



**Attending to the present:  
Mindfulness meditation reveals distinct neural modes of self-reference**

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| Complete List of Authors:     | Farb, Norman; University of Toronto, Psychology<br>Segal, Zindel; University of Toronto, Psychology; University of Toronto and Centre for Addiction and Mental Health, Psychiatry<br>Mayberg, Helen; Emory University School of Medicine, Department of Psychiatry and Behavioral Sciences<br>Bean, Jim; St. Joseph's Health Centre, Stress Reduction Clinic<br>McKeon, Deborah; St. Joseph's Health Centre, Stress Reduction Clinic<br>Fatima, Zainab; University of Toronto, Institute of Medical Science<br>Anderson, Adam; University of Toronto, Psychology |
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1  
2 **Running Head:** Dissociable neural modes of self-reference

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4 **Keywords:** Self-reference, Attention, Meditation, fMRI, Insula, Prefrontal Cortex, Somatosensory,  
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6 Plasticity

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10 **Attending to the present:**

11 **Mindfulness meditation reveals distinct neural modes of self-reference**

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15 N.A.S. Farb<sup>1</sup>, Z.V. Segal<sup>1,2</sup>, H. Mayberg<sup>3</sup>, J. Bean<sup>4</sup>, D. McKeon<sup>4</sup>, Z. Fatima<sup>5</sup> & A.K. Anderson<sup>1</sup>

16  
17 <sup>1</sup>Department of Psychology, University of Toronto

18  
19 <sup>2</sup>Department of Psychiatry, University of Toronto and

20  
21 Centre for Addiction and Mental Health

22  
23 <sup>3</sup>Department of Psychiatry, Emory University

24  
25 <sup>4</sup>St Joseph's Health Centre, Toronto

26  
27 <sup>5</sup>Institute of Medical Science, University of Toronto

28  
29  
30  
31 Address correspondence to:

32 Adam K. Anderson

33 Department of Psychology

34 University of Toronto

35 100 St George Street

36 Toronto, ON M5S 3G3, Canada

37 Email: anderson@psych.utoronto.ca

38 Phone: 416 946-0207, Fax: 416 978-4811

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1  
2 It has long been theorized that there are two temporally distinct forms of self-reference: extended self-  
3 reference linking experiences across time, and momentary self-reference centered on the present. To  
4 characterize these two aspects of awareness, we used fMRI to examine monitoring of enduring traits  
5 (“narrative” focus, NF) or momentary experience (“experiential” focus, EF) in both novice  
6 participants and those having attended an 8-week course in mindfulness meditation, a program that  
7 trains individuals to develop focused attention on the present. In novices, EF yielded focal reductions  
8 in self-referential cortical midline regions (medial prefrontal cortex, mPFC) associated with NF. In  
9 trained participants, EF resulted in more marked and pervasive reductions in the mPFC, and increased  
10 engagement of a right lateralized network, comprising the lateral PFC and viscerosomatic areas such  
11 as the insula, secondary somatosensory cortex and inferior parietal lobule. Functional connectivity  
12 analyses further demonstrated a strong coupling between the right insula and the mPFC in novices  
13 that was uncoupled in the mindfulness group. These results suggest a fundamental neural dissociation  
14 between two distinct forms of self-awareness that are habitually integrated but can be dissociated  
15 through attentional training: the self across time and in the present moment.  
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Dissociable neural modes of self-reference 3

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2 Since William James' early conceptualization, the "self" has been characterized as a source of  
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4 permanence beneath the constantly shifting set of experiences that constitute conscious life. This  
5  
6 permanence is often related to the construction of narratives that weave together the threads of  
7  
8 temporally disparate experiences into a cohesive fabric. To account for this continuity, William James  
9  
10 posited an explanatory "me" to make sense of the "I" acting in the present moment (James, 1890).  
11  
12 Recently progress has been made in characterizing the neural bases of the processes supporting  
13  
14 William James' "me" in the form of "narrative" self-reference (Gallagher, 2004), highlighting the role  
15  
16 of the medial prefrontal cortices (mPFC) in supporting self-awareness by linking subjective  
17  
18 experiences across time (Neisser, 1997; Northoff & Bermpohl, 2004). The mPFC has been shown to  
19  
20 support an array of self-related capacities, including memory for self-traits (Craig et al., 1999; Fossati  
21  
22 et al., 2003; Kelley et al., 2002; Macrae et al., 2004), traits of similar others (Mitchell, Macrae, &  
23  
24 Banaji, 2006), reflected self-knowledge (Lieberman, Jarcho, & Satpute, 2004; Ochsner et al., 2005),  
25  
26 and aspirations for the future (Johnson et al., 2006). As such, cortical midline processes may be  
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28 characterized as supporting narrative self-reference that maintains continuity of identity across time  
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30 (Gallagher, 2004).

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32 Narrative self-reference stands in stark contrast to the immediate, agentic "I" supporting the  
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34 notion of momentary experience as an expression of selfhood. Most examinations of self-reference  
35  
36 ignore mechanisms of momentary consciousness, which may represent core aspects of self-experience  
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38 achieved earlier in development (Damasio, 1999; Gallagher, 2004; Zelazo & Frye, 1998) and may  
39  
40 have evolved in earlier animal species (Panksepp, 2005). Indeed, little is known about whether the  
41  
42 neural substrates underlying momentary self-reference are one and the same, or distinct from, cortical  
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44 midline structures supporting narrative experience. One hypothesis suggests that awareness of  
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46 momentary self-reference is neurally distinct from narrative self-reference and is derived from neural  
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48 markers of transient bodily states, in particular, right lateralized exteroceptive somatic and

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interoceptive insular cortices (Craig, 2004; Critchley et al., 2004; Damasio, 1999). In the present study, we examined this thesis.

Deleted: , thereby constituting a more basic form of awareness that represents evolutionarily older substrates and origins of selfhood.

We investigated these hypothesised dual modes of self-reference by employing functional magnetic resonance imaging (fMRI) during attention to two temporally distinct foci of attention; the self as experienced across time and in the immediate moment. One obstacle to investigating present-centred awareness is the well-established tendency for the mind to wander and become distracted from the present moment in favour of temporally distant, stimulus-independent thought (Smallwood & Schooler, 2006). Stimulus-independent thought (SIT) consists of automatically-generated verbal or visual experiences (Teasdale et al., 2003; McGuire, Paulesu, Frackowiak & Frith, 1996) akin to William James' notion of a running 'stream of consciousness' (James, 1890), the basis of the narrative form of self-reference described above. SIT-related neural activation has been shown to reflect an automatic tendency to engage in narrative processes in the absence of a strong requirement to respond to external stimuli (McKiernan, Angelo, Kaufman & Binder, 2006).

