The Effect of Implementation Intentions on Prospective Memory Performance in Patients with Schizophrenia: A Multinomial Modeling Approach

Abstract:

Patients with schizophrenia (SCZ) consistently show prospective memory (PM) impairments, and the technique of implementation intentions has been shown to improve PM performance in these patients. PM is considered to have prospective and retrospective components. However, it remains unclear which component of PM is impaired in patients with SCZ and which component(s) is facilitated by implementation intentions (II). The present study aimed to examine these two issues. Forty-two patients with SCZ and 42 matched healthy controls were randomly assigned to an II group or a typical instruction group. All participants were administered a color-matching PM task. Results showed that, using a multinomial-modeling approach, patients with SCZ exhibited impairment in the retrospective component of PM. In addition, while II improved the prospective PM component in healthy controls, both prospective and retrospective PM components in patients with SCZ were improved. Together, our results shed light on the mechanism of PM impairment in SCZ patients and the mechanism of II in improving PM performance.

Keywords:

Prospective memory; implementation intentions; schizophrenia; multinomial modeling; preparatory attentional and memory process theory

1. Introduction

In our daily lives, we often need to remember to carry out an action in the future, which is an ability referred to as prospective memory (PM)(Einstein and McDaniel, 1990). Impairment in PM is one of the severe deficits observed in patients with schizophrenia (SCZ) (Ordemann et al., 2014; Shum et al., 2004; Wang et al., 2018; Wang et al., 2009). PM failures can have serious consequences to a person’s daily living, particularly for patients. For example, if they forget to take medications or miss a doctor’s appointment, their illness will deteriorate. Therefore, it is important to investigate the mechanisms of PM failure and ways to improve PM. However, few studies have examined these issues.

It is generally recognized that there are two components of PM: prospective (remembering to carry out the intended action at the appropriate time) and retrospective (remembering the what and when of the PM task) (Ellis, 1996). Results of previous studies suggested that the prospective component was the main cause of PM impairment in SCZ patients. For example, Altgassen et al. (2008) found that SCZ patients exhibited PM impairments when the retrospective memory (RM) requirement was minimal and suggested that the prospective component contributed to PM failures in this clinical group. Henry et al. (2007) examined PM in SCZ patients using the Virtual Week and found that patients showed significantly more "Miss" errors (totally forget the PM cues), again suggesting that the prospective component played an important role in PM impairment. Woods et al. (2007) used the Memory for Intention Screening Test (MIST) to examine PM in SCZ patients, and found that patients exhibited more "No Response" (do nothing on PM cues), "Loss of Time" (make a correct response at a wrong time) and "Task Substitution" (make a wrong response on a PM cue) errors than controls. Raskin et al. (2014) also used the MIST to examine PM performance in SCZ, and found that patients only exhibited more "No Response" errors than controls, affirming the role of the prospective component in PM impairment. Taken together, these findings suggest that the prospective component is a major cause of PM failures in patients with SCZ, while the retrospective component (indicated by "Loss of Time" and "Task Substitution" errors in the MIST) may also played a role. However, all these studies used an indirect way to examine or assess the two components of PM impairment in SCZ and may not separately them precisely. Thus, a more direct way to measure these two PM components is needed.

Implementation intentions (II) is an encoding method to facilitate goal achievement in the form of "if situation Y is encountered, then I will do X" (Gollwitzer, 1999; Gollwitzer and Sheeran, 2006). II has been shown to be effective in improving PM performance in individuals across the lifespan from children to older adults (Chasteen et al., 2001; Chen et al., 2015; Liu and Park, 2004; Zimmermann and Meier, 2010) and clinical populations, such as individuals with multiple sclerosis (Kardiasmenos et al., 2008) and SCZ (Chen et al., 2018; Chen et al., 2016; Liu et al., 2018). II includes two components: the identification of a suitable occasion to initiate the response (the "if" part) and a response that promotes goal attainment (the "then" part). It has been suggested that II improves PM performance through strengthening the encoding of PM intention and the link between PM cues and associated actions (Gollwitzer and Sheeran, 2006; McDaniel and Scullin, 2010).

