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Thoughts and sensations, twin galaxies of the inner space: The propensity to mind-wander relates to spontaneous sensations arising on the hands

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ABSTRACT

Sensations and thoughts have been described as potentially related to self-awareness. We therefore asked whether sensations that arise in the absence of external triggers, i.e., spontaneous sensations (SPS), which were shown to relate to interoception and perception of the self, vary as a function of the individual propensity to generate spontaneous thoughts, i.e., mind-wandering. The Mind Wandering Questionnaire (MWQ) was used as a specific tool to assess the frequency and propensity to mind-wander several weeks before completing an SPS task. Correlational analyses between the MWQ score and SPS showed that greater propensity to mind-wander coincided with widespread perception of SPS, while lesser propensity to mind-wander coincided with more spatially restricted perception of SPS. The results are interpreted in light of the role of spontaneous thoughts and sensations in self-awareness. The potential psychological processes and the way they might regulate the relation between mind-wandering and the perception of SPS are discussed.

1. Introduction

Recognizing oneself as an individual entity separate from the environment and other individuals requires focusing attention on one's own subjective experience and being aware of one's own self-concept. This is self-awareness (Morin, 2006). Being self-aware is, therefore, having access to one's own thoughts, autobiographical memories, and bodily sensations.

Spontaneous thoughts may potentially contribute to self-awareness (Buckner, Andrews-Hanna, & Schacter, 2008; Ingvar, 1979; Mason et al., 2007). They are defined as mental states arising freely due to loose engagement on a task or another mental state (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016). Mind-wandering is considered to be a category of internal activity and consists in a spontaneous and dynamic drift of attention away from its current focus to internal mental content generated by the individual (Christoff et al., 2016; Smallwood & Schooler, 2015). It has been considered as a psychological baseline that emerges when the brain is otherwise unoccupied (Mason et al., 2007). Some authors pose that mind-wandering ensues when conscious supervision of a task is ceased, whether or not we want it to be (Braboszcz & Delorme, 2010), and a global reduction of sensory input lets the mind

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become occupied with its own consciousness (Ingvar, 1979). Its effects are not found only in tasks that engage higher-order processes, like those involved in reading and discourse comprehension, but they are also found at multiple levels of perceptual and sensorimotor processing (Carriere, Seli, & Smilek, 2013; Kam & Handy, 2013; Kam et al., 2011; Smallwood, 2011). For instance, changes in response variability and in response accuracy in motor tracking tasks during episodes of mind-wandering (Kam et al., 2012) suggest decrements in response stability and constancy, and increased fidgeting during such episodes intimates decreased control over motor activity. Mind-wandering trims down processing of incoming information at early perceptual levels and across multiple sensory modalities and, as a consequence, low-level decoupling cascades through the cognitive system causing decoupling at higher levels (Smallwood, 2011). Such global and seemingly amodal effects are consistent with and reinforce the hypothesis that mind-wandering may play a role in self-awareness (Giambra, 1995), since they suggest that attention turns towards inner cognitive activity.

Consistent with this idea is the fact that heightened activity in the brain's default mode network (DMN), which plays a role in self-referential thought (e.g., Fingelkurts & Fingelkurts, 2011; Northoff et al., 2006) and autobiographical memory retrieval (Svoboda, McKinnon, & Levine, 2006), has been observed during episodes of mind-wandering (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Christoff et al., 2016; Kirschner, Kam, Handy, & Ward, 2012; Mason et al., 2007; O'Callaghan et al., 2015; Raichle, 2015; Smallwood, 2013). Despite the regular occurrence of mind-wandering, for as much as 30–50% of our waking life, not all minds wander to the same degree. The propensity to mind-wander appears to be a stable individual cognitive characteristic. Some people mind-wander more often than others (Mrazek, Phillips, Franklin, Broadway, & Schooler, 2013), whether mind-wandering can be related to the current task or not (Carriere et al., 2013; Christoff et al., 2016; Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011).

However, self-awareness may relate not only to thoughts like those occurring during mind-wandering. Other kinds of activity also seem to contribute towards self-awareness, such as those related to the interoceptive system (Cameron, 2002). This background of bodily sensations maintains the integrity of the body (Craig, 2009) and is partly responsible for how the self is perceived (Kinsbourne, 1998). When this system is damaged, it causes the body image to slip out from consciousness (Kinsbourne, 1998; Wolpert, Goodbody, & Husain, 1998). This system includes, among others, the systems responsible for perception of visceral activity (Herbert, Muth, Pollatos, & Herbert, 2012; Schandry, 1981) and perception of sensations arising on the body without any external triggers (spontaneous sensations or SPS; Michael, Naveteur, Dupuy, & Jacquot, 2015). Attention to such sensations enables the image of the body to be maintained in consciousness (Michael & Naveteur, 2011). As regards SPS, these are normal spontaneous phenomena that are experienced by nearly everyone, which possess their own spatial, qualitative, and quantitative properties (Michael & Naveteur, 2011; Naveteur, Honoré, & Michael, 2005). It has been reported that diverting attention away from these sensations may cause their perception to fade (Michael & Naveteur, 2011; Michael et al., 2012). By contrast, abnormally heightened attention (i.e., hypervigilance) produces excessive increases in the perception of their frequency and intensity (Borg, Carrier-Emond, Colson, Laurent, & Michael, 2015). One of their characteristics is that they are better perceived when at rest (Beaudoin & Michael, 2014), that is, when attention is free to turn inwards and when the conditions are met for spontaneous thoughts to be born. Thus, having access to one's own bodily sensations provides access to self-awareness. Finally, imaging techniques have shown that part of the DMN is active during perception of SPS (Bauer, Díaz, Concha, & Barrios, 2014), suggesting that those functional specificities of the brain that are related to mind-wandering are also related to the perception of SPS, at least partly.

