Consciousness and Cognition 81 (2020) 102920

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

The impact of state and dispositional mindfulness on prospective memory: A virtual reality study

Jean-Charles Girardeau[a,*], Philippe Blondé[a], Dominique Makowski[b], Maria Abram[a], Pascale Piolino[a,c,1], Marco Sperduti[a,1]

[a] Laboratoire Mémoire, Cerveau & Cognition (MC²Lab, EA7536), Institut de Psychologie, Université de Paris, Paris, France
[b] School of Social Sciences, Nanyang Technological University, Singapore, Singapore
[c] Institut Universitaire de France (IUF), France

ARTICLE INFO

Keywords:
Mindfulness
Mind wandering
Prospective memory
Five Facets Mindfulness Questionnaire
Virtual reality

ABSTRACT

Prospective memory (PM) consists of remembering to perform an action that was previously planned. The recovery and execution of these actions require attentional resources. *Mindfulness*, as a state or a dispositional trait, has been associated with better attentional abilities while *mind wandering* is linked with attentional failures. In this study, we investigated the impact of *mindfulness* on PM. Eighty participants learned 15 cue-action associations. They were, then, asked to recall the actions at certain moments (time-based items) or places (event-based items) during a walk in a virtual town. Before the PM task, participants were randomly assigned to a *mindfulness* or *mind wandering* (control condition) session. Dispositional *mindfulness* was measured via the Five Facets Mindfulness Questionnaire (FFMQ). Although considered as two opposite states, we did not report any difference between the two groups on PM abilities. Nevertheless, the natural tendency to describe one's own sensations (the *Describing* facet of the FFMQ) predicted *time-based* performance in both groups. We discuss different hypotheses to explain this finding in light of recent findings on the impact of *mind wandering* on future oriented cognition. Our main observation is a positive link between the *Describing* facet and *time-based* PM performances. We propose that this link could be due to the common association of this *mindfulness* facets and PM with attentional and interoceptive abilities. Additional studies are needed to explore this hypothesis.

1. Introduction

"Memory is the future of the past" (Valery, 1975)

Planning, organizing, thinking up, foreseeing are daily mental activities everyone has to handle. Particularly useful for these activities, prospective memory (PM) is much more essential than we can realize in maintaining an adaptive behavior and a personal and social autonomy. It is indispensable, for example to remember to send a message to wish a birthday, to honor an appointment, to pay taxes before the deadline or to take medicines at a precise time of the day. A failure of PM constitutes an important social discomfort and a major decline of this memory can hinder a person's autonomy. PM failures are a hallmark of normal and

* Corresponding author at: Laboratoire Mémoire, Cerveau & Cognition (MC2Lab EA7536), Institut de Psychologie, Université Paris Descartes, 71 Ave Édouard Vaillant, 92100 Boulogne-Billancourt, France.

E-mail address: jean-charles.girardeau@parisdescartes.fr (J.-C. Girardeau).

[1] Sharing last co-authorship.

https://doi.org/10.1016/j.concog.2020.102920
Received 29 April 2019; Received in revised form 4 February 2020; Accepted 19 March 2020

pathological cognitive aging (Gonneaud, Eustache, & Desgranges, 2009; Kalpouzos, Eustache, & Desgranges, 2008; Kliegel & Martin, 2003; Rouleau et al., 2016). Thus, defining a cognitive intervention program aimed at stimulating PM could have important clinical applications.

PM is a rather singular form of memory. It consists of "remembering to remember". In other words, it is the ability to remember to carry out, at the appropriate moment, an action that was previously planned. PM encompasses different phases such as: the formation and encoding of an intention; its maintenance over a given period of time occupied by other ongoing activities; the recovery, at the opportune moment, of the intention in memory; and finally, the execution of the corresponding action (Kliegel, Martin, McDaniel, & Einstein, 2002). All these phases are underpinned by various cognitive processes such as planning, cognitive flexibility, inhibition and attention (Bisiacchi, Schiff, Ciccola, & Kliegel, 2009; Kliegel, Jäger, & Phillips, 2008; Kliegel, Martin, McDaniel, Einstein, & Moor, 2007; Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013; Smith & Bayen, 2004).

Nevertheless, not all PM tasks require the same cognitive resources. Indeed, according to the multiprocess theory (Einstein et al., 2005), the performance of PM can be modulated by different features of the PM task such as when few attentional resources are devoted to the ongoing task or when the detection of prospective cues rests on the same processes (*e.g.*, perceptive, semantic) as the one involved in the current task, or when the prospective cues are semantically linked to the corresponding action (Einstein & McDaniel, 2005; Einstein, Smith, McDaniel, & Shaw, 1997; Gonneaud, Piolino, Lecouvey, Madeleine, Orriols, Fleury, & Desgranges, 2012; Marsh, Hicks, & Watson, 2002; McDaniel & Einstein, 1993). Thus, in certain situations, the recovery of an intention can be done automatically, while in other circumstances, the commitment of controlled processes is required. This theory is supported by cerebral activations specific to the two modes of operation. Frontal regions are engaged when strategic processes are at stake, while medio-temporal structures (especially the hippocampus) are recruited when a more automatic recall occurs (Kalpouzos et al., 2008; McDaniel & Einstein, 2011).

Additionally, the recovery of PM intentions can be triggered by an external event (*e.g.*, remembering to buy bread when encountering a bakery) or can be auto-initiated at a specific moment (*e.g.*, remembering to take the cake out of the oven after 30 min). In the first case, we talk about *event-based*, and in the latter of *time-based* (Kvavilashvili & Ellis, 1996). Contrary to *event-based*, *time-based* actions do not depend on environmental monitoring but are based on the internal time monitoring. Time estimation require more self-initiation by individuals and the commitment of attentional and executive processes allocated to time management. As a consequence, *time-based* intentions is more costly and difficult to implement (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995). Thus, *time-based* PM are significantly more sensitive to a modification of the cognitive load and are more prone to errors than *event-based* ones (Khan, Sharma, & Dixit, 2008).

If *time-based* and *event-based* PM share common brain activations reflecting the involvement of strategic processes (Gonneaud et al., 2014), a lesional approach (Volle, Gonen-Yaacovi, de Lacy Costello, Gilbert, & Burgess, 2011) and a transcranial magnetic stimulation study (Debarnot et al., 2015) revealed some dissociation between the two. A large network comprising the dorsolateral prefrontal cortex, the cuneus/precuneus and, to a lesser extent, the inferior parietal lobule, the superior temporal gyrus and the cerebellum, is particularly involved in *time-based* PM, notably because it would underlie the management and time perception (Gonneaud et al., 2014). Conversely, the left frontopolar cortex and occipital areas were more activated during *event-based* PM, probably reflecting target-checking (Gonneaud et al., 2014). These observations confirm the results of a previous study on the involvement of a broad frontoparietal network throughout the entire task for the maintenance of intentions, followed by an activation of the occipital cortex during target-searching and finally the activation of a fronto-hippocampal network during the retrieval of intentional content (Kalpouzos, Eriksson, Sjölie, Molin, & Nyberg, 2010).

Given the importance of attentional and executive functions for the correct function of PM, and the growing body of literature showing a positive impact of *mindfulness* on these functions, this could be a promising candidate as a cognitive stimulation tool for the PM.

