalized to the general population. Further studies should recruit a large sample size with a wider age range from the community. Second, individuals with SPD proneness are still people without a proper clinical diagnosis of schizophrenia or psychosis. It is still not clearly understood whether similar effect of implementation intention on PM performance could be observed in patients with schizophrenia. Thirdly,

implementation intention may improve PM through cognitive factors (e.g., cognitive resources) which were the main focus of the present study. However, some social factors such as motivation and personality might have also been involved in the implementation intention, which should be addressed in future studies. Finally, despite that implementation intention would improve people's PM performance, it would also bring some drawbacks such as increasing false alarm rate (Meiser & Rummel, 2012) and commission error rate (Bugg, Scullin, & McDaniel, 2013). Further study can also examine whether such phenomena would be manifested in SPD proneness population.

Conclusion

In conclusion, individuals with SPD proneness suffered event-based PM impairment. Implementation intention was an effective technique to improve young adults' PM performance including those with schizotypal proneness. However, the mechanisms for implementation intention might be different for people with SPD proneness and the controls. For the controls, implementation intention did not affect their cognitive resources allocation strategy; for individuals with SPD proneness, implementation intention made them allocate more cognitive resources to PM task.

Conflicts of interest

None.

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