Schizophrenia and prospective memory impairments: A review

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Abstract

Objective: Prospective memory (PM) is the ability to remember to carry out intended actions in the future. Prospective forgetting has been shown to be one of the key cognitive impairments that contribute to medication non-adherence, reduced independence, and social dysfunction in individuals with schizophrenia. This review aimed to provide an up to date appraisal of the nature and extent of PM impairments in individuals with schizophrenia and those who are at risk and to discuss clinical applications in this area. **Method:** We searched and reviewed relevant studies in this area between 2013 and August 2017. **Results:** Findings of studies conducted so far indicate that PM is severely impaired in schizophrenia. The most frequent type of PM errors in individuals with schizophrenia is no response, or failure to carry out the intended action. PM impairments in schizophrenia have been found to be related to everyday functioning. For individuals with schizophrenia, a number of assessment techniques have been developed to assess PM. These include: self-report questionnaires, computerized tasks, psychometric test batteries, and virtual reality tasks. So far, a few studies have used the compensatory approach to improve PM performance in individuals with schizophrenia and those who are at risk, and the results reported are promising. Based on findings of these studies, suggestions for the development of interventions for PM impairments in individuals with schizophrenia are provided. **Conclusions:** PM dysfunction is an important impairment

in individuals with schizophrenia, and more rehabilitation studies to improve PM performance in these individuals are needed.

Keywords: prospective memory, schizophrenia, review

Introduction

Prospective memory (PM) refers to the ability to remember to do something at a particular point in the future (Einstein & McDaniel, 1990), for example, to remember to attend a doctor's appointment to review medication management on Wednesday at 10 am. PM is important because many daily activities are dependent on it. In a typical PM task, an intention needs to be formed first (e.g., what needs to be done and under what conditions), then the individual engages in something else called the ongoing task. While performing the ongoing task, the individual needs to maintain the intention and monitor the PM cue. When a PM cue appears and is detected, the individual needs to retrieve the intention and make a PM response.

According to the nature of the cue, PM can be divided into time-, event- and activity-based (Kvavilashvili & Ellis, 1996). Time-based PM requires an individual to remember to execute an intention at a particular time, or after a period of time (e.g., attend a wedding next Sunday). Event-based PM requires someone to execute an intention at the appearance of a cue (e.g., buy bread when one passes by a supermarket). Activity-based PM requires someone to execute an intention at the end of an activity (e.g., send an email after dinner). It is generally accepted that there are two components of PM: prospective and retrospective (Ellis, 1996). The prospective component involves the retrieval of and carry out the intended action at the appropriate point in the future, and the retrospective component involves recalling the content of the intended action (Ellis, 1996). In the literature, the most widely cited theories of PM are the Preparatory Attention and Memory (PAM) (R. E.

Smith, 2003) theory and the Multi-Process Theory (Einstein & McDaniel, 2005). While the former proposes that all PM processing requires cognitive resources, the latter hypothesizes that PM can be executed with or without effort or cognitive resources, depending on a number of factors (e.g., the cognitive demands of the ongoing task, the saliency of the PM cue, the association between the ongoing and PM task, etc.).

Schizophrenia is a world-wide severe psychiatric disease and is associated with a wide range of cognitive impairments (Green & Harvey, 2014; Heinrichs, 2005; Schulz & Murray, 2016). Compared to retrospective memory (RM) impairments, PM impairments have not been studies as systematically and extensively in individuals with schizophrenia. To date, a meta-analytic review (viz., Wang et al., 2009) and a systematic review (viz., Ordemann et al., 2014) have been undertaken. Wang et al.'s (2009) meta-analysis showed that schizophrenia patients were impaired in all types of PM, with time-based PM more impaired than event-based PM. In addition, it was found that PM was inversely correlated with negative symptoms and education. Ordemann et al.'s (2014) review showed that schizophrenia patients lacked awareness of their PM impairments. Furthermore, they found that PM impairments were not related to chronicity and medications, but were related to independent living skills in schizophrenia. The present study aimed to include updated findings in this area, and to include aspects not covered in Wang et al. (2009) and Ordemann et al. (2014). These include components of PM impairments and types of PM errors, longitudinal studies, approaches to clinical assessment of PM, evidence-based approaches to treatment, and suggestions for development of interventions for PM impairments. Since schizophrenia has been considered to be part of a spectrum, we also included studies with non-psychotic first-degree of relatives and individuals with schizotypal personality features in our review.

Method

The selection of papers was based on the PRISMA guideline (Hutton et al., 2015). We searched the *Web of Science* from 2013 [Ordemann et al. (2014) searched for papers up to 2013] to August 2, 2017 using the keywords: schizophrenia and prospective memory. We restricted the studies to peer-reviewed papers written in English. A total of 117 entries were retrieved. After excluding studies not on PM or not in schizophrenia-related samples, 23 studies remained. After further excluding 1 review, 1 meta-analysis, and 3 papers covered by Ordemann et al. (2014), 18 studies remained for the final review (Figure 1 shows the flowchart of paper selection). A summary of these studies is presented in Table 1. For some parts of the review (e.g., studies related to participants with schizotypal personality features, non-psychotic first-degree relatives of schizophrenia), papers published before 2013 were also reviewed if the content was not discussed in detail in Wang et al. (2009) and Ordemann et al. (2014).