Mindfulness is a cognitive state emerging from intentionally bringing attention on the present moment with a non-reactive, non-judgmental and accepting stance toward the current experience (Kabat-Zinn, 1982). As such, *mindfulness* can be trained by meditation practices, but also be considered as personality trait (Baer et al., 2008). In the following, we will refer to these two aspects as *mindfulness* meditation and dispositional *mindfulness*, respectively. *Mindfulness* meditation necessitates attentional regulation processes allowing keeping one's attentional focus on the lived experience, while ignoring distraction. There is nowadays a quite general scientific consensus on the positive impact of *mindfulness* meditation (Jha, Krompinger, & Baime, 2007; Lutz, Slagter, Dunne, & Davidson, 2008; Tang et al., 2007; Tang, Hölzel, & Posner, 2015) on attentional abilities, in particular of the executive component. Concerning dispositional *mindfulness*, several studies have reported a positive correlation between self-reported *mindfulness* and sustained attention performance (Galla, Hale, Shrestha, Loo, & Smalley, 2012; Josefsson & Broberg, 2011) or the efficiency of the executive component of attention (Ainsworth, Eddershaw, Meron, Baldwin, & Garner, 2013; Galla et al., 2012; Josefsson & Broberg, 2011). Nevertheless, one study did not find any association between dispositional *mindfulness* and the efficiency of the alerting, the orienting or the executive attentional network (Jaiswal, Tsai, Juan, Liang, & Muggleton, 2018). Di Francesco et al. (2016) even reported that dispositional *mindfulness* was associated with longer reaction times under conflict resolution. Interestingly, Sørensen et al. (2018) replicated the null findings concerning the association between dispositional *mindfulness* and the efficiency of the three attentional networks, but they did show a positive correlation with the interaction scores of orienting by conflict detection. The authors interpreted this finding as a more flexible and efficient orienting of attention with increased dispositional *mindfulness*. This is coherent with a more recent study showing that dispositional *mindfulness* was related to reduced attentional blink driven by emotional material, likely witnessing a faster disengagement of attentional resources from irrelevant distractors (Makowski, Sperduti, Lavallée, Nicolas, & Piolino, 2019). Beyond attention, meditation practice has also been shown to have a positive effect on executive functions (Mrazek, Franklin, Phillips, Baird, & Schooler, 2013), in particular on inhibition (Gallant, 2016).

Since attention and executive functions play a pivotal role in PM, it is likely that *mindfulness* meditation could enhance PM performances. *Mindfulness* meditation could also have a positive influence on the retrospective aspect of memory necessary to PM. Indeed, during PM, we do not have to remember to just doing something, but we have to remember exactly what to do. Brown, Goodman, Ryan, and Anālayo (2016), for example, have shown that a single brief *mindfulness* meditation session (10 min) improved free recall and recognition. Moreover, recently, a positive link between the rate of self-caught *mind wandering* and the monitoring of PM *time-based* goals has been reported (Seli, Smilek, Ralph, & Schacter, 2018). This finding suggests a common monitoring system for the content of consciousness and PM intentions. Given that even the most basic *mindfulness* meditation exercise consists in catching the occurrence of *mind wandering* in order to re-orient the attentional focus on the chosen object of attention, these data ground a direct theoretical link between *mindfulness* and PM.

Our main hypothesis is that *mindfulness* meditation and dispositional *mindfulness* should be linked with better PM performance. This effect should be more important for *time-based* intentions given the higher involvement of attentional resources (Einstein et al., 1995; Khan et al., 2008). Moreover, we expected that the effect of *mindfulness* meditation on PM performances would be amplified in subjects showing higher scores of dispositional *mindfulness*. To test our hypotheses, we employed a virtual reality PM task (Debarnot et al., 2015) permitting to assess both *event-* and *time-based* PM in a naturalistic context similar to real life. Before the PM task, participants were randomly assigned to a *mindfulness* meditation exercise of 15 min or to a *mind wandering* induction (control condition) of the same duration. Indeed, *mind wandering*, being characterized by the occurrence of task-unrelated and stimulus-independent thoughts (Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011; Xu, Purdon, Seli, & Smilek, 2017), is consensually held to be antithetical to *mindfulness* (Arch & Craske, 2006; Garland, Hanley, Farb, & Froeliger, 2015). This is the main reason why it has been commonly employed as a control condition in studies investigating the effect of short *mindfulness* sessions on cognition (Dickenson, Berkman, Arch, & Lieberman, 2012; Garland et al., 2015; Rosenstreich & Ruderman, 2017; Wilson, Mickes, Stolarz-Fantino, Evrard, & Fantino, 2015). Moreover, *mind wandering* occupies a large portion of our waking everyday mental activity (Killingsworth & Gilbert, 2010), thus having a good ecological validity (Cahn & Polich, 2009). Finally, we chose this control condition as we wanted to conduct a double-blind study in order to minimize biases linked to the subjects' expectations. We reasoned that an induction of *mind wandering* could reasonably be taken, by meditation naive subjects, as a meditation session. Other control conditions such as listening to a story, reading a book or doing nothing could have hardly be presented as a meditation session.

Brief *mindfulness* inductions have successfully been employed to affect different cognitive functions in numerous studies (Droit-Volet, Fanget, & Dambrun, 2015; Immink, Colzato, Stolte, & Hommel, 2017; Larson, Steffen, & Pimosch, 2013). This approach permits experimentally manipulating the participants' cognitive state comparing a meditation induction with an appropriate control condition. Thus, on the one hand, it allows a more straightforward conclusion compared to cross sectional studies, about causality, and on the other hand, it is less burdening compared to longitudinal studies. To our knowledge, this is the first study directly investigating the links between *mindfulness* and PM.

2. Material and methods

2.1. Subjects

Participants were recruited from the Institute of Psychology at the University of Paris Descartes. To be eligible for the study, subjects should: i) be aged between 18 and 30 years old; ii) not practice meditation, ii) be native French speakers. They received credits for their participation. We recruited 80 young adults that were randomly assigned to a *mindfulness* (N = 39, 34 females and 5 males, age 21.69 ± 2.95 years) or a *mind wandering* (N = 41, 36 females and 5 males, age 20.97 ± 2.23 years) induction. Subjects in the two groups were matched on demographic (age, academic level), affective (Anxiety assessed by the State-Trait Anxiety Inventory; Spielberger, Gorsuch, & Lushene, 1970; Depression assessed by the Beck Depression Inventory; Beck, Steer, & Brown, 1996) and executive functions abilities (Inhibition measured by the STROOP; Stroop, 1935; Flexibility measured by the Trail Making Test; Crowe, 1998) (See Table 1). This study was conducted in double blind. All subjects were recruited by an announcement offering to test meditation, and experimenters were blind to what condition subjects were assigned. They were informed of the academic nature of the study and accepted that their responses would be processed anonymously. After the nature of the procedure had been fully explained, all participants gave written informed consent before carrying out the study. The protocol was carried out in accordance with the local ethical standards.

Table 1
Demographic data. BDI = Beck Depression Inventory; STAI = State-Trait Anxiety Inventory; TMT = Trail Making Test.

	Mindfulness	Mind-wandering	*t*-test
Participants	39 (34 female)	41 (36 female)	
Age	21.69 ± 2.95	20.97 ± 2.23	t(78) = 1.23, p = 0.22
BDI	6.69 ± 4.98	6.28 ± 6.27	t(78) = 0.007, p = 0.99
STAI	47.05 ± 10.51	44.17 ± 12.06	t(78) = 1.14, p = 0.26
STROOP	0.3 ± 1.24	0.27 ± 1.98	t(78) = 0.09, p = 0.92
TMT	−0.1 ± 1.43	−0.1 ± 1.39	t(78) = 0.001, p = 0.99
Retrospective score	24.77 ± 4.02	24.56 ± 3.72	t(78) = 0.24, p = 0.81

2.2. Procedure

The protocol started with a brief neuropsychological assessment, followed by a familiarization phase with the virtual reality equipment consisting in a walk in a virtual town similar to that employed in the main experimental task. This familiarization phase also served as a retrospective task leading to a recognition task. Then, participants carried out the encoding phase of the prospective task, before being randomly assigned to one of the inductions (administered through headphones). After each inductions participant had to answer 6 questions assessing their cognitive state during the induction, immediately following by the virtual reality PM task. Finally, a free and a cued recall of *event/time* action associations were carried out. At the end of the protocol, participants completed the last questionnaires containing ad-hoc questions on the induction experience. The whole protocol lasted about 90 minutes.

