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

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

Keywords: self-reference; attention; meditation; fMRI; insula; prefrontal cortex; somatosensory; plasticity

Since William James' early conceptualization, the 'self' has been characterised as a source of permanence beneath the constantly shifting set of experiences that constitute conscious life. This permanence is often related to the construction of narratives that weave together the threads of temporally disparate experiences into a cohesive fabric. To account for this continuity, William James posited an explanatory 'me' to make sense of the 'I' acting in the present moment (James, 1890). Recently, progress has been made in characterizing the neural bases of the processes supporting William James' 'me' in the form of 'narrative' self-reference (Gallagher, 2004), highlighting the role of the medial prefrontal cortices (mPFC) in supporting self awareness by linking subjective experiences across time (Neisser, 1997; Northoff and Bermpohl, 2004). The mPFC has been shown to support an array of self-related capacities, including memory for self-traits (Craik *et al.*, 1999; Kelley *et al.*, 2002; Fossati *et al.*, 2003; Macrae *et al.*, 2004), traits of similar others (Mitchell *et al.*, 2006), reflected self-knowledge (Lieberman *et al.*, 2004; Ochsner *et al.*, 2005), and aspirations for the future (Johnson *et al.*, 2006). As such,

cortical midline processes may be characterised as supporting narrative self-reference that maintains continuity of identity across time (Gallagher, 2004).

Narrative self-reference stands in stark contrast to the immediate, agentic 'I' supporting the notion of momentary experience as an expression of selfhood. Most examinations of self-reference ignore mechanisms of momentary consciousness, which may represent core aspects of self-experience achieved earlier in development (Damasio, 1999; Zelazo and Frye, 1998; Gallagher, 2004) and may have evolved in earlier animal species (Panksepp, 2005). Indeed, little is known about whether the neural substrates underlying momentary self-reference are one and the same, or distinct from, cortical midline structures supporting narrative experience. One hypothesis suggests that awareness of momentary self-reference is neurally distinct from narrative self-reference and is derived from neural markers of transient body states, in particular, right lateralised exteroceptive somatic and interoceptive insular cortices (Damasio, 1999; Craig, 2004; Critchley *et al.*, 2004). In the present study, we examined this thesis.

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 (SIT) (Smallwood and Schooler, 2006). SIT consists of automatically generated verbal or visual experiences (McGuire et al., 1996; Teasdale et al., 1995) 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 et al., 2006).

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., 2007) 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 (Kabat-Zinn et al., 1992; Segal et al., 2002). The current study examined individuals with mindfulness meditation training (MT) in addition to a novice group without such training, in an effort to determine whether the MT group would show an increased capacity to disengage from narrative generation and reveal the neural networks supporting present-centred self-awareness.

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

MATERIALS AND METHODS
Participants
Participants were recruited upon enrolment in the mindfulness-based stress reduction (MBSR) program at St Joseph's Hospital in Toronto, an 8 week intensive course (Kabat-Zinn et al., 1992) that involves daily exercises in focusing attention on the present moment, as described in Kabat-Zinn et al. (1992). The MBSR program featured weekly in-class sessions in which participants were trained in several exercises, consisting chiefly of practicing the continuous focus of attention on one's breathing and other sensations, as well as attentional body scans and some basic hatha yoga postures. On each of the six days between classroom sessions, participants were asked to practice the attentional exercises on their own for at least 45 min (Kabat-Zinn, 1982). Participants were randomly assigned to either a pre-training waitlist group (twelve women and four men, mean age 42.00 ± 9.24) or a post MT group (fifteen women and five men, mean age 45.55 ± 13.38). A cross-sectional design was chosen to limit the effects of repeated exposure to the task and scanner environment. No group differences were found for age, gender, prior meditation experience, pre-training anxiety ((BAI) Beck Anxiety Inventory; Beck and Steer, 1990; novices 13.38 ± 8.49, MT 16.35 ± 12.59), depression ((BDI-II) Beck Depression Inventory; Beck et al., 1996; novices 20.56 ± 13.10, MT 23.35 ± 14.22) or other psychological symptoms (SCL-90-R; Derogatis, 1984; novices 79.88 ± 50.41, MT 108.25 ± 64.68). All were right-handed volunteers that gave informed consent to procedures that were approved by the Sunnybrook and Women's College Health Sciences Clinical Ethics Committee. Subjects were reimbursed for their participation.