However, most of the previous studies that have examined II have focused on whether II improves PM performance and whether II is a controlled or automatic process (e.g., by examining whether it added additional cost to the ongoing task) (McDaniel et al., 2008). Moreover, prior research has not considered the different components of PM. Thus, it remains unclear which component(s) of PM (prospective, retrospective, or both) is improved by II. To answer this question, a more direct way of measuring the two PM components is needed.

Smith and Bayen (2004) used a multinomial modeling approach to separate the retrospective and prospective components of PM. The modeling approach was based on the Preparatory Attentional and Memory Process Theory of PM, which proposes that all PM processing requires cognitive resources or preparatory attention (Smith, 2003). The multinomial model assumes that people have discrete cognitive states that can be demonstrated by certain probabilities during specific tasks. The probabilities can represent model parameters and can be estimated from observed data (more details about the model can be found in Appendix A). The model has two main parameters that are related to task performance. The parameter *P* is a measure of the prospective component, and indicates preparatory attentional processing. A larger value of *P* parameter means increased preparatory attentional resources allocated to PM cues. The parameter *M* is a measure of the retrospective component, which represents the memory process of recognizing and discriminating PM cues from other events (Horn et al., 2011; Smith and Bayen, 2004).

The model developed from the multinomial modeling approach has been applied in recent studies to examine the impaired components of PM in patients with traumatic brain injury (Pavawalla et al., 2012), the development of different PM components in young children and older adults (Smith and Bayen, 2006; Smith et al., 2010), and the influence of working memory capacity on the two PM components (Smith and Bayen, 2005). These studies suggest that the multinomial modeling approach is a valid and useful method and can be applied in clinical populations. Keefe and collegues (1999) had employed this model and confirmed the source monitoring deficits in SCZ patients. However, this approach has not been used in research on PM, and the present study aimed to adopt this model to examine the nature of PM impairments in SCZ patients. A recent study (Smith et al., 2014) examined the effect of II in healthy adults, and adopted the multinomial modeling approach to examine which component of PM was improve by II. They found that II improved preparatory attentional processing (*P*) of PM but not the retrospective component (*M*) in the sample of healthy adults. However, no study has examined the effect of II on the two PM components in SCZ, and this was the second aim of the present study.

Given that previous findings (Altgassen et al., 2008; Henry et al., 2007; Woods et al., 2007) suggest that the prospective component is the main cause of PM impairment in SCZ, we hypothesized that using a multinomial modeling approach, parameter *P* would be significantly lower in SCZ compared to HC. Given the mixed results on retrospective component of PM, we did not have specific hypothesis on parameter *M*. Also, given the previous findings in healthy participants (Smith et al., 2014), we hypothesized that II would improve the prospective but not the retrospective component of PM in SCZ patients.

2. Method

2.1 Participants

Forty-two patients with SCZ were recruited from the Mental Health Hospital of the Haidian District, Beijing. All patients met the following inclusion criteria: (1) fulfilling the diagnostic criteria of SCZ according to DSM-IV (American Psychiatric Association, 1994); (2) right handedness; (3) at least nine years of education; (4) normal vision or corrected visual acuity. Patients with a history of neurological illness, drug or substance addiction, electroconvulsive therapy in the recent three months or color blindness were excluded. All patients were clinically stable and taking atypical antipsychotic medications at the time of the study.

Forty-two healthy controls (HC) were recruited from general communities in Beijing via advertisement. These participants did not have a history of psychiatric or neurological disease, a family history of mental illness or color blindness. SCZ and HC groups were matched on age, gender ratio and education. Both SCZ and HC groups were further randomly assigned to the II or typical instruction group.

2.2 Design

A 2 (Group: SCZ, HC) ×2 (PM instruction type: II, typical instruction) between-subject design was adopted. The dependent variables were the behavioral performance (accuracy & reaction time) of the PM and ongoing tasks, and the multinomial model parameters *P* and *M*.

2.3 Experimental tasks and measures

The PM task was adapted from the color-matching PM task developed by (Smith and Bayen, 2004). A total of 68 commonly used two-character words were selected from a Chinese word database (973 Chinese Linguistic Data Consortium). Of these words, six were selected for use in the practice block and the remaining 62 words were repeated once (each word appeared twice) in the two task blocks (a baseline and a PM block). Participants were instructed to complete the baseline block without the PM instructions (62 trials) first, and then complete the PM block with three words as PM cues ("curtain", "butterfly", "cow") and with PM instructions (either II or typical). Each of the three PM cues was presented twice (about 10% of total trials were PM cues) at a random order and on trials 10 / 20 / 30 / 40 / 50 / 60 to maximize the interval between each PM cue.