Table 1 Summary of studies

Study	Participants	PM type	Measure	Results
Behavioral studies				
Au, Man, Shum et al., 2014	Chronic schizophrenia patients (n=44) and matched controls (n=44)	Event, time	CAMPROMPT-C	Patients were impaired on total and subscale of the CAMPROMPT-C. Patients showed comparable deficits in PM subtypes. Education, IQ, and retrospective memory were correlated with PM. The clinical utility of the CAMPROMPT-C was supported.
Au, Man, Xiang et al., 2014	Chronic schizophrenia patients (n=44)	Event, time	CAMPROMPT-C	In bivariate analyses, overall community living skills correlated with PM total and subscales scores. In multivariate analyses, event-based PM was more predictive of community living skills than time-based PM.
Au et al., 2016	Chronic schizophrenia patients (n=44), bipolar disorder (n=76), and healthy controls (n=44)	Event, time	CAMPROMPT-C	Both patient groups showed similar level of PM impairments.
Cheung et al., 2015	First-episode schizophrenia (n=58) and matched healthy controls (n=37)	Event, time	Computer test	Both event- and time-based PM were impaired at baseline in schizophrenia patients, only time-based PM was impaired at 1 year follow-up. Schizophrenia patients showed a gradual improvement in both time- and event-based PM 12 months after illness onset. Compared to event-based PM, deficit in time-based PM persisted.

Demeter et al., 2016	Chronic schizophrenia patients (n=20) and matched healthy controls (n=20)	Event	Computer test	Patients showed impairments in the execution condition but not maintenance condition. PM performance in execution condition was correlated with impaired executive function in schizophrenia.
Lam et al., 2013	Chronic schizophrenia patients (n=82)	Event, time, activity	Computer test, CAPM	Time- and event-based PM predicted medication management at baseline. At three-month follow-up, medication non-adherent group performed poorer in time- and event-based PM. Insight and PANSS general score significantly predicted medication non-adherence in the community. Time- and event-based PM moderated the predictive power of insight and PANSS general score.
Liu et al., 2017	First-episode schizophrenia patients (n=30), healthy controls (n=30)	Event	Computer test	Both cue identification and intention retrieval were impaired in schizophrenia compared with healthy controls, with a large effect size for cue identification and a medium effect size for intention retrieval. After controlling for working memory and retrospective memory, the patients were still impaired in cue identification. However, the difference in intention retrieval between the two groups was no longer significant.

Lui et al., 2015	First-episode schizophrenia patients (n=91), healthy controls (n=83)	Event, time	Computer test, PRMQ	Patients were impaired in time- and event-based PM. Cognitive flexibility predicted time- and event-based PM, working memory predicted event-based PM. "Cognitive-preserved" patients tended to perform poorer in time-based PM than controls matched in IQ and other neuropsychological functions.
Man et al., 2016	First-episode schizophrenia patients (n=44), healthy controls (n=42)	Event, time	VRPMT-CV, CAMPROMPT-C	VRPMT-CV showed good construct validity, test-retest reliability, sensitivity and specificity in first-episode schizophrenia.
Zhou, Hou et al., 2014	First-episode schizophrenia (n=47), first-degree non-psychotic relatives (n=50), healthy controls (n=51)	Event, time	CAMPROMPT-C	First-degree relatives were impaired in both time- and event-based PM. Time-based PM was related to verbal learning and inhibition, event-based PM was related to flexibility in first-degree relatives of schizophrenia.
Zhou, Xiang et al., 2014	First-episode schizophrenia (n=55)	Event, time	CAMPROMPT-C	Higher scores on time-based PM at baseline predicted remission at 8-week follow-up.
Zhou et al., 2017	First-episode schizophrenia patients (n=32), healthy controls (n=17)	Event, time	CAMPROMPT-C	Event-based PM showed significant improvement in patients at 1-year follow-up. Remitters performed better on event-based PM than non-remitters.
Neural basis studies				

Chen et al., 2015	Symptom remitted chronic schizophrenia (n=20) and healthy controls (n=20)	Event	ERP	Patients with schizophrenia performed poorly on the PM task compared with healthy controls. On the neural level, the N300 (related to PM cue detection) was reliable across these 2 groups, and did not show significant group difference. However, the amplitude of the prospective positivity (related to PM intention retrieval) was significantly attenuated in symptomatically remitted schizophrenia patients relative to healthy controls.
Chen et al., 2016	Chronic schizophrenia patients (n=22) and healthy controls (n=25)	Event	fMRI	Patients performed significantly worse on the PM task. Furthermore, they exhibited decreased brain activation in frontal cortex including the right superior frontal gyri (Brodmann area 10), and other related brain areas like the anterior cingulate gyrus, parietal and temporal cortex, including precuneus, parahippocampal gyrus and putamen.
Wang et al., 2014	Individuals with schizotypal features (n=19) and without schizotypal features (n=22)	Event	fMRI	Schizotypal and control groups did not differ in behavioral PM performance. However, participants with schizotypal features showed decreased activations in the inferior and medial frontal cortex (BA 45, and 8) compared to those without schizotypal features.
Intervention studies				

Chen et al., 2014	Individuals with schizotypal features (n=51) and without schizotypal features (n=51)	Event	Computer test	Implementation intentions improved PM performances in both schizotypal and control groups. In the low cognitive load condition, both the schizotypal and non-schizotypal groups in the implementation intention condition showed improvement on PM task without ongoing task cost, suggesting automatic processing. In the high cognitive load condition, the non-schizotypal group did not show improvement on PM performance with implementation intention; the schizotypal group showed improvement on PM performance with ongoing task cost.
Chen et al., 2016	Chronic schizophrenia patients (n=50) and healthy controls (n=50)	Event	Computer test	Patients were impaired in PM. Implementation intentions improved PM performances for both patients and controls. Implementation intentions improved PM performance in patients in both the low and high cognitive load conditions without ongoing task cost, suggesting that implementation intentions improved PM remembering in an automatic way.
Khoyratty et al., 2015	Participants with early psychosis (n=30) and healthy controls (n=33)	Event, time	Computer test, BAPM, CAMPROMPT	Participants with early psychosis showed PM deficits, implementation intentions improved PM performance in individuals with early psychosis.