Materials and procedure
Verbal stimuli. Eight sets of six personality-trait adjectives were constructed from a well-established list of personality-trait words (Anderson, 1968; please see Appendix for the word groups). Each of the eight lists of words contained three mildly positive traits and three negative traits (e.g. confident, melancholy), selected from the top and bottom 20% of Anderson's sample (Fossati et al., 2003), as these traits would lend themselves naturally towards self-reference. Word lists were randomly assigned to each self-focus condition.

Training procedure. Participants were first trained on the distinction between experiential and narrative forms of self-focus, derived from Watkins and Teasdale (2001). EF was characterised as engaging present-centred self-reference, sensing what is occurring in one's thoughts, feelings and

body state, without purpose or goal, other than noticing how things are from 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. NF was characterised as judging what is occurring, trying 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 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 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 analyzed for the present report. Training required ∼20–25 min in total. During the experiment each condition lasted for 36 s and was preceded immediately by a 10-s 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 randomised for each participant.

Self-focus task. To enable comparison of these hypothesised 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 s for 4 s in duration. To aid in accessing momentary EF, no overt responses were collected during scanning.

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 analysis of variance (ANOVA), with group (novice *vs* mindfulness trained, MT) and self-focus (narrative *vs* experiential), revealed that NF was easier to employ than EF, $F(1, 34) = 8.59$, $P < 0.007$. Additionally, the MT group found both forms of self-focus easier to engage than the pre-group, $F(1, 34) = 5.54$, $P < 0.03$, with no differential effect of training on ease of engaging a particular self-focus mode, $F(1, 34) < 1$. A further examination of whether the groups differed in a tendency to mind wander during scanning revealed no group differences, $F(1, 34) < 1$.

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 quadrate birdcage head coil. *Functional MRI (fMRI)* was conducted using T2*-weighted single-shot spiral in–out k-space trajectories optimised for sensitivity to the blood-oxygenation-level-dependent (BOLD)effect (TE/TR/flip angle = 30 ms/2000 ms/70°, 20 cm field-of-view (FOV), 5 mm slice thickness, 64×64 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 and 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°, 24 cm FOV with 0.75 phase FOV right-to-left, 256×192 matrix, 124 slices 1.3 mm thick). Stimulus presentation was controlled by Presentation software (Neurobehavioral Systems, Inc., Albany, California, USA) 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 coregistered and re-aligned to correct for small head motions within and between functional scans. Data were then normalised into a common stereotactic reference space (Montreal Neurological Institute, MNI) and spatially smoothed (FWHM = 8 mm). fMRI responses to the presentation of each event type were modelled by a canonical hemodynamic response function scaled relative to the block duration, with the entire 36 s word presentation period modelled as a single 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 $P < 0.001$ were considered; (ii) only clusters of activation including $k \geq 6$ voxels in which all voxels met an uncorrected threshold of $P < 0.005$ were considered, yielding a functional threshold equivalent of $P < 0.001$ according to cluster size significance level corrections (Forman *et al.*, 1995). The cluster volume threshold was based on voxels resampled into an isotropic $4 \times 4 \times 4$ mm space. Group contrast images were overlaid on an average high-resolution FSPGR T1 image for viewing.