In each trial, four different colored rectangles were presented sequentially at the center of a computer screen (black background), and then followed by a colored word (38-point font size, about 13 mm). Five colors were used for those rectangles and words: red, yellow, blue, green and white. Participants were required to judge whether the color of the word matched the color of any of the four rectangles shown before as accurately and quickly as possible. Participants responded by pressing the "F" key if there was a match and to press the "J" key if there was not. Half the trials were match trials and the other half were non-match trials. Each colored rectangle was presented for 500 ms, followed by a blank screen (250 ms), and then a word was presented for 3000 ms. Between trials, there was a 1000 ms blank screen (see Figure 1).

For the baseline block, participants were only required to make the color-matching judgments without having received any PM instructions. For the PM block, the participants were given the instruction that when any of the three PM cues appeared, no matter what the color of the word was, they were required to press the spacebar. Accuracy and reaction time were recorded for the two blocks.

INSERT FIGURE 1 HERE

The Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1987) was used to measure the clinical symptoms of the patients by qualified psychiatrists. The medication side effect was measured by the Abnormal Involuntary Movement Scale (AIMS) (Smith et al., 1979) and the Barnes Akathisia Rating Scale (BARS) (Barnes, 1989).

IQ was prorated using the brief version of the Chinese revised version of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) (information, arithmetic, similarity, and digit span)(Gong, 1992). The Chinese Letter Number Span Test (LNS) was used to measure working memory (Chan et al., 2008).

2.5 Procedure

Participants first completed practice for the color-matching task. They next completed the baseline block. At the end of baseline block, participants were given the PM task instructions. A previous meta-analysis (Chen et al., 2015) indicated that the combination of verbal (repeat the PM instruction in the “if… then…” form) and mental imagery (imagine performing PM task for a period of time) format had a larger beneficial effect on PM performance than either the verbal and imagery methods alone. Therefore, we used the combined method in the II instructions for this study. Participants in the II condition received the instructions as “during the color-matching task, if I see the words ‘窗帘‘ (curtain), ’蝴蝶’ (butterfly), ’奶牛’ (cow), then I will press the spacebar”. They were required to read the instruction loudly three times and then imagine performing the PM task for 45 s. Participants in the typical instruction condition received the standard PM task instructions without reading the instructions aloud three times or imagination. The instructions were “during the color-matching task, on seeing the words ‘窗帘‘ ’蝴蝶’ ’奶牛’, I will press the spacebar”. Participants first completed the baseline block of PM task, then they completed an IQ subtest (i.e., a five-min delay). Finally, the participants completed the PM block.

The protocol of the project was approved by the ethics committees of the Institute of Psychology, Chinese Academy of Sciences and the Mental Health Hospital of Haidian District. All participants provided signed informed consent prior to the study. All other measures were completed after the PM task.

2.6 Statistical Analyses

Baseline task performance was compared using independent sample *t*-tests between SCZ patients and HC first. Then analyses of ongoing and PM task accuracies were conducted using 2 (Group: SCZ, HC) *2 (Instruction type: II, typical) ANCOVAs using baseline accuracy as a covariate with SPSS 18.0. Ongoing task reaction times were analyzed using 2 (Group: SCZ, HC) *2 (Instruction type: II, typical) ANOVAs.

For the multinomial modeling analyses, we used the MultiTree Software (Moshagen, 2010) for parameter estimation and statistical analysis. First, we tested the model fit in each of the four conditions using a goodness-of-fit index (G^2), which was asymptotically χ^2-distributed (Hu and Batchelder, 1994). We then calculated the parameters *P* and *M*, and subsequently used χ^2 tests to compare these parameters between SCZ patients and HC and between II and typical instruction conditions. The HC and SCZ in the typical instruction condition were initially compared to examine which component was impaired in SCZ patients independent of II. Next, the II and typical instruction groups were compared for HC participants only to examine which component of PM was improved by II in this group. The same analyses were repeated for SCZ patients.

