Supplementary material

for

Ventromedial prefrontal damage reduces mind-wandering and biases its temporal focus

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Lesion analysis

Patients' individual lesions, derived from the most recent magnetic resonance imaging (MRI; N = 12) or computerized tomography (CT; N = 5) images, were manually drawn by an expert neurologist (not involved in the present study, and blind to task performance), or by E.B., and then verified by the same neurologist, directly on each slice of the normalized T1-weighted template MRI scan from the Montreal Neurological Institute (Rorden & Brett, 2000). This template is approximately oriented to match Talairach space (Talairach & Tournoux, 1988) and is distributed with MRIcro (Rorden & Brett, 2000). This manual procedure combines segmentation (identification of lesion boundaries) and registration (to a standard template) into a single step, with no additional transformation required (Kimberg et al., 2007). MRIcro software was used to estimate lesion volumes (in cc) and generate lesion overlap images. As anticipated, for one patient artifacts due to the presence of a metallic clip made it impossible to reconstruct precisely the extension of the lesion. The lesion appeared relatively small, and located in the ventral part of vmPFC, in line with the etiology (ACoA aneurysm). We, therefore, included the patient in our vmPFC sample (note that the results do not change if we excluded this patient from the analyses). Figure 1 shows the extent and overlap of brain lesions in the remaining 6 vmPFC patients. Brodmann's areas (BA) mainly affected were areas BA 10, BA 11, BA 24, BA 25, BA 32, BA 46, BA 47, with the region of maximal overlap occurring in BA 11 (M = 22.55 cc, SD = 8.80), BA 10 (M = 14.14 cc, SD = 4.36), and BA 32 (M = 9.25 cc, SD = 2.76). Two patients also had minimal damage in BA 46 and BA 47, accounting for about 6% and 3% of patients' total lesion size, respectively.

Figure 1S shows the extent and overlap of brain lesions in the 11 control patients. Lesion sites mainly included the occipital cortex, extending into the paraventricular occipital area and the posterior forceps, with the region of maximal overlap occurring in BA 17 (M = 3.18 cc, SD = 3.28), BA 18 (M = 5.21 cc, SD = 3.61), BA 19 (M = 3.36 cc, SD = 3.55). In two patients, the lesions included areas beyond the occipital cortex, which were the premotor cortex (BA 6, in both cases; 3% of patients' total lesion size), the lateral temporal cortex (BAs 20-22, in both cases; 24% of

patients' total lesion size), the angular gyrus (BA 39, in one case, 11% of patient's total lesion size), and the cerebellum (in both cases; 9% of patients' total lesion size). Given that the lateral temporal cortex and the angular gyrus are part of the default network, it may be worth noting that even in these two patients mind-wandering ratings were comparable to the healthy controls' (Individual t tests < 1.31, $p > 0.20$ in both cases; Crawford & Garthwaite, 2002). Of course, ad hoc studies with patients with focal lesions will be needed to investigate the role of other nodes of the default network in mind-wandering.

Please insert Figure 1S about here

Cognitive profile

Patients' general cognitive functioning was generally preserved, as indicated by the scores they obtained in the Raven Standard Matrices (RMS), the phonemic fluency test (PF), and the digit span test (DS), which were within the normal range in all cases, and similar between patient groups (t test: $t < 0.83$, $p > 0.41$ in all cases). All groups were also evaluated on working memory and cognitive flexibility, two aspects of executive functioning that may have an impact on mind-wandering and be impaired following prefrontal cortex lesions (Baldo & Shimamura, 2002; DeLuca & Diamond, 1995; Mesulam, 2002; Shallice, 1982; Stuss & Benson, 1984). Working memory was assessed with a 2-back task (based on Zimmermann & Fimm, 2002), requiring to monitor a series of numbers and signal when the current number matches the one appearing 2 steps earlier in the sequence (1 control patient was no longer available for testing). Cognitive flexibility was assessed with the Weigl Color-Form Sorting Test (Weigl, 1927), which requires classifying a series of stimuli according to different criteria (e.g., shape, color, size) and switch to a different criterion upon request (2 control patients and 2 healthy controls were no longer available for testing). Group differences in accuracy in the 2-back task did not reach conventional levels of statistical significance ($F(2,34) = 2.76$, $p = 0.08$), although vmPFC patients' performance tended to be weaker than control patients' and healthy controls'. As well, there was a marginally significant difference in

the Weigl Test accuracy score (highest possible score = 15; Weigl, 1927) across groups ($F(2,31) = 3.14$, $p = 0.06$), with vmPFC patients' performance weaker than that of control patients and healthy controls (see Table 1).

vmPFC patients also received a more extensive neuropsychological battery aimed at qualifying their cognitive profile further. This revealed normal performance in most standard tests of executive functioning, such as the Tower of London test (t-score = 43.57; cut off = 30) (Culbertson & Zillmer, 2000), phonemic fluency (mean equivalent score (ES) = 2.29. Note that the equivalent score ranges from 0 = impaired performance, and 1 = borderline performance, to 2 - 4 indicating normal performance), semantic fluency (ES = 3), and the Stroop test (mean number of errors = 0.79, cut off > 7.5) (Spinnler & Tognoni, 1987). Verbal short-term memory (Digit span; ES = 3.14) and spatial short-term memory (Corsi test; ES = 3) (Spinnler & Tognoni, 1987) were also preserved. Long-term memory was weak, but within the normal limits, as assessed with the Buschke–Fuld list-learning Test (Buschke & Fuld, 1974; Long Term Retrieval ES = 1.57) and a prose-passage recall test (ES = 1.86) (Spinnler & Tognoni, 1987). Patients did not show spontaneous confabulation, based on clinical evidence, their behavior in real life, and interviews with family members: patients did not confabulate without apparent prompting (Kopelman, 1987) or act upon erroneous memories (Schnider, 2008).