Note: BAPM, Brief Assessment of Prospective Memory; CAMPROMPT, Cambridge Prospective Memory Test; CAMPROMPT-C, Chinese version of the Cambridge Prospective Memory Test; CAPM, Comprehensive Assessment of Prospective Memory; ERP, Event-Related Potential; fMRI, functional Magnetic Resonance Imaging; PRMQ, Prospective and Retrospective Memory Questionnaire; VRPMT-CV, Virtual Reality Prospective Memory Test – Chinese version.

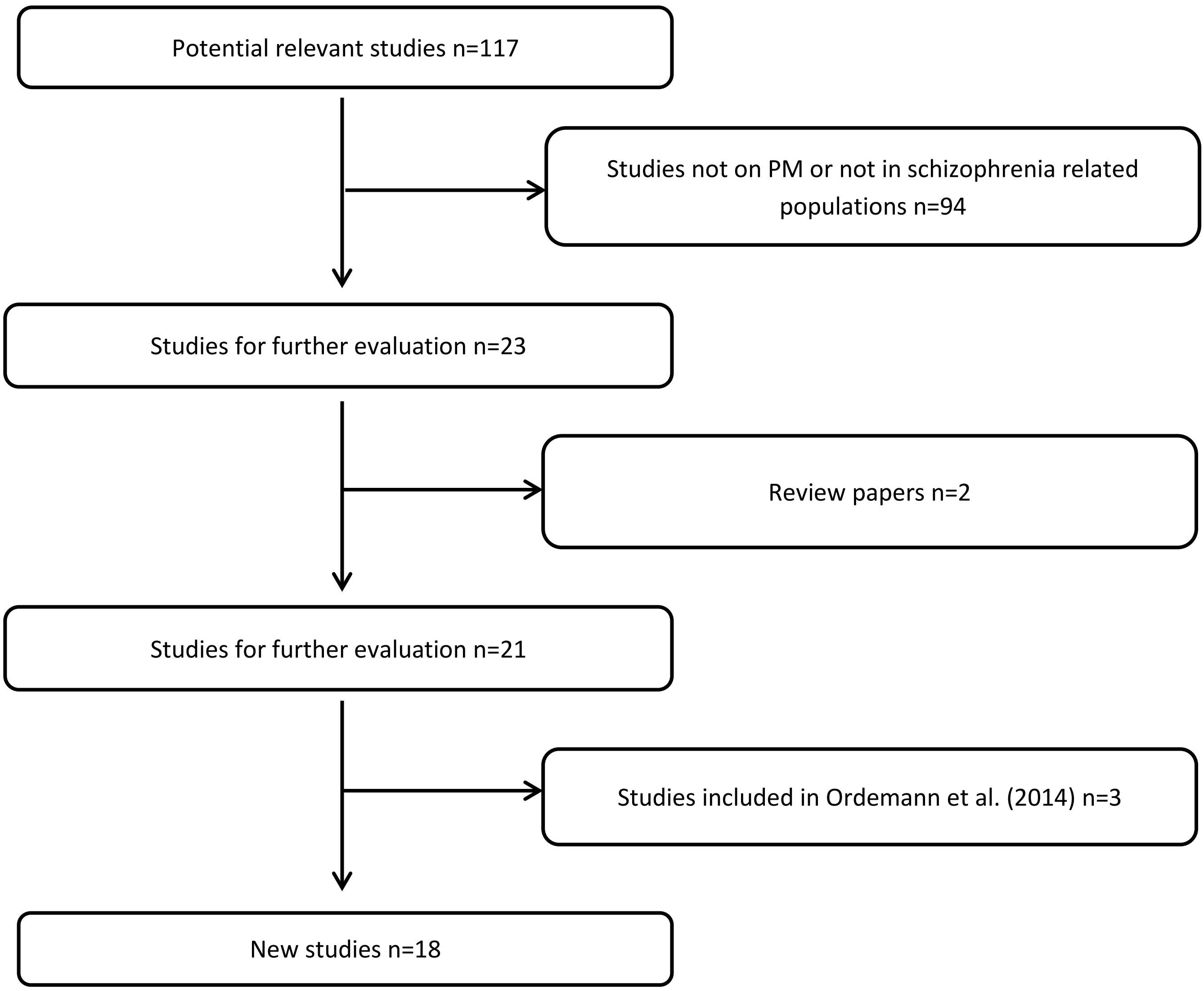

Figure 1. Flowchart of paper selection

Results and discussion

Current knowledge of PM impairments in individuals with schizophrenia

PM impairments in individuals with schizophrenia and related populations

Results of Wang et al.'s (2009) meta-analytic study showed that individuals with chronic schizophrenia were impaired on PM with a large effect size, with time-based PM more impaired than event-based PM. Moreover, they reported that PM impairments were correlated with a number of factors such as severity of negative symptoms and education. In their systematic review, Ordemann et al. (2014) showed that PM impairments were not related to chronicity in schizophrenia, specifically, that individuals with first-episode schizophrenia also showed PM impairments. They also suggested that PM impairments in individuals with schizophrenia are considered a primary impairment. Since these two reviews, a number of studies that examined PM impairments in individuals with schizophrenia have been published. Three studies (Au, Man, Shum, et al., 2014; Au et al., 2016; Demeter et al., 2016) found severe PM impairments in individuals with chronic schizophrenia. Three studies (Cheung et al., 2015; Liu et al., 2017; Lui et al., 2015) showed that first-episode and even first-episode medication-naïve individuals with schizophrenia demonstrated PM impairments. Overall, results of these subsequent studies are generally consistent with the findings of previous studies reviewed by Wang et al. (2009) and Ordemann et al. (2014).

Among the recent research, two studies examined the neural basis of PM impairments in schizophrenia. Adopting a functional magnetic resonance imaging (fMRI) paradigm, Chen et al. (X. J. Chen et al., 2016) indicated that individuals with schizophrenia showed lower accuracy on an event-based PM task than healthy controls, and these clinical individuals presented decreased activations in the prefrontal cortex, including Brodmann Area 10, and other brain areas such as the anterior cingulate gyrus, precuneus, parahippocampal gyrus, and putamen. These results suggest that PM impairments in schizophrenia are related to brain areas that mediate neurocognitive processes such as attentional control, intention encoding, and maintenance. In another study, Chen et al. (G. Chen et al., 2015) used event-related potentials (ERP), and showed that compared to healthy controls, remitted individuals with schizophrenia did not show significant difference on N300, but they showed significantly reduced prospective positivity amplitude. While N300 is a component related to PM cue detection, prospective positivity is a component related to intention retrieval. These results, therefore, suggested that remitted individuals with schizophrenia were impaired in the retrieval of intention but not in the detection of PM cues. In addition, the amplitude of prospective positivity was significantly correlated with PM performance in individuals with remitted schizophrenia but not in healthy controls.

First-degree relatives of individuals with schizophrenia have a higher rate of developing schizophrenia than general population (Gottesman, 1991), and they have been found to show cognitive impairments compared to healthy controls (Trandafir, Meary, Schurhoff, Leboyer, & Szoke, 2006). Several studies (Lui et al., 2011; Wang et al., 2010; Zhou, Hou, et al., 2014) have examined PM performance in non-psychotic first-degree relatives of individuals with schizophrenia. The results of these studies are not consistent. Wang et al. (2010) found that non-psychotic first-degree relatives (consisting of both parents and siblings) of individuals with schizophrenia showed impairments in both time- and event-based PM but not activity-based PM. However, in that study, they did not present the results of parents and siblings separately. Zhou, Hou, et al. (2014) recruited the offspring and siblings of individuals with schizophrenia, and found that compared to healthy controls, these non-psychotic relatives were impaired in both time- and event-based PM. In addition, offspring and siblings did not show significant difference on PM performance. However, in that study, the relatives were less educated than the healthy controls, and statistical control were used to address this difference. In their study, Lui et al. (2011) specifically compared PM performance among non-psychotic siblings of schizophrenia patients, schizophrenia patients, and healthy controls, and found that compared to healthy controls, non-psychotic siblings did not show impairments in any types of PM. To date, no studies have been conducted to examine the neural correlates of PM in relatives of schizophrenia patients. Future studies should separate parents, siblings, and offspring into participant subgroups and to recruit healthy controls that are better matched to them, and to explore the neural basis of PM in these subgroups.

Individuals with schizotypal personality features are considered to fall into the lower end of the schizophrenia spectrum and are at high risk for developing schizophrenia (Cadenhead, Perry, Shafer, & Braff, 1999). Individuals with schizotypal personality features have also been shown to exhibit cognitive impairments (Bergida & Lenzenweger, 2006; Kopp, 2007). A number of studies (Chan et al., 2008; X. J. Chen et al., 2014; Henry, Rendell, Rogers, Altgassen, & Kliegel, 2012; Wang, Chan, Yu, et al., 2008; Wang et al., 2011; Wang et al., 2014) have examined PM performance in individuals with schizotypal personality features. Wang et al. (2008) found that these individuals (screened using the Schizotypal Personality Questionnaire) showed significantly poorer performance on perceptual time-based and semantic event-based PM tasks than healthy controls. In another study, Chan et al. (2008) showed that individuals with schizotypal personality features were impaired in event-based PM. However, the demographic variables of the two groups of participants in these two studies were not well matched with their respective controls, and these differences had to be statistically controlled for. Using a computerized PM task that included both focal and nonfocal PM cues and the Virtual Week, Henry et al. (2012), did not find any PM impairments in individuals with schizotypal personality features. Therefore, whether PM is impaired in these individuals, requires further study.

One study has explored the neural correlates of PM in individuals with schizotypal personality features. Wang et al. (2014) conducted an fMRI study using an event-based PM task in these individuals. Results showed that participants with schizotypal personality features showed reduced activations in the inferior and medial frontal lobes (Brodmann Areas 45 and 8) compared to the controls, even though the two groups did not show significant differences in their behavioral PM performance.

Impairment of different types of PM in schizophrenia

Regarding performance on different types of PM tasks in individuals with schizophrenia, results are consistent in that all types of PM were impaired. To determine if one type of PM task is significantly more impaired in individuals with schizophrenia, we compared their performance on time- and event-based PM tasks because these are most commonly used in research studies. As mentioned in Ordemann et al. (2014), some studies found that time-based PM were significantly more impaired than event-based PM (e.g., Shum, Ungvari, Tang, & Leung, 2004; Wang, Chan, Hong, et al., 2008), while other studies did not find this difference (e.g., Au, Man, Shum, et al., 2014; Henry, Rendell, Kliegel, & Altgassen, 2007; Lui et al., 2011; Woods, Twamley, Dawson, Narvaez, & Jeste, 2007). In their meta-analytic study, Wang et al. (2009) confirmed that time-based PM was significantly more impaired than event-based PM in individuals with schizophrenia. However, in looking at the results of studies that were published since 2009 (e.g., Au, Man, Shum, et al., 2014; Lui et al., 2011; Lui et al., 2015; Raskin et al., 2014; Zhou et al., 2012; Zhuo et al., 2013), most of them did not show that individuals with schizophrenia were disproportionally more impaired in time-based PM than event-based PM (Au, Man, Shum, et al., 2014; Lui et al., 2011; Lui et al., 2015; Raskin et al., 2014). Several studies (Zhou et al., 2012; Zhuo et al., 2013) did not analyze whether schizophrenia patients showed differential impairments in time- and event-based PM, but reported similar effect sizes for these two types of PM impairment in individuals with schizophrenia.