3. Results

3.1 Demographic, clinical information and basic cognitive measures

The SCZ and HC groups showed no significant differences in gender ratio, age, length of education, IQ estimates and working memory capacity (all *p*s > 0.05). There were no significant differences in these variables (age, gender ratio, education years, IQ, and working memory capacity) between the participants in the two PM instruction conditions either. The demographic and clinical characteristics of participants are summarized in Table 1.

INSERT TABLE 1 HERE

3.2 Baseline task performance

Table 2 shows the descriptive characteristics of baseline and PM task performances in each condition. There was no significant group difference in baseline task reaction time ($p > .05$), but HC exhibited significantly higher baseline task accuracy than the SCZ group ($t(82) = -2.52$, $p < 0.05$). Therefore, baseline task accuracy was controlled for in the subsequent analyses involving PM or ongoing task accuracy.

INSERT TABLE 2 HERE

3.3 PM performance

The ANCOVA analysis on PM accuracy showed significant main effect of Group

($F(1,79) = 4.85$, $p = 0.031$, $\eta^2 = 0.058$), with lower accuracy in SCZ than in HC ($M_{SCZ} = 0.60$, $M_{HC} = 0.75$). The main effect of PM Instruction Type was also significant ($F(1,79) = 8.99$, $p = 0.004$, $\eta^2 = 0.102$), indicating a beneficial effect of II on PM performance ($M_{II} = 0.78$, $M_{Typical} = 0.56$). There was no significant interaction between Group and PM Instruction Type in PM accuracy ($F(1,79) = 0.16$, $p > 0.05$).

3.4 Ongoing task performance

The ANCOVA analysis for on ongoing task accuracy showed a significant main effect of Group ($F(1,79) = 4.38$, $p = 0.040$, $\eta_p^2 = 0.053$). SCZ patients were less accurate ($M = 0.71$) than that of HC ($M = 0.75$). There was no significant main effect of PM Instruction Type or Group by PM Instruction Type interaction (ps > 0.05).

For ongoing task reaction time, there was a significant main effect of PM Instruction Type ($F(1,79) = 5.05$, $p = 0.027$, $\eta_p^2 = 0.059$). Participants' reaction time in the II condition was significantly longer than that in the typical instruction condition ($M_{II} = 1523$ ms, $M_{Typical} = 1464$ ms). There was no significant main effect of Group or interaction between Group and PM Instruction Type (ps > 0.05).

3.5 Multinomial modeling results

The model showed a good fit to the data in each condition and group. The range of $G^2(4)$ was 3.35-8.24. These values are smaller than the critical value of 9.49 at $p = 0.05$, indicating that the multinomial tree model was suitable to analyze the data in this study. The parameters of P and M were calculated in each group and condition (see Figure 2). In the typical instruction condition, SCZ patients showed similar parameter *P* with that of HC ($G^2(1) = 0.84$, with critical value of 3.84 at $p = 0.05$), but significantly smaller parameter *M* than HC ($G^2(1) = 12.65$). These results indicated that SCZ patients had a significant deficit in the retrospective component but not in the prospective component of PM.

Subsequent analyses showed that for HC, II significantly improved parameter *P* compared to the typical instruction ($G^2(1) = 32.93$), but there was no significant difference for parameter *M* ($G^2(1) = 0.37$). These differences indicate a benefit of II on the prospective, but not the retrospective component of PM. For SCZ patients, II significantly improved parameter *P* ($G^2(1) = 10.17$) and parameter *M* ($G^2(1) = 10.07$) compared to typical instruction, indicating that II benefited both the prospective and retrospective components in these patients.

INSERT FIGURE 2 HERE

4. Discussion

The present study showed that patients with SCZ were impaired in PM and that this difference mainly reflected a deficit in the retrospective component of PM. In addition, II improved the prospective component of PM in HC and the prospective and retrospective components in patients with SCZ.