Region of interest (ROI) 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 this group showed major differentiation of narrative and EF through the recruitment of a priori regions of interest. The ROI analyses were,
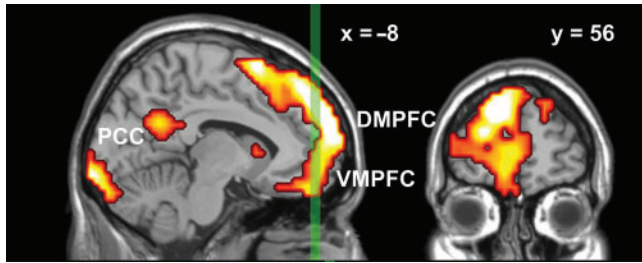
Fig. 1 Cortical midline areas associated with the narrative self focus condition (Narrative > time-series baseline) collapsed across MT (following 8 weeks of MT) and novice (pre MT) groups. VMPFC, ventromedial prefrontal cortex; DMPFC, dorsomedial prefrontal cortex; PCC, posterior cingulate cortex.
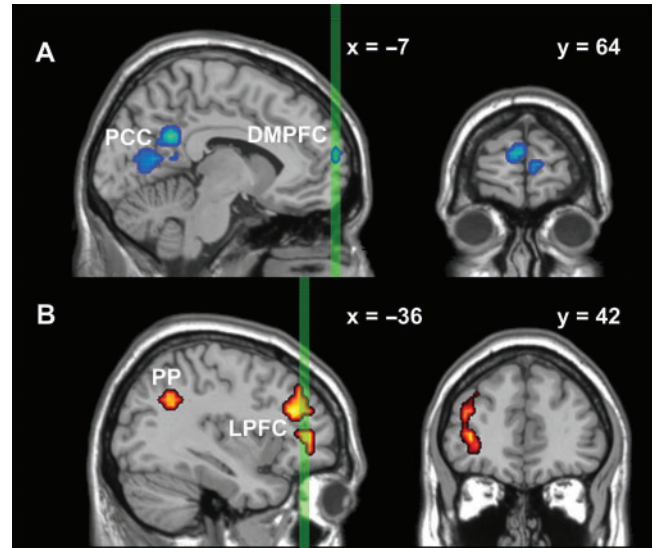

Fig. 2 Experiential and Narrative self-focus conditions in the novice (pre MT) group. (A) Areas of greater association with the Narrative condition (Narrative > Experiential) are in blue, and (B) areas of greater association with the Experiential condition (Experiential > Narrative focus) are in red. VMPFC, ventromedial prefrontal cortex; DMPFC, dorsomedial prefrontal cortex; PCC, posterior cingulate cortex; LPFC, lateral prefrontal cortex; PP, posterior parietal cortex.

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 in each ROI were extracted and submitted to an additional ANOVA. The 5 mm spherical ROIs were derived from peak voxels in each cluster allowing independent examination of contiguous activated regions.

Functional connectivity analyses. Linearly detrended whole-brain time-series activation patterns were compared to activation in a volume of interest (spherical, 5 mm radius) defined in the narrative *vs* experiential contrast in the MT group. Seed voxels were used in a physiophysiological interaction (PPI; Friston *et al.*, 1997) to test for significant correlations with activity in the rest of the brain voxels across the observed time series. Functional connectivity regions of interest were defined by selecting areas that demonstrated significant connectivity differences with the seed ROIs in a comparison between novice and MT groups. These areas were then subjected to more detailed linear regression analysis. Any activation outliers greater than 3 s.d. within a given region were excluded from the time-series data.

RESULTS

Narrative self-focus

To characterise the narrative self-focus state, participants from both the novice and MT groups were collapsed into a single analysis of NF compared to the baseline conditions. Consistent with a higher order and linguistically mediated mode of self-reference and replicating prior studies of self-reference (Craik *et al.*, 1999; Johnson *et al.*, 2002; Kelley *et al.*, 2002; Fossati *et al.*, 2003; Northoff and Bermpohl, 2004; Ochsner *et al.*, 2005), NF resulted in pronounced recruitment of midline cortical structures, including the rostral and dorsal extent of the mPFC (BA 8/9/10/32; at peak height: x, −16; y, 52; z, 36; $Z = 6.75$), and the posterior cingulate (BA 23/31, −8 − 56 24; $Z = 3.91$) (Figure 1), left hemisphere language areas, including the inferolateral PFC (BA 44/45, −56 20 12; $Z = 5.94$) and middle temporal gyrus (BA 21, −64 − 40 − 4; $Z = 5.45$), as well as the left

hippocampus (BA 34, −28 − 24 − 12; $Z = 3.51$) right inferior frontal gyrus (BA 47, 56 32 − 8; $Z = 3.58$), right precentral gyrus (BA 4, 28 − 20 72; $Z = 3.38$), cuneus (BA 19, 0 − 96 32; $Z = 4.12$), and left head of caudate (−12 12 4; $Z = 3.36$) and cerebellum (32, −80, −48, $Z = 6.53$).