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The theory of narrative generation as a default state of self-reference is increasingly supported by neural evidence: the cortical midline activity which underlies narrative-generating mind-wandering (Mason et al., 2006) is very similar to activity associated with the 'default mode' of resting attention (Gusnard et al., 2001; Raichle et al., 2001). This default mode suggests an endemic reliance upon the networks supporting temporally-extended narrative processing, potentially obscuring recruitment of distinct networks for more immediate self-reflection. It may, therefore, be important to study individuals with specific training in monitoring moment-to-moment experience to more reliably recruit the brain regions supporting momentary self-focus in the face of a narrative generation bias. Mindfulness meditation is a form of attentional control training by which individuals develop the ability to direct and maintain attention towards the present moment (Segal et al., 2002; Kabat-Zinn et al., 1992). The current study examined individuals with mindfulness meditation training (MT) in

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Deleted: . Indeed, recent work suggests that dispositional mindfulness, a trait reflecting orientation toward

Deleted: centered awareness, is related to altered medial prefrontal recruitment (Creswell et al, in press). To this end, the

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Dissociable neural modes of self-reference 5

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2 addition to a novice group without such training, in an effort to determine whether the MT group  
3 would show an increased capacity to disengage from narrative generation and reveal the neural  
4 networks supporting present-centred self-awareness.

Deleted: , who were trained through daily exercises to deploy their attention to focus on the

Deleted: moment (Kabat-Zinn et al., 1992).

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8 To characterize the brain regions supporting the hypothesized dual-modes of self-reference,  
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10 participants were instructed to assume distinct modes of self-focus. Narrative focus calls for cognitive  
11 elaboration of mental events, thereby reducing attention towards other temporally proximal sensory  
12 objects. By contrast, experiential focus calls for the inhibition of cognitive elaboration on any one  
13 mental event in favour of broadly attending to more temporally proximal sensory objects, canvassing  
14 thoughts, feelings, and physical sensations without selecting any one sensory object. As such,  
15 narrative focus has been associated with increased ruminative thoughts about the self, while  
16 experiential focus avoids rumination by disengaging attentional processes of self-referential  
17 elaboration (Watkins & Teasdale, 2001). In response to reading trait-related adjectives participants in  
18 the present study were asked to engage either: 1) a “narrative” mode, reflecting on what the adjective  
19 meant about them as a person, or 2) an “experiential” mode, monitoring their moment-to-moment  
20 experience in response to the adjectives. Trait-related adjectives were chosen for their ability to  
21 promote self-reflection as evidenced by previous research (e.g., Fossati et al, 2003).

Deleted: focus that have been shown to either increase ruminative thoughts about the self or to stay centered in the present moment

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## 32 33 34 35 **Materials and Methods**

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37 *Participants.* Participants were recruited upon enrolment in the Mindfulness-Based Stress Reduction  
38 (MBSR) program at St. Joseph’s Hospital in Toronto, an 8-week intensive course (Kabat-Zinn et al.,  
39 1992) that involves daily exercises in focusing attention on the present moment, as described in  
40 Kabat-Zinn et al. (1992). The MBSR program featured weekly in-class sessions in which participants  
41 were trained in several exercises, consisting chiefly of practicing the continuous focus of attention on  
42 one’s breathing and other sensations, as well as attentional body scans and some basic hatha yoga  
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2 postures. On each of the six days between classroom sessions, participants were asked to practice the  
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4 attentional exercises on their own for at least 45 minutes (Kabat-Zinn, 1982). Participants were  
5  
6 randomly assigned to either a pre-training waitlist group (twelve women and four men, mean age  
7  
8  $42.00 \pm 9.24$ ); or a post mindfulness training (MT) group (fifteen women and five men, mean age  
9  
10  $45.55 \pm 13.38$ ). A cross-sectional design was chosen to limit the effects of repeated exposure to the  
11  
12 task and scanner environment. No group differences were found for age, gender, prior meditation  
13  
14 experience, pre-training anxiety (BAI; Beck & Steer, 1990; Novices  $13.38 \pm 8.49$ , MT  $16.35 \pm 12.59$ ),  
15  
16 depression (BDI-II; Beck, Steer & Brown, 1996; Novices  $20.56 \pm 13.10$ , MT  $23.35 \pm 14.22$ ), or other  
17  
18 psychological symptoms (SCL-90-R; Derogatis, 1984; Novices  $79.88 \pm 50.41$ , MT  $108.25 \pm 64.68$ ).

Deleted: curtailing mind wandering, specifically through focusing attention on the present moment. Participants were randomized to

19  
20 All were right handed volunteers that gave informed consent to procedures that were approved by the  
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22 Sunnybrook and Women's College Health Sciences Clinical Ethics Committee. Subjects were  
23  
24 reimbursed for their participation.

Deleted: and time.

### 25 26 27 28 *Materials and procedure.*

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30 Verbal Stimuli. Eight sets of six personality-trait adjectives were constructed from a well-established  
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32 list of personality-trait words (Anderson, 1968). Each of the 8 lists words contained 3 mildly positive  
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34 traits and 3 negative traits (e.g., confident, melancholy), selected from the top and bottom 20% of  
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36 Anderson's sample (Fossati et al., 2003), as these traits would lend themselves naturally themselves  
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38 towards self-reference. Word lists were randomly assigned to each condition.

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40 Training procedure. Participants were first trained on the distinction between experiential and  
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42 narrative forms of self-focus, derived from Watkins & Teasdale (2001). Experiential focus was  
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44 characterized as engaging present-centered self-reference, sensing what is occurring in one's  
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46 thoughts, feelings and body state, without purpose or goal, other than noticing how things are from  
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one moment to the next; if a participant noticed themselves getting distracted by a particular thought or memory, they were asked to calmly return their attention to their current experiences whenever they noticed such distraction. Narrative focus was characterized as judging what is occurring, trying

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to figure out what that trait word means to the participant, whether it describes the participant, and allowing oneself to become caught up in a given train of thought. Participants were given multiple

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examples of each mental-state and were invited to ask questions and generate examples about the distinction. Once participants could competently describe the experiential/narrative distinction in their

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own words, they were then trained in these conditions as well as additional baseline tasks (1-back working memory, arrow key-press, monitor breathing, and thought suppression), which were not

Deleted: memory),

analyzed for the present report. Training required approximately 20-25 minutes in total. During the experiment each condition lasted for 36 seconds and was preceded immediately by a 10 second

instruction screen with a condition cue to inform and prepare participants for the next task. The instruction screen consisted of a cue word and icon to inform the participant of which type of self-focus to perform; the instruction screen was presented for a 10 s duration to allow participants

adequate time to disengage from one focus and reorient themselves for the next task. One run in the scanner consisted of two repetitions of each condition and each participant completed two runs. The condition order was randomized for each participant.

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Self-focus task. To enable comparison of these hypothesized distinct modes of self-reference, narrative and experiential self-focus were separately applied while reading intermixed mildly positive (e.g., charming) and negative (e.g., greedy) trait descriptive words. Trait-adjectives appeared on the screen singly every 6 seconds for 4 seconds in duration. To aid in accessing momentary experiential focus, no overt responses were collected during scanning.

