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Space-Time interaction:

Visuo-spatial processing affects the temporal focus of mind wandering

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Abstract

Our understanding of mind wandering (MW) has dramatically increased over the past decade. Studies have shown that in the vast majority of cases, MW is directed to times other than the present, and a bias toward the future has been reported (prospective bias).

The processing of time is not independent of the processing of space: humans represent time along a spatial continuum, on a "mental time line" (MTL). In cultures with a left to right reading/writing system, the MTL expands from left to right. Capitalizing on these findings, here we aimed at investigating the effects of visuo-spatial processing on the temporal orientation of spontaneous MW, and specifically we asked whether we could steer the temporal focus of MW towards the past or the future, by experimentally inducing a leftward and a rightward orienting of attention, respectively. To this aim, we experimentally manipulated the spatial orientation demands associated with the focal task in two independent groups, with a leftward orienting of attention (left-pointing arrows, LA group) and a rightward orienting of attention (right-pointing arrows, RA group).

We found that the temporal orientation of MW critically depended on the spatial orientation demands of the task: specifically, the proportion of spontaneous past-oriented MW episodes was higher under the induction of a leftward orienting attention (LA group) than under the induction of a rightward orienting attention (RA group). The opposite pattern was found for spontaneous future-oriented MW episodes. Possible mechanisms involved in this effect and their implications for research on MW and spontaneous cognition are discussed.

Keywords: mind wandering; task-unrelated thoughts; temporal orientation

1. Introduction

In many situations in our daily lives we find ourselves being engaged in private thoughts or feelings that have come to our mind spontaneously, that is, without any conscious or deliberate attempt at eliciting them. These forms of cognition may occur while we are facing a task that requires our attention (e.g., reading a paper, attending a seminar, or driving a car).

For a long time such spontaneous internally-directed cognition has been relegated to the sidelines of psychological research (e.g., studies on daydreaming in the 1960-1980s, Antrobus, Singer, & Greenberg, 1966; Giambra, 1979; Klinger & Cox, 1987; Singer, 1966) and mainstream research has been focused almost exclusively on the investigation of deliberate cognitive processes, associated with specific cognitive tasks (*task-centric view of mental processes*, Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016). However, during the last two decades, there has been a surge of interest in both psychology and neuroscience toward the investigation of spontaneous cognition and, among the different kinds, a growing interest has been devoted to mind wandering (MW)/task-unrelated thoughts (TUTs) (see, for a review, Smallwood & Schooler, 2015). Specifically, MW refers to the "shift of attention away from a primary task toward internal information" (Smallwood & Schooler, 2006, p. 946) whose content is unrelated to the task and may comprise memories or prospective thoughts.

An increasing number of studies has shown that MW is ubiquitous and pervasive (Killingsworth & Gilbert, 2010), with people spending a lot of their daytime engaged in MW (on average, somewhere between 25% and 50% of the waking hours in Kane et al., 2007; Killingsworth & Gilbert, 2010). The experience of MW has been found to be associated with both costs – a reduction in the processing of external events (e.g., Barron, Riby, Greer, & Smallwood, 2011), interfering with performance on a wide range of cognitive tasks (e.g., Smallwood, McSpadden & Schooler, 2007) – and benefits – facilitation of autobiographical planning (Baird, Smallwood, & Schooler, 2011) and the maintenance of a sense of self-identity and continuity across time (e.g., Suddendorf & Corballis, 2007).

When our mind wanders, where does it go? Several studies on the temporal orientation of MW in healthy young adults have documented a prospective bias: people are more likely to think about the future compared to the past and the present, both in the laboratory and in daily life (e.g. Baird et al., 2011; Song & Wang, 2012; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011).

However, this prospective bias has not been reported under all conditions. Recently, a number of studies has revealed that the temporal focus of MW might be affected by several experimental manipulations, being more flexible than originally suggested. For example, some studies have shown that negative/low mood tends to skew MW toward the past in the laboratory (e.g., Ruby, Smallwood, Engen & Singer, 2013; Smallwood & O'Connor, 2011) and daily life (Poerio, Totterdell & Miles, 2013), whereas cognitive load negatively affects the frequency of future thoughts (e.g., Smallwood, Nind & O'Connor, 2009).

Although, in the MW literature, MW episodes have been mainly described as self-generated (e.g., Smallwood, 2013) and stimulus-independent (Antrobus, 1968), terms that emphasize their independence from perception and ongoing actions, some recent findings (e.g. Plimpton, Patel, & Kvavilashvili, 2015; Vannucci, Pelagatti, & Marchetti, 2017) suggest that both the frequency and the temporal focus of MW may vary as a function of the external context, rather than being completely self-generated. For example, Vannucci and colleagues (2017) have recently shown that the exposure to task-irrelevant verbal cues (i.e.

word-phrases) during a vigilance task increases the frequency of spontaneous MW and steers its temporal orientation toward the past.

Miles, Karpinska, Lumsden, and Macrae (2010) have found that apparent movement through space influenced the temporal focus of MW. Specifically, in the study participants performed a vigilance task and they were exposed to an animated star-field display that elicited an illusion of self-motion (i.e., vection). The contents of their MW were assessed retrospectively. The results revealed that the direction of vection modulates the temporal orientation of MW: in the forward vection condition participants reported a significantly higher proportion of future-related day dreams compared to their counterparts in the backward vection condition. The authors interpreted this effect according to the viewpoint that mental time travel (a higher cognitive capacity) can have a sensory-motor grounding, so that the direction of thoughts is influenced by apparent movement in space.

In a different but related research field, that is the study of time processing and time representation, consistent evidence has been reported that time processing is not independent of space processing: time and space are tightly linked in the physical world as well as in the human mind (Anelli, Candini, Cappelletti, Oliveri & Frassinetti, 2015; Anelli, Ciaramelli, Arzy & Frassinetti, 2016; Bonato, Zorzi & Umiltà, 2012; Thomas & Takarangi, 2017; for a meta-analysis, see Macnamara, Keage & Loetscher, 2017).

Specifically, several investigations revealed the influence of spatial coding on heterogeneous aspects of time processing, as sensory time (i.e. perception of temporal duration) and more conceptual aspects (i.e. concept of past and future). For example, some studies have shown that manipulation of spatial attention biases temporal judgments according to the side of space where attention is oriented: leftward attentional shifts induce an underestimation of the temporal duration of a stimulus, rightward attentional shifts induce overestimation (e.g. Frassinetti, Magnani, Oliverio, 2009; Vicario, Caltagirone & Oliveri, 2007;

Vicario, Pecoraro, Turriziani, Koch, Caltagirone & Oliveri, 2008). As for the concept of past and future, studies have shown that people are faster to categorize past-related words when they are presented in the left hemispace, compared to the right part, with an opposite pattern for future words (e.g Kong & You, 2012; Santiago, Lupianez, Perez & Funes, 2007). In line with these findings in healthy individuals, neuropsychological studies have shown that patients suffering from spatial neglect do not only neglect the left side of space but also past events (Saj, Fuhrman, Vuilleumier & Boroditsky, 2014).