Experiential focus: novice participants. We were specifically interested in examining how EF differed from NF in each of the novice and MT groups. Beginning with the novice group, directly contrasting these conditions revealed several focal differences in activation (Figure 2A and B). Relative to narrative self-focus, experiential self-focus was associated with relative reductions in several discrete regions along the cortical midline: gyrus rectus of the subgenual cingulate (BA 25; 27 voxels, 16 16 − 12; $Z = 3.29$), posterior cingulate (BA 23/31; 41 voxels, −8 − 52 28; $Z = 3.29$), and with a lower cluster threshold, a relatively restricted reduction in the rostral mPFC (BA 10; 4 voxels, −4 64 16; $Z = 3.16$). Experiential self-focus was associated with a relative increase in left lateralised regions, yielding significantly greater activations in the dorsolateral PFC (BA 45/46; 23 voxels, −36 32 24; $Z = 3.60$), ventrolateral PFC (BA 47; 11 voxels, −36 40 4; $Z = 3.13$) and posterior parietal cortices (BA 39, 23 voxels, −48 −48 56; BA 40; 9 voxels, −32 − 52 28; $Z = 3.06$).

Experiential focus: mindfulness-trained participants. Increased left-sided dorsolateral and posterior parietal recruitment may reflect greater task-related executive control and attentional allocation (Gusnard *et al.*, 2001) or at the very least, an attempt to resist narrative mind wandering (Mason *et al.*, 2007), rather than the neural correlates of