Patients with SCZ exhibited a PM impairment, which is consistent with previous studies (Ordemann et al., 2014; Wang et al., 2018; Wang et al., 2009). However, SCZ patients demonstrated an impairment in the retrospective, but not prospective component. This is contrary to our hypothesis that an impairment in the prospective component would be the main cause of PM deficits in SCZ patients. Previous studies suggested that SCZ patients had impairment in prospective component based on the finding that SCZ patients showed PM impairment even when the retrospective memory load was minimal (Altgassen et al., 2008). Moreover, the typical errors SCZ patients committed in the VW and MIST were “Miss” and “No Response”, indicating the primary role of prospective component in PM impairment in SCZ (Henry et al., 2007; Woods et al., 2007). Nevertheless, these studies examined the prospective component impairment indirectly but not directly. In the present study, we used the multinomial tree model and examined the prospective and retrospective components directly and independently. Furthermore, most of the previous studies did not measure working memory (Henry et al., 2007; Woods et al., 2007) or found that SCZ patients showed significantly impaired working memory performance (Altgassen et al., 2008). In two experiments, Smith and Bayen (2005) found that working memory capacity was positively related to the prospective component of PM (parameter *P*), suggesting that working memory provided the preparatory attention resources needed in PM and was important for the prospective component of PM (Smith and Bayen, 2005). In the present study, SCZ patients did not show significant impairment in working memory, this might explain why SCZ patients were not impaired on parameter *P* compared to HC. Thus, the results of this study are not entirely contradictory to the previous findings.

II was found to improve PM performance for both HC and SCZ patients, which is consistent with previous studies (Chen et al., 2018; Chen et al., 2016; Chen et al., 2015; Liu et al., 2018; Smith et al., 2014). For HC, II improved the prospective component, which is consistent with a previous study (Smith et al., 2014). We also found that participants in the II group showed significantly longer reaction time for ongoing trials compared to the typical instruction group. However, increase in the ongoing task reaction time or ongoing cost does not necessarily indicate more preparatory attention processing. This might be due to the increased rehearsal of PM cue or action (Smith et al., 2014). With this multinomial modeling approach, it is clear that II improved the preparatory attention processing and thus the prospective component. However, in Smith et al.'s (2014) study, with three experiments, they varied the PM cue encoding time (3 s or 10 s for each PM cue word), number of PM cue words and responses (6 PM cues with the same response or 2 PM cues with different responses), the delay between instruction and PM task (4 mins or 10 mins), form of II (silently repeating if-then sentence or write down the sentence; with or without imagery), and the retrospective component was not improved. The present study did not observe an increase in retrospective component either. Nevertheless, it might be because the healthy participants reached the ceiling on parameter M (all above 0.8) both in Smith et al.'s (2014) study and the present study.

For the SCZ patients, II was found to improve both the prospective and retrospective components of PM, which are partly consistent with our hypothesis. Similar to HC, II improved the prospective component, indicating that increased preparatory attentional resources was also allocated to PM task in SCZ patients in the II group. However, SCZ patients in the present study showed a significantly smaller parameter *M* (impaired retrospective component), indicating room for further improvement by II. Previous studies suggested that II strengthened processing of the PM cue and the link between the PM cue and response (Gollwitzer and Sheeran, 2006; McDaniel and Scullin, 2010). These effects might be related to the retrospective recognition memory processing needed for the discrimination between PM cue and other events and cue related reaction, which can be reflected in increased *M* parameter. The present results suggested that II increased both preparatory attentional resources (prospective component) and strengthened the link between PM cue and action (retrospective component) in SCZ patients. We suggest that whether II would improve the retrospective component of PM can be examined in participants with memory impairments rather than healthy participants, since the mechanisms may be different in participants with memory impairments and healthy participants. Together, these results have shed new light on the mechanisms of II on PM in SCZ.

There are several limitations in the current study. Firstly, the sample size in each group was relatively small, and future studies need to recruit a larger sample to corroborate our findings. Secondly, the years of education was matched between SCZ patients and HC in this study. The lower level of education in HC might lead to a lower PM performance in this group. Thirdly, the SCZ patients in this study were chronic community patients, so future research may consider including patients at different stages of the schizophrenia spectrum (e.g., first-episode, high risk individuals) and explore whether the mechanisms of II facilitation identified in this study are the same or different in these other populations.

In conclusion, schizophrenia patients were impaired in PM, and the impairment was mainly due to difficulties in the retrospective component of PM. II was found to improve PM performance in both HC and patients with SCZ. II mainly improved the prospective component in HC, but improved both the prospective and retrospective components in SCZ patients. Our findings suggest that II maybe an effective strategy for use in clinical settings.

Conflict of interest

None.