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Post-scanning ratings. To acquire a subjective index of task effort and compliance, following exiting the scanner participants rated the ease they found employing each self-focus mode. A two-way mixed

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ANOVA, with group (novice vs mindfulness trained, MT) and self-focus (narrative vs. experiential), revealed that narrative focus was easier to employ than experiential focus,  $F(1, 34) = 8.59, p < .007$ .

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Additionally, the MT group found both forms of self-focus easier to engage than the pre-group,  $F(1, 34) = 5.54, p < .03$ , with no differential effect of training on ease of engaging a particular self-focus

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mode,  $F(1, 34) < 1$ . A further examination of whether the groups differed in a tendency to mind

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wander during scanning revealed no group differences,  $F(1, 34) < 1$ .

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Data acquisition. Imaging was performed at Sunnybrook and Women's College Health Sciences

Centre (S & W) using a 3-T Signa MRI system (CV/i hardware, LX8.3 software; General Electric

Medical Systems, Waukesha, Wis.) with a standard quadrature birdcage head coil. *Functional MRI*

(*fMRI*) was conducted using T2\*-weighted single-shot spiral in-out k-space trajectories optimized for

sensitivity to the blood-oxygenation-level-dependent (BOLD) effect (TE/TR/flip angle = 30 ms/2000

ms/70 degrees, 20 cm field-of-view (FOV), 5 mm slice thickness, 64 by 64 matrix, 26 slices in axial

oblique orientation. Spiral in-out technique provided improved capability to acquire fMRI signals in

regions of high magnetic susceptibility (Glover & Law, 2001). The first 15 TRs of each run were

discarded due to scanner equilibration effects. Structural imaging was conducted with 3D inversion

recovery-prepped fast spoiled gradient echo imaging (IR-prep FSPGR; 300 ms prep time, TE/flip

angle=min. full/15 degrees, 24 cm FOV with 0.75 phase FOV right-to-left, 256 by 192 matrix, 124

slices 1.3 mm thick). Stimulus presentation was controlled by Presentation software (Neurobehavioral

Systems, Inc., Albany, Calif.) viewed via a back-projection screen.

Data pre-processing and analysis. Statistical Parametric Mapping (SPM; version 2) was used to

extract time series functional data, which was spatially co-registered and re-aligned to correct for

small head motions within and between functional scans. Data were then normalized into a common

stereotactic reference space (MNI) and spatially smoothed (FWHM=8mm). fMRI responses to the

presentation of each event type were modeled by a canonical hemodynamic response function scaled

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relative to the block duration, with the entire 36 second word presentation period modelled as a single

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block. For each individual, contrast images were calculated by applying appropriate weights to the

parameter estimates for each event type. Group analyses were then performed on these individual

subject contrast images, which were submitted to paired t-tests, with subject entered as a random

effect. Cluster thresholding was applied to increase power in identifying heavily recruited neural areas

while maintaining a reasonably low Type-I error rate (Forman et al., 1995). Two criteria were

employed in evaluating activations: i) only regions with peak voxels of  $p < .001$  were considered; ii)

only clusters of activation including  $k \geq 6$  voxels in which all voxels met an uncorrected threshold of

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$p < .005$  were considered, yielding a functional threshold equivalent of  $p < .001$  according to cluster

size significance level corrections (Forman et al., 1995). The cluster volume threshold was based on

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voxels resampled into an isotropic 4x4x4 mm space. Group contrast images were overlaid on an

average high-resolution FSPGR T1 image for viewing.

Region of interest analyses. As a follow up to the voxel-wise analyses, functionally defined regions

from the MT group were used to interrogate whether these activations reflected subthreshold contrasts

between modes of self-focus in the novice group. ROIs were recruited from the MT group since only

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this group showed major differentiation of narrative and experiential focus through the recruitment of

a priori regions of interest. The ROI analyses were therefore designed to support the qualitative

observation of an increased distinction between focus conditions by showing that the neural

distinctions made in the MT group analysis were significantly more reliable than activation

differences in the novice group. Weighted parameter estimates from the peak voxel in each ROI were

extracted and submitted to an additional ANOVA to confirm an increased neural distinction between

focus conditions in the MT relative to the novice group. The 5mm spherical ROIs were derived from

peak voxels in each cluster allowing independent examination of contiguous activated regions.

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Functional connectivity analyses. Linearly detrended whole-brain time series activation patterns were

Dissociable neural modes of self-reference<sup>10</sup>

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2 compared to activation in a volume of interest (~~spherical, 5mm radius~~) defined in the narrative vs.  
3  
4 experiential contrast in the MT group. ~~Seed voxels were~~ used in a physio-physiological interaction  
5  
6 (~~PPI; Friston et al., 1997~~) to ~~test~~ for significant correlations ~~with activity in the rest of the brain voxels~~  
7  
8 ~~across the observed time series~~. Functional connectivity regions of interest were defined by ~~selecting~~  
9  
10 ~~areas that demonstrated significant~~ connectivity ~~differences~~ with the seed ROIs in a comparison  
11  
12 between novice and MT groups ( $p < .001$ ). ~~These areas~~ were then subjected to more detailed linear  
13  
14 regression analysis. Any activation outliers greater than 3 standard deviations within a given region  
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16 were excluded from the time series data.

## Results

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21 ~~Narrative self-focus~~. To characterize the narrative self-focus state, ~~participants from both the novice~~  
22  
23 ~~and MT groups were collapsed into a single analysis of narrative self-focus compared to the baseline~~  
24  
25 ~~conditions~~. Consistent with narrative focus reflecting a higher-order and linguistically mediated mode  
26  
27 of self-reference and replicating prior studies of self-reference (Craig et al., 1999; Fossati et al., 2003;  
28  
29 Johnson et al., 2002; Kelley et al., 2002; Northoff & Bermpohl, 2004; Ochsner et al., 2005), ~~narrative~~  
30  
31 ~~self-focus~~ resulted in pronounced recruitment of midline cortical structures, including the rostral and  
32  
33 dorsal extent of the mPFC (BA 8/9/10/32; at peak height:  $x, -16; y, 52; z, 36; Z = 6.75, p < 0.001$ ), and  
34  
35 the posterior cingulate (BA 23/31,  $-8 -56 24; Z = 3.91, p < 0.001$ ) [Figure 1], left hemisphere  
36  
37 language areas, including the inferolateral PFC (BA 44/45,  $-56 20 12; Z = 5.94, p < 0.001$ ) and middle  
38  
39 temporal gyrus (BA 21,  $-64 -40 -4; Z = 5.45, p < 0.001$ ), ~~as well as the left hippocampus~~ (BA 34,  $-28 -$   
40  
41  $24 -12; Z = 3.51, p < 0.001$ ) ~~right inferior frontal gyrus~~ (BA 47,  $56 32 -8; Z = 3.58, p < 0.001$ ), ~~right~~  
42  
43 ~~precentral gyrus~~ (BA 4,  $28 -20 72; Z = 3.38, p < 0.001$ ), cuneus (BA 19,  $0 -96 32; Z = 4.12, p <$   
44  
45  $0.001$ ), and left head of caudate ( $-12 12 4; Z = 3.36, p < 0.001$ ), and cerebellum ( $32, -80, -48, Z =$   
46  
47  $6.53, p < 0.001$ ),

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Deleted: peak right insula ROI seed voxel defined by the

Deleted: The insular seed voxel was

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Deleted: investigate the time series activations of the rest of the brain

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Deleted: Novice participants.

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Deleted: focus was compared with the rest of the task time series, it

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Deleted: 5.30,  $p < 0.001$  [Figure 1a].

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*Experiential Focus: Novice participants.* We were specifically interested in examining how experiential focus differed from narrative focus in each of the novice and MT groups. Beginning with the novice group, directly, contrasting these conditions revealed several focal differences in activation

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[Figure 2ab], Relative to narrative self-focus, experiential self-focus was associated with relative

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reductions in several discrete regions along the cortical midline: gyrus rectus of the subgenual cingulate (BA 25; 27 voxels, 16 16 -12;  $Z = 3.29$ ,  $p < 0.001$ ), posterior cingulate (BA 23/31; 41 voxels, -8 -52 28;  $Z = 3.29$ ,  $p < 0.001$ ), and with a lower cluster threshold, a relatively restricted

reduction in the rostral mPFC (BA 10; 4 voxels, -4 64 16;  $Z = 3.16$ ,  $p < 0.001$ ). Experiential self-

focus was associated with a relative increase in left lateralized regions, yielding significantly greater

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activations in the dorsolateral PFC (BA 45/46; 23 voxels, -36 32 24;  $Z = 3.60$ ,  $p < 0.001$ ),

ventrolateral PFC (BA 47; 11 voxels, -36 40 4;  $Z = 3.13$ ,  $p < 0.001$ ) and posterior parietal cortices

(BA 39, 23 voxels, -48 -48 56; BA 40; 9 voxels, -32 -52 28;  $Z = 3.06$ ,  $p < 0.001$ ).

*Experiential Focus: Mindfulness-Trained participants.* Increased left sided dorsolateral and posterior

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parietal recruitment may reflect greater task related executive control and attentional allocation

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(Gusnard et al., 2001), or at the very least an attempt to resist narrative mind wandering (Mason et al.,

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2006), rather than the neural correlates of present-centered experiential focus. As such, the above

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results suggest that moment-by-moment self-experience may rely simply on task-related suppression

of midline cortical representations very similar to those supporting narrative self-focus. Another

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possibility is that dissociable neural markers of self-reference may be more evident following

extensive training in present-centered self-focus in the MT group, where engaging distinct modes of

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self reference may be more effortless.

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In the MT group, experiential self-focus did result in pervasive deactivations along the anterior

Deleted: training revealed that relative to narrative focus,

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cortical midline relative to narrative focus, including the rostral subregions of the dorsal mPFC (BA

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9/10/32; 87 voxels, -12 56 40;  $Z = 3.77$ ,  $p < 0.001$ ) and ventral mPFC (BA 10; 86 voxels, 8 68 8;  $Z =$

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Dissociable neural modes of self-reference<sup>12</sup>

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3.98,  $p < 0.001$ ) [Figure 3a], as well as reduced activity in the left dorsal amygdala (BA 34; 9 voxels, -24 -8 -8;  $Z = 3.20$ ,  $p < 0.001$ ), suggesting that moment-by-moment self-experience may rely on

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suppression of mPFC cortical representations supporting narrative self-focus. In addition to the mPFC reductions, experiential focus resulted in increased recruitment of a right lateralized cortical network,

Deleted: 0.001). Experiential focus in the MT group also

including the dorsal and inferolateral PFC (BA 46/45; 77 voxels, 48 56 -8;  $Z = 3.50$ ,  $p < 0.001$ ),

insular cortex (BA 48; 6 voxels, 40 -8 16;  $Z = 3.24$ ,  $p < 0.001$ ), a region along the supramarginal

gyrus consistent with the secondary somatosensory cortex (SII, BA 40; 24 voxels, 40 -40 20;  $Z =$

3.61,  $p < 0.001$ ) extending posteriorly and dorsally into the angular gyrus of the inferior parietal

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lobule (BA 39; 7 voxels, -36 -76 48;  $Z = 3.11$ ,  $p < 0.001$ ) [Figure 3bcd]. This pattern is consistent

with the MT group demonstrating a marked shift from midline mPFC-centered recruitment during

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experiential focus towards right lateralized prefrontal cortical and paralimbic structures, in particular

demonstrating recruitment of hypothesized posterior viscerosomatic representations.

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To examine whether the distinct experiential focus regions revealed in the MT group were

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novel areas of recruitment compared to novices rather than the product of subthreshold but similar

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patterns of activation, we further performed ROI analyses of activation patterns from each participant

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in both the MT and Novice groups [Figure 3, right panel]. Experiential relative to narrative self-

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focus was associated with significant reductions in the ventral ( $F = 11.88$ ,  $p < 0.003$ ) and dorsal

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mPFC ( $F = 19.09$ ,  $p < 0.001$ ), in the MT but not the novice group ( $p$ 's  $> .3$ ). By contrast, experiential

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self-focus resulted in significantly greater recruitment of the right lateral PFC ( $F = 14.75$ ,  $p < .001$ ),

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right insula ( $F = 14.41$ ,  $p < .001$ ), and SII/inferior parietal lobule ( $F$ 's  $> 10.28$ ,  $p$ 's  $< .003$ ) in the MT

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but not the novice group ( $p$ 's  $> .3$ ).

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Functional connectivity analyses. One reason that novices may have difficulty separately attending to

distinct modes of self awareness is the habitual coupling of posterior-lateral and mPFC

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representations. To examine this more directly, we assessed functional connectivity between the

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viscero-somatic cortices and the mPFC across the entire time series [Figure 4]. Out of the potential posterolateral seed regions, the right insula was chosen as being the best documented in supporting viscerosomatic awareness (Craig, 2004; Critchley et al., 2004; Adolphs, 2002; Damasio, 1999). An analysis of right insular functional connectivity revealed that novices demonstrated strong coupling with midline cortical regions, including the orbital sectors of the vmPFC (BA 11; 6 voxels, -4 56 -24;  $Z = 3.68$ ,  $p < 0.001$ ) ( $R = .609$ ,  $p < .001$ ), suggesting viscerosomatic signals are by default associated with activation in the ventral medial prefrontal cortices. Such a strong correlation may preclude dissociation of these modes of self-focus in novice participants. Successfully maintaining present-moment awareness may require MT individuals to decouple the automatic responsiveness of the vmPFC to insular activation. Supporting this hypothesis, the right insular and vmPFC cortices were rendered uncorrelated in the MT group ( $R = .056$ , Fisher's  $r$  to  $Z = 13.36$ ,  $p < .001$ ). This decoupling was replaced by an increased coupling of the right insula with the dorsolateral prefrontal cortices (BA 9/44; 17 voxels, -56 20 32;  $Z = 3.18$ ,  $p < 0.001$ ), as seen in the change from a modest correlation in the novice group ( $R = .283$ ) to a very strong correlation ( $R = .783$ , Fisher's  $r$  to  $Z = 12.09$ ,  $p < .001$ ) in the MT group. This pattern of results suggests MT may afford greater access to distinct modes of self-focus by promoting a shift away from viewing viscerosomatic activity through the lens of the mPFC towards a distinct mode of sensory awareness supported by the lateral PFC.