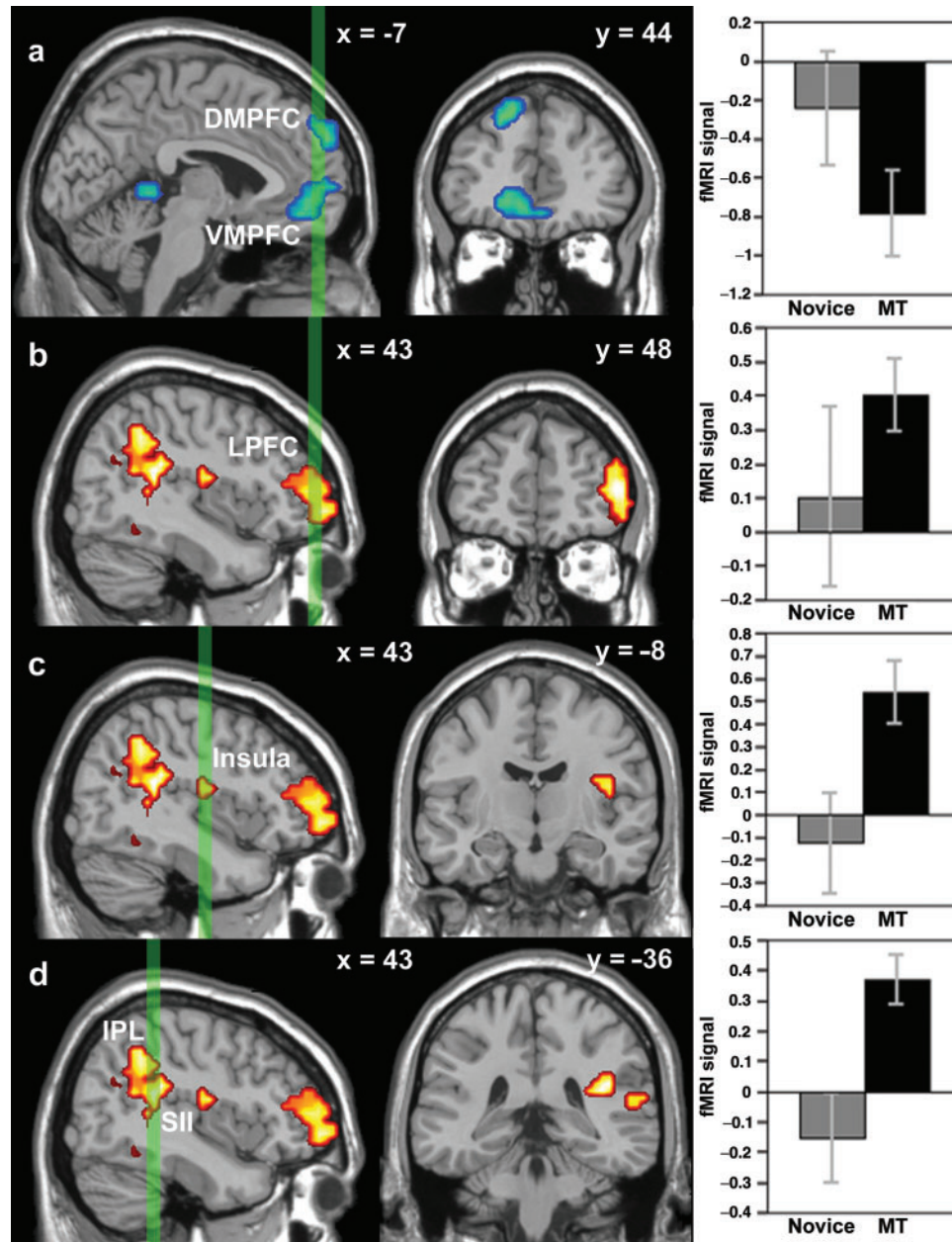
Fig. 3 Experiential *vs* Narrative focus conditions following 8 weeks of MT. Areas of activation showing a greater association with the experiential condition (Experiential > Narrative focus) are in red, and narrative-associated areas (Narrative > Experiential) are in blue: (A) ventral and dorsal MPFC, (B) right LPFC, (C) right Insula and (D) right SII cortex. Bar graphs indicate region of interest analyses of the magnitude of activation associated with the Narrative *vs* Experiential contrast in the MT and novice groups. Left panel green region represents *y* coordinate of each ROI. novice, pre MT group; MT, post MT group; VMPFC, ventromedial prefrontal cortex; DMPFC, dorsomedial prefrontal cortex; LPFC, lateral prefrontal cortex; Insula, insula; IPL, inferior parietal lobule; SII, secondary somatosensory area.

present-centred EF. As such, the above 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 possibility is that dissociable neural markers of self-reference may be more evident following extensive training in present-centred self-focus in the MT group, where engaging distinct modes of self reference may be more effortless.