Altogether, these results demonstrate that humans represent time flow using a spatial layout that is along a spatial continuum akin to a “mental time line” (see for a review, Bonato et al., 2012; Bonato & Umiltà, 2014). In cultures with a left to right reading system, the mental time line expands from left to right: the past is associated with the left side of space and the future with the right side of space (e.g. Vallesi, Weisblatt, Semenza & Shaki, 2014; but see Casasanto & Bottini, 2014 for the flexibility of the mental time line).

In the present study, we aimed at capitalizing on these findings, by investigating in how far visuo-spatial processing and attention may impact upon the temporal orientation of MW. Specifically, we sought to assess whether we could steer the temporal focus of MW towards the past or the future, by experimentally inducing a leftward and a rightward orienting of attention, respectively.

To address this question, in a context of a *between-subjects* design, we experimentally manipulated the spatial orientation demands associated with the focal task in two independent groups, with a leftward orienting of attention and a rightward orienting of attention. To investigate MW, we employed a modified version of the vigilance task, already used in previous studies on MW (Plimpton et al., 2015; Vannucci et al., 2017) and we used a probe-catching procedure, by which participants were intermittently and pseudo-randomly interrupted and probed regarding the contents of their experience.

Since several studies have shown that spontaneous and deliberate forms of MW are dissociable cognitive experiences (see for a review, Seli et al., 2016), when participants reported a thought at the probe, they were asked about the spontaneity of the thought. Given the association reported in the literature between past-oriented MW and negative mood, participants were screened for depression.

In the present study, we also assessed and analyzed the phenomenological properties of spontaneous MW episodes, with a special focus on past and future oriented MW. To this regard, recent diary and laboratory studies comparing past and future involuntary thoughts have shown that the latter are reliably rated as more positive ('future positivity bias', see Berntsen & Jacobsen, 2008; Cole, Staugaard & Berntsen, 2016; Finnbogadóttir & Berntsen, 2013), more important to the self (Addis, Wong, & Schacter, 2008; Berntsen & Bohn, 2010, although see Berntsen & Jacobsen, 2008, Cole, Staugaard and Berntsen, 2016) and more strongly associated with current concerns (i.e., uncompleted personal goals) than their mnemonic counterparts (Cole & Berntsen, 2015). Moreover, in some studies, future representations were found to be less subjectively vivid compared to past events (Berntsen & Bohn, 2010; D'Argembeau & Van der Linden, 2004, 2006; Gamboz, Brandimonte & de Vito, 2010; Hassabis, Kumaran, & Maguire, 2007) and less specific (Berntsen & Jacobsen, 2008; Miles & Berntsen, 2011, but see Cole, Staugaard and Berntsen, 2016).

To replicate and extend these findings, in the present study we assessed some phenomenological properties of past, future, present and a-temporal MW episodes, namely the specificity, emotional valence of the thought, intensity of the feeling experienced during the thought, and the strength of association between the content and personal current currents. For past and future MW episodes we also assessed the intensity of the reliving/preliving experience.

In the study, phenomenological properties were also analyzed for exploratory purposes to verify whether the experimental manipulation of visuo-spatial processing might also affect the way in which MW episodes were experienced (i.e., increasing the accessibility of thoughts with different properties).

Finally, since people may differ in their daily life frequency of past and future oriented MW episodes, and this might confound the effects of our experimental manipulation, we asked participants also to complete two scales on the frequency of spontaneous and deliberate mind wandering in daily life and to report about the frequency of past and future MW, in a second small-group session, carried out 7-10 days after the experimental laboratory session.

2. **Method**

2.1.Participants

Fifty-eight participants[1] were recruited from a pool of undergraduate students from the University of Florence (40 females, age range 18-28 years, *M* = 20.58 years). All participants spoke Italian as their first language, they were right-handed, and they were screened for depressive symptoms. Six participants were thus excluded because they ~~(we excluded participants who~~ scored 16 or above at the Italian adaptation of the Beck Depression Inventory-II (Beck, Steer, & Brown, 1996; Italian adaptation in Ghisi, Flebus, Montano, Sanavio, & Sica, 2006). Of the remaining 52 participants, half were randomly assigned to the Left-pointing arrows (LA group) condition (n = 26; 19 females, age range: 18-28) and the other half to the Right-pointing arrows condition (RA group) (n = 26; 21

[1] Since we planned to mainly run independent samples t-tests, we computed with G*Power3 (Faul, Erdfleder, Lang, & Buchner, 2007) that with a total of 50 participants we could have reached a power of approximately .80 to statistically (alpha = .05) detect effects in the upper part of the moderate range of effect sizes (in terms of Cohen's *d*, a moderate effect is in the .50-.80 range, we mean here .65-.80). We enrolled a few more than 50 in case some participants had to be excluded because they did not meet inclusion criteria or turned out to be outliers.

females, age range: 18-25). Groups did not significantly differ in age and sex ratio. The experimental protocol is in line with the declaration of Helsinki and with the regulations of the University of Florence that hosted the study.

2.2.Materials

Participants volunteered to participate in two sessions, that were 7-10 days apart. The two sessions were presented as (i) a laboratory session on attention and concentration and (ii) a small-group session on individual differences in different dimensions of cognitive functioning, that is, attention and visual imagery.

Session 1:

Vigilance task. Participants completed a modified version of the computer-based vigilance task developed by Schlagman and Kvavilashvili (2008) and already used in previous studies on spontaneous cognition (Plimpton et al., 2015; Vannucci, Batool, Pelagatti & Mazzoni, 2014; Vannucci, Pelagatti, Hanczakowski, Mazzoni & Rossi Paccani, 2015). The task consisted of 800 trials, presented in a fixed order, each remaining on the screen for 1.5 sec.

In the LA condition, on each trial, an image was shown on the computer screen depicting either a pattern of black left-pointing horizontal arrows (non-target stimuli) or a pattern of black horizontal lines (target stimuli). In the RA condition, non-target stimuli consisted of a pattern of right-pointing horizontal arrows, whereas the target consisted of a pattern of black horizontal lines (as in the LA condition) (Figure 1). In both groups, target stimuli appeared on 48 trials (6%) and they were presented pseudo-randomly, that is, every 15-25 trials, in order to ensure that they occurred at long and irregular intervals. At 15 fixed points during the presentation, the vigilance task was stopped and some questions (a probe trial) appeared on the screen. The first question was “What were you thinking about just immediately prior to the probe?" with response options "I was focused on the task", "I was thinking about" (and write down a short sentence describing their mental content and the trigger, if any), and "My mind was blank". If participants reported a thought, they were asked two more questions about the spontaneity of the thought and its trigger, if any. As for the question about spontaneity, participants had to select one of the following options (putting an "X" on the selected option): (1) spontaneous (i.e., simply popped into my mind) (2) deliberate (i.e., intentional), or (3) I don't know. As for the trigger, participants had to select one of the following options (putting an "X" on the selected option): (1) the thought has been triggered by something in the environment; (2) the thought has been triggered by my own thoughts; (3) the thought has not trigged by anything (no trigger).

The first probe was presented at trial 35 and there were a minimum of 35 and a maximum of 72 trials between each probe trial.