All the abovementioned findings suggest that spontaneous cognition is a shared human experience that probably relates to self-awareness, and some people are more inclined to this than others. Then again, this leads to a strange question: If self-awareness were related to spontaneous sensations, feelings, or thoughts, then what would self-awareness of people who have increased and more frequent spontaneous cognitive activity look like? The answer could be even more strange, since it might be expected that the more a person is prone to spontaneous thoughts, the bigger his/her self-awareness would be because of a tendency to turn attention towards the inner world. The present study aimed at investigating this hypothesis through exploring the potential links between the propensity to mind-wander and the perception of SPS. We therefore used a questionnaire as a specific tool to assess the frequency and propensity to mind-wander followed, several weeks later, by the completion of a task assessing the perception of SPS (Michael & Naveteur, 2011). A direct hypothesis is that if both the propensity to mind-wander and SPS are linked to self-awareness (Buckner et al., 2008; Michael et al., 2012, 2015), then being more prone to mind-wander would coincide with increased perceived frequency and intensity of SPS.

2. Material and methods

2.1. Participants

The study was conducted in accordance with the Helsinki Declaration. All participants were students at the University of Franche-Comté (east of France) participating in neuroscience programs. Participants were excluded if they self-reported a history of neurological or psychiatric disorders or had taken any psychoactive substances in the three months preceding the test session. This information was gathered during the first steps of the experimental procedure, where participants were required to complete a questionnaire containing questions on their sociodemographic and health characteristics. Items included age, gender, use of psychotropic medication (and if so, the reason why; antidepressants, anxiolytics, neuroleptics, anticonvulsants, hypnotics, tranquilizers etc.), and regular use of other psychoactive substances (alcohol, marijuana, etc.). In addition, participants were free to report any other information they considered to be important for the study. Provided a power of 90% to detect the most prominent characteristic of SPS, which is the proximo-distal gradient in frequency (average effect size based on 4 published experiments from two studies $\eta^2 = 0.44$; Beaudoin & Michael, 2014; Michael et al., 2012), the sample size needed is 24. On the basis of the above-mentioned criteria, 29 participants (22 female) with a mean age of 21.8 ± 2.6 (age range: 20–33) were included in the study. None of them reported any disease that could affect tactile perception, such as diabetes mellitus or cardiovascular disease. All of them gave their informed written consent for their participation prior to the test. With $N = 29$, there is enough power (> 95%) to avoid a Type II error.

2.2. Mind wandering questionnaire

Participants were required to complete the Mind Wandering Questionnaire (MWQ; Mrazek et al., 2013), which measures the frequency and propensity to mind-wander. It consists of 5 items written in simple language (1: I have difficulty maintaining focus on simple or repetitive work; 2: While reading, I find I haven't been thinking about the text and must therefore read it again; 3: I do things without paying full attention; 4: I find myself listening with one ear, while thinking about something else at the same time; 5: I mind-wander during lectures or presentations) and response options are designated along a 6-point Likert scale (1 = almost never, 2 = very infrequently; 3 = somewhat infrequently; 4 = somewhat frequently; 5 = very frequently; 6 = almost always). It has a good face validity, a good convergent validity (since it strongly correlates with behavioral tasks of mind-wandering and with other questionnaires assessing daydreaming and mind-wandering), a high internal consistency and homogeneity, and principal component analyses revealed that it assesses a single underlying construct (see Mrazek et al., 2013).

2.3. SPS task

Each participant completed the SPS task 1–3 weeks after having completed the MWQ. This variable delay was mostly due to organizational reasons but it allowed a clear dissociation between the MWQ and the SPS task. The SPS task was performed in a quiet and normally lit room with an ambient temperature of 20–23 °C. Participants were invited to take a seat behind a desk. The experimenter began by describing SPS, pointing out that they are normal phenomena, and listed eleven sensations that might be felt (beat/pulse, itch, tickle, numbness, skin stretch, tingling, warming, cooling, muscular stiffness, flutter, and vibration). The list was provided so that participants had some idea of what they could identify as SPS. It was based on the lists used by Ochoa and Torebjörk (1983) and Macefield, Gandevia, and Burke (1990) to study sensations evoked by microstimulation, and adapted by Naveteur et al. (2005) to study SPS. Participants were then asked to remove any jewelry from their hands and wrists. To ensure a homogeneous glabrous skin surface across participants, all of them were required to spend 15 s cleansing their hands with an antiseptic gel (Aniosgel® 85 NPC, ≈3 ml per participant) to remove any external agents that might interfere with the task. A minimum 15-s latency was respected between the cleansing operation and the beginning of the test (Naveteur et al., 2005). The experimenter then gave each participant a pencil, a 25 × 25cm piece of smooth white cotton fabric, and a protocol containing the standardized reduced pictures of each hand shown palm up (with a distance of 11.2 cm between the tip of the middle finger and the palm/wrist frontier) and, below each picture, the list of 11 SPS, and two visual analogue scales (i.e. two continuous horizontal lines without markers at each end) for confidence ratings. The beginning of the test session was then announced. Each hand was tested once in a balanced order across participants. To ensure there was no interference from visual stimuli, participants had to place the protocol away from them on the desk, together with the pencil. They were seated with their back supported by the backrest of a large chair. The leg ipsilateral to the tested hand was laterally abducted by about 60 deg from the midline. Participants placed the white cotton fabric on their thigh, with their arm resting on their inner thigh. Their hand was placed palm up so that, apart from the fingers, only a dorsal part of the hand was in contact with their thigh. The fingers were spaced slightly apart. The hand not being tested was placed on the edge of the chair, on the outer side of the leg contralateral to the tested hand. Following the “start” signal given verbally by the experimenter to mark the beginning of each trial, participants directed their gaze toward their tested hand for 10 s, during which time they focused on the whole glabrous part of their hand and kept their attention there so they could detect and report any sensations that might occur. They were also told there was a possibility no sensations would occur. The experimenter uttered a “stop” signal to mark the end of the 10-s period, after which participants were immediately asked to take the protocol and to indicate whether or not they had detected any sensations in the tested hand. If they had, they were asked to (a) map the extent and topography of the sensations by shading in on the picture of the tested hand the areas where sensations had occurred; (b) estimate the overall perceived intensity of the sensations according to a 10-point scale (1 = just perceptible; 10 = very intense but not painful). They were also told that, if they could attribute different intensities to each sensation, they were free to do so. As such, they were also asked to (c) indicate their degree of confidence in the location and extent of the perceived sensations according to two 10 cm visual analogue scales (ranging from “not confident” to “very confident”); and (d) identify the sensations using the list of descriptors, with the possibility, of course, of choosing more than one descriptor, or even using additional descriptors not present on the list. The task lasted approximately 15 min.

3. Results

3.1. MWQ

The sum of the scores in the 5 items is taken as an index of the propensity to mind-wander as a trait. This score ranges from 5 to 30 and the higher the score, the more frequently one experiences mind-wandering in everyday life. The mean score was 17.6 ± 4.4 and the range was 8–27, which is close to the scores reported by Mrazek et al. (2013). No difference was found between men and women (Mann-Whitney $U = 91$, ns). The mean inter-item correlation was quite good ($|\rho| = 0.39$) and within the expected range (Clark & Watson, 1995).

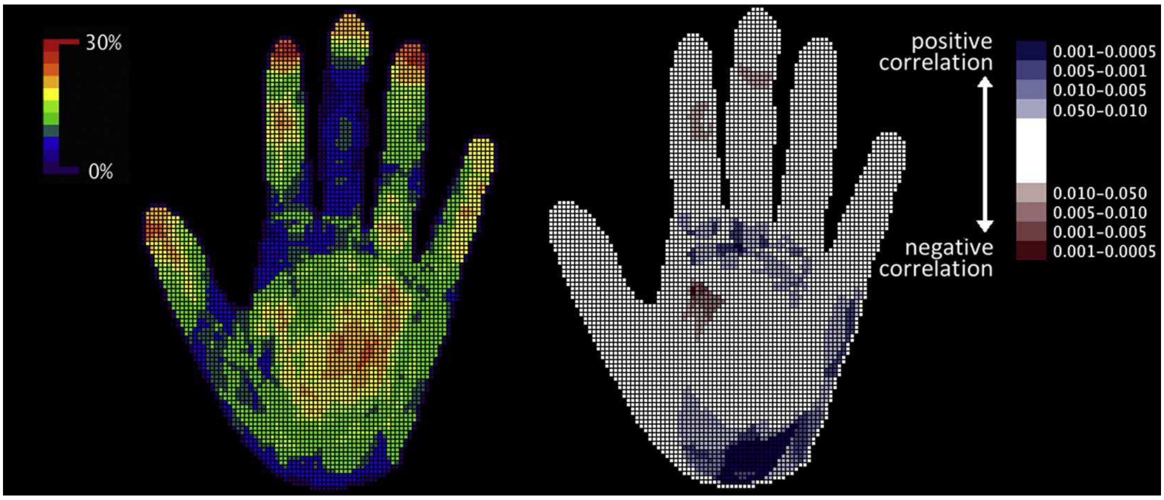

Fig. 1. Topographical analyses of the frequency of SPS. The hand is shown palm up. **Left:** Raw frequency of SPS showing the proximo-distal gradient. **Right:** Probability map of the topographical cell-wise point biserial correlation analysis carried out between individual scores obtained in the *Mind Wandering Questionnaire* (MWQ) and the presence of SPS. Only significant clusters are presented. Bluish cells denote significant positive correlations between the frequency of SPS and the score in the MWQ. Reddish cells denote significant negative correlations between the frequency of SPS and the score in the MWQ. Color shading on the probability map represents different probabilities. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.2. SPS

3.2.1. Topography of SPS frequency

This analysis was carried out to detect any significant effects in the spatial distribution of SPS as a function of the propensity to mind-wander. First, shaded areas on each printed hand were projected onto a 140 mm × 140 mm grid with 1 mm^2 resolution. Second, shaded areas were converted into binary codes (0 = not shaded cell; 1 = shaded cell). The result, for each hand of each participant, was an individual map of spatially distributed binary codes representing the shaded areas. A frequency map was obtained by superimposing the individual binary maps, with the value in each cell representing the percentage of participants who had shaded it in (Fig. 1, left).

3.2.1.1. Relative surface of SPS and the proximodistal gradient. The first step was to ensure that the SPS task was successful, and this was done through examination of the proximo-distal gradient in the frequency of SPS. From a descriptive point of view, the left panel of Fig. 1 shows that the gradient is present. Furthermore, based on the logic of the relative receptor density (Johansson & Vallbo, 1979), we computed the relative spatial extent of sensations, i.e., the percentage of shaded surface within a segment (distal phalanx, intermediate phalanx, proximal phalanx and palm) as compared to the surface of the whole segment (see Michael et al., 2012 for pilot studies). Relative surfaces were entered into a nonparametric analysis of variance with the anatomical segment as the unique within-subjects factor (the other factor was the tested hand but it was not of interest for the purpose of the present study). The effect of segment was significant ($F(3,84) = 3.41$; $p < 0.021$, $\eta^2 = 0.11$), since the relative surface of SPS was greater in the distal phalanx (18.7%) than the intermediate (9.1%) and the proximal (7.2%) phalanges, as well as in the palm (9.9%).

3.2.1.2. The relationship between SPS frequency and MWQ. Topographical statistics were compiled by means of cell-by-cell comparisons using home-made software. Due to the oriented hypotheses described previously, i.e., that being more prone to mind-wander would relate to increased frequency of SPS, the alpha level was set to 0.05 unicaudal. For each participant and for each hand, a map of the hand was completely filled with the MWQ score of that participant. A point biserial cell-wise correlation between the presence of SPS and the MWQ score was then conducted. This is a special case of Pearson product moment correlation that follows the *t*-distribution and in which one variable is dichotomous (here, 0 = not shaded cell; 1 = shaded cell) and the other variable is continuous (here, the MWQ score). In order to eliminate randomly distributed significant cells, the significance map resulting from the aforementioned analysis was subsequently converted to binary values (0 = nonsignificant; 1 = significant), and a spatial scan procedure for binary data (Kulldorff, 1997) was used. It consists of a circular window that scans the maps, detects, and localizes significant clusters in a stepwise fashion. Clusters are defined as abnormally high numbers of significant cells, the grouping and pattern of which is statistically different from random. The detection of the area that is most likely to be a cluster is based on a maximum likelihood estimator. Based on previous studies (Michael et al., 2012, 2015), the maximal radius of the window was set at 6 cells (representing a maximal scanned surface of 113 cells). Nine hundred and nine iterations of the Bernouilli (binomial) model were run before convergence. All detected and localized clusters were significant, at least at the $p < 0.005$ level bicaudal, with the remaining being non-significant. The right panel of Fig. 1 depicts only those significant clusters. Positive significant correlations between the presence of SPS and the MWQ score (bluish cells) were found in an area covering as much as 16.0% of the whole hand. Conversely, negative significant correlations between the presence of SPS and the MWQ score (reddish cells) were found in an area covering only 2.6% of the hand. The opposite signs thus denote adversely correlated effects suggesting functional dissociation. A chi-

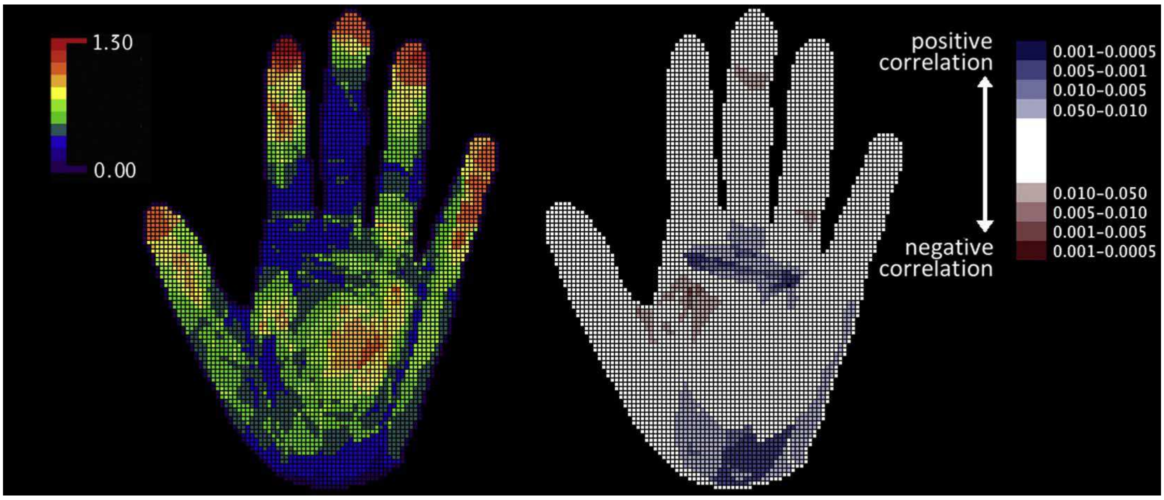

Fig. 2. Topographical analyses of the intensity of SPS. The hand is shown palm up. **Left:** Mean intensity of SPS across the whole hand. **Right:** Probability map of the topographical cell-wise correlation analysis carried out between individual scores obtained in the *Mind Wandering Questionnaire* (MWQ) and the intensity of SPS. Only significant clusters are presented. Bluish cells denote significant positive correlations between the intensity of SPS and the score in the MWQ. Reddish cells denote significant negative correlations between the intensity of SPS and the score in the MWQ. Color shading on the probability map represents different probabilities. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

square test was conducted in order to compare the spatial extent of these two effects. It was found that positive correlations covered an area significantly larger than that covered by negative correlations ($\chi^2(1) = 466.3$; $p < 0.001$).

3.2.2. Topography of SPS intensity and its relationship with the MWQ

The topography of SPS intensity as a function of the propensity to mind-wander was also examined. As before, shaded areas on each printed hand were projected onto a 140 mm × 140 mm grid with 1 mm^2 resolution but, this time, shaded cells were converted into continuous variables representing the perceived intensity (e.g., if the participant reported an intensity of 2 for an SPS in the fingertip, all cells of that SPS were converted to 2 s). The result, for each hand of each participant, was an individual map of spatially distributed mean intensity values representing the shaded areas. A mean intensity map was obtained by superimposing the individual maps, with the value in each cell representing the mean intensity reported there (Fig. 2 left). Finally, as before, for each participant and for each hand, a map of the hand was completely filled with the MWQ score of that participant. As before, the alpha level was set to 0.05 unicaudal. A Pearson cell-wise correlation between the intensity of SPS and the MWQ score was then conducted. The resulting significance map was then converted to binary values (0 = nonsignificant; 1 = significant), and a spatial scan procedure for binary data (Kulldorff, 1997) was used with 999 iterations before convergence. All detected and localized clusters were significant at least at the $p < 0.008$ level bicaudal, the remaining being non-significant. The right panel of Fig. 1 depicts only those significant clusters. Positive significant correlations between the presence of SPS and the MWQ score (bluish cells) were found in an area covering as much as 14.86% of the whole hand. Conversely, negative significant correlations between the presence of SPS and the MWQ score (reddish cells) were found in an area covering only 3.16% of the hand. A chi-square test revealed that the spatial extent of these two effects was different ($\chi^2(1) = 370.9$; $p < 0.001$).

3.2.3. Other parameters

The remaining dependent variables were also considered for analyses. The mean inter-item correlation, used as a straightforward measure of internal consistency (the minimum recommended value is 0.15; Clark & Watson, 1995), was good for the total size of shaded areas ($|\rho| = 0.72$), the number of disjoined shaded areas ($|\rho| = 0.25$), variety of SPS ($|\rho| = 0.51$), confidence in extent ($|\rho| = 0.30$), and confidence in location ($|\rho| = 0.53$). Since data did not meet normality criteria, nonparametric tests were used. No differences were found between men and women in either of these parameters, using the Mann-Whitney test. Spearman correlation analyses showed that all parameters correlated positively with each other, except for the variety of SPS, which did not correlate with confidence in extent. Finally, the relationship between these parameters and the MWQ was also examined through Spearman correlation analyses. Only confidence in the location of SPS correlated with the MWQ score, and this correlation was negative ($\rho = -0.43$; $p < 0.02$). The results are presented in Table 1.

Even though the propensity to mind-wander and the total size of SPS did not relate with each other ($\rho = 0.15$, ns), two questions still remain. The first concerns the origin of the negative relationship between the propensity to mind-wander and confidence in the location of SPS. One possibility would be that pinpointing with high confidence the locations of frequent and widespread SPS perceived within a brief window of 10 s is more difficult than for less frequent and narrow sensations. In this case, two specific patterns would be observed. First, a negative correlation would be found between measures of the spread of SPS and confidence in their location. Instead, positive correlations were found between the scores in the MWQ and the total surface of SPS as well as with the number of sensitive areas. Second, mediation analyses would show that the propensity to mind-wander would decrease confidence in the location of SPS by first increasing the values of measures of the spread of SPS. The Sobel test of mediation (Sobel, 1982)

Table 1
The results of the analyses of the parameters collected in the SPS task other than their spatial distribution and intensity. Mean (1 SD) values and Spearman correlation coefficients between each of the parameters of the SPS and between these parameters and the *Mind Wandering Questionnaire* (MWQ) are presented. Asterisks denote significant correlations.

	Mean (SD)	Number of Areas	Spearman ρ Correlation Coefficient			MWQ
			Variety	Confidence in Extent	Confidence in Location	
Total Surface	11.9 (11.1)	0.59***	0.54**	0.48**	0.40*	0.15
Number of Areas	4.97 (3.9)		0.76***	0.55**	0.68***	−0.08
Variety	2.45 (1.5)			0.34	0.57**	−0.11
Confidence in Extent	5.71 (2.9)				0.66***	−0.22
Confidence in Location	5.04 (2.5)					−0.43*
MWQ	17.6 (4.4)					

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

failed to demonstrate such an indirect causal relationship whatever measure was taken as mediator (total surface $z = 0.66$; $p > 0.51$; number of areas $z = -0.12$; $p > 0.90$). The second questions is whether the propensity to mind-wander increases the perceived surface of SPS (as seen in the topographic analyses) through first decreasing the participant's confidence in their location. In order to investigate this issue, a mediation analysis, using the Sobel test (Sobel, 1982), was conducted in order to uncover any indirect causal effect. No significant mediation was found ($z = -1.49$; $p > 0.13$). Furthermore, confidence in location, which relates negatively to the propensity to mind-wander, also correlates positively with the size of SPS ($\rho = 0.40$; $p < 0.05$). Such a pattern of results suggests that the propensity to mind-wander relates differently with confidence in location and with the size of SPS, and this was confirmed by the significant difference between those correlations ($t(26) = 3.25$; $p < 0.005$; Williams, 1959). These findings suggest that the propensity to mind-wander does not increase the surface of SPS through decreasing the participant's confidence in the location of SPS.

3.2.4. *Types of sensations*

The variety of the reported sensations was analyzed with chi-squared tests. All of the 11 sensations proposed were reported at least once, and one participant added "pins and needles" to the list of sensations. The number of times each sensation was reported was not the same ($\chi^2(11) = 50.2$; $p < 0.01$), the most frequent SPS being beats/pulses and cooling (both at 14.6%), followed by numbness (13.9%) and warming (11.8%). No correlation was found between the MWQ score and the frequency of each of these SPS.

4. Discussion

The aim of the present study was to assess the potential relationship between the propensity to mind-wander as an individual trait and the perception of SPS arising on the hands. The working hypothesis was that, if both the propensity to mind-wander and SPS relate to self-awareness, then being more prone to mind-wander would coincide with increased perception of SPS. Participants completed the MWQ and, several weeks later, a task of SPS. The results showed that the propensity to mind-wander was indeed related to the perception of SPS, and point to two aspects of the perception of SPS to which the propensity to mind-wander is likely to be related: (i) the spatial distribution of their frequency and intensity and (ii) the confidence participants report regarding their location. Each of these points is considered separately in the following sections. The remaining parameters (total size, number of disjoined areas, variety of SPS, and confidence in extent) were not found to relate to the propensity to mind-wander, and this may be due to inter-individual variability.

4.1. *Anticorrelated patterns: twin competing galaxies?*

It is true that, except from the abovementioned general hypothesis that the perception of SPS would be related to the propensity to mind-wander, we did not have any specific hypothesis as to the localization and the spatial distribution and extent of such an effect. A visual inspection of the results (Figs. 1 and 2) tentatively suggests that low propensity to mind-wander is related to increased perception of SPS in some small, well circumscribed foci in the palm and the fingers, while higher propensity to mind-wander is related to increased perception of SPS in larger and mostly coarsely delimited peripheral areas of the palm, even if such a distinction is not perfect. Interestingly, this pattern was found in the topographic analysis of both frequency and intensity of SPS. Does such a pattern have any functional significance? Previous investigations had consistently shown that manipulating attention by directing it towards or away from the tested hand influenced the perception of SPS in both the center of the palm and the fingers, and this was found several times in different samples of participants (Michael & Naveteur, 2011; Michael et al., 2012; Naveteur, Dupuy, Gabrieli, & Michael, 2015). It is therefore tempting to associate such circumscribed and well-localized effects with attention directed to the hand *per se* and on sensory experience. Conversely, perception of SPS in more peripheral parts of the palm was found to relate with higher interoceptive sensitivity (Michael et al., 2015), and seminal work on hand physiology suggested that perception in the palm would be more subject to influence from central cognitive mechanisms (Vallbo & Johansson, 1984). It may thus be suggested that such coarse and peripherally located effects relate more to attention turned inwards, be it towards internal bodily sensations or towards spontaneous thoughts.

Now, the two patterns seemingly depend on each other, since the correlational analysis showed that they are adverse: negative correlations were found in the palm and fingers while positive correlations were found in the peripheral parts of the palm. This tallies well with the idea that attention to sensory events and attention to thoughts are two mutually exclusive and competing states. Attention and the focus of thoughts frequently shift back and forth between the internal and external environment (Randall, Oswald, & Beier, 2014). Disengaging attention from the external environment is necessary before directing it toward internal signals and thoughts (Kajimura, Kochiyama, Nakai, Abe, & Nomura, 2016; Tracy et al., 2007), and *vice versa*. Furthermore, that such adverse patterns of perception of SPS may originate within the distinction between attention to the internal and external environment is supported by imaging techniques on the brain's DMN. This network is active during self-referential thought (Fingelkurts & Fingelkurts, 2011) and episodes of mind-wandering (Christoff et al., 2016; Smallwood, 2013), yet it anticorrelates with tasks requiring increased attention to sensory events involving the attention network (Buckner et al., 2008; Christoff et al., 2016; Corbetta & Shulman, 2002; Fox et al., 2005). The attention network and the DMN participate in functions that compete with each other for control of information processing, and this is why they are antagonistic: as activity within the DMN increases, activity in the attention network decreases, and *vice versa* (Buckner et al., 2008; Fox et al., 2005), in a shift between these two distinct modes of information processing. Thus, associating localized perception of SPS with attention to task, and more diffuse perception of SPS with mind-wandering would make sense, and such a distinction may represent functionally dissociable and competing systems. The concomitant presence of positive and negative correlations can be understood as reflecting opposing effects of two mutually exclusive states of attention, since turning attention inwards cannot take place without disengaging from the world, and *vice versa*. Closer examination of the 5 questions that compose the MWQ (see the Methods section) confirms that those two states are naturally presented as being intermixed, and this is most probably the origin of the anticorrelated patterns. Consequently, even if our interpretation of the adverse patterns of correlation remains speculative, it is an interesting hypothesis that should be further assessed. Further research is needed to specifically address the direct relationship of those two states with the perception of SPS.

4.2. I have confidence, and confidence in me

An isolated result was that the propensity to mind-wander was negatively related to the confidence participants reported in localizing the SPS they perceived. To our knowledge, only one study tried to find links between confidence ratings and mind-wandering (Seli, Jonker, Cheyne, Cortes, & Smilek, 2015). However, ratings reported in that study concerned confidence in mind-wandering reports, not confidence in performance. Our finding would be expected, since mind-wandering affects cognitive performance (e.g., Smallwood & Schooler, 2015). What is more surprising is that this is not a relation between mind-wandering occurring during the SPS task and that SPS task. It is hardly conceivable that mind-wandering would occur and affect confidence ratings within the 10-s period during which participants focused on their hands in search of SPS. It was the overall proclivity to mind-wander declared by participants that related to the SPS task completed several weeks later. The positive correlation found between confidence in the location of SPS on one hand and their total surface and the number of sensitive areas on the other hand, as well as the absence of evidence for any causal link between the propensity to mind-wander and confidence in the location of SPS mediated by increments in the perception of SPS, preclude retaining the idea that pinpointing the locations of frequent, richer and more widespread SPS with high confidence would be more difficult than if sensations were less frequent and narrow.

A question that comes to mind concerns whether the propensity to mind-wander is linked to increased perceived surface of SPS through first decreasing the participant's confidence in their location. This is not a trivial question, since, if one is not confident in what he/she feels, he/she might report larger areas of SPS (e.g., the size variable) in order to signify that the SPS he/she felt were included within those coarse frontiers. However, the analyses failed to show any relation between the propensity to mind-wander and the total size of SPS, as well as any mediated relationship between the propensity to mind-wander, confidence in location, and the total size of SPS. Most importantly, they also showed that the propensity to mind-wander related differently to confidence in location and to total size of SPS. Such findings run counter the hypothesis that changes in the perceived surfaces of SPS are mediated by changes in confidence in their location. It seems that the relationship between the propensity to mind-wander and confidence in the location of the perceived SPS is independent from changes in other aspects of SPS.

4.3. Limitations and future directions

The present study has some limitations that should be taken into account while considering the results. Perhaps the most important limitation is that, due to the behavioral and declarative nature of the protocol, it is not possible to understand exactly how and through what mechanisms the perception of SPS is related to the propensity to mind-wander. One possibility that has already been mentioned is the involvement of common brain areas that are part of the same DMN (Bauer et al., 2014). A future investigation should specifically assess this hypothesis by showing, for instance, that the activity of the DMN relates to the perception of SPS assessed separately. Similarly, the declarative nature of the protocol might have increased the possibility that the results reflect demand characteristics or self-report bias. For instance, any tendency to give a positive response to the MWQ when in doubt and any tendency to report what they think the experimenter wants, might lead them to report many sensations in the SPS task to please the experimenter. In that case, the likelihood that the observed relationship between the MWQ and SPS is misleading would increase. However, there are several observations suggesting that the results are not due to distorted responses. First, response biases of this kind would produce only positive correlations between the MWQ and SPS. Instead, negative correlations were also found in the topographic analyses of frequency and intensity, but also with ratings of confidence in the location of SPS. Furthermore, if participants reported many sensations in the SPS task to please the experimenter, then the proximo-distal gradient, which is the hallmark of a successful SPS task, would not be observed: homogenously distributed SPS would be observed all over the surface of the hand. Finally, it should be noted that participants completed the MWQ and the SPS task in two sessions separated by a time interval varying from 1 to 3 weeks. This procedure minimizes the pressure to produce concordant responses in the MWQ and SPS task, regardless of what participants are required to do. Therefore, the technical setting and the observed results are difficult to reconcile with any response bias.

Another potential limitation of the present study is that bodily sensations are far broader than sensations on the hand. The protocol used here investigates a quite large range of sensations but focuses exclusively on the hand. The reason is because this is the most sensitive part of our body that we can directly see and attend to (our lips are the most sensitive part our body but cannot be directly viewed without a mirror). This may be problematic in regard to generalizing hand sensory experiences to self-awareness. However, it is not our claim that SPS represents self-awareness *per se*, but rather that they are related to the construction of self-awareness as spontaneous thoughts and mind-wandering are. This background of bodily sensations would maintain the integrity of the body (Craig, 2009) and would be partly responsible of how the self is perceived (Kinsbourne, 1998).

5. Conclusions

The aim of the present study was to investigate whether spontaneous thoughts are related to sensations that contribute to self-awareness. Our results suggest, indeed, that such a link exists, by showing a close relationship between the propensity to mind-wander, i.e., a psychological trait of the frequency of spontaneous thoughts (Mrazek et al., 2013), and the perception of SPS, i.e., a hallmark of self-awareness and interoception (Michael et al., 2015). It can therefore be concluded that turning attention inwards, towards spontaneous thoughts, is also focusing on the background of bodily sensations that relate to the self: the propensity to mind-wander relates to self-awareness.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.concog.2017.08.007.

References

Bauer, C. C. C., Díaz, J.-L., Concha, L., & Barrios, F. A. (2014). Sustained attention to spontaneous thumb sensations activates brain somatosensory and other proprioceptive areas. *Brain and Cognition, 87*, 86–96.

Beaudoin, R., & Michael, G. A. (2014). Gating of spontaneous somatic sensations by movement. *Somatosensory & Motor Research, 31*, 111–121.

Borg, C., Carrier-Emond, F., Colson, D., Laurent, B., & Michael, G. A. (2015). Attentional focus on subjective interoceptive experience in patients with fibromyalgia. *Brain & Cognition, 101*, 35–43.

Braboszcz, C., & Delorme, A. (2010). Lost in thoughts: Neural markers of low alertness during Mind Wandering. *NeuroImage, 54*, 3040–3047.

Buckner, R., Andrews-Hanna, J., & Schacter, D. (2008). The brain's default network. Anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences, 1124*, 1–38.

Cameron, O. G. (2002). *Visceral sensory neuroscience.* New York: Oxford University Press.

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*, 19–31.

Christoff, K., Gordon, A. M., Smallwood, J., Smith, R., & Schooler, J. W. (2009). Experience sampling during fMRI reveals default network and executive system contributions to mind wandering. *Proceedings of the National Academy of Science of the USA, 106*, 8719–8724.

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

Clark, L. A., & Watson, D. (1995). Constructing validity: Basic issues in objective scale development. *Psychological Assessment, 7*, 309–319.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*, 201–215.

Craig, A. D. (2009). How do you feel–now? The anterior insula and human awareness. *Nature Reviews Neuroscience, 10*, 59–70.

Fingelkurts, A. A., & Fingelkurts, A. A. (2011). Persistent operational synchrony within brain default-mode network and self-processing operations in healthy subjects. *Brain & Cognition, 75*, 79–90.

Fox, M. D., Snyder, A. Z., Vincent, J. L., Corbetta, M., Van Essen, D. C., & Raichle, M. E. (2005). The human brain is intrinsically organized into dynamic, anticorrelated functional networks. *Proceedings of the National academy of Sciences of the United States of America, 102*, 9673–9678.

Giambra, L. M. (1995). A laboratory method for investigating influences on switching attention to task-unrelated imagery and thought. *Consciousness and Cognition, 4*, 1–21.

Herbert, B. M., Muth, E. R., Pollatos, O., & Herbert, C. (2012). Interoception across modalities: On the relationship between cardiac awareness and the sensitivity for gastric functions. *PLoS ONE, 7*, e36646.

Ingvar, D. H. (1979). “Hyperfrontal” distribution of the cerebral grey matter flow in resting wakefulness: On the functional anatomy of the conscious state. *Acta Neurologica Scandinavica, 60*, 12–25.

Johansson, R. S., & Vallbo, A. B. (1979). Tactile sensibility in the human hand: Relative and absolute densities of four types of mechanoreceptive units in glabrous skin. *Journal of Physiology, 286*, 283–300.

Kajimura, S., Kochiyama, T., Nakai, R., Abe, N., & Nomura, M. (2016). Causal relationship between effective connectivity within the default mode network and mind-wandering regulation and facilitation. *NeuroImage, 133*, 21–30.

Kam, J. W. Y., Dao, E., Blinn, P., Krigolson, O. E., Boyd, L. A., & Handy, T. C. (2012). Mind wandering and motor control: off-task thinking disrupts the online adjustment of behavior. *Frontiers in Human Neuroscience, 6*. http://dx.doi.org/10.3389/fnhum.2012.00329 article 329.
Kam, J. W. Y., Dao, E., Farley, J., Fitzpatrick, K., Smallwood, J., Schooler, J. W., & Handy, T. C. (2011). Slow fluctuations in attentional control of sensory cortex. *Journal of Cognitive Neuroscience, 23*, 460–470.
Kam, J. W. Y., & Handy, T. C. (2013). The neurocognitive consequences of the wandering mind: A mechanistic account of sensory-motor decoupling. *Frontiers in Psychology, 4* article 725.
Kinsbourne, M. (1998). Awareness of one's own body: An attentional theory of its nature, development, and brain basis. In J. Bermudéz (Ed.). *The body and the self* (pp. 205–223). The MIT Press.
Kirschner, A., Kam, J. W., Handy, T. C., & Ward, L. M. (2012). Differential synchronization in default and task-specific networks of the human brain. *Frontiers in Human Neuroscience, 6*. http://dx.doi.org/10.3389/fnhum.2012.00139 article 139.
Kulldorff, M. (1997). A spatial scan statistic. *Commun Statist, 26*, 1481–1496.
Macefield, G., Gandevia, S., & Burke, D. (1990). Perceptual responses to microstimulation of single afferents innervating joints, muscles and skin of the human hand. *Journal of Physiology, 429*, 113–129.
Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C. N. (2007). Wandering minds: The default network and stimulus-independent thought. *Science, 315*, 393–395.
Michael, G. A., Dupuy, M.-A., Deleuze, A., Humblot, M., Simon, B., & Naveteur, J. (2012). Interacting effects of vision and attention in perceiving spontaneous sensations arising on the hands. *Experimental Brain Research, 216*, 21–34.
Michael, G. A., & Naveteur, J. (2011). The tickly homunculus and the origins of spontaneous sensations arising on the hands. *Consciousness and Cognition, 20*, 603–617.
Michael, G. A., Naveteur, J., Dupuy, M.-A., & Jacquot, L. (2015). My heart is in my hands: The interoceptive nature of the spontaneous sensations felt on the hands. *Physiology & Behavior, 143*, 113–120.
Morin, A. (2006). Levels of consciousness and self-awareness: A comparison and integration of various neurocognitive views. *Consciousness & Cognition, 15*, 358–371.
Mrazek, M. D., Phillips, D. T., Franklin, M. S., Broadway, J. M., & Schooler, J. W. (2013). Young and restless: Validation of the Mind-Wandering Questionnaire (MWQ) reveals disruptive impact of mind-wandering for youth. *Frontiers in Psychology, 4*, 560. http://dx.doi.org/10.3389/fpsyg.2013.00560.
Naveteur, J., Dupuy, M.-A., Gabrieli, F., & Michael, G. A. (2015). Aging and how we perceive our own hands: The effect of attention and gender. *Somatosensory & Motor Research, 32*, 227–235.
Naveteur, J., Honoré, J., & Michael, G. A. (2005). How to detect an electrocutaneous shock that is not delivered? Overt spatial attention influences decision. *Behavioural Brain Research, 165*, 254–261.
Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brai – A meta-analysis of imaging studies on the self. *NeuroImage, 31*, 440–457.
O'Callaghan, C., Shine, J. M., Lewis, S. J., Andrews-Hanna, J. R., & Irish, M. (2015). Shaped by our thoughts – A new task to assess spontaneous cognition and its associated neural correlates in the default network. *Brain & Cognition, 93*, 1–10.
Ochoa, J., & Torebjörk, R. (1983). Sensations evoked by intraneural microstimulation of a single mechanoreceptor units innervating the human hand. *Journal of Physiology, 342*, 633–654.
Raichle, M. E. (2015). The brain's default mode network. *Annual Review of Neuroscience, 38*, 433–447.
Randall, J. G., Oswald, F. L., & Beier, M. E. (2014). Mind-wandering, cognition, and performance: A theory-driven meta-analysis of attention regulation. *Psychological Bulletin, 140*, 1411–1431.
Schandry, R. (1981). Heart beat perception and emotional experience. *Psychophysiology, 18*, 483–488.
Seli, P., Jonker, T. R., Cheyne, J. A., Cortes, K., & Smilek, D. (2015). Can research participants comment authoritatively on the validity of their self-reports of mind wandering and task engagement? *Journal of Experimental Psychology: Human Perception and Performance, 41*, 703–709.
Smallwood, J. (2011). Mind-wandering while reading: Attentional decoupling, mindless reading and the cascade model of inattention. *Language and Linguistics Compass, 5*(2), 63–77.
Smallwood, J. (2013). Escaping the here and now: Evidence for a role of the default mode network in perceptually decoupled thought. *NeuroImage, 69*, 120–125.
Smallwood, J., & Schooler, J. (2015). The science of mind wandering: Empirically navigating the stream of consciousness. *Annual Review of Psychology, 66*, 487–518.
Sobel, M. E. (1982). Asymptotic intervals for indirect effects in structural equations models. In S. Leinhart (Ed.). *Sociological methodology* (pp. 290–312). San Francisco: Jossey-Bass.
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), e16997.
Svoboda, E., McKinnon, M. C., & Levine, B. (2006). The functional neuroanatomy of autobiographical memory: A meta-analysis. *Neuropsychologia, 44*, 2189–2208.
Tracy, J., Goyal, N., Flanders, A., Weening, R., Laskas, J., Natale, P., & Waldron, B. (2007). Functional magnetic resonance imaging analysis of attention to one's heartbeat. *Psychosomatic Medicine, 69*, 952–960.
Vallbo, A. B., & Johansson, R. S. (1984). Properties of cutaneous mechanoreceptors in the human hand related to touch sensation. *Human Neurobiology, 3*, 3–14.
Williams, E. J. (1959). The comparison of regression variables. *Journal of the Royal Statistical Society, Series B, 21*, 396–399.
Wolpert, D. M., Goodbody, S. J., & Husain, M. (1998). Maintaining internal representations: The role of the human superior parietal lobe. *Nature Neuroscience, 1*, 529–533.