Regarding the original finding in the Wang et al. (2009) meta-analytic review that time-based PM was more severely impaired than event-based PM in schizophrenia, it was suggested that time-based PM need more self-initiation than event-based PM because time-based PM does not have an external cue to trigger retrieval of the planned intention (Shum et al., 2004; Wang et al., 2009). However, one cannot simply say that time-based PM is more difficult than event-based PM because there are other factors which also influenced PM performance. For example, how often the participants were required to perform PM actions (every minute, every two minutes or every 15 minutes) could also affect performance. This delay was found to have an effect on PM performance (Raskin et al., 2014). In addition, for event-based PM, the focality (focal or nonfocal) of PM cue has also been found to have an effect on performance (Kliegel, Jager, & Phillips, 2008). Although Henry et al. (2012) did not find an effect of cue saliency on the degree of PM impairments in individuals with schizophrenia, cue focality has been found to affect PM performance (Kliegel, Jager, & Phillips, 2008) and focal and nonfocal cues are considered to involve different neural mechanisms (Cona, Bisiacchi, Sartori, & Scarpazza, 2016; McDaniel, LaMontagne, Beck, Scullin, & Braver, 2013). Thus, when comparing whether one type of PM is significantly more impaired than the other type, one needs to take these factors into consideration and to ensure that the tasks used are comparable.

Components of PM impairment and types of PM errors in schizophrenia

The questions of which component(s) of PM is impaired and what types of PM errors are commonly found in individuals with schizophrenia were not covered or discussed in the reviews by Wang et al. (2009) or Ordemann et al. (2014). Several studies have been conducted to examine which component(s) of PM was impaired in schizophrenia. Woods et al. (2007) used the Memory for Intention Screening Test (MIST) to assess PM in individuals with schizophrenia. Results of their study showed that these individuals were impaired on PM. However, the schizophrenia and control groups did not differ on a recognition task after test, suggesting that intention formation and maintenance were relatively intact, with cue detection and intention retrieval likely being responsible for the overall PM failure. Wang, Chan, Hong, et al. (2008) further examined this issue. In their study, participants were asked to recall task requirements after they have finished the PM task. Results indicated that individuals with schizophrenia showed impairment on free recall of task requirements. Furthermore, even including only those individuals with schizophrenia who could recall task requirements, the schizophrenia group was still found to perform significantly poorer than the control group. These results suggested that intention maintenance, cue detection, and intention retrieval all contributed to the overall PM impairments. In another study that examined this issue, Liu et al. (2017) manipulated the load in cue detection and intention retrieval. Results of their study showed that both cue detection and intention retrieval components of PM were impaired in schizophrenia. After controlling for working memory and retrospective memory, cue detection PM was still impaired in individuals with schizophrenia. Altgassen, Kliegel, Rendell, Henry, and Zöllig (2008) found that PM was impaired even when the retrospective memory load was minimal. In addition, both prospective and retrospective components of PM were found to contribute to PM impairment in individuals with schizophrenia. Taken together, these results suggested that cue detection, intention retrieval, prospective, and retrospective components of PM are all impaired in individuals with schizophrenia.

Several studies have been conducted to examine what were the common types of PM errors in individuals with schizophrenia. In studies that use the MIST and the Virtual Week, types of errors were recorded and reported. Henry et al. (2007) explored the pattern of errors on the Virtual Week in schizophrenia, and five types of errors were recorded for this task: Late (PM response was made after the correct time period but before the virtual day), Miss (participants totally forget the PM cue), No Content (participants remembered something should be done at the right time, but did not know what to do), Wrong Content (participants remembered a wrong thing to do at a correct time), and Other Wrong (participants remembered to do something at a wrong time). Results demonstrated that individuals with schizophrenia showed more Misses on all types of PM tasks and took longer time to respond on the time-check task. No significant difference was found on other types of errors.

Woods et al. (2007) examined types of PM errors in individuals with schizophrenia using the MIST. Results of their study indicated that these individuals showed more No Response (participant did not make any responses to a PM cue), Loss of Time (participants make a correct response but at an incorrect time), and Task Substitution (participants make a wrong response on a PM cue) errors than healthy controls. In another study, Raskin et al. (2014) showed that individuals with schizophrenia only showed more No Response errors than healthy controls, and the differences in other error types did not reach statistical significance. Overall, results of the studies reviewed suggest that Miss or No Response errors were consistently found to be more frequent in individuals with schizophrenia than in healthy controls, suggesting the primacy of problems with the prospective component of PM.

Relationship between PM and other cognitive functions

PM is a complex construct that involves multiple cognitive functions, such as attention, retrospective memory, switching, inhibition, and executive function. Therefore, it has been found to correlate significantly with these cognitive functions (Lui et al., 2015; Twamley et al., 2008; Wang, Chan, Hong, et al., 2008). A question has been raised regarding whether individuals with schizophrenia will still be impaired on PM if these cognitive processes have been controlled for. According to Ordemann et al. (2014), several studies (Altgassen et al., 2008; Henry et al., 2007; Wang, Chan, Hong, et al., 2008) have found that PM impairment still remained in individuals with schizophrenia after controlling for other cognitive processes. Thus, they suggested that PM impairment is a primary rather than secondary impairment of schizophrenia. The same conclusion was drawn by Lui et al. (2015) based on the results of their study. Nevertheless, Liu et al. (2017) found that after controlling for working memory and retrospective memory, only the cue identification but not intention retrieval component of PM remained significantly different between individuals with schizophrenia and controls. These results suggest that further studies are needed to clarify this issue, albeit that at least PM cue identification could be considered a primary impairment of schizophrenia.

Relationship between PM with medication adherence and functional outcome

PM has been reported to correlate significantly with medication adherence and functional outcome. This issue was not mentioned in Wang et al. (2009), and not discussed in detail in Ordemann et al.'s (2014) review. Zogg, Woods, Sauceda, Wiebe, and Simoni (2012) reviewed the literature and found that PM impairment was a risk factor for medication non-adherence in general. Lam, Lui, Wang, Chan, and Cheung (2013) found that in individuals with schizophrenia all three types of PM correlated significantly with medication management ability as measured by the Medication Management Ability Assessment. In addition, at three-month follow-up, the medication adherent and non-adherent groups showed significant difference in time- and event-based PM performance. The relationship between PM and medication management ability was also found by Raskin et al. (2014) in their study.

Twamley et al. (2008) explored the relationship between PM and functional capacity and found that better PM was predictive of higher functional capacity, better than that provided by demographic and disease factors. Au, Man, Xiang, et al. (2014) found that community living skills were correlated with event- and time-based PM performance, and event-based PM performance was found to be predictive of the level of community living skills after controlling for demographic and clinical variables. Although Xiang, Shum, Chiu, Tang, and Ungvari (2010) did not find a significant relationship between PM and social functioning, most previous studies have shown that PM plays an important role in medication adherence and functional outcome in schizophrenia patients.

Longitudinal studies of PM in schizophrenia

The topic of longitudinal study of PM in individuals with schizophrenia was not included in the reviews by Wang et al. (2009) and Ordemann et al. (2014). Longitudinal studies allow us to determine whether PM impairments in these individuals are stable over time. There are three longitudinal studies on PM performance in individuals with schizophrenia and those who are at risk. Wang et al. (2011) explored the 6-month test-retest reliability of PM performance in participants with schizotypal personality features, and found that PM performance was stable in these participants. Cheung et al. (2015) conducted a one-year follow-up study in individuals with first-episode schizophrenia and found that these individuals showed gradual improvement in time- and event-based PM in 12 months after the onset of disease. While time-based PM impairment was found to be stable and persisted over the 12 months, event-based PM seemed to have improved and did not remain impaired. In their study, Zhou, Xiang, et al. (2014) found that higher scores on time-based PM at baseline predicted remission at 8-week follow-up. However, they did not measure PM at follow-up. Zhou et al. (2017) conducted a 1-year follow-up study in first-episode schizophrenia and found that event-based PM improved over time, and this improvement was associated with clinical remission. Clinically remitted patients showed significantly better performance in event-based PM than non-remitted patients. More longitudinal studies that involve longer follow up are needed to clarify the stability of PM impairment in these individuals and those who are at risk.

Approaches to clinical assessment of PM for individuals with schizophrenia

A number of assessment instruments have been developed to assess PM. In this section, we review the instruments that have been applied in the schizophrenia population. Table 2 presents a brief summary of these instruments.

Table 2. Summary of PM assessments

PM assessment	Definition and/or example item	Studies reported psychometric properties	Studies in schizophrenia
Self-report questionnaires			
PRMQ	It is a 16-item questionnaire and included prospective and retrospective factors. An example item on PM: "Do you forget to buy something you planned to buy, like a birthday card, even when you see the shop?"	Crawford et al. (2003)	Chan et al. (2008), Lui et al. (2015)
CAPM	It originally includes 36 items and includes 33 items in the Chinese version. It includes 2 factors: instrumental activities of daily living (e.g., Forgetting an appointment with your doctor or therapist) and basic activities of daily living (e.g., Forgetting to eat a meal).	Chau et al. (2007)	Lam et al. (2013)
BAPM	Short version of CAPM. It includes 16 items and the same two factors as CAPM.	Man et al. (2011)	Khoyratty et al. (2015)
Computerized tasks			
Computerized tasks	PM is embedded in computerized ongoing task (e.g., answering general knowledge questions, doing word categorization, or making lexical/idiom decision). The PM task usually involves pressing a specified key under different conditions, depending on whether one wants to assess time-, event-, or activity PM.		Altgassen et al. (2008), Wang et al. (2008), Cheung et al. (2015), Henry et al. (2012), Liu et al. (2017), Lui et al. (2015)
Psychometric test batteries			
MIST	It measures event- and time-based PM with short (2 min) or long (15 min) delays, participants need to make verbal or action responses when a PM cue is detected. An example task is "In exactly 15 minutes please tell me it is time to take a break".	Raskin (2009), Woods et al. (2008)	Woods et al. (2007), Twamley et al. (2008), Raskin et al. (2014)

Virtual Week	It is a test battery that simulates daily life activities using a board game. In each virtual day, there are 10 PM tasks: 4 regular, 4 irregular and 2 time check. An example of a regular event-based task is "take antibiotics at breakfast and dinner".	Henry et al. (2007), Rendell & Henry (2009)	Henry et al. (2007, 2012)
CAMPROMPT(-C)	It consists of 3 event-based and 3 time-based PM tasks. They are embedded in a general knowledge quiz and word finding puzzles. An example task is to give a map to the examiner when he/she comes across a question containing the words "great wall".	Man, Chan, &Yip (2015)	Au, Man, Shum et al. (2014), Au, Man, Xiang et al. (2014), Au et al. (2016), Khoyratty et al. (2015), Zhou, Hou et al. (2014), Zhou, Xiang et al. (2014), Zhou et al. (2017)
Virtual reality assessment			
VRPMT	It is a non-immersive virtual reality test of PM. In the test, the participant is required to navigate different shops in a virtual shopping center to buy things from the shopping list. Three event-based (e.g., press the "T" key in response to sales announcements) and 3 time-based (e.g., send a text message 4 minutes after the start of the test) PM tasks are embedded in the shopping task.	Man et al. (2016)	Man et al. (2016)

Note: BAPM, Brief Assessment of Prospective Memory; CAMPROMPT, Cambridge Prospective Memory Test; CAPM, Comprehensive Assessment of Prospective Memory; MIST, Memory for Intentions Screening Test; PRMQ, Prospective and Retrospective Memory Questionnaire; VRPMT, Virtual Reality Prospective Memory Test.

Self-report questionnaires

Two of the most commonly used self-report PM questionnaires are the Prospective and Retrospective Memory Questionnaire (PRMQ; G. Smith, Sala, Logie, & Maylor, 2000) and the Comprehensive Assessment of Prospective Memory (CAPM; Roche, Fleming, & Shum, 2002). The PRMQ was originally developed to measure memory problems in older adults and dementia. Several studies have used this questionnaire in individuals with schizophrenia (Chan et al., 2013; Chan et al., 2008; Lui et al., 2015). They found that schizophrenia did not report significantly poorer PM problems than controls, and the self-reported PM problems did not correlate with objective PM performance.

The CAPM was originally developed to examine PM failure in patients with brain injuries. Lam et al. (2013) used this questionnaire in their study and found that individuals with schizophrenia did not report more PM problems than healthy controls. A short version of the CAPM, Brief Assessment of Prospective Memory (BAPM) has also been developed (Man, Fleming, Hohaus, & Shum, 2011).

Computerized tasks

For objective assessment of PM, many studies used computerized PM tasks pioneered by Einstein and McDaniel (1990). In this kind of task, the person is usually asked to undertake two tasks, an ongoing and a PM task. The strength of this task is that the reaction time of PM task and ongoing task can be recorded, and the PM task can be easily controlled and manipulated. For example, RM load (Altgassen et al., 2008), PM cue focality (focal/nonfocal; Henry et al., 2012), and component of processing (cue detection/intention retrieval) have been introduced as task manipulations (Liu et al., 2017). The limitation of these tasks is they are different from daily PM activities that individuals might normally be required to perform.

Psychometric test batteries

There are several commonly used psychometric PM test batteries, namely, the Memory for Intentions Screening Test (MIST) (Raskin, 2009), the Virtual Week (Rendell & Henry, 2009), and the Cambridge Prospective Memory Test (CAMPROMPT) (Groot, Wilson, Evans, & Watson, 2002). The MIST takes about 30 minutes to administer and complete. In designing the battery, the authors took several variables related to PM into consideration: type of cue (event-based, time-based), type of response (verbal, action), length of delay period (short, long). It has eight PM measures. Details of the test can be found in Raskin (2009). The ongoing task in this test includes word search puzzles. Woods et al. (2007), Twamley et al. (2008), and Raskin et al. (2014) have used the MIST with individuals with schizophrenia in their study.

The Virtual Week (Rendell & Craik, 2000) is a test battery that simulates daily life activities using a board game. In undertaking the battery, the test taker move around the board with the roll of a dice. The hours of a day are marked on the board and each circuit of the board represents a virtual day. When participants move around the board, they are required to make choices on the daily activities and remember to carry out everyday activities (PM tasks). The regular and irregular tasks all include the same numbers of time- and event-based tasks. Details of the test can be found in Rendell and Henry (2009).The original version has seven virtual days, however, five virtual days and three virtual days versions have also been developed. Henry et al. (2007, 2012) have used this test in their study of individuals with schizophrenia and at-risk individuals.

The CAMPROMPT (Groot et al., 2002) consists of three event-based and three time-based PM tasks and its administration takes about 30 minutes. During the ongoing task, the test taker is required to make PM responses. Six studies (Au, Man, Shum, et al., 2014; Au, Man, Xiang, et al., 2014; Au et al., 2016; Zhou, Hou, et al., 2014; Zhou et al., 2017; Zhou, Xiang, et al., 2014) have used this test in their study of individuals with schizophrenia.

The strength of these psychometric PM test batteries is that they are similar to daily PM activities, but their weaknesses are the time and effort required to administer and score the tests, while observing the test takers. One of these batteries, namely, the Virtual Week has been computerized to overcome some of these limitations.

Virtual reality assessment

The Virtual Reality Prospective Memory Test (VRPMT) (Man et al., 2016) is a non-immersive virtual reality test of PM. It is the Chinese version of the Virtual Reality Shopping Test (VRST) (Canty et al., 2014), which was developed to measure PM in patients with traumatic brain injury. In their study, Man et al. (2016) showed that the VRPMT is a valid and reliable test, and had good sensitivity and specificity in discriminating individuals with first episode schizophrenia from healthy controls. The test takes approximately 14 minutes to administer. The strength of this test is its similarity with daily PM activities, with the primary drawback being that some clinical participants found it difficult to understand and follow the instructions even after tutorial sessions (Man et al., 2016).

Evidence-based approaches to treatment of PM impairment in schizophrenia

There are two primary approaches of cognitive training: restorative and compensatory. The restorative approach aims to augment or repair the underlying impaired functions, whereas the compensatory approach attempts to develop strategies to overcome the impaired underlying function to reach a good level of performance (Twamley, Jeste, & Bellack, 2003). Both approaches have been shown to improve PM performance in older adults (Hering, Rendell, Rose, Schnitzspahn, & Kliegel, 2014).

For individuals with schizophrenia and those who are at risk, four studies have been conducted to improve PM. All of them adopted the compensatory approach. Twamley, Vella, Burton, Heaton, and Jeste (2012) conducted a randomized controlled trial that included 69 patients with primary psychotic disorders. These individuals were assigned to the standard pharmacotherapy alone (control group) and standard pharmacotherapy and compensatory cognitive training (training group) groups. The training group received a two-hour training session once a week for 12 weeks. The training included intervention targets for PM, attention, learning/memory, and executive functioning. The strategies targeting PM included activities such as calendar use, to-do-lists, and prioritizing tasks. Results showed that compared to the control group, the training group showed improvement on PM as measured by the MIST ($p = 0.05$) at three-month follow-up.

Three other studies used implementation intentions as the strategy to improve PM. This is a brief encoding strategy in the form of “if I meet X, then I will do Y” (Gollwitzer, 1999). When applied to PM, participants received the PM instructions in the “if… then…” format, and read the instructions aloud for a few times (most studies used three times). Sometimes it was used in combination with a self-imagery strategy. X. J. Chen et al. (2014) applied implementation intentions to individuals with schizotypal personality features and their results showed that event-based PM performance can be improved in both high and low cognitive load conditions. In another study, Khoyratty et al. (2015) applied this strategy to individuals with early psychosis and their results showed that event-based PM benefited from implementation intentions in these participants. In the standard instruction condition, PM performance in the early psychosis group was significantly lower than the matched controls. However, in the implementation intentions condition, PM performance in individuals with early psychosis and healthy controls did not show significant differences. Furthermore, PM improvement was not found to be at the cost of ongoing task performance. Finally, X.J. Chen et al. (2016) applied implementation intentions to individuals with schizophrenia and their results showed that this technique improved event-based PM in both low and high cognitive load conditions without ongoing task cost. However, evidence of improvement is lacking for time-based PM. These results showed that compensatory strategies were effective in improving PM performance in individuals with schizophrenia and those who are at risk. However, most of these studies are not randomized control trials. Moreover, most of the reviewed studies instructed participants to use the strategy once. Therefore, the effects of longer and more frequent intervention are not known. Finally, it is unclear if the effects of these interventions will last very long or if they can be generalized to other everyday PM tasks.

Suggestions for the development of interventions for PM in schizophrenia

For the development of interventions for PM impairments in schizophrenia, an important consideration is to make them aware of the PM impairments. Educating patients with schizophrenia about the prevalence of PM deficits may increase their willingness to adopt compensatory strategies. Given that some previous studies have shown that self-reported PM problems in schizophrenia were not significantly different from those of healthy controls (Chan et al., 2008; Lui et al., 2011; Lui et al., 2015), this means that individuals with schizophrenia may lack self-awareness of PM impairments and some training may be carried out to improve their self-awareness before PM treatment.

After patients have developed awareness of their PM impairments, clinicians or rehabilitation workers can teach them how to use some strategies to avoid PM failures, and ask them to use compensatory strategies both consciously and automatically. Although there are only a few studies on PM rehabilitation in schizophrenia, some suggestions can be developed based on results of studies conducted using other populations. For example, in the encoding phase, implementation intentions can be used to increase PM performance (X.J. Chen et al., 2016). Enactment in encoding can also improve PM performance (Pereira et al., 2015). In addition, encoding the intention in multiple modality (e.g., verbal, visual) may also help (Potvin, Rouleau, Senechal, & Giguere, 2011). For example, to give a message to a friend, one can rehearse the friend's name and visualize the face of the friend at the same time.

During the maintenance phase, one possible technique is to reduce the delay. This is because as the delay between intention formation and execution increases, the performance on PM tasks would decrease (McBride, Beckner, & Abney, 2011). For instance, individuals with schizophrenia can be taught to carry out intended actions immediately when he/she thinks about it, and not to wait until later. Another technique is to use the "stop" strategy (Fish et al., 2007), during which an individual can occasionally stop the things he/she is doing and thinks about his/her goal and see what needs to be done.

A number of strategies can be used during the retrieval phase. These include making the PM cue more salient (e.g., to place the garbage bin near the door to remind one to empty it); associating the PM task with a routine activity (e.g., taking medicine after dinner); writing notes and using calendar (write down things that need to be done in the diary and to develop a habit of checking the diary regularly). Other related strategies are to use external aids such as alarm clock, cell phone text message, and to-do-list, etc. It is also possible that playing some computer games can increase working memory and/or executive functions (Hayden, 2012), which subsequently may improve PM (R. E. Smith & Bayen, 2005; West & Bowry, 2005).

Conclusion

This study aimed to provide an update review of studies on PM in individuals with schizophrenia and related populations, and highlight findings that were not covered by the previous two reviews/meta-analysis. We found that individuals with schizophrenia showed severe PM impairments, and this finding mainly reinforces the conclusions of the previous reviews. Moreover, time-based PM impairments tended to be more stable over time, and the type of PM errors (no response, miss) suggested that prospective component seem to be an important impairment in PM. These findings extended the conclusions reported in previous reviews. Importantly, PM impairments in schizophrenia have been found to be related to medication adherence and functional outcomes in schizophrenia, and again these findings extended the conclusions of previous reviews. Another finding that extends the conclusion of previous reviews is that PM impairments were related to dysfunctions in prefrontal cortex and other related regions in schizophrenia. Two parts of our paper were not covered by previous reviews. First, there are several approaches to assess PM in schizophrenia and each has its own strengths and weaknesses. Second, only a small number of rehabilitation studies (<5) have been conducted to improve PM in this population. While there is some encouraging evidence of improvement in PM, more randomized controlled trials that examine dosage, retention and generalization of treatment effects are needed. The present review concluded with some suggestions for the development of interventions for PM impairments in individuals with schizophrenia.

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