<u>Thought questionnaire:</u> After completing the vigilance task, participants provided details of their mental contents on a questionnaire. First, they were asked to indicate the temporal orientation of each mental content, distinguishing among "past", "present", "future", and "a-temporal". Participants were told that an "a-temporal" mental content refers to every thought with no specific temporal orientation (i.e., *I am a very anxious person; I like very much eating pizza*) whereas a "present" mental content refers to every thought related either to something occurring here and now (i.e., *I miss my dog, that is now with my boyfriend*) or to something occurring in the current period of life (i.e., *I don't get along with my mother in this period*). Moreover, participants were asked to specify for each event (i) whether it was general or specific (ii) the emotional valence (-3 = very negative; 0 = neutral; +3 = very positive) of the event (iii) the intensity of the emotion experienced during the thought (1 = not at all; 7 = completely). If they chose a memory or future thought,

they also rated the intensity of the reliving/preliving experience (1 = not at all; 7 = completely).

At the end of this short questionnaire they were also asked to rate on a 7-point scale their overall level of concentration (1 = not at all concentrated; 7 = fully concentrated) and boredom (1 = not at all; 7 = very bored) experienced during the task and to list their most relevant "current concerns"[2] (maximum: 5). Moreover, for each thought they had to report whether it was associated with one or more current concerns and specify which one/ones and the strength of association, by using a 7-point scale (1= not at all; 7= completely).

<u>Space-time explicit assessment:</u> After completing the thought questionnaire, participants were asked to indicate their explicit horizontal and vertical spatial association for the concepts future and past (Hartmann, Martarelli, Mast & Stocker, 2014). To this aim, they received two horizontal and two vertical oriented 7-point Likert scales where the center of the line indicated no spatial association, and the left, right, upper, and lower endpoints indicated a strong association with this spatial direction. The two scales are reported in the supplementary materials of Hartmann et al. (2014).

Session 2:

Participants completed the *Mind Wandering: Spontaneous (MW-S)* and *Mind Wandering: Deliberate (MW-D)* scales (Carriere. Seli & Smilek, 2013; Italian version in Chiorri & Vannucci, 2017) and they answered separate questions about the frequency of spontaneous and deliberate past-oriented and future-oriented MW. In the same session participants also completed a questionnaire on individual differences in visual object and spatial

[2] The concept of current concern (Klinger, 1999, 2013) was described as follows: Now we ask you to indicate your "current concerns", that is the most relevant and important topics in this period of your life, your "hot topics". By current concerns we do not mean just "problems". You might have concerns about unpleasant things that you want to get rid of, prevent, or avoid. Or you might have concerns about pleasant things you want to get, obtain, or accomplish. Current concerns could be both emotionally negative and positive.

imagery (Object-Spatial Imagery Questionnaire, Blajenkova, Kozhevnikov & Motes, 2006; adaptation for the Italian population in Vannucci, Cioli, Chiorri, Grazi, & Kozhevnikov, 2006). The data collected with this questionnaire are not presented and discussed here, because they were not relevant for the aims of the present study.

Mind Wandering: Spontaneous (MW-S) and Mind Wandering: Deliberate (MW-D) scale (Carriere et al., 2013; Italian version in Chiorri & Vannucci, 2017). The MW-D and the MW-S are 4-item scales that assess individual differences in trait levels of spontaneous and deliberate MW, respectively. Items are scored using 7-point, Likert-type, frequency or intensity scales and participants are asked to select the answer that most accurately reflects their everyday MW. Higher scores reflect a greater tendency to mind wander spontaneously or deliberately. Previous studies reported adequate reliability and discriminant validity of the two scales (Carriere et al., 2013; Chiorri & Vannucci, 2017).

The daily-life frequency of spontaneous and deliberate past-oriented and future-oriented MW was assessed in 4 separate questions on scales ranging from 1 (never) to 5 (always).

2.3.Procedure

In Session 1, participants were tested individually. After being welcomed into the laboratory, participants were briefly introduced to the research project, presented as a study examining concentration and its correlates, and signed a consent form.

Once this stage was completed, they received the instructions for the vigilance task. In this task they were asked to detect target stimuli (black horizontal lines) among a large number of non-target stimuli (black horizontal arrows), by pressing a button each time they detected a target stimulus. Participants were informed that, due to the task being quite monotonous, they could find themselves thinking about other things (e.g., thoughts, plans, considerations, past events, images, etc.). These thoughts might simply pop into their mind spontaneously or they might be intentionally generated. Participants were informed that they would be interrupted during the performance and presented with thought probes consisting of questions about their focus of attention just immediately prior to the probe. After the instructions, participants were given a short practice of the vigilance task (50 trials). When the vigilance task was over, they were presented with the brief descriptions of their mental contents and asked to complete a brief questionnaire (thought questionnaire, see Materials). They were also asked to rate their level of concentration and boredom experienced during the task, to report the association between their thoughts and their current concerns and to indicated their explicit horizontal and vertical spatial association for the concepts future and past (space-time explicit assessment, see Materials). Finally, participants were debriefed and dismissed.

The total session1 lasted from approximately 70 to 90 minutes.

Session 2 took place 7-10 days after Session 1. Participants were tested in small groups, and they were administered two scales on the frequency of spontaneous and deliberate MW in daily-life (see Materials), questions on the frequency of past and future MW, and a questionnaire on individual differences in visual object and spatial imagery. At the end, participants were fully debriefed about the questionnaires and the association between the two sessions and dismissed.

3. Results

3.1. Performance on vigilance task

All participants completed the vigilance task successfully, with an average of 47.46 (*SD* = 1.13) targets detected (out of 48), and no significant differences between the groups (LA group: *M* = 47.54; RA group: *M* = 47.38), $t < 1$. There were no significant group differences in the level of concentration experienced during the task (LA group: *M* = 4.69;

RA group: *M* = 4.77), *t* < 1, and in the level of boredom (LA group: *M* = 4.00; RA group: *M* = 4.23), *t* < 1.

3.2. The role of visuo-spatial cues in mind-wandering

Before conducting the data analyses on the mental contents, all thoughts recorded by participants were independently coded by the first and second authors as either task-related or task-unrelated. Task-related contents consisted of any reference to some task features or to the participant's overall performance (i.e., thoughts about the experiment's duration), whereas task-unrelated mental contents did not include references to the task at hand (see Plimpton et al., 2015) and included "external distraction" (ED) and "mind wandering" (MW) (see Stawarczyk et al., 2011; Stawarczyk, Majerus, Catale, & D' Argembeau, 2014). Task-unrelated mental contents were coded as ED, when the participant's attention was focused on stimuli that were present in the current environment but unrelated to the task at hand. The ED category comprised all thoughts whose content was focused on current sensory perceptions unrelated to the task, with the origin of these perceptions being either external or internal (i.e., bodily sensations). Task-unrelated mental contents were coded as MW when participants had their attention decoupled from the current environment and they were experiencing thoughts unrelated to the task at hand. The MW episodes may have been triggered by external or internal cues.

For both categorizations, inter-rater reliability between the coders was very good (categorization of task-related vs. task-unrelated contents, Kappa = 0.98, SE = 0.01, 95% confidence interval [CI]: 0.96-1.00; categorization of MW vs. ED reports, Kappa = 0.99, SE = 0.01, 95% CI: 0.97-1.00) and minor disagreements were solved by discussion.