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Table 1. Demographic and clinical information of the participants

	SCZ				HC					
	II (n=21)		Typical (n=21)		II (n=21)		Typical (n=21)			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	T/χ^2	*p*
Male : Female	12:9		11:10		9:12		10:11		0.76	0.383
Age	43.24	9.71	43.57	8.41	44.00	11.18	43.52	9.93	-0.17	0.867
Education (years)	12.29	2.81	12.00	2.59	11.95	2.60	11.67	2.52	0.59	0.559
IQ	105.71	13.84	110.33	17.19	110.10	11.57	112.24	12.84	-1.03	0.307
CLN	12.53	2.55	14.33	4.44	14.62	3.84	15.48	3.37	-1.98	0.052
Duration of illness (years)	19.95	10.07	19.95	8.01					0.00	1.000
Medication*	311.74	188.59	313.40	108.74					-0.03	0.973
PANSS Total Score	47.89	10.42	49.90	9.32					-0.63	0.530
Positive Symptoms	10.00	3.04	9.45	2.80					-0.59	0.560
Negative Symptoms	13.21	3.19	15.20	4.49					-1.59	0.121
General Psychopathology	24.68	6.18	25.25	5.50					-0.30	0.764
AIMS	1.00	2.05	1.20	1.99					-0.31	0.759
BARS	1.42	2.09	1.35	1.87					-0.11	0.911

Note. * Chlorpromazine equivalence mg/day for medication. CLN = Chinese Letter-Number Span total correct, SCZ = schizophrenia, HC = healthy control, II = implementation intention, PANSS = Positive and Negative Syndrome Scale, AIMS = Abnormal Involuntary Movement Scale, BARS = Barnes Akathisia Rating Scale.

Table 2. The descriptive statistics for baseline and PM task performance in each condition

Condition	**Task**		**Schizophrenia**	**Healthy Controls**
			Mean (SD)	*Mean (SD)*
	Baseline Task	Accuracy	0.72 (0.20)	0.81 (0.13)
		RT (ms)	1321 (311)	1333 (216)
II condition	Ongoing task	Accuracy	0.68 (0.19)	0.77 (0.10)
		RT (ms)	1591 (201)	1558 (264)
	PM task	Accuracy	0.69 (0.28)	0.91 (0.14)
		RT (ms)	1710 (342)	1649 (253)
Typical condition	Ongoing task	Accuracy	0.68 (0.18)	0.80 (0.11)
		RT (ms)	1440 (268)	1370 (186)
	PM task	Accuracy	0.45 (0.41)	0.70 (0.38)
		RT (ms)	1698 (310)	1811 (282)