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## Discussion

Consistent with a theory of self-reference as mentalizing (Zelazo & Frye, 1998), linguistically mediated (Rochat, 1995) and of higher order executive origin (Amodio & Frith, 2004; Craik et al., 1999; Fossati et al., 2003; Johnson et al., 2002; Kelley et al., 2002; Macrae et al., 2004; Northoff & Heinzel, 2006; Ochsner et al., 2005), participants engaged midline prefrontal cortices (ventral and dorsal mPFC) and a left lateralized linguistic-semantic network (inferior lateral PFC, middle temporal

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and angular gyri) while processing events with a narrative focus. Demonstrating a default bias towards narrative self-focus as previously revealed in “resting” mind wandering states (Mason et al., 2006), relatively restricted reductions in the cortical midline network were found when attention was explicitly directed towards a moment-to-moment experiential focus in novice participants with little training in this form of self-reflection. These individuals revealed increased left lateralized prefrontal-parietal activations likely reflecting greater task related linguistic processing that has been shown to be associated with decreased medial prefrontal recruitment (Gusnard et al., 2001).

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Participant inexperience with different forms of self-focus might limit the ability to accurately reveal functionally and neurally distinct forms of self-awareness. We also examined individuals with more extensive training in present moment centered self-awareness. Following an intensive 8 week course in mindfulness meditation, during which individuals learn to develop the capacity to monitor moment-to-moment experience, experiential focus resulted in a pronounced shift away from midline cortices towards a right lateralized network comprised of the ventral and dorsolateral PFC, as well as right insula, secondary somatosensory (SII), and inferior parietal lobule. Consistent with a dual-mode hypothesis of self-awareness, these results suggest a fundamental neural dissociation in modes of self-representation that support distinct, but habitually integrated, aspects of self-reference: 1) higher order self-reference characterized by neural processes supporting awareness of a self that extends across time and 2) more basic momentary self-reference characterized by neural changes supporting awareness of the psychological present. The latter, represented by evolutionary older neural regions, may represent a return to the neural origins of identity, in which self-awareness in each moment arises from the integration of basic interoceptive and exteroceptive bodily sensory processes (Craig, 2004; Critchley et al., 2004; Damasio, 1999; Panksepp, 2005). By contrast, the narrative mode of self-reference may represent an overlearned mode of information processing that has become automatic

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2 through practice, consistent with established findings on training-induced automaticity (e.g. MacLeod  
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4 & Dunbar, 1988).

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6 Altered cortical midline activation, particularly in the vmPFC, has been associated with  
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8 judgments of self-relevance (Phan et al., 2004), as well as appreciation of emotional valence, ranging  
9  
10 from simple sensory to more complex and abstract events (Anderson et al., 2003; Cunningham, Raye,  
11 & Johnson, 2004; O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001). As this region receives  
12 connections from all exteroceptive (Barbas, 2000) and interoceptive modalities (Carmichael & Price,  
13 1996), it has been viewed as a polymodal convergence zone (Rolls, 2000), supporting the integration  
14 of external and internal stimuli with judgments about their affective relevance to the self (Ochsner &  
15 Gross, 2005). Following MT, experiential focus resulted in a shift away from both the vmPFC and the  
16 amygdala, toward more lateral prefrontal regions supporting a more self-detached and objective  
17 analysis of interoceptive (insula) and exteroceptive (somatosensory cortex) sensory events, rather than  
18 their affective or subjective self-referential value. This pattern mirrors neural dissociations between  
19 the affective and sensory components of pain sensation, with the former supported by anterior midline  
20 structures, and latter supported by posterior lateral sensory cortices (Rainville et al., 1997). This  
21 detached or objective mode of self-focus may be aided by the recruitment of the right angular gyrus of  
22 the inferior parietal lobule. In addition to studies showing that this region is involved in switching  
23 between first and third person perspectives (Ruby & Decety, 2004), stimulation of this region has  
24 been associated with “out of body experiences” (Blanke et al., 2002) where an individual experiences  
25 stepping outside of themselves, affording a detached perspective on their corporeal self. Altered  
26 access to these posterolateral body schema representations may underlie neurological conditions such  
27 as anosognosia or de-personalization syndrome (Berlucchi & Aglioti, 1997), where there is loss of  
28 body ownership, with the body no longer being perceived as belonging to the “self.”  
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The shift toward dorsal lateral PFC regions following MT may reflect an enhanced capacity to represent a non-linguistic based awareness of the psychological present in working memory (Gray, Braver, & Raichle, 2002; Miller & Cohen, 2001); whereas increased activity in the ventrolateral PFC may represent augmented inhibitory control (Bunge et al., 2001; Gusnard et al., 2001) necessary to curtail a default tendency toward narrative self-reference. The right posterior paralimbic and neocortical regions, including the insula, SII, and inferior parietal lobule likely represent the contents of this present-focused awareness, with these regions associated with feedback regarding the interoceptive physiologic, exteroceptive somatic condition of the body, and overall corporeal awareness. Indeed, prior structural and functional imaging research has linked right insular volume and activity with increased sensitivity to interoceptive signals and global visceral awareness (Critchley et al., 2004) and thus has been hypothesized to reflect a global representation of interoceptive activity (Craig, 2004). In conjunction with the secondary somatosensory cortex, these regions have been argued to serve as somatic markers (Adolphs, 2002; Damasio, 1999), enabling a cortical representation of the overall somatic and physiologic state of the body (Craig, 2004; Damasio, 1999).

It is important to underscore that although a present-centered focus may involve aspects of monitoring one's body state, meditation practice is associated with **developing** moment-to-moment awareness of all available stimuli. Accordingly, during experiential focus participants were not instructed to narrowly attend to the body, rather they were encouraged to maintain a temporally narrow but experientially broad attentional focus centered on momentary experience, including internal thoughts, emotions, and physical sensations as well as external sensory events. The insula, somatosensory cortices, and inferior parietal lobule may then have a special role to play in the representation of transitory experience in all its forms (Craig, 2004). While these areas have been associated with a default or resting state in which self-narration and momentary awareness co-mingle

(Mason et al., 2006), training in maintaining momentary awareness suggests viscerosomatic cortical areas support an immediate information processing network of identity, distinct from abstract and narrative representations of the self. Indeed, converging with the present results, meditation practice is associated with cortical thickening in the right insular, somatosensory and inferior parietal lobule cortices (Lazar et al., 2005), suggesting these regions may be altered with extended daily focused attention to moment-to-moment experience, and thus may represent the neural underpinnings of self-reference in the psychological present.