Out of 570 valid thought probes, 109 were classed as task-related (*M* = 2.10, *SD* = 2.06 per participant) and 461 as task-unrelated mental contents (*M* = 8.87, *SD* = 2.98). Out of 461 task-unrelated contents, 74 were classed as ED reports (*M* = 1.42, *SD* = 1.33, range

= 0-5) and 387 as MW reports (*M* = 7.44, *SD* = 3.32, range = 1-15). As MW was the focus of the present study, task-related thoughts and external distractions were excluded from the analyses. In addition, during each though probe, participants were asked to indicate whether their thought had arisen spontaneously, deliberately, or whether they did not know. Fifty-two participants reported a total of 387 MW episodes and out of the all MW, 282 were reported as spontaneous MW (*M* = 5.42, *SD* = 3.03, range 1-13) and only 69 were reported as intentional MW (*M* = 1.33, *SD* = 1.32, range 0-5). Given the low amount of intentional MW episodes, these reports were not further considered in our analyses and we focused only on spontaneous MW.

Of the 282 spontaneous MW episodes, 138 (48.9%) were reported by participants as triggered by internal thoughts (M = 2.65, SD = 1.63, range: 0-6), 57 (20.2%) by environmental triggers (M = 1.10, SD = 1.54, range: 0-8), and the remaining 87 (30.9%) by no trigger (M = 1.67, SD = 1.56, range: 0-6).

To assess the effects of the experimental manipulation of spatial cues on the frequency of spontaneous MW episodes, we calculated the average number of spontaneous MW reports per person and entered them into a t student (Group: LA group *vs*. RA group). Analyses were run on 51 participants out of 52, one outlier (in the RA group) was excluded from the analyses because of the very high frequency with which he reported spontaneous past-oriented MW.

No significant differences between the two groups (LA group: *M* = 5.35, *SD* = 3.03; RA group: *M* = 5.64, *SD* = 3.07) were found ($t(49) = -0.34$, $p = 0.73$, $d = -0.10$).

Globally, these results suggest that the manipulation of spatial orientation demands of the task did not affect the amount of spontaneous MW experienced during the task.

3.3. *Temporal focus of mind wandering and visuo-spatial cues*

At the end of the vigilance task, participants coded each of their recorded thoughts as past memories, future thoughts, thoughts about a current situation, or a-temporal thoughts.

To assess the effects of the experimental manipulation on the temporal focus of spontaneous MW, the mean proportion of each type of thought (past, present, future, and a-temporal) was calculated per person and entered into a 2 (Group: LA group *vs.* RA group) x 4 (Temporal focus: past, present, future, and a-temporal) mixed ANOVA.

The analysis was carried out on participants who reported at least 3 spontaneous MW episodes, and the epsilon correction for the degrees of freedom suggested by Greer and Dunlap (1997) was used to take into account that, for each participant, the sum of the values (proportion) across the conditions of the temporal focus factor is constant, namely 1. The analysis revealed a significant main effect of Temporal focus, F (2.40, 98) = 8.12, p < 0.001, η^2_p = 0.17). Pairwise comparisons with Bonferroni adjustment indicated that the proportion of present (M = .12) was significantly lower than past (M = .29, p < 0.001, d = 0.87) and future (M = .29, p < 0.01, d = 0.73) and a-temporal (M = .30, p < 0.01, d = 0.75). The Group x Type of temporal focus interaction was also significant, F (2.40, 98) = 8.32, p < 0.001, η^2_p = 0.17. The LA group reported a higher proportion of past events compared to RA group (M = .42 *vs.* M = .17, p < 0.001, d = 1.00) and a lower proportion of future events (M = .20 *vs.* M = .37, p = 0.002, d = 0.60).

In the LA group the proportion of past events was significantly higher than present thoughts (p < 0.001, d = 1.07) and future thoughts (p < 0.001, d = 0.85). In the RA group the proportion of future thoughts was significantly higher than present thoughts (p < 0.001, d = 0.76) and past thoughts (p < 0.001, d = 0.80), the proportion of a-temporal was significantly higher than present thoughts (p = 0.013, d = 0.60) (Figure 2).

3.4. Phenomenological properties of mind wandering

To assess and compare the phenomenological properties of past, future, present and a-temporal spontaneous MW episodes we asked participants to indicate, for each thought, the specificity, emotional valence of the thought, intensity of the feeling experienced during the thought, and the strength of association between the content and personal current concerns. For past and future MW episodes we also assessed the intensity of the reliving/preliving experience.

However, for METHODOLOGICAL reasons, analyses were carried out only on past and future spontaneous MW, as present and a-temporal MW had to be excluded. Out of 51 participants, only 10 participants reported more than one present-related MW episode, and among these 4 had three or more episodes. Even if we allowed a multilevel structure to the data, information about present-related MW episodes would come from very few participants, with the large majority of the others having missing data. Moreover, the content of such episodes was quite heterogeneous, at it is spanned from interpersonal to academic issues, from current activities to weather conditions, or generically reported as "personal". Classifying these contents in the same category would have raised an issue about its distinctivity, i.e., whether observations could have been considered "equal" with respect to the characteristic being investigated (see, e.g., Thompson, 2006, pp. 14-15) - differently from what happened for the past and future categories, in which content was way more homogeneous. We did not consider atemporal MW episodes for the same reason, as their contents were very heterogeneous, spanning from songs, to personal preferences and self-evaluations, that advised against grouping everything in the same category.

To assess the effects of the experimental manipulation on the phenomenological characteristics of past and future spontaneous MW episodes, we used a multilevel (or hierarchical) dataset, in which past and future spontaneous MW episodes were nested into participants. The unit of analysis was a single MW episode. The use of this strategy of analysis not only allowed us to take into account the non-independence of the units of analysis, but also to accommodate for unequal numbers of data points within participants (Jahng, Wood, & Trull, 2008). We specified random-intercept multilevel models to test for associations of the factors (Group: LA group vs. RA group; Temporal focus: past, future) with the ratings of phenomenological qualities of the MW episodes, which were considered as the dependent variables. As for the specificity of MW episodes (dichotomous variable), we used a generalized linear mixed model (family = binomial).

The analysis revealed that future spontaneous MW episodes were more strongly associated with current concerns compared to past spontaneous MW episodes (future Estimated Marginal Mean = 3.87, 95% CI: 3.25-4.50; past Estimated Marginal Mean = 2.92, 95% CI: 2.28-3.56), $F(1, 139.33) = 5.66$, $p = .019$, $d = 0.40$). The effect of Group ($F(1, 42.24) = 1.68$, $p = 0.202$, $d = 0.40$) and the interaction ($F(1, 139.33) = 0.15$, $p = 0.703$, $d = 0.06$) were not significant.

Moreover, past episodes were associated with a significantly higher intensity of reliving experience than future episodes (preliving) (past Estimated Marginal Mean = 4.64, 95% CI: 4.16-5.13; future Estimated Marginal Mean = 3.95, 95% CI: 3.47-4.43), $F(1,128.22) = 7.61$, $p = .007$, $d = 0.49$). The effect of Group ($F(1, 46.32) = 0.13$, $p = 0.720$, $d = 0.11$) and the interaction ($F(1, 128.22) = 0.04$, $p = 0.833$, $d = 0.04$) were not significant..