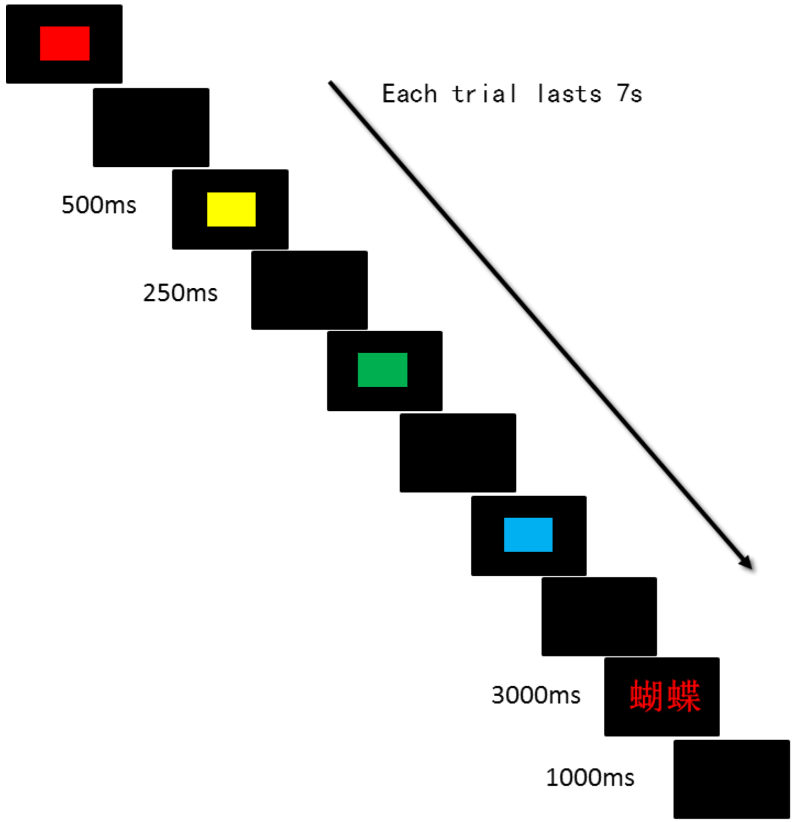

Figure 1. The flow chart of a trial in the PM task

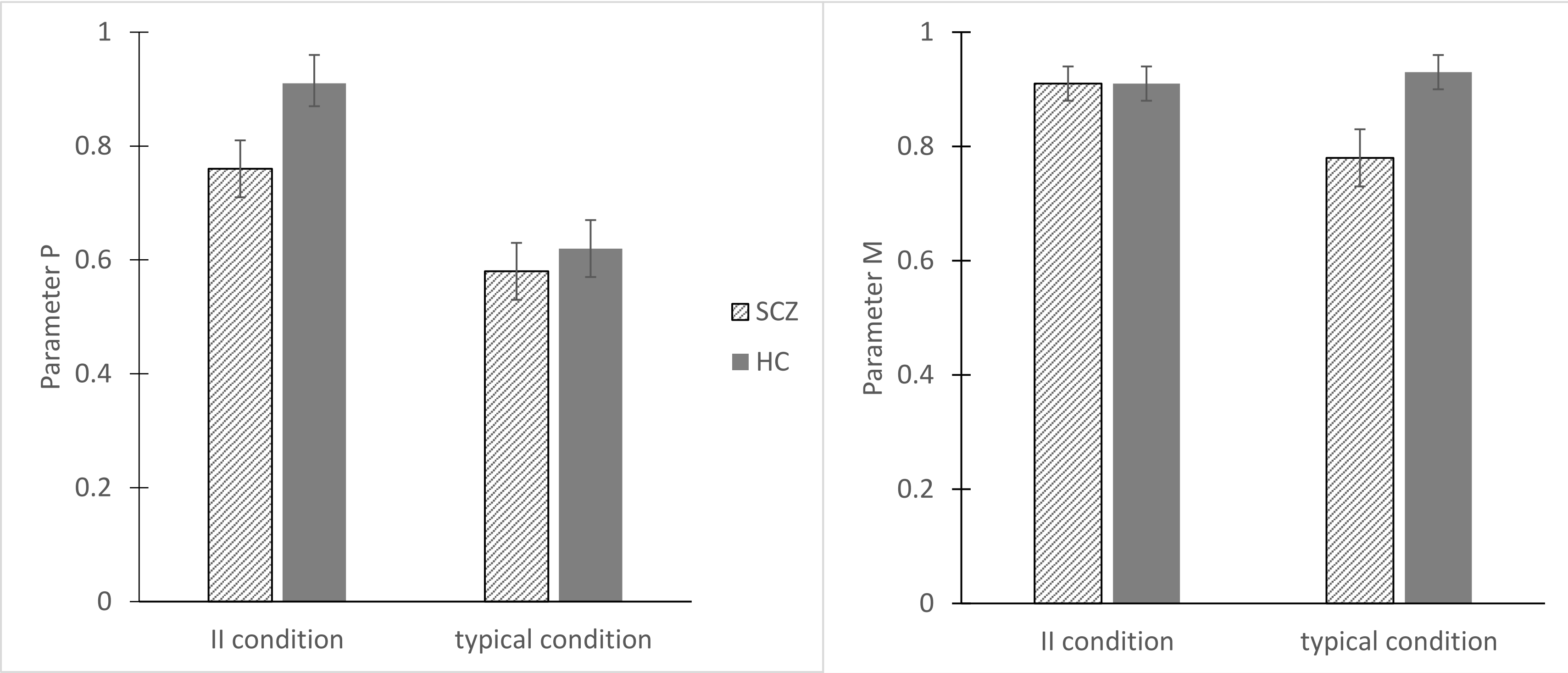

Figure 2. Estimate of parameter P (preparatory attentional processing) and M (retrospective recognition process) in the two participant groups in the two task conditions