Task instructions

Our experimental procedures rest on the assumption that patients understood the distinction between being on-task and off-task, and were able to classify their mental states based on that distinction. To make sure this was indeed the case, we adopted several measures. First, before the first testing session, participants were familiarized with the concept of mind-wandering. We told them that individuals' attention is typically focused on the task at hand (i.e., on-task), but occasionally it may wander away from current activities (i.e., off-task), towards something unrelated to the task (mind-wandering). We paid attention not to give either a positive or negative connotation of mind-wandering to avoid social desirability biases. We provided an example of

mind-wandering: mentally planning the next vacation while washing the dishes. All participants, including vmPFC patients, related immediately to the concept of mind-wandering, and could provide additional examples on their own. The distinction between being on-task vs. off-task was reiterated in the context of the WM, CRT, and "Passive" tasks. Participants were instructed to classify their attention as "on-task" when they were focusing strictly on the execution of the computerized tasks, for example thinking about the stimuli and task procedures (e.g., "green 5, odd"), and as "off-task" when their thoughts were unrelated to the task (e.g., "I need to see the dentist later") or irrelevant to task execution ("This is so boring").

As an additional check, at the end of the experiment we had a subset of vmPFC patients and healthy controls classify another person's thoughts as on-task or off-task. In the context of a pilot experiment using the CRT task, we had asked (healthy) participants to report what they were thinking while classifying their attention as on-task vs. off-task. We chose 20 such thoughts, of which 5 on-task (e.g., "3, that's odd") and 15 off-task. The 15 off-task thoughts comprised 5 past-related thoughts (e.g., "When we purchased that washing machine we made a big mistake"), 5 present-related thoughts (e.g., "I wonder what my son is doing right now"), and 5 future-related thoughts (e.g., "Next week beach for sure"). Five vmPFC patients and twelve healthy controls were presented with the 20 thoughts in a randomized order. They were told that another individual, Mario, had performed a task requiring to monitor black and green digits on a computer screen, and classify green digits as even or odd. Mario had reported 20 thoughts that had popped into his mind while doing the task, and we now wanted their opinion as to whether they would consider each thought as reflecting on-task or off-task attention. We found no significant difference in classification accuracy (on-task/off-task) between vmPFC patients and healthy controls (0.96 vs. 0.91, $t = -0.88$, $p = 0.39$), suggesting vmPFC patients could comply with task instructions.

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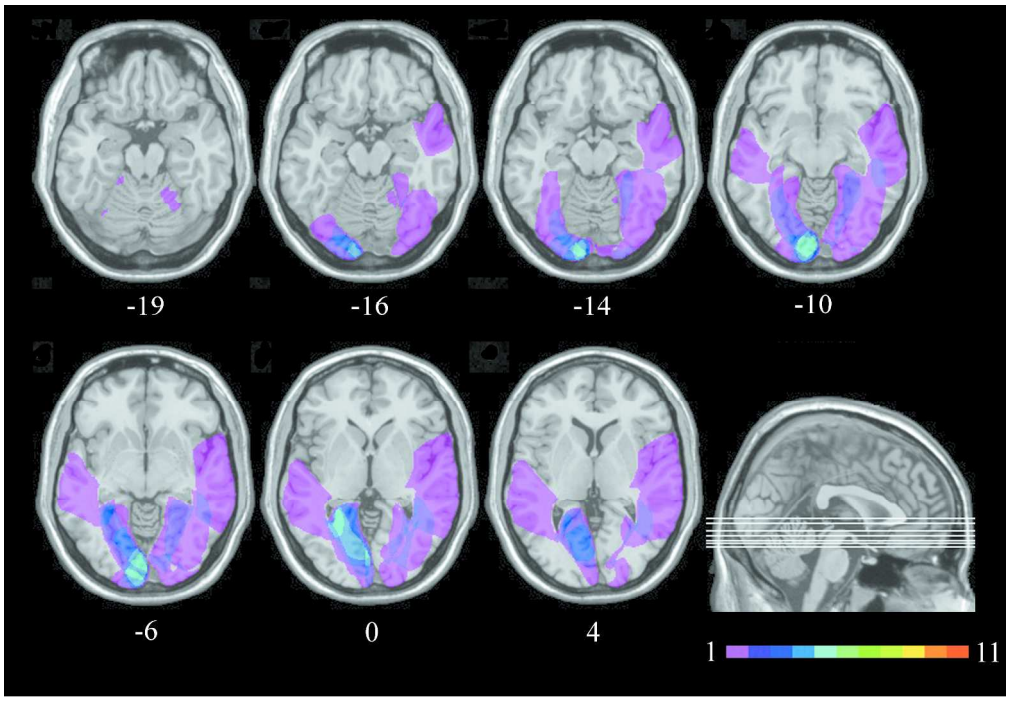
Figure caption

Figure 1S. Extent and overlap of brain lesions in control patients. The figure represents control patients' lesions projected on the same seven axial slices of the standard Montreal Neurological Institute brain. The white horizontal lines on the sagittal view are the positions of the axial slices, and the white numbers under the axial views are the z-coordinates of each slice. The color bar indicates the number of overlapping lesions. Maximal overlap occurs in BAs 17-19. The left hemisphere is on the left side.



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