No significant differences were found in the emotional valence of MW episodes (Group: $F(1, 159) = 0.78$, $p = 0.377$, $d = 0.14$; Temporal focus: $F(1, 159) = 0.10$, $p = 0.750$, $d = 0.05$; Interaction: $F(1, 159) = 0.95$, $p = 0.331$, $d = 0.15$), nor in the intensity of the emotion experienced during the thought (Group: $F(1, 47.54) = 0.25$, $p = 0.617$, $d = 0.15$; Temporal focus: $F(1, 130.55) = 3.35$, $p = 0.070$, $d = 0.32$; Interaction: $F(1, 130.55) = 0.09$, $p = 0.761$, $d = 0.05$) or in the specificity of events (dichotomous variable) (Group: log-odds [reference: RA] = 1.37, standard error [SE] = 0.82, $p = 0.117$, odds ratio = 3.94 [0.71-

21.87]; Temporal focus: log-odds [reference: past] = 1.29 p = 0.127, odds ratio = 3.64 [95% CI: 0.69-19.19]; Interaction: log-odds [reference: past-RA] = -1.03 p = 0.310, odds ratio = 0.96 [95% CI: 0.05-2.61]).

3.5. Space-time explicit assessment

At the end of Session 1, participants were asked to indicate their explicit associations between future and past and the horizontal and vertical space.

As for the horizontal spatial association, from the total of 52 participants, 48 associated past with the left space, 2 with the right space, and 2 indicated no spatial association. Similarly, 48 participants associated future with the right space, 2 with the left space, and 2 indicated no spatial association.

As for the vertical spatial association, 37 associated past with the lower space, 10 with the upper space, and 5 indicated no spatial association. Similarly, 42 participants associated future with the upper space, 9 with the lower space, and 1 indicated no spatial association. For the horizontal spatial association, paired *t*-test revealed that the mean score for past (M = -1.88, SD = 1.04) was significantly lower than for future (M = 2.23, SD = 1.06), $t(51) = 16.29$, $p < .001$, $d = 2.26$. Similarly, for the vertical spatial association, paired t-test revealed that mean scores for past (M = -1.17, SD = 1.81) were significantly lower than for future (M = 1.48, SD = 1.95), $t(51) = 5.39$, $p < .001$, $d = 0.75$.

In line with previous findings (Hartmann et al., 2014), these results confirm that participants explicitly associate the past with the lower left, and the future with the top right space.

3.6. Temporal focus of mind wandering in daily-life

In Session 2, participants completed the MW-S and MW-D scale and they rated the frequency of past and future spontaneous and deliberate MW in daily life. Independent samples t-tests were performed to compare the scores on these scales between the LA group and the RA group. Cohen's d was computed as effect size for independent-sample mean comparisons.

The two groups did not significantly differ in either MW-S (LA group: $M = 4.85$, $SD = 1.23$; RA group: $M = 4.86$, $SD = 1.31$; $p = .96$, $d < 0.01$) or MW-D (LA group: $M = 5.18$, $SD = 1.19$; RA group: $M = 4.67$, $SD = 1.32$; $p =.15$ $d = 0.41$) scale scores. Moreover, the two groups did not significantly differ in their daily life frequency of spontaneous past MW (LA group: $M = 3.31$, $SD = 1.01$; RA group: $M = 3.16$, $SD = 0.85$; $p = 0.58$, $d = 0.16$), future MW (LA group: $M = 3.54$, $SD = 1.21$; RA group: $M = 3.52$, $SD = 1.05$; $p = 0.95$, $d = 0.18$), deliberate past MW (LA group: $M = 2.65$, $SD = 0.94$; RA group: $M = 2.84$, $SD = 1.03$; $p= 0.50$; $d = -0.19$), and future MW (LA group: $M = 3.88$, $SD = 0.71$; RA group: $M = 3.96$, $SD = 0.79$; $p = 0.72$, $d = -0.11$).

Even more interesting, we did not find any significant correlations between the number of past and future spontaneous MW episodes experienced during the task and the amount of past and future spontaneous MW episodes reported in daily life ($r = 0.16$, $p = 0.26$; past; $r = 0.09$, $p = 0.52$ future).

4. Discussion

The present study aimed at investigating the causal role of spatial orientation demands of the ongoing task in shaping the temporal orientation of MW. Specifically, we tested the hypothesis that the experimental induction of leftward/rightward orienting of attention (Left-pointing arrows –LA-group and Right-pointing arrows- RA-group) during a vigilance task might steer the temporal focus of MW towards the past and the future respectively. To assess MW, participants were stopped 15 times during the task and recorded their thoughts at that moment. Our findings showed that the experimental manipulation affected the temporal orientation of spontaneous MW, with the LA group reporting a higher proportion of past-oriented MW compared to the RA group and a lower proportion of future-oriented MW. The two groups did not significantly differ in the proportion of present and a-temporal MW episodes.

More importantly, the two groups did also not significantly differ in their daily-life frequency of past and future spontaneous MW and the amount of past and future spontaneous MW reported during the vigilance task was not significantly correlated with the amount of past and future spontaneous MW experienced in daily life. This lack of an association rules out the possibility that the difference between the two experimental groups could be due to already existing differences in the daily-life frequency of past and future MW.

Globally, these results provide an important contribution to the research field of mind wandering and to the investigation of the mental representation of time. Several studies on MW have documented a bias toward thinking about the future (prospective bias) (Smallwood & Schooler, 2015). However, increasing evidence has been reported suggesting that the temporal focus of MW is much more flexible than expected and sensitive to several variables, as task (e.g. cognitive load of the on-going task; exposure to verbal cues; elicitation of the illusion of self-motion) and participants' characteristics (e.g. mood) (Miles et al., 2010; Plimpton et al., 2015; Poerio et al., 2013; Vannucci et al., 2017).

Our results confirm the flexibility of the temporal focus of MW and its sensitivity to space manipulation, and they go a step further by showing that time can be also manipulated by systematically modifying the spatial orientation demands of the ongoing task.

Specifically, our study shows that the experimental manipulation affects the accessibility of different temporal perspectives in spontaneous MW.

Two different explanations might be advanced for this effect. First, since we manipulated visuo-spatial orientation demands of the task, spatial attention is most presumably the mechanism involved in this effect. To this regard, some studies have already shown that time and space are *processed* similarly and they are directly influenced by experimental manipulation of spatial attention, as for example prismatic adaptation (e.g, see Anelli et al., 2016; Frassinetti et al., 2009; Magnani, Oliveri, Mangano, & Frassinetti, 2010; Oliveri, Magnani, Filippelli, Avanzi, & Frassinetti, 2013).

For example, Frassinetti, Magnani, and Olivieri (2009) have shown that the perception of temporal durations can be altered through the manipulation of spatial attention, with leftward attentional shift, induced by prismatic adaptation, resulting in underestimation of temporal durations, and rightward attentional shift resulting in overestimation.

More recently, Anelli et al. (2016) have found that the experimental manipulation of spatial attention can also influence the processing of more conceptual aspects of time, as humans' ability to travel mentally back and forward in time. In the study, the authors found that leftward and rightward shifts of spatial attention, induced by prismatic adaptation, facilitated mental time travel towards the past and the future respectively. The effects of prismatic adaptation on mental time travel suggest that "*spatial attention can also prioritize processing of particular locations in time, tuning individuals to the past or the future*" (Anelli et al., 2016, p. 4).