2.3. Questionnaire

Dispositional *mindfulness* was assessed by the Five Facet Mindfulness Questionnaire - FFMQ (Baer et al., 2008; Heeren, Douilliez, Peschard, Debrauwere, & Philippot, 2011). It is composed by 39 items (5-point Likert scales) evaluating 5 sub-components: *Observing* (tendency to pay attention to our feelings and what surrounds us), *Describing* (ability to verbalize feelings), *Acting with awareness* (degree of attention to what one does), *Nonjudging of inner experience* (adopting a neutral attitude towards one's thoughts and actions), and *Nonreactivity to inner experience* (tendency to not react to our thoughts and feelings). In Supplementary Material are reported the descriptive statistics and the comparisons between the groups for each facet.

A self-assessment comprising 6 questions (visual analog scales ranging from 0 to 100) assessed the participants' cognitive state during the induction. The questions assessed: the degrees of sleepiness ("I felt sleepy", *Drowsiness*), the tendency to mindwander ("My thoughts flowed freely, without control", *Mind wandering*), the degrees of focused attention ("I was focused on a particular idea, sensation or perception", *Focused Attention*), the tendency to remain focused on bodily sensations ("My thoughts were directed to what was happening in my body (physical sensations, breathing, heart…, *Absorption Body*), the tendency to stay focused on thoughts ("My thoughts were focused on events that I imagined or remembered", *Absorption Internal*), or to be focused on external elements of the environment ("My thoughts were focused on what was happening around me (noises, voices…, *Absorption External*).

To control the impact of inductions on mood, we used a mood assessment grid inspired by Russell, Weis, and Mendelsohn (1989). Participants had to complete the assessment at the beginning of the experience and just after the inductions. Individuals indicated the valence and intensity of their mood by affixing a mark at the intersection of the two axes. The scale of the two axes (valence and arousal) ranged from 0 to 9, providing two scores, one for valence and one for intensity.

At the end of the protocol we employed two ad-hoc questions (5-point Likert scales) to assess the degree of effort during the inductions (Follow the instructions was effortful), and the time spent thinking to the PM action during the inductions (I have often thought back to the actions I had to perform during the task).

2.4. Memory task in virtual reality

The memory task was carried out in a virtual urban environment representing a city inspired by Paris with buildings, passers, signs and background sounds evoking an urban environment. It was constructed with Virtools and in-house software for creation and visualization of virtual environments (EditoMem and SimulaMem). The same task has been already employed by Abram, Cuny, Picard, and Piolino (2014) and Debarnot et al. (2015). The participant moved with a joystick and followed street signs indicating the route leading to the train station. This was done to be sure that all participants followed the same itinerary and, thus, met the same events in the same order.

2.4.1. Retrospective task

The retrospective phase consisted of a first walk in the virtual city in order to become familiar with the environment. Participants followed a precise route with the instructions "to go to the station" (following signs for this purpose) and to pay attention to the elements/events encountered along the way. They were told that they would be subsequently asked to recognize pictures of the elements encountered during their walk. Immediately after the end of navigation, they performed a recognition task. During recognition, 24 items that actually belonged to the virtual environment (*e.g.*, fire hydrant, cars, letter box) and 12 new items (lures) were presented. We computed a correct response score (max = 36).

2.4.2. Prospective task

The PM task was composed of two parts: the encoding of 15 event-action pairs (phase preceding the inductions) and the proper prospective task (after the inductions). During the encoding phase, participants were asked to memorize a series of 15 pairs of items composed of a cue-event (spatial or temporal) and an action which they had to carry out during a second exploration of the virtual environment. The items were divided into 3 categories: *event-based* semantically linked (*e.g.*, At the kiosk, buy crosswords); *event-based* semantically non-linked (*e.g.*, In front of the church, eat an ice cream) and *time-based* (*e.g.*, After 1 min, call a friend). The subjects had to read aloud the whole list of event-action pairs that were visually presented one-by-one. At the end of this encoding phase, they were immediately submitted to a cued recall to verify that they had correctly memorized each event-action pair (the cue corresponded to the event and the subjects had to recall the associated action). Participants had a maximum of three trials to correctly memorize the event-action list. If at the end of the three trials, the subjects could not recall more than 8 items, we excluded it from the subsequent analysis (no participants had to be excluded for this reason). Participants were not subjected to any temporal pressure during this encoding and recall phase. During the prospective recall phase, participants were again invited to navigate the same virtual environment. Their task was to stop whenever a prospective cue (spatial or temporal) was detected and had to enunciate the associated action. To allow them to recall *time-based* items, a stopwatch was placed next to the computer screen. One point was awarded for each correct action recalled at the right time/right place. The maximum total score was 15 (5 points for each type of cues). A tolerance of +/- 10s for *time-based* cues was accepted to assign the point for stopping at the time. The total duration of the task, from the starting point to the station, lasted approximately 4 min (234 ± 62s).

Finally, subjects were submitted to a free and a cued recall of event/time action associations. This was done to control that any eventual differences in PM between groups were not due to differences in the retrospective component of PM.

2.5. Induction

Inductions lasted 15-min and were recorded by the same male voice. The *mindfulness* and *mind wandering* inductions were constructed on the basis of various inductions used in different studies (Arch & Craske, 2006; Colzato, Sellaro, Samara, Baas, & Hommel, 2015; Kiken & Shook, 2011, 2014). The structure of the *mindfulness* and *mind wandering* inductions was identical, only the instructions differed. Inductions began in the same way by instructing the participant about posture (sit straight, put their hands on their thighs and keep their eyes half closed). Induction of *mindfulness* invited the subjects to focus their attention on their breathing and to come back to the breath each time their mind wandered. On the contrary, the *mind wandering* induction encouraged participants to follow any of their thoughts. The two texts were constructed in symmetry by alternating periods of instructions and period of silence.

3. Statistical analysis

We employed independent sample *t*-test (bilateral) to compare the two groups (*mindfulness*, *mind wandering*) on demographic, neuropsychological and manipulation check variables. In order to examine the effects of the inductions and the type of PM cue, we ran a mixed ANOVA on the PM scores with Induction Type (*mindfulness*, *mind wandering*) as a between-subjects factor and the Cue Type (*event-based linked*, *event-based not linked* and *time-based*) as a within-subjects factor. Post-hoc tests were carried out using Holm correction for multiple comparisons. Separate multiple regressions were conducted to predict the scores of each of the three prospective cues with the different facets of the FFMQ. We reported effect size for ANOVA with partial eta squared (η_p^2) and Cohen's d for t-tests. All statistical analyzes were performed using R (version 3.5.2).

4. Results

4.1. Verification of experimental manipulation

In order to verify whether the type of induction had the expected effect on the participants' cognitive state, we calculated a mood modification score by subtracting the measured pre/post induction of the valence and the arousal scores of the self-assessment mood grid. The two group did not differ on the valence score, with $t(78) = -1.11$, $p = 0.27$, $d = 0.12$ (*Mindfulness*: 0.16 ± 0.34, *Mind wandering*: 0.37 ± 1.12). Similarly, the difference on arousal was not significant, with $t(78) = 0.53$, $p = 0.59$, $d = -0.25$ (*Mindfulness*: -0.24 ± 0.75, *Mind wandering*: -0.31 ± 0.47). We also tested for each group this differential score against 0. We reported a significant increase of 0.16 points in valence score after the *mindfulness* induction, $t(38) = 2.99$, $p < 0.005$, 95% CI [0.05 ; 0.27]. For the *mind wandering* induction, a significant increase of 0.37 points was observed, $t(40) = 2.11$, $p < 0.05$, 95% CI [0.016 ; 0.72]. Similarly, we obtained a significant decrease of 0.24 points in arousal scores after *mindfulness* induction, $t(38) = -2.00$, $p < 0.05$, 95% CI [−0.48 ; 0.003]. In the same way, we noticed a significant decrease of 0.31 points in arousal scores after the *mind wandering* induction, $t(40) = -4.25$, $p < 0.001$, 95% CI [-0.46 ; -0.16].

Then we compared the two groups on the scores of each of the 6 post-induction questions aiming at evaluating the participants' cognitive state during the inductions. We reported here only significant differences, complete results are reported in Supplementary Material. The *t*-test on *Absorption Internal*, showed a significant effect of induction type $t(78) = -3.73$, $p < 0.001$, $d = -0.83$. *Mind wandering* group's score was higher (0.86 ± 0.17) compared to the *Mindfulness* group's score (0.68 ± 0.25). The *t*-test conducted on *Absorption Body*, showed a significant effect of induction type $t(78) = -2.01$, $p < 0.05$, $d = 0.45$. *Mindfulness* group's score was higher (0.7 ± 0.27) compared to the *Mind wandering* group's score (0.57 ± 0.28).

The *t*-test on the level of effort reported to follow the induction exercise showed a significant group effect, with $t(78) = 2.69$, $p < 0.009$, $d = 0.6$. *Mindfulness* group (3.51 ± 1.29) reported more effort to follow the induction compared to the *Mind wandering* group (2.76 ± 1.22). The two groups did not differ with respect to the time that participants spent thinking to the prospective actions during the inductions, with $t(78) = 1.52$, $p = 0.13$, $d = 0.34$ (*Mindfulness*: 2.92 ± 1.26 and *Mind wandering*: 2.49 ± 1.29).

The length of the navigation in the virtual city during the PM task did not significantly differ between the two groups, with $t(78) = -1.03$, $p = 0.31$, $d = -0.23$ (*Mindfulness*: 241.25 ± 71.55 and *Mind wandering*: 257.11 ± 66.68).

4.2. Effect of induction and prospective cue on PM performance

We did not observe neither a significant main effect of the Induction Type, $F(1,234) = 0.35$, $p = 0.56$, $\eta_p^2 = 0.001$, nor a significant interaction between Induction Type and Cue Type, $F(2,234) = 0.25$, $p = 0.78$, $\eta_p^2 = 0.002$. Nevertheless, the main effect of Cue Type was significant, with $F(2,234) = 25.76$, $p < 0.001$, $\eta_p^2 = 0.18$. Post-hoc comparisons revealed that the *time-based* actions were

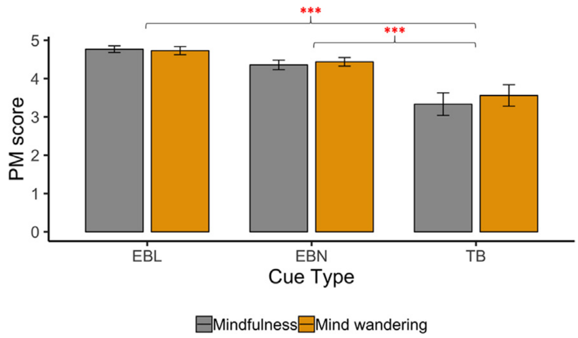

Fig. 1. Mean prospective memory score for each Cue Type in the two groups. Error bars represent standard error mean (SEM). ***p < 0.001.

significantly less well recovered (3.45 ± 1.81, 95% CI [3.19 ; 3.71]) than *event-based not linked* (4.4 ± 0.74, 95% CI [4.14 ; 4.66], $p < 0.001$) and *event-based linked* (4.75 ± 0.61, 95% CI [4.49 ; 5], $p < 0.001$). The difference between the two types of *event-based* actions showed a trend, but was not significant ($p = 0.06$). For a graphical representation of the results (see Fig. 1).

4.3. Effect of induction and prospective cue on retrospective action cued-recall

We observed a significant main effect of the Cue Type, $F(2,234) = 33.28$, $p < 0.001$, $\eta_p^2 = 0.22$. Post-hoc comparisons revealed that the *time-based* cues (4.15 ± 122, 95% CI [3.99 ; 4.31]) were significantly less recalled than the *event-based not linked* cues (4.92 ± 0.31, 95% CI [4.76 ; 5.08], $p < 0.001$) and *event-based linked* cues (5.00 ± 0.00, 95% CI [4.84 ; 5.16], with $p < 0.001$. The two *event-based* cues did not differ from each other ($p = 0.52$). Critically, the main effect of the Induction Type, with $F(1,234) = 0.76$, $p = 0.38$, $\eta_p^2 = 0.003$, as well as the interaction between the two factors, $F(2,234) = 0.72$, $p = 0.48$, $\eta_p^2 = 0.006$, were not significant.

4.4. Relationship between dispositional mindfulness and prospective memory

We conducted separate multiple regressions for each PM cues. We entered each PM score as a dependent variable, and the scores of the five facet of the FFMQ as continuous predictors. The *Describing* trait significantly predicted better PM performance for *time-based* cues, $t(74) = 4.24$, $p < 0.001$, 95% CI [0.62 ; 1.75], $\beta = 1.21$ (Fig. 2). Moreover, the global model was significant, $F(5,74) = 4.95$, $p < 0.001$. The regression models for the other two type of cues were not significant, with $F(5,74) = 1.06$, $p = 0.39$ for *event-based linked* cues and $F(5,74) = 0.23$, $p = 0.95$ for *event-based not linked* cues.

We ran the same analysis on the *time-based* cued-recall score. We reported that the global model was not significant, $F(5,74) = 2.24$, $p = 0.06$. Crucially, the *Describing* facet did not significantly predict this score, $t(74) = 0.76$, $p = 0.45$.

5. Discussion

The goal of this study was to explore the impact of state and dispositional *mindfulness* on PM. On the one hand, we compared the effect of a one-shot short *mindfulness* session to a *mind wandering* control condition on PM performance. On the other hand, we investigated the link between dispositional *mindfulness*, assessed with a standard questionnaire, and PM. Our main findings suggest that dispositional *mindfulness* is linked with better PM performances, while we did not report an effect of the short *mindfulness* exercise.

Firstly, our results on the different aspects of PM showing a greater difficulty for *time-based* PM, compared to the *event-based*, are coherent with previous findings (Debarnot et al., 2015; Einstein et al., 1995; Henry, MacLeod, Phillips, & Crawford, 2004; Kalpouzos et al., 2008). They thus confirm the validity and relevance of our virtual reality PM task.

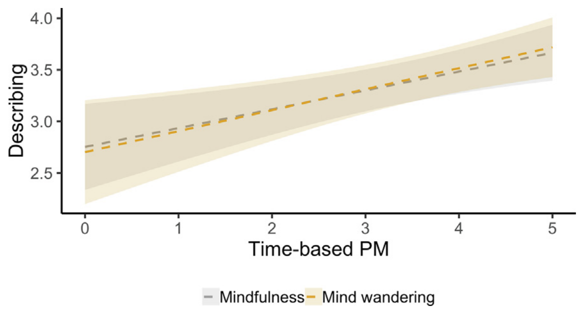

Fig. 2. Relationship between the Describing facets of mindfulness and time-based prospective memory score for the *mindfulness* and *mind wandering* group separately. Dotted lines represent regression lines and transparent areas represent 95% confidence interval.

Contrary to our first hypothesis, we did not observe any difference in PM performances after a *mindfulness*, compared to a *mind wandering* session. Several hypotheses could be advanced to explain this null result. The first one is that we employed a double-blind protocol, thus minimizing the risk of biases linked to the subjects and experimenters' expectations. This is not the case in most of previous studies reporting an effect of short *mindfulness* inductions on cognition. A second explanation would be that these two exercises do not differ enough to differently impact the participants' performances. This suggestion is supported by the fact that the two inductions similarly impacted participants' self-reported mood (decrease in arousal and increase in valence). Interestingly, Johnson, Gur, David, and Currier (2015) found similar result on mood comparing a *mindfulness* and a sham-*mindfulness* induction, without reporting any effect on cognitive measures (attention and working memory tasks). However, it seems that the two inductions were lived differently by the subjects. Indeed, the *mindfulness* group reported significantly more effort to follow the instructions than the *mind wandering* group. This observation is not surprising considering the difficulty of the exercise, above all for naïve subjects. This is coherent with the results of Immink et al. (2017), demonstrating that the degree of effort deployed during a meditation exercise was a determining factor for its effectiveness. In addition, the tendency to remain focused on bodily sensations was significantly higher in *mindfulness* group compared to the *mind wandering* group. On the contrary, the reported tendency to stay focused on thoughts was greater for the *mind wandering* group. These differences suggest that the two inductions produced two different cognitive states corresponding to the desired experimental manipulation. Obviously, these results should be taken with caution since they are based on subjective reports. Future studies should employ objective measure of meditative engagement, such as physiological ones, to verify the effectiveness of the experimental manipulation.

If we accept the idea that the two exercises indeed produced different cognitive states, a third hypothesis could be that 15 min of meditation are not enough to produce a measurable effect on PM. Accordingly, some previous studies also did not find any effect on cognition after a short meditation session (Droit-Volet et al., 2015; Johnson et al., 2015; Larson et al., 2013). While these studies did not report an effect after a single *mindfulness* meditation session, other studies reported an effect after 5 days of training (Droit-Volet et al., 2015; Tang et al., 2015). So, these results emphasize the fact that an induction alone is sometimes not sufficient to show an effect. The dose effect in meditation research is certainly a crucial topic for both methodological reasons and clinical applications.

An alternative intriguing hypothesis is that the two inductions had divergent effect on the participants' cognitive state, but similar effect on PM. *Mindfulness* and *mind wandering* are often considered as two opposite cognitive states being linked with positive and negative outcomes, respectively (for a review, see Schooler et al., 2014). *Mindfulness* indeed improves executive control and sustained attention (MacLean et al., 2010; Tang et al., 2007). Thus, the *mindfulness* induction may have facilitated the detection of temporal and contextual cues through a greater focus on the present moment and the environment. Even if *mind wandering* is negatively associated with attentional and memory capacities (Poerio et al., 2017), recently, its positive impact on cognitive functions is beginning to be recognized. Indeed, *mind wandering* is linked to elaborating and planning of future activities (Seli, Risko, Smilek, & Schacter, 2016). These cognitive processes are central to PM. Moreover, a distinction between two types of *mind wandering*, one intentional and the other involuntary, has been proposed (Seli et al., 2018). In contrast to involuntary *mind wandering*, intentional episodes of *mind wandering* are strongly associated with planning and the awareness of the initiation of the episode of *mind wandering*, resulting in a *meta-cognitive* awareness of its occurrence (Seli et al., 2016). Our manipulation was probably more similar to intentional *mind wandering* and could have had a positive impact on PM performances. Interestingly, Seli, Carriere, and Smilek (2015) reported that the self-reported tendency to deliberately and spontaneously engage in *mind wandering* in daily life was positively and negatively correlated with dispositional *mindfulness*, respectively. Thomson, Ralph, Besner, and Smilek (2015) reported a negative relationship between the tendency to mind wander and the magnitude of the attentional blink, even if in this study, the correlation was found with the spontaneous but not with the deliberate dimension of *mind wandering*. The authors noted that a similar effect has been reported in expert meditators under "open" as opposed to "focused" attention meditation (Van Vugt & Slagter, 2014). They interpreted these findings proposing that *mind wandering* could represent a natural tendency to engage with the world in an "open" attentional state as meditators do willfully. They conclude that "[…] *mind wandering* may be the behavioral outcome of a cognitive style that serves to prevent individuals from "over-investing" in *particular* events in the environment, since over-investment can be severely detrimental to the processing of other (potentially critical) stimuli" (Thomson et al., 2015, p. 189). This description fits well PM tasks. Indeed, during PM tasks, participants have to accomplish an ongoing task while detecting other critical stimuli (the PM cues). Thus, if this hypothesis is true, interindividual differences in the tendency to mind wander should likely predict PM performances. This proposal is also supported by a recent neuroimaging study showing a correlation between the tendency to mind wander and the resting state functional coupling between the default mode network and the frontoparietal control network (Godwin et al., 2017). The authors interpreted these results, in particular the contribution of the latter neural network, as the engagement in deliberate form of *mind wandering* such as prospective thoughts. Thus, while *mindfulness* and *mind wandering* are often seen as opposing sides of the same coin, the well-established disruptive role of *mind wandering* on cognition seems more nuanced. In particular, it seems that the nature of *mind wandering* (deliberate *vs.* spontaneous) could be a crucial feature that should be taken into account in future research. Given that we do not have a third passive control condition, our results can not directly sustain the hypothesis of a positive impact of *mind wandering* on PM. Nevertheless, investigating how and in which conditions state and dispositional *mind wandering* affect PM certainly deserve future efforts.

The last hypothesis to explain the lack of effect of the *mindfulness* induction is that the type of chosen meditation exercise was not the most appropriate to impact PM. Indeed, meditation techniques can be divided between focused attention (FA) and open monitoring (OM). FA practices are based on the concentration of attention on a single object (*e.g.*, the breath) while ignoring all irrelevant stimuli. During OM meditation, practitioners try to enlarge the attentional focus to the ongoing stream of experience without engaging attention on a specific phenomenon (Lutz et al., 2008). According to Hommel and Colzato (2017), OM and FA would induce two different *meta-cognitive* control states. FA would enhance top-down attentional control favoring goal maintenance, while OM would lessen the top-down influence prompting behavioral flexibility. Thus, OM practice could have a greater effect on PM performances than FA due to a more distributed attentional control allowing greater flexibility. To test this hypothesis, future studies could compare the effect of these two types of meditation on PM performances.

The major observation of our study is a correlation between the natural tendency to describe our internal feelings, like emotions or physical sensations, through words (Baer et al., 2008) and the *time-based* PM scores. Importantly, *Describing* was not associated with retrospective cued-recall performance of *time-based* action, suggesting that its impact is specific to the prospective component of PM. The ability of describing one's experience involves the capacity of verbalization and likely the awareness of one's personal cognitive state. Thus, our results seem coherent with the previously reported finding of a positive link between the ability to monitor one's conscious content and PM *time-based* performances (Seli et al., 2018). From a neuro-anatomical point of view, Zhuang et al. (2017) found that the FFMQ *Describing* facet was associated with greater surface area in the right dorsolateral prefrontal cortex, the right inferior parietal lobule and the grey matter volume of dorsolateral prefrontal cortex. These two structures belong to the frontoparietal network that is known to support cognitive control, enabling the dynamic top-down regulation and control of mental operations in response to environmental change and goal achievement (Duncan, Chylinski, Mitchell, & Bhandari, 2017). Moreover, the dorsal attentional network is involved in activities reflecting shifts of attention in space and predicting goal-directed attention (Fellrath, Mottaz, Schnider, Guggisberg, & Ptak, 2016). Finally, the inferior parietal lobule seems to be involved in attentional processes directed toward the maintenance of intention (Kalpouzos et al., 2010; Ramaekers, Kuypers, Wingen, Heinecke, & Formisano, 2009; Rusted, Ruest, & Gray, 2011). In addition to the links between the description facet and attentional processes, a positive association between the *Describing* facet and the gray matter volume of the right anterior insula has been observed (Murakami et al., 2012; Zhuang et al., 2017). The insula is involved in several cognitive processes, between others: time-estimation and interoceptive awareness (Craig, 2009; Critchley, Wiens, Rotshtein, Öhman, & Dolan, 2004; Wittmann et al., 2014). Thus, an intriguing explanation of the link between *Describing* facet and *time-based* PM would be that people higher in *Describing* would have greater awareness of their bodily states and, thus, a better monitoring of elapsing time. This hypothesis is supported by recent findings showing a direct link between interoceptive abilities and PM. Indeed, Umeda, Tochizawa, Shibata, and Terasawa (2016) reported that subjects with higher interoceptive accuracy had also better PM performances. Nevertheless, the authors only tested *event-based* PM. Future studies should investigate the relationship between interoception, time estimation abilities and *time-based* PM.

6. Conclusions and limitations

This is, to our knowledge, the first study on the effects of *mindfulness* on PM. We do not find a significant difference in PM performance between *mindfulness* and *mind wandering* inductions. We proposed several complementary hypotheses to explain this null finding. We acknowledge that some of these explications are speculative. Nevertheless, they are easily testable in future studies. For example, the possible impact of subjects' expectation on the efficacy of a *mindfulness* session could be tested by comparing a group of participants that are told that they will undergo a meditation session with another in which the same exercise is presented in a more neutral way (*e.g.*, a relaxing pause). The impact of different forms of meditation can be easily implemented as has already been done in previous studies on other cognitive functions (Colzato et al., 2015; Colzato, van der Wel, Sellaro, & Hommel, 2016). The possibility that a single bout of *mindfulness* meditation is not enough to impact PM performances should be tested with longitudinal study employing several meditation sessions. One of the most intriguing suggestions is that *mind wandering* had a positive effect on PM. This proposal is in line with the increased interest for this cognitive state, in particular for its possible positive impact on some cognitive functions. We think that this hypothesis deserves further attention and that future studies should try to disentangle the differential role of spontaneous and voluntary *mind wandering* on PM.

Our main finding was that higher scores on the description facet of the FFMQ predicted the success of *time-based* prospective tasks. We propose that this link could be explained by two different, but possibly interacting, processes: attentional control, mediated by the frontoparietal network, and interoceptive awareness, mediated by the insular cortex. While the attentional contribution seems quite straightforward, the role of interoception in PM certainly deserves more studies.

In conclusion, our study is encouraging on the possible positive impact of *mindfulness* on PM. If a short induction is not sufficient to bring about a substantial effect, it is likely that a longer-term practice could enhance PM performance. Additional research is expected to investigate the positive gain of *mindfulness* in cognitive stimulation and remediation program in population suffering from a decline of PM, such as healthy or pathological elderly.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Credit authorship contribution statement

Jean-Charles Girardeau: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Philippe Blondé:** Investigation. **Dominique Makowski:** Software, Resources. **Maria Abram:** Resources. **Pascale Piolino:** Project administration, Writing - review & editing, Supervision. **Marco Sperduti:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank Morghane Aubert and Anaïs Giacomoni, Master's students at the University Paris Descartes for their help in collecting data. We are very greatful to the participants that took part in the study. Special thanks to Eloan Girardeau for his helpful naps.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2020.102920.

References

Abram, M., Cuny, M., Picard, L., & Piolino, P. (2014). Retrospective and prospective memory, short-term binding and executive functions' abilities in two adolescents with medial temporal and frontal brain lesions: A virtual reality study. *International Journal of International Neuroscience, 47*, 122.

Ainsworth, B., Eddershaw, R., Meron, D., Baldwin, D. S., & Garner, M. (2013). The effect of focused attention and open monitoring meditation on attention network function in healthy volunteers. *Psychiatry Research, 210*(3), 1226–1231.

Arch, J. J., & Craske, M. G. (2006). Mechanisms of mindfulness: Emotion regulation following a focused breathing induction. *Behaviour Research and Therapy, 44*(12), 1849–1858.

Baer, R. A., Smith, G. T., Lykins, E., Button, D., Krietemeyer, J., Sauer, S., ... Williams, J. M. G. (2008). Construct validity of the five facet mindfulness questionnaire in meditating and nonmeditating samples. *Assessment, 15*(3), 329–342.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). Beck depression inventory-II. *San Antonio, 78*(2), 490–498.

Bisiacchi, P. S., Schiff, S., Ciccola, A., & Kliegel, M. (2009). The role of dual-task and task-switch in prospective memory: Behavioural data and neural correlates. *Neuropsychologia, 47*(5), 1362–1373. https://doi.org/10.1016/j.neuropsychologia.2009.01.034.

Brown, K. W., Goodman, R. J., Ryan, R. M., & Anālayo, B. (2016). Mindfulness enhances episodic memory performance: evidence from a multimethod investigation. *PloS one, 11*(4), e0153309.

Cahn, B. R., & Polich, J. (2009). Meditation (Vipassana) and the P3a event-related brain potential. *International Journal of Psychophysiology, 72*(1), 51–60.

Colzato, L. S., Sellaro, R., Samara, I., Baas, M., & Hommel, B. (2015). Meditation-induced states predict attentional control over time. *Consciousness and Cognition, 37*, 57–62.

Colzato, L. S., van der Wel, P., Sellaro, R., & Hommel, B. (2016). A single bout of meditation biases cognitive control but not attentional focusing: Evidence from the global–local task. *Consciousness and Cognition, 39*, 1–7.

Craig, A. D. (2009). Emotional moments across time: A possible neural basis for time perception in the anterior insula. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1525), 1933–1942.

Critchley, H. D., Wiens, S., Rotshtein, P., Öhman, A., & Dolan, R. J. (2004). Neural systems supporting interoceptive awareness. *Nature Neuroscience, 7*(2), 189.

Crowe (1998). The differential contribution of mental tracking, cognitive flexibility, visual search, and motor speed to performance on parts A and B of the Trail Making Test. *Journal of Clinical Psychology, 54*, 585–591.

Debarnot, U., Crépon, B., Orriols, E., Abram, M., Charron, S., Lion, S., ... Piolino, P. (2015). Intermittent theta burst stimulation over left BA10 enhances virtual reality-based prospective memory in healthy aged subjects. *Neurobiology of Aging, 36*(8), 2360–2369.

Dickenson, J., Berkman, E. T., Arch, J., & Lieberman, M. D. (2012). Neural correlates of focused attention during a brief mindfulness induction. *Social Cognitive and Affective Neuroscience, 8*(1), 40–47.

Di Francesco, S. A., Simione, L., López-Ramón, M. F., Belardinelli, M. O., Lupiáñez, J., & Raffone, A. (2016). Dispositional mindfulness facets predict the efficiency of attentional networks. *Mindfulness,* 1–9.

Droit-Volet, S., Fanget, M., & Dambrun, M. (2015). Mindfulness meditation and relaxation training increases time sensitivity. *Consciousness and Cognition, 31*, 86–97.

Duncan, J., Chylinski, D., Mitchell, D. J., & Bhandari, A. (2017). Complexity and compositionality in fluid intelligence. *Proceedings of the National Academy of Sciences of the United States of America, 114*, 5295–5299.

Einstein, G. O., McDaniel, M. A., Richardson, S. L., Guynn, M. J., & Cunfer, A. R. (1995). Aging and prospective memory: Examining the influences of self-initiated retrieval processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*(4), 996.

Einstein, G. O., Smith, R. E., McDaniel, M. A., & Shaw, P. (1997). Aging and prospective memory: The influence of increased task demands at encoding and retrieval. *Psychology and Aging, 12*, 479–488.

Einstein, G. O., & McDaniel, M. A. (2005). Prospective memory multiple retrieval processes. *Current Directions in Psychological Science, 14*(6), 286–290.

Einstein, G. O., McDaniel, M. A., Thomas, R., Mayfield, S., Shank, H., Morrisette, N., & Breneiser, J. (2005). Multiple processes in prospective memory retrieval: Factors determining monitoring versus spontaneous retrieval. *Journal of Experimental Psychology: General, 134*(3), 327.

Fellrath, J., Mottaz, A., Schnider, A., Guggisberg, A. G., & Ptak, R. (2016). Theta-band functional connectivity in the dorsal fronto-parietal network predicts goal-directed attention. *Neuropsychologia, 92*, 20–30.

Galla, B. M., Hale, T. S., Shrestha, A., Loo, S. K., & Smalley, S. L. (2012). The disciplined mind: Associations between the Kentucky Inventory of Mindfulness Skills and attention control. *Mindfulness, 3*(2), 95–103.

Gallant, S. N. (2016). Mindfulness meditation practice and executive functioning: Breaking down the benefit. *Consciousness and cognition, 40*, 116–130.

Garland, E. L., Hanley, A., Farb, N. A., & Froeliger, B. (2015). State mindfulness during meditation predicts enhanced cognitive reappraisal. *Mindfulness, 6*(2), 234–242.

Godwin, C. A., Hunter, M. A., Bezdek, M. A., Lieberman, G., Elkin-Frankston, S., Romero, V. L., ... Schumacher, E. H. (2017). Functional connectivity within and between intrinsic brain networks correlates with trait mind wandering. *Neuropsychologia, 103*, 140–153.

Gonneaud, J., Eustache, F., & Desgranges, B. (2009). La mémoire prospective dans le vieillissement normal et la maladie d'Alzheimer: intérêts et limites des études actuelles. *Revue de neuropsychologie, 1*(3), 238–246.

Gonneaud, J., Piolino, P., Lecouvey, G., Madeleine, S., Orriols, E., Fleury, P., … & Desgranges, B. (2012). Assessing prospective memory in young healthy adults using virtual reality. In Disability, virtual reality, and associated technologies, Proc. of the 9th Int. Conf (pp. 211–218).

Gonneaud, J., Rauchs, G., Groussard, M., Landeau, B., Mézenge, F., de La Sayette, V., ... Desgranges, B. (2014). How do we process event-based and time-based intentions in the brain? An fMRI study of prospective memory in healthy individuals. *Human Brain Mapping, 35*(7), 3066–3082.
Heeren, A., Douilliez, C., Peschard, V., Debrauwere, L., & Philippot, P. (2011). Cross-cultural validity of the Five Facets Mindfulness Questionnaire: Adaptation and validation in a French-speaking sample. *Revue européenne de psychologie appliquée/European Review of Applied Psychology, 61*(3), 147–151.
Henry, J. D., MacLeod, M. S., Phillips, L. H., & Crawford, J. R. (2004). A meta-analytic review of prospective memory and aging. *Psychology and Aging, 19*(1), 27–39.
Hommel, B., & Colzato, L. S. (2017). Meditation and metacontrol. *Journal of Cognitive Enhancement, 1*(2), 115–121.
Immink, M. A., Colzato, L. S., Stolte, M., & Hommel, B. (2017). Sequence learning enhancement following single-session meditation is dependent on metacontrol mode and experienced effort. *Journal of Cognitive Enhancement,* 1–14.
Jaiswal, S., Tsai, S. Y., Juan, C. H., Liang, W. K., & Muggleton, N. G. (2018). Better cognitive performance is associated with the combination of high trait mindfulness and low trait anxiety. *Frontiers in Psychology, 9*, 627.
Jha, A. P., Krompinger, J., & Baime, M. J. (2007). Mindfulness training modifies subsystems of attention. *Cognitive, Affective, & Behavioral Neuroscience, 7*(2), 109–119.
Johnson, S., Gur, R. M., David, Z., & Currier, E. (2015). One-session mindfulness meditation: A randomized controlled study of effects on cognition and mood. *Mindfulness, 6*(1), 88–98.
Josefsson, T., & Broberg, A. (2011). Meditators and non-meditators on sustained and executive attentional performance. *Mental Health, Religion & Culture, 14*(3), 291–309.
Kabat-Zinn, J. (1982). An outpatient program in behavioral medicine for chronic pain patients based on the practice of mindfulness meditation: Theoretical considerations and preliminary results. *General Hospital Psychiatry, 4*(1), 33–47.
Kalpouzos, G., Eustache, F., & Desgranges, B. (2008). La mémoire prospective au cours du vieillissement: déclin ou préservation. *NPG Neurologie - Psychiatrie – Gériatrie, 8*, 25–31.
Kalpouzos, G., Eriksson, J., Sjölie, D., Molin, J., & Nyberg, L. (2010). Neurocognitive systems related to real-world prospective memory. *PloS one, 5*(10), e13304.
Khan, A., Sharma, N. K., & Dixit, S. (2008). Cognitive load and task condition in event-and time-based prospective memory: An experimental investigation. *The Journal of Psychology, 142*(5), 517–532.
Kiken, L. G., & Shook, N. J. (2011). Looking up: Mindfulness increases positive judgments and reduces negativity bias. *Social Psychological and Personality Science, 2*(4), 425–431.
Kiken, L. G., & Shook, N. J. (2014). Does mindfulness attenuate thoughts emphasizing negativity, but not positivity? *Journal of Research in Personality, 53*, 22–30.
Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science, 330*(6006), 932.
Kliegel, M., Martin, M., McDaniel, M. A., & Einstein, G. O. (2002). Complex prospective memory and executive control of working memory: A process model. *Psychologische Beitrage, 44*(2), 303–318.
Kliegel, M., & Martin, M. (2003). Prospective memory research: Why is it relevant? *International Journal of Psychology, 38*(4), 193–194.
Kliegel, M., Martin, M., McDaniel, M. A., Einstein, G. O., & Moor, C. (2007). Realizing complex delayed intentions in young and old adults: The role of planning aids. *Memory & Cognition, 35*(7), 1735–1746.
Kliegel, M., Jäger, T., & Phillips, L. H. (2008). Adult age differences in event-based prospective memory: A meta-analysis on the role of focal versus nonfocal cues. *Psychology and aging, 23*(1), 203.
Kvavilashvili, L., & Ellis, J. (1996). Varieties of intention: Some distinctions and classifications. *Prospective memory. Theory and applications, 6*, 183–207.
Larson, M. J., Steffen, P. R., & Pimosch, M. (2013). The impact of a brief mindfulness meditation intervention on cognitive control and error-related performance monitoring. *Frontiers in Human Neuroscience, 7*.
Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in Cognitive Sciences, 12*(4), 163–169.
Makowski, D., Sperduti, M., Lavallée, S., Nicolas, S., & Piolino, P. (2019). Dispositional mindfulness attenuates the emotional attentional blink. *Consciousness and Cognition, 67*, 16–25.
Marsh, R. L., Hicks, J. L., & Watson, V. (2002). The dynamics of intention retrieval and coordination of action in event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(4), 652.
McDaniel, M. A., & Einstein, G. O. (1993). The importance of cue familiarity and cue distinctiveness in prospective memory. *Memory, 1*, 23–41.
McDaniel, M. A., & Einstein, G. O. (2011). The neuropsychology of prospective memory in normal aging: A componential approach. *Neuropsychologia, 49*(8), 2147–2155.
MacLean, K. A., Ferrer, E., Aichele, S. R., Bridwell, D. A., Zanesco, A. P., Jacobs, T. L., ... Saron, C. D. (2010). Intensive meditation training improves perceptual discrimination and sustained attention. *Psychological Science, 21*(6), 829–839.
Mrazek, M. D., Franklin, M. S., Phillips, D. T., Baird, B., & Schooler, J. W. (2013). Mindfulness training improves working memory capacity and GRE performance while reducing mind wandering. *Psychological science, 24*(5), 776–781.
Murakami, H., Nakao, T., Matsunaga, M., Kasuya, Y., Shinoda, J., Yamada, J., & Ohira, H. (2012). The structure of mindful brain. *PloS one, 7*(9), e46377.
Poerio, G. L., Sormaz, M., Wang, H. T., Margulies, D., Jefferies, E., & Smallwood, J. (2017). The role of the default mode network in component processes underlying the wandering mind. Social Cognitive and Affective Neuroscience, nsx041.
Ramaekers, J. G., Kuypers, K. P. C., Wingen, M., Heinecke, A., & Formisano, E. (2009). Involvement of inferior parietal lobules in prospective memory impairment during acute MDMA (ecstasy) intoxication: An event-related fMRI study. *Neuropsychopharmacology, 34*, 1641–1648.
Rosenstreich, E., & Ruderman, L. (2017). A dual-process perspective on mindfulness, memory, and consciousness. *Mindfulness, 8*(2), 505–516.
Rouleau, I., Lajeunesse, A., Drolet, V., Potvin, M. J., Marcone, S., Lecomte, S., ... Joubert, S. (2016). L'évaluation clinique de la mémoire prospective dans le MCI. *NPG Neurologie-Psychiatrie-Gériatrie, 16*(93), 152–158.
Russell, J. A., Weis, A., & Mendelsohn, G. A. (1989). Affect grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology, 57*, 493–502.
Rusted, J., Ruest, T., & Gray, M. A. (2011). Acute effects of nicotine administration during prospective memory, an event related fMRI study. *Neuropsychologia, 49*, 2362–2368.
Schooler, J. W., Mrazek, M. D., Franklin, M. S., Baird, B., Mooneyham, B. W., Zedelius, C., & Broadway, J. M. (2014). The middle way: Finding the balance between mindfulness and mind-wandering. In Psychology of learning and motivation (Vol. 60, pp. 1–33). Academic Press.
Schnitzspahn, K. M., Stahl, C., Zeintl, M., Kaller, C. P., & Kliegel, M. (2013). The role of shifting, updating, and inhibition in prospective memory performance in young and older adults. *Developmental Psychology, 49*(8), 1544–1553. https://doi.org/10.1037/a0030579.
Seli, P., Carriere, J. S., & Smilek, D. (2015). Not all mind wandering is created equal: Dissociating deliberate from spontaneous mind wandering. *Psychological Research, 79*(5), 750–758.
Seli, P., Risko, E. F., Smilek, D., & Schacter, D. L. (2016). Mind-wandering with and without intention. *Trends in Cognitive Sciences, 20*(8), 605–617.
Seli, P., Kane, M., Smallwood, J., Schacter, D. L., Maillet, D., Schooler, J., & Smilek, D. (2018). Mind-wandering as a natural kind: A family-resemblances view. *Trends in Cognitive Sciences, 22*(6), 479–490.
Seli, P., Smilek, D., Ralph, B. C., & Schacter, D. L. (2018). The awakening of the attention: Evidence for a link between the monitoring of mind wandering and prospective goals. *Journal of Experimental Psychology: General, 147*(3), 431.
Smith, R. E., & Bayen, U. J. (2004). A multinomial model of event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(4), 756–777. https://doi.org/10.1037/0278-7393.30.4.756.
Sørensen, L., Osnes, B., Visted, E., Svendsen, J. L., Adolfsdottir, S., Binder, P. E., & Schanche, E. (2018). Dispositional mindfulness and attentional control: The specific association between the mindfulness facets of non-judgment and describing with flexibility of early operating orienting in conflict detection. *Frontiers in Psychology, 9*, 2359.
Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). *State-trait anxiety inventory manual.* Mind Garden Inc.
Stawarczyk, D., Majerus, S., Maquet, P., & D'Argembeau, A. (2011). Neural correlates of ongoing conscious experience: both task-unrelatedness and stimulus-independence are related to default network activity. *PloS one, 6*(2).
Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*(6), 643.

Tang, Y. Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., ... Posner, M. I. (2007). Short-term meditation training improves attention and self-regulation. *Proceedings of the National Academy of Sciences, 104*(43), 17152–17156.

Tang, Y. Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. *Nature Reviews Neuroscience, 16*(4), 213–225.

Thomson, D. R., Ralph, B. C., Besner, D., & Smilek, D. (2015). The more your mind wanders, the smaller your attentional blink: An individual differences study. *Quarterly Journal of Experimental Psychology, 68*(1), 181–191.

Umeda, S., Tochizawa, S., Shibata, M., & Terasawa, Y. (2016). Prospective memory mediated by interoceptive accuracy: A psychophysiological approach. *Philosophical Transactions of the Royal Society B, 371*(1708), 20160005.

Valery, P. (1975) Cahiers I. Gallimard, 248p.

Van Vugt, M. K., & Slagter, H. A. (2014). Control over experience? Magnitude of the attentional blink depends on meditative state. *Consciousness and Cognition, 23*, 32–39.

Volle, E., Gonen-Yaacovi, G., de Lacy Costello, A., Gilbert, S. J., & Burgess, P. W. (2011). The role of rostral prefrontal cortex in prospective memory: A voxel-based lesion study. *Neuropsychologia, 49*(8), 2185–2198.

Wilson, B. M., Mickes, L., Stolarz-Fantino, S., Evrard, M., & Fantino, E. (2015). Increased false-memory susceptibility after mindfulness meditation. *Psychological Science, 26*(10), 1567–1573.

Wittmann, M., Peter, J., Gutina, O., Otten, S., Kohls, N., & Meissner, K. (2014). Individual differences in self-attributed mindfulness levels are related to the experience of time and cognitive self-control. *Personality and Individual Differences, 64*, 41–45.

Xu, M., Purdon, C., Seli, P., & Smilek, D. (2017). Mindfulness and mind wandering: The protective effects of brief meditation in anxious individuals. *Consciousness and cognition, 51*, 157–165.

Zhuang, K., Bi, M., Li, Y., Xia, Y., Guo, X., Chen, Q., ... Qiu, J. (2017). A distinction between two instruments measuring dispositional mindfulness and the correlations between those measurements and the neuroanatomical structure. *Scientific Reports, 7*(1), 6252.