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

relative to NF, including the rostral subregions of the dorsal mPFC (BA 9/10/32; 87 voxels, −12 56 40; Z = 3.77) and ventral mPFC (BA 10; 86 voxels, 8 68 8; Z = 3.98) (Figure 3A), as well as reduced activity in the left dorsal amygdala (BA 34; 9 voxels, −24 − 8 − 8; Z = 3.20), suggesting that moment-by-moment self-experience may rely on suppression of mPFC cortical representations supporting narrative self-focus. In addition to the mPFC reductions, EF resulted in increased recruitment of a right lateralised cortical network, including the dorsal and inferolateral
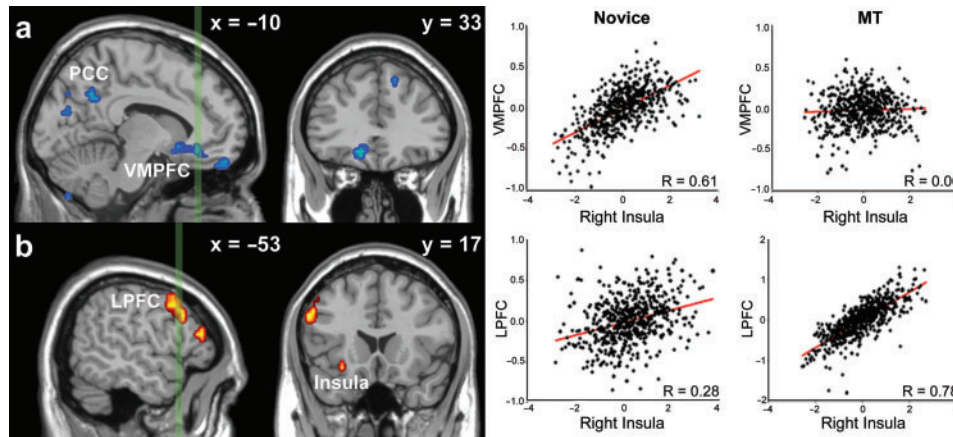
Fig. 4 Functional connectivity in the novice and MT groups. Areas showing reduced connectivity with the right insula (novice > MT) are in blue (A), and areas showing increased connectivity (MT > novice) are in red (B). The right panel demonstrates rank ordered inter-regional correlations with the right insular ROI in both the novice and MT groups. VMPFC, ventromedial prefrontal; PCC, posterior cingulate; LPFC, lateral prefrontal cortex.

PFC (BA 46/45; 77 voxels, 48 56 − 8; $Z = 3.50$), insular cortex (6 voxels, 40 − 8 16; $Z = 3.24$), a region along the supramarginal gyrus consistent with the secondary somatosensory cortex (SII, BA 40; 24 voxels, 40 − 40 20; $Z = 3.61$) extending posteriorly and dorsally into the angular gyrus of the inferior parietal lobule (BA 39; 7 voxels, −36 − 76 48; $Z = 3.11$) (Figure 3B–D). This pattern is consistent with the MT group demonstrating a marked shift from midline mPFC-centred recruitment towards right lateralised prefrontal cortical and paralimbic structures, in particular demonstrating recruitment of hypothesised posterior viscerosomatic representations.

To examine whether the distinct EF regions revealed in the MT group were novel areas of recruitment compared to novices rather than the product of subthreshold but similar patterns of activation, we further performed ROI analyses of activation patterns from each participant in both the MT and novice groups (Figure 3, right panel). Experiential relative to narrative self-focus was associated with significant reductions in the ventral ($F = 11.88$, $P < 0.003$) and dorsal mPFC ($F = 19.09$, $P < 0.001$), in the MT but not the novice group (P's > 0.3). In contrast, experiential self-focus resulted in significantly greater recruitment of the right lateral PFC ($F = 14.75$, $P < 0.001$), right insula ($F = 14.41$, $P < 0.001$), and SII/inferior parietal lobule ($F > 10.28$, $P < 0.003$) in the MT but not the novice group (P's > 0.3).

Functional connectivity analyses. One reason that novices may have difficulty in separately attending to distinct modes of self-awareness is the habitual coupling of viscero-somatic and mPFC representations. To examine this more directly, we assessed functional connectivity between the viscerosomatic 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 (Damasio, 1999; Adolphs, 2002; Craig, 2004; Critchley *et al.*, 2004). An analysis of right insular functional connectivity revealed that

novices demonstrated strong coupling with midline cortical regions, including the orbital sectors of the ventromedial prefrontal cortices (vmPFC) (BA 11; 6 voxels, −4 56 − 24; $Z = 3.68$, $P < 0.001$) ($R = 0.609$, $P < 0.001$), suggesting viscerosomatic signals are by default associated with activation in the vmPFC. 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 ($R = 0.056$, reflecting a significant decrease relative to novices, Fisher's *r* to $Z = 13.36$, $P < 0.001$). 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 ($R = 0.283$) to a very strong correlation ($R = 0.783$, Fisher's *r* to $Z = 12.09$, $P < 0.001$) 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.