In line with these findings, the effects we found on the temporal orientation of spontaneous MW can be interpreted as a result of the shifts of visuo-spatial attention induced by our experimental manipulation: leftward and rightward shifts of attention would orient individuals more toward the past and the future respectively, thereby increasing the number of spontaneous past and future-oriented MW episodes.

However, a second explanation of our findings needs also to be considered. In our study we used directional stimuli, namely left-pointing and right-pointing arrows, and the exposure to these stimuli might, strictly speaking, not have produced a shift in spatial attention *per se*, but simply evoked an abstract association between spatial and temporal codes ("left" being stronger associated with the past and "right" with the future; Santiago et al., 2007). Future studies are needed to distinguish between these explanations. Ideally, they would directly compare the arrow condition we used in the present experiment with a more direct manipulation of spatial attention, such as prismatic adaptation.

Future studies could also include a control condition without directional arrows in order to determine the relationship between past- and future directed MW in the present paradigm. As mentioned in the Introduction section, many MW studies have described a "prospective bias", and the effect of left- and right-pointing arrows would thus not be expected to be symmetric.

In the present study, we also examined the phenomenological properties of MW, with a special focus on the comparison of past and future spontaneous MW episodes. Differences emerged between the two temporal orientation in a few phenomenological properties. In line with the results of previous studies on involuntary autobiographical memories and future thoughts (Cole & Berntsen, 2015), we found that future-related spontaneous MW episodes were more strongly associated with personal current concerns compared to past-related MW episodes. Significant differences were also found in the intensity of the experience of reliving *vs* pre-living, with stronger intensity for the reliving compared to the pre-living. This difference is in line with the results of previous studies, showing that involuntary future event representations are less detailed than involuntary memories of past events (Berntsen & Jacobsen, 2008) and less vivid (Cole & Berntsen, 2015).

We originally intended to examine also present-related and atemporal episodes of MW. Unfortunately, the sparseness of these episodes and the heterogeneity of their contents prevented us to considered them for any reasonable analysis. More research is therefore needed to address this issue and the methodological challenges related to it.

Our experimental manipulation affected the temporal orientation of MW with less, if any, effect on their phenomenological properties. These results suggest that the characteristics of MW are largely unaffected by the way visuo-spatial processing impacts upon the accessibility of past and future events. However, future studies should assess the effects on other characteristics of MW which have not been assessed in the present study, that are nevertheless related to the temporal dimension of events. One example is the temporal distance of an event from the present, that is how far in the past an event had occurred, or how far in the future participants were projecting themselves during a MW episode.

In a recent study on MW, Plimpton et al (2015) found that the majority of future thoughts were projections into the immediate future (less than one month) and very few into the distant future. The opposite pattern was found for past events (see also Cole et al., 2015 for similar findings).

The results of a recent study by Ding et al. (2015) suggest that spatial representations of past and future are symmetric in near past and near future in mental time line, but they are asymmetric in distant past and future, with the spatial representation of past being stronger than that of future (ie., the distance effect for the past was stronger than that of the future).

On the basis of these findings, one might hypothesize that temporal distance in MW (i.e., accessibility of near versus distant past or future) might be differentially altered through the manipulation of spatial attention, with a stronger effect on the past than the future. Analogous effects have been described for number space, where lateral eye movements are a fairly reliable predictor of whether a person thinks of a small or a large number (Loetscher, Bockisch, Nicholls & Brugger, 2010). Also along the number line, the magnitude of an eye movement in one direction is related to the distance from a given standard, and the orienting effects toward small numbers are larger than toward large numbers (Loetscher, Bockisch, & Brugger, 2008). Mapping the arrow of time onto space in a comparably continuous way may reveal new insights onto a general magnitude processing system in the human brain. To this end, MW may serve as an ideal paradigm.

Finally, it should also be noted that this study enrolled only young adults. Future studies might extend the investigation to other populations of special interest for research on MW, such as elderly people and people who exhibit clinical depression. Studies on aging have shown a reduction in MW in healthy older adults compared to young adults (for a discussion, see Maillet & Schacter, 2016a), and an age-related increase in reliance on the environment (Craik, 1986; Maillet & Schacter, 2016b) and a retrospective bias. Future studies should examine the effects of the exposure to visuo-spatial cues on the temporal orientation of MW in elderly people and verify whether the presence of right-ward attention induction might increase the frequency of future-oriented MW and reduce the retrospective bias in elderly people. Within the field of MW research, several studies have reported a positive relationship between past-oriented MW, and measures of negative mood and dysphoria (e.g. Poerio et al., 2013; Smallwood & O'Connor, 2011). Hence, an investigation of the effects of visuo-spatial orientation on the temporal focus of MW in dysphoric and depressed individuals would help to expand the results of this study.

References

Anelli, F., Candini, M., Cappelletti, M., Oliveri, M., & Frassinetti, F. (2015). The re-mapping of time by active tool-use. *PLoS ONE, 10*(12), e0146175. doi:10.1371/journal.pone.0146175

Anelli, F., Ciaramelli, E., Arzy, S., & Frassinetti, F. (2016). Prisms to travel in time: Investigation of time-space association through prismatic adaptation effect on mental time travel. *Cognition, 156*, 1−5. doi:10.1016/j.cognition.2016.07.009

Antrobus, J. S. (1968). Information theory and stimulus-independent thought. *British Journal of Psychology, 59*(4), 423−430. doi:10.1111/j.2044-8295.1968.tb01157.x

Antrobus, J. S., Singer, J. L., & Greenberg, S. (1966). Studies in stream of consciousness: Experimental enhancement and suppression of spontaneous cognitive processes. *Perceptual and Motor Skills*, *23*(2), 399–417. doi:10.2466/pms.1966.23.2.399

Baird, B., Smallwood, J., & Schooler, J. W. (2011). Back to the future: Autobiographical planning and the functionality of mind-wandering. *Consciousness and Cognition, 20*(4), 1604–1611. doi:10.1016/j.concog.2011.08.007

Barron, E., Riby, L., Greer, J., & Smallwood, J. (2011). Absorbed in thought: The effect of mind wandering on the processing of relevant and irrelevant events. *Psychological Science, 22*(5), 596–601. doi:10.1177/0956797611404083

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the Beck Depression Inventory-II*. San Antonio, TX: Psychological Corporation.

Berntsen, D., & Bohn, A. (2010). Remembering and forecasting: The relation between autobiographical memory and episodic future thinking. *Memory and Cognition, 38* (3), 265-278. doi: 10.3758/MC.38.3.265.

Berntsen, D., & Jacobsen, A. S. (2008). Involuntary (spontaneous) mental time travel into the past and future. *Consciousness and Cognition, 17*(4), 1093–1104. doi:10.1016/j.concog.2008.03.001

Bonato, M., & Umiltà, C. (2014). Heterogeneous timescales are spatially represented. *Frontiers in Psychology, 5*, 542. doi:10.3389/fpsyg.2014.00542

Bonato, M., Zorzi, M., & Umiltà, C. (2012). When time is space: Evidence for a mental time line. *Neuroscience and Biobehavioral Review, 36*(10), 2257–2273. doi:10.1016/j.neubiorev.2012.08.007

Carriere, J. S. A., Seli, P., & Smilek, D. (2013). Wandering in both mind and body: Individual differences in mind wandering and inattention predict fidgeting. *Canadian Journal of Experimental Psychology, 67*(1), 19–31. doi:10.1037/a0031438

Casasanto, D., & Bottini, R. (2014). Mirror-reading can reverse the flow of time. *Journal of Experimental Psychology: General, 143*(2), 473–479. doi:10.1037/a0033297

Chiorri, C., & Vannucci, M. (2017). Replicability of the psychometric properties of trait levels measures of spontaneous and deliberate mind wandering. *European Journal of Psychological Assessment*. Advance online publication. doi:10.1027/1015-5759/a000422

Christoff, K., Irving, Z. C., Fox, K. C. R., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews Neuroscience, 17*(11), 718–731. doi:10.1038/nrn.2016.113

Cole, S. N., & Berntsen, D. (2015). Do future thoughts reflect personal goals? Current concerns and mental time travel into the past and future. *Quarterly Journal of Experimental Psychology, 69*(2), 273–284. doi:10.1080/17470218.2015.1044542

Cole, S. N., Staugaard, S. R., & Berntsen, D. (2016). Inducing involuntary and voluntary mental time travel using a laboratory paradigm. *Memory & Cognition, 44*(3), 376–389. doi: 10.3758/s13421-015-0564-9

Craik, F. I. M. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (Eds.), *Human memory and cognitive capabilities: Mechanisms and performances* (pp. 409–422). Amsterdam: Elsevier.

D'Argembeau, A., & Van der Linden, M. (2004). Phenomenal characteristics associated with projecting oneself back into the past and forward into the future: Influence of valence and temporal distance. *Consciousness and Cognition*, *13*(4), 844–858. Doi: 10.1016/j.concog.2004.07.007

D'Argembeau, A., & Van der Linden, M. (2006). Individual differences in the phenomenology of mental time travel: The effect of vivid visual imagery and emotion regulation strategies. *Consciousness and Cognition, 15*(2), 342–350. doi: 10.1016/j.concog.2005.09.001

Ding, X., Feng, N., Cheng, X., Liu, H., & Fan, Z. (2015). Are past and future symmetric in mental time line? *Frontiers in Psychology, 6,* 208, 1-8. doi: 10.3389/fpsyg.2015.00208

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3. A Flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavioral Research Methods*, *39*(2), 175–191. doi:10.3758/BF03193146

Finnbogadóttir, H., & Berntsen, D. (2013). Involuntary future projections are as frequent as involuntary memories, but more positive. *Consciousness and Cognition*, *22*(1), 272–280. doi: 10.1016/J.CONCOG.2012.06.014

Frassinetti, F., Magnani, B., & Oliveri, M. (2009). Prismatic lenses shift time perception. *Psychological Science, 20(8),* 949–954. doi: 10.1111/j.1467-9280.2009.02390.x

Gamboz, N., Brandimonte, M. A., & De Vito, S. (2010). Role of past in the simulation of autobiographical future episodes. *Experimental Psychology, 57*(6), 419–428. doi: 10.1027/1618-3169/a000052

Ghisi, M., Flebus, G. B., Montano, A., Sanavio, E., & Sica, C. (2006). *Beck Depression Inventory-II. Manuale italiano.* Firenze: Organizzazioni Speciali.

Giambra, L. M. (1979). Sex differences in daydreaming and related mental activity from the late teens to the early nineties. *International Journal of Aging and Human Development, 10*(1), 1–34. doi:10.2190/01BD-RFNE-W34G-9ECA

Greer, T., & Dunlap, W. P. (1997). Analysis of variance with ipsative measures. *Psychological Methods, 2*(2), 200–207. doi:10.1037/1082-989X.2.2.200

Hartmann, M., Martarelli, C. S., Mast, F. W., & Stocker, K. (2014). Eye movements during mental time travel follow a diagonal line. *Consciousness and Cognition, 30*, 201–209. doi:10.1016/j.concog.2014.09.007

Hassabis, D., Kumaran, D., & Maguire, E. A. (2007). Using imagination to understand the neural basis of episodic memory. *Journal of Neuroscience, 27(52),* 14365–74. doi. 10.1523/JNEUROSCI.4549-07.2007

Jahng, S., Wood, P. K., & Trull, T. J. (2008). Analysis of affective instability in ecological momentary assessment: Indices using successive difference and group comparison via multilevel modeling. *Psychological Methods, 13*(4), 354–375. doi:10.1037/a0014173

Kane, M. J., Brown, L. E., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. *Psychological Science, 18*(7), 614–621. doi:10.1111/j.1467-9280.2007.01948.x

Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science, 330*, 932. doi:10.1126/science.1192439

Klinger, E., & Cox, W. M. (1987). Dimensions of thought flow in everyday life. *Imagination, Cognition, and Personality, 7*(2), 105–128. doi:10.2190/7K24-G343-MTQW-115V

Klinger, E. C. (1999). Thought flow: Properties and mechanisms underlying shifts in content. In J. A. Singer & P. Salovey (Eds.), *At play in the fields of consciousness, Essays in honour of Jerome L. Singer* (pp. 29–50). Mahwah, NJ: Erlbaum.

Klinger, E. (2013). Goal commitments and the content of thoughts and dreams: Basic principles. *Frontiers in Psychology, 4,* 415. doi:10.3389/fpsyg.2013.00415.

Kong, F., & You, X. (2012). Space-time compatibility effects in the auditory modality. *Experimental Psychology, 59*(2), 82–87. doi:10.1027/1618-3169/a000129

Macnamara, A., Keage, H.A.D., & Loetscher, T. (2017). Mapping of non-numerical domains on space: a systematic review and meta-analysis. *Experimental Brain Research,* Dec 26. Advance online publication. doi: 10.1007/s00221-017-5154-6

Maillet, D., & Schacter, D. L. (2016a). From mind wandering to involuntary retrieval: Age-related differences in spontaneous cognitive processes. *Neuropsychologia, 80*, 142–156. doi:10.1016/j.neuropsychologia.2015.11.017

Maillet, D., & Schacter, D. L. (2016b). When the mind wanders: Distinguishing stimulus-dependent from stimulus-independent thoughts during incidental encoding in young and older adults. *Psychology and Aging, 31*(4), 370–379. doi:10.1037/pag0000099

Magnani, B., Oliveri, M., Mangano, G. R., & Frassinetti, F. (2010). The role of posterior parietal cortex in spatial representation of time: A TMS study. *Behavioural Neurology, 23(4),* 213–215. doi: 10.3233/BEN-2010-0298.

Miles, A. N., & Berntsen, D. (2011). Odour-induced mental time travel into the past and future: Do odour cues retain a unique link to our distant past? *Memory*, *19*(8), 930–940. doi:10.1080/09658211.2011.613847

Miles, L. K., Karpinska, K., Lumsden, J., & Macrae, C. N. (2010). The meandering mind: Vection and mental time travel. *PLoS ONE, 5*(5), e10825. doi:10.1371/journal.pone.0010825

Oliveri, M., Magnani, B., Filipelli, A., Avanzi, S., & Frassinetti, F. (2013). Prismatic adaptation effects on spatial representation of time in neglect patients. *Cortex, 49*(1), 120–130. doi:10.1016/j.cortex.2011.11.010

Plimpton, B., Patel, P., & Kvavilashvili, L. (2015). Role of triggers and dysphoria in mind-wandering about past, present and future: A laboratory study. *Consciousness and Cognition, 33*, 261–276. doi:10.1016/j.concog.2015.01.014

Poerio, G., Totterdell, P., & Miles, E. (2013). Mind-wandering and negative mood: does one thing really lead to another? *Consciousness and Cognition*, *22*, 1412–1421. doi:10.1016/j.concog.2013.09.012

Rasmussen, A. S., & Berntsen, D. (2013). The reality of the past versus the ideality of the future: emotional valence and functional differences between past and future mental time travel. *Memory & Cognition, 41*, 187-200. doi: 10.3758/s13421-012-0260-y.

Ruby, F. J., Smallwood, J., Engen, H., & Singer, T. (2013). How self-generated thought shapes mood—The relation between mind-wandering and mood depends on the socio-temporal content of thoughts. *PLoS ONE, 8*(10), e77554. doi:10.1371/journal.pone.0077554

Saj, A., Fuhrman, O., Vuilleumier, P., & Boroditsky, L. (2014). Patients with left spatial neglect also neglect the "left side" of time. *Psychological Science, 25*(1), 207–214. doi:10.1177/0956797612475222

Santiago, J., Lupianez, J., Perez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin & Review, 14*(3), 512–516. doi:10.3758/BF03194099

Schlagman, S., & Kvavilashvili, L. (2008). Involuntary autobiographical memories in and outside the laboratory: How different are they from voluntary autobiographical memories? *Memory & Cognition, 36*(5), 920–932. doi:10.3758/MC.36.5.920

Singer, J. L. (1966). *Daydreaming. An introduction to the experimental study of inner experience*. New York: Random House.

Smallwood, J. (2013). Distinguishing how from why the mind wanders: A process-occurrence framework for self-generated mental activity. *Psychological Bulletin, 139*(3), 519–535. doi:10.1037/a0030010

Smallwood, J., McSpadden, M., & Schooler, J. W. (2007). The lights are on but no one's home: Meta-awareness and the decoupling of attention when the mind wanders. *Psychonomic Bulletin & Review, 14*(3), 527–533. doi:10.3758/BF03194102

Smallwood, J., Nind, L., & O'Connor, R. C. (2009). When is your head at? An exploration of the factors associated with the temporal focus of the wandering mind. *Consciousness and Cognition, 18*(1), 118–125. doi:10.1016/j.concog.2008.11.004

Smallwood, J., & O'Connor, R. C. (2011). Imprisoned by the past: Unhappy moods lead to a retrospective bias to mind wandering. *Cognition and Emotion, 25*(8), 1481–1490. doi:10.1080/02699931.2010.545263

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin, 132*(6), 946–958. doi:10.1037/0033-2909.132.6.946

Smallwood, J., & Schooler, J. W. (2015). The science of mind wandering: Empirically navigating the stream of consciousness. *Annual Review of Psychology, 66*, 487–518. doi:10.1146/annurev-psych-010814-015331

Song, X., & Wang, X. (2012). Mind wandering in Chinese daily lives – An experience sampling study. *PLoS ONE, 7*(9), e44423. doi:10.1371/journal.pone.0044423

Stawarczyk, D., Majerus, S., Catale, C., & D'Argembeau, A. (2014). Relationships between mind-wandering and attentional control abilities in young adults and adolescents. *Acta Psychologica, 148,* 25–36. doi:10.1016/j.actpsy.2014.01.007

Stawarczyk, D., Majerus, S., Maj, M., Van der Linden, M., & D'Argembeau, A. (2011). Mind-wandering: Phenomenology and function as assessed with a novel experience sampling method. *Acta Psychologica*, *136*(3), 370–381. doi:10.1016/j.actpsy.2011.01.002

Suddendorf, T., & Corballis, M. C. (2007). The evolution of foresight: What is mental time travel and is it unique to humans? *Behavioral and Brain Sciences, 30*, 299–351. doi:10.1017/S0140525X07001975

Thompson. B. (2006). *Foundations of behavioral statistics*. New York: Guilford.

Vallesi, A., Weisblatt, Y., Semenza, C., & Shaki, S. (2014). Cultural modulations of space-time compatibility effects. *Psychonomc Bulletin Review, 21*, 666-669. doi: 10.3758/s13423-013-0540-y.

Vannucci, M., Batool, I., Pelagatti, C., & Mazzoni, G. (2014). Modifying the frequency and characteristics of involuntary autobiographical memories. *PLoS ONE*, *9*(4), e89582. doi:10.1371/journal.pone.0089582

Vannucci, M., Pelagatti, C., Hanczakowski, M., Mazzoni, G., & Rossi Paccani, C. (2015). Why are we not flooded by involuntary autobiographical memories? Few cues are more effective than many. *Psychological Research*, *79*(6), 1077–1085. doi:10.1007/s00426-014-0632-y

Vannucci, M., Pelagatti, C., & Marchetti, I. (2017). Manipulating cues in mind wandering: Verbal cues affect the frequency and the temporal focus of mind wandering. *Consciousness and Cognition, 53*, 61–69. doi:10.1016/j.concog.2017.06.004

Vicario, C. M., Caltagirone, C., & Oliveri, M. (2007). Optokinetic stimulation affects temporal estimation in healthy humans. *Brain and Cognition*, *64*, 68–73. doi:10.1016/j.bandc.2006.12.002

Vicario, C. M., Pecoraro, P., Turriziani, P., Koch, G., Caltagirone, C., & Oliveri, M. (2008). Relativistic compression and expansion of experiential time in the left and right space. *PLoS ONE*, *3*(3), e1716. doi:10.1371/journal.pone.0001716

Captions

Figure 1. Example of the stimulus displays in LA group (left) and RA group (right)

Figure 2. Mean proportion of past-focused, present-focused, future-focused, and a-temporal mind wandering in the LA group and RA group.

Fig. 1 Example of the stimulus displays in LA group (left) and RA group (right)

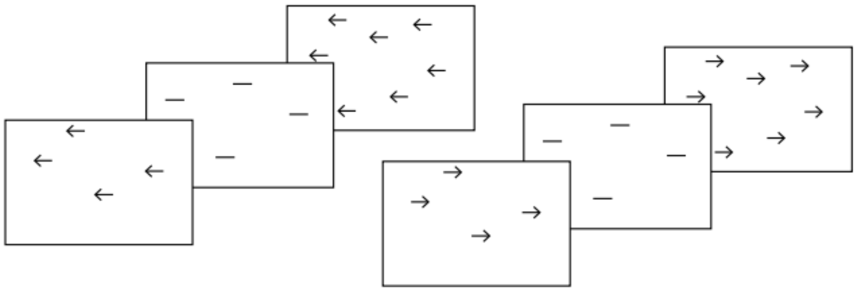

Fig. 2 Mean proportion of past-focused, present-focused, future-focused, and atemporal mind wandering in the LA group and RA group