One important limitation of the present study is the lack of a true pre/post intervention design; as such, the evidence does not support a claim that mindfulness training *per se* allowed for the increased differentiation between narrative and experiential attentional networks, but rather that those with MT show qualitatively different distinctions between self-referential focus modes than those only anticipating MT (the novice group). It can be reasonably inferred from these results that expertise in developing momentary awareness is associated with the ability to disengage from these default mPFC centered networks, even when subjective effort and perceived task-efficacy is equated. Testing participants before and after MT would allow us to investigate whether our observation of neural decentering is a pervasive, trait-like training effect resulting in chronic suppression of the mPFC-centered network, or whether instead MT results in greater voluntary, but state-like, suppression of an otherwise undiminished mPFC-centered network. Such a pre/post design would clarify the mechanisms underlying the enhanced recruitment of viscerosomatic representations of the momentary self.

The functional connectivity results suggest that a default mode of self-awareness may depend upon habitual coupling between mPFC regions supporting cognitive-affective representations of the self and more lateral viscerosomatic neural images of body state. This dual-mode of self-reference is better revealed following MT, where these modes become uncoupled through attentional training.

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2 This hypothesized cortical reorganization following MT is consistent with the notion that mindfulness  
3 training allows for a distinct experiential mode in which thoughts, feelings and bodily sensations are  
4 viewed less as being good or bad or integral to the “self” and treated more as transient mental events  
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6 that can be simply observed (Williams et al., 2007). As such, the capacity to disengage temporally  
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8 extended narrative and engage more momentary neural modes of self-focus has important  
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10 implications for mood and anxiety disorders, with the former having been shown to increase illness  
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12 vulnerability (Segal et al., 2006). Conversely, a growing body of evidence suggests approaching self-  
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14 experience through a more basic present-centered focus may represent a critical aspect of human well-  
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16 being (Davidson, 2004).  
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**Figure 1.** Narrative self-focus condition in the collapsed Novice (pre mindfulness training) and MT (following 8 weeks of mindfulness training) groups. Cortical midline areas associated with narrative focus (Narrative > times series baseline). VMPFC = ventromedial prefrontal cortex; DMPFC = dorsomedial prefrontal cortex; PCC = posterior cingulate cortex.

**Figure 2.** Experiential and Narrative self-focus conditions in the Novice (pre mindfulness training)

group. a) Areas of greater association with the Narrative condition (Narrative > Experiential) are in blue, and b) areas of showing greater association with the experiential condition (Experiential >

Narrative focus) are in red. VMPFC = ventromedial prefrontal cortex; DMPFC = dorsomedial prefrontal cortex; PCC = posterior cingulate cortex; LPFC = lateral prefrontal cortex; PP = posterior parietal cortex.

**Figure 3.** Experiential versus Narrative focus conditions following 8 weeks of mindfulness training

(MT). Areas of activation showing a greater association with the experiential condition (Experiential > Narrative focus) are in red, and narrative-associated areas (Narrative > Experiential are in blue: a) rostral and dorsal MPFC b) right LPFC c) right Insula; d) right secondary somatosensory cortex (SII).

Bar graphs indicate region of interest analyses of the magnitude of activation associated with the Narrative vs. Experiential contrast in the MT (post) and novices (pre) groups. Left panel green region represents y coordinate of each ROI. NF = narrative focus; EF = experiential focus; VMPFC = ventromedial prefrontal cortex; DMPFC = dorsomedial prefrontal cortex; LPFC = lateral prefrontal cortex; Insula = insula; IPL = inferior parietal lobule; SII = secondary somatosensory area.

**Figure 4.** Functional connectivity in the Novice and MT groups. Areas showing increased connectivity with the right insula (MT > Novice) are in red, and areas showing reduced connectivity (Novice > MT) are in blue. a) ventromedial prefrontal cortex; and b) dorsolateral prefrontal cortex.

The right panel demonstrates rank ordered inter-regional correlations with the right insular ROI in

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both the Novice and MT groups. VMPFC = ventromedial prefrontal; PCC = posterior cingulate;  
LPFC = lateral prefrontal cortex.

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**Appendix: Trait Words**

Trait words are grouped as they were in the experiment. Word groups were randomly selected for

each participant. Word lists were generated from Anderson (1968). Lik = likability rating; Var =

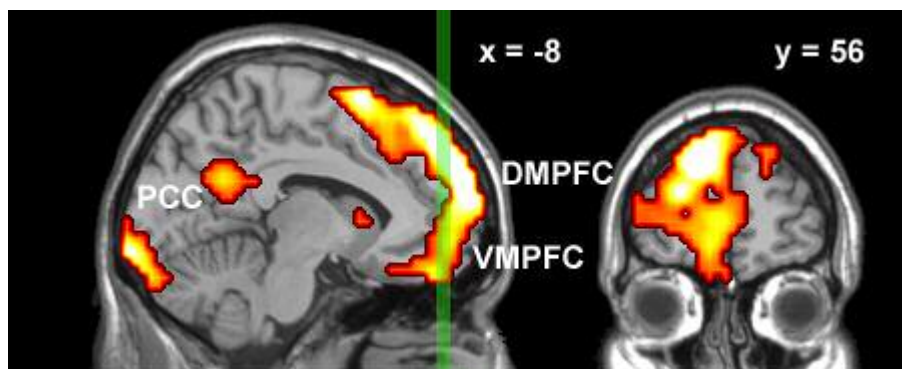
Variance of likability ratings; Mean = meaningfulness.

| <b><u>Word</u></b> | <b><u>Lik</u></b> | <b><u>Var</u></b> | <b><u>Mean</u></b> |
|--------------------|-------------------|-------------------|--------------------|
| <u>bitter</u>      | <u>162</u>        | <u>0.79</u>       | <u>376</u>         |
| <u>envious</u>     | <u>157</u>        | <u>0.77</u>       | <u>364</u>         |
| <u>antisocial</u>  | <u>144</u>        | <u>1.24</u>       | <u>358</u>         |
| <u>productive</u>  | <u>468</u>        | <u>0.81</u>       | <u>362</u>         |
| <u>lively</u>      | <u>466</u>        | <u>0.75</u>       | <u>360</u>         |
| <u>delicate</u>    | <u>467</u>        | <u>0.78</u>       | <u>361</u>         |
| <u>angry</u>       | <u>169</u>        | <u>0.9</u>        | <u>374</u>         |
| <u>resentful</u>   | <u>150</u>        | <u>0.9</u>        | <u>352</u>         |
| <u>lifeless</u>    | <u>127</u>        | <u>0.68</u>       | <u>354</u>         |
| <u>mature</u>      | <u>522</u>        | <u>0.66</u>       | <u>344</u>         |
| <u>decisive</u>    | <u>427</u>        | <u>1.03</u>       | <u>360</u>         |
| <u>ambitious</u>   | <u>484</u>        | <u>1.14</u>       | <u>378</u>         |
| <u>unhappy</u>     | <u>203</u>        | <u>0.98</u>       | <u>376</u>         |
| <u>abusive</u>     | <u>100</u>        | <u>0.83</u>       | <u>330</u>         |
| <u>incompetent</u> | <u>110</u>        | <u>0.68</u>       | <u>364</u>         |
| <u>sensitive</u>   | <u>358</u>        | <u>2.00</u>       | <u>354</u>         |
| <u>daring</u>      | <u>360</u>        | <u>1.03</u>       | <u>358</u>         |
| <u>athletic</u>    | <u>384</u>        | <u>0.75</u>       | <u>385</u>         |
| <u>nervous</u>     | <u>196</u>        | <u>0.83</u>       | <u>380</u>         |
| <u>cowardly</u>    | <u>110</u>        | <u>0.82</u>       | <u>374</u>         |
| <u>indecisive</u>  | <u>219</u>        | <u>0.90</u>       | <u>376</u>         |
| <u>powerful</u>    | <u>357</u>        | <u>0.87</u>       | <u>345</u>         |
| <u>energetic</u>   | <u>457</u>        | <u>0.81</u>       | <u>384</u>         |
| <u>hopeful</u>     | <u>406</u>        | <u>0.92</u>       | <u>328</u>         |
| <u>foolish</u>     | <u>140</u>        | <u>0.83</u>       | <u>348</u>         |
| <u>moody</u>       | <u>182</u>        | <u>1.36</u>       | <u>370</u>         |
| <u>insecure</u>    | <u>198</u>        | <u>0.75</u>       | <u>370</u>         |
| <u>emotional</u>   | <u>283</u>        | <u>1.23</u>       | <u>376</u>         |
| <u>tolerant</u>    | <u>461</u>        | <u>0.91</u>       | <u>372</u>         |
| <u>cheerful</u>    | <u>504</u>        | <u>0.83</u>       | <u>372</u>         |

Dissociable neural modes of self-reference 29

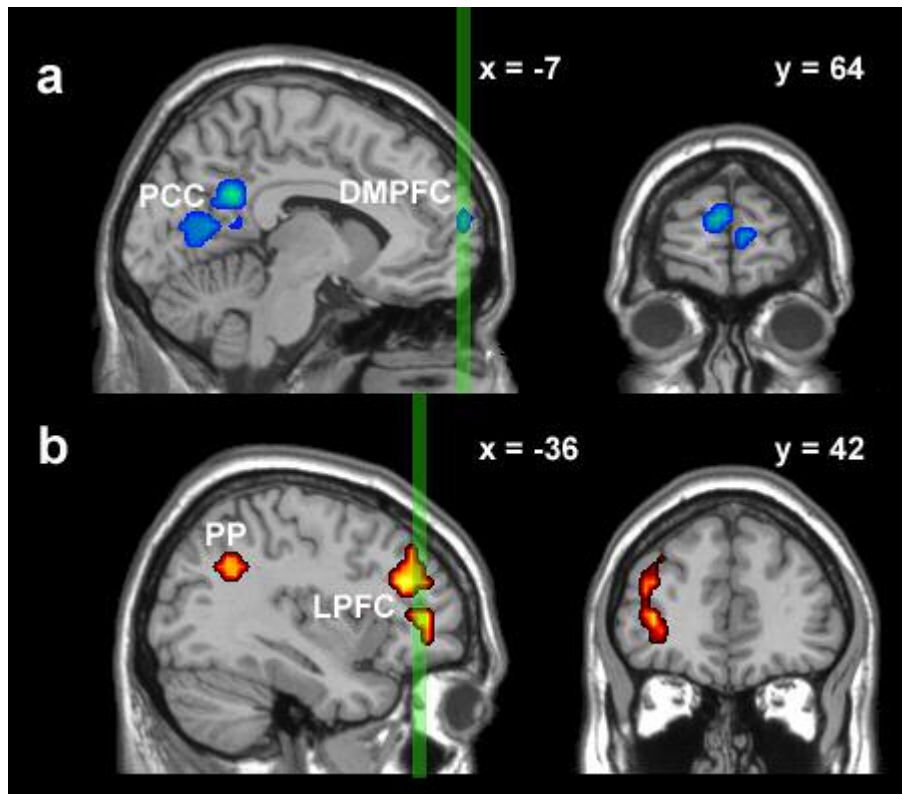
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| 1  |                    |            |             |            |
| 2  | <u>cruel</u>       | <u>40</u>  | <u>0.54</u> | <u>376</u> |
| 3  | <u>pessimistic</u> | <u>164</u> | <u>1.06</u> | <u>376</u> |
| 4  | <u>unkind</u>      | <u>66</u>  | <u>0.71</u> | <u>378</u> |
| 5  | <u>independent</u> | <u>455</u> | <u>1.32</u> | <u>374</u> |
| 6  | <u>talented</u>    | <u>478</u> | <u>0.84</u> | <u>368</u> |
| 7  | <u>fearless</u>    | <u>366</u> | <u>1.12</u> | <u>358</u> |
| 8  |                    |            |             |            |
| 9  | <u>shallow</u>     | <u>118</u> | <u>1.00</u> | <u>332</u> |
| 10 | <u>clumsy</u>      | <u>199</u> | <u>0.92</u> | <u>376</u> |
| 11 | <u>unskilled</u>   | <u>224</u> | <u>0.71</u> | <u>360</u> |
| 12 | <u>positive</u>    | <u>403</u> | <u>1.28</u> | <u>342</u> |
| 13 | <u>outgoing</u>    | <u>412</u> | <u>1.46</u> | <u>364</u> |
| 14 | <u>sociable</u>    | <u>429</u> | <u>0.85</u> | <u>360</u> |
| 15 |                    |            |             |            |
| 16 |                    |            |             |            |
| 17 | <u>fearful</u>     | <u>214</u> | <u>0.69</u> | <u>370</u> |
| 18 | <u>depressed</u>   | <u>166</u> | <u>1.01</u> | <u>370</u> |
| 19 | <u>unreliable</u>  | <u>104</u> | <u>0.93</u> | <u>386</u> |
| 20 | <u>patient</u>     | <u>478</u> | <u>0.70</u> | <u>376</u> |
| 21 | <u>idealistic</u>  | <u>384</u> | <u>1.35</u> | <u>350</u> |
| 22 | <u>industrious</u> | <u>322</u> | <u>1.54</u> | <u>342</u> |
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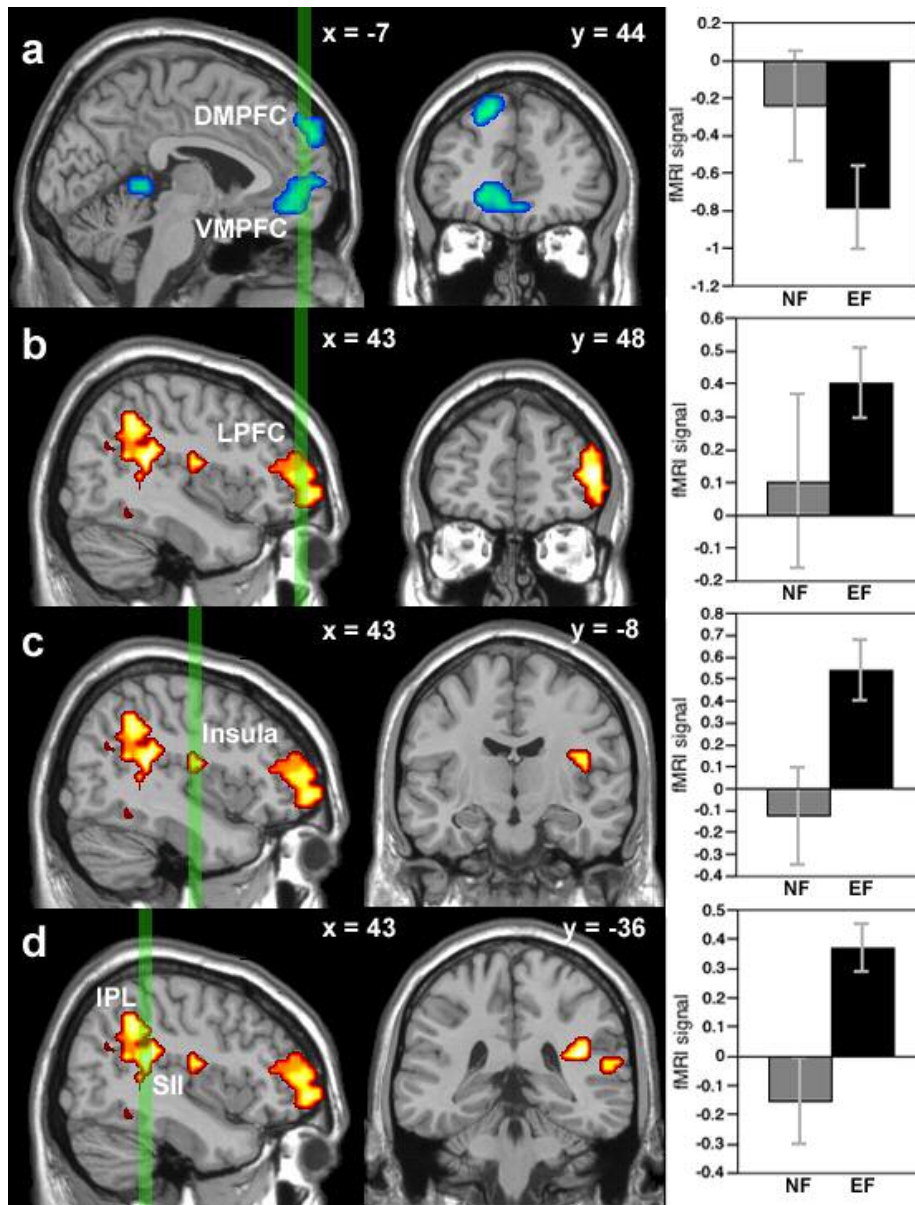
**Figure 1. Narrative self-focus condition in the collapsed Novice (pre mindfulness training) and MT (following 8 weeks of mindfulness training) groups. Cortical midline areas associated with narrative focus (Narrative > times series baseline). VMPFC = ventromedial prefrontal cortex; DMPFC = dorsomedial prefrontal cortex; PCC = posterior cingulate cortex.**

159x64mm (72 x 72 DPI)



**Figure 2. Experiential and Narrative self-focus conditions in the Novice (pre mindfulness training) group. a) Areas of greater association with the Narrative condition (Narrative > Experiential) are in blue, and b) areas of showing greater association with the experiential condition (Experiential > Narrative focus) are in red. VMPFC = ventromedial prefrontal cortex; DMPFC = dorsomedial prefrontal cortex; PCC = posterior cingulate cortex; LPFC = lateral prefrontal cortex; PP = posterior parietal cortex.**

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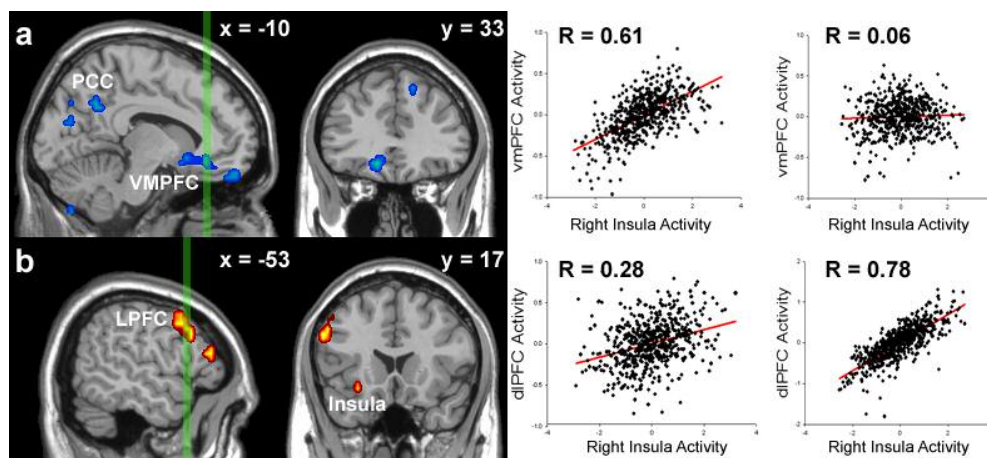


**Figure 3. Experiential versus Narrative focus conditions following 8 weeks of mindfulness training (MT). Areas of activation showing a greater association with the experiential condition (Experiential > Narrative focus) are in red, and narrative-associated areas (Narrative > Experiential) are in blue: a) rostral and dorsal MPFC b) right LPFC c) right Insula; d) right secondary somatosensory cortex (SII). Bar graphs indicate region of interest analyses of the magnitude of activation associated with the Narrative vs. Experiential contrast in the MT (post) and novices (pre) groups. Left panel green region represents y coordinate of each ROI. NF = narrative focus; EF = experiential focus; VMPFC = ventromedial prefrontal cortex; DMPFC = dorsomedial prefrontal cortex; LPFC = lateral prefrontal cortex; Insula = insula; IPL = inferior parietal lobule; SII = secondary somatosensory area.**

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**Functional connectivity in the Novice and MT groups. Areas showing increased connectivity with the right insula (MT > Novice) are in red, and areas showing reduced connectivity (Novice > MT) are in blue. a) ventromedial prefrontal cortex; and b) dorsolateral prefrontal cortex. The right panel demonstrates rank ordered inter-regional correlations with the right insular ROI in both the Novice and MT groups. VMPFC = ventromedial prefrontal; PCC = posterior cingulate; LPFC = lateral prefrontal cortex.**  
282x127mm (72 x 72 DPI)