DISCUSSION

Consistent with a theory of self-reference as mentalising (Zelazo and Frye, 1998), linguistically mediated (Rochat, 1995) and of higher order executive origin (Craik *et al.*, 1999; Johnson *et al.*, 2002; Kelley *et al.*, 2002; Fossati *et al.*, 2003; Amodio and Frith, 2004; Macrae *et al.*, 2004; Ochsner *et al.*, 2005; Northoff and Heinzel, 2006), participants engaged midline prefrontal cortices (ventral and dorsal mPFC) and a left lateralised linguistic-semantic network (inferior lateral PFC, middle temporal and angular gyri) during NF. Demonstrating a default bias towards NF as previously revealed in 'resting' mind wandering states

(Mason et al., 2007), relatively restricted reductions in the cortical midline network were found when attention was explicitly directed towards a moment-to-moment EF in novice participants with little training in this form of self-reflection. These individuals revealed increased left lateralised prefrontal-parietal activations during EF likely reflecting greater task-related linguistic processing that has been shown to be associated with decreased medial prefrontal recruitment (Gusnard et al., 2001).

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 centred 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, EF resulted in a pronounced shift away from midline cortices towards a right lateralised network comprised of the ventral and dorsolateral PFC, as well as right insula, 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: (i) higher order self-reference characterised by neural processes supporting awareness of a self that extends across time and (ii) more basic momentary self-reference characterised 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 (Damasio, 1999; Craig, 2004; Critchley et al., 2004; Panksepp, 2005). In contrast, the narrative mode of self-reference may represent an over-learned mode of information processing that has become automatic through practice, consistent with established findings on training-induced automaticity (MacLeod and Dunbar, 1988).

Altered cortical midline activation, particularly in the vmPFC, has been associated with judgements of self-relevance (Phan et al., 2004), as well as appreciation of emotional valence, ranging from simple sensory to more complex and abstract events (O'Doherty et al., 2001; Anderson et al., 2003; Cunningham et al., 2004). As this region receives connections from all exteroceptive (Barbas, 2000) and interoceptive modalities (Carmichael and Price, 1996), it has been viewed as a polymodal convergence zone (Rolls, 2000), supporting the integration of external and internal stimuli with judgements about their affective relevance to the self (Ochsner and Gross, 2005). Following MT, EF resulted in a shift away from both the vmPFC and the amygdala, toward more lateral prefrontal regions supporting a more self-detached and objective analysis of interoceptive (insula) and exteroceptive (somatosensory cortex) sensory events, rather than their affective or subjective self-referential value. This pattern mirrors neural dissociations between the affective and sensory components of pain sensation, with the former supported by anterior midline structures, and latter supported by posterior lateral sensory cortices (Rainville et al., 1997). This detached or objective mode of self-focus may be aided by the recruitment of the right angular gyrus of the inferior parietal lobule. In addition to studies showing that this region is involved in switching between first and third person perspectives (Ruby and Decety, 2004), stimulation of this region has been associated with 'out of body experiences' (Blanke et al., 2002) where an individual experiences stepping outside of themselves, affording a detached perspective on their corporeal self. Altered access to these posterolateral body schema representations may underlie neurological conditions such as anosognosia or de-personalisation syndrome (Berlucchi and Aglioti, 1997), where there is loss of body ownership, with the body no longer being perceived as belonging to the 'self'.

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 (Miller and Cohen, 2001; Gray et al., 2002); 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 hypothesised to reflect a global representation of interoceptive activity (Craig, 2004). In conjunction with the SII cortex, these regions have been argued to serve as somatic markers (Damasio, 1999; Adolphs, 2002), enabling a cortical representation of body state (Damasio, 1999; Craig, 2004).

It is important to underscore that although a present-centred 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 EF participants were instructed to maintain a broad attentional focus centred on momentary experience, including internal thoughts, emotions and external sensory events, in addition to bodily sensations. 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.*, 2007), 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 MT *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-centred 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 decentring is a pervasive, trait-like training effect resulting in chronic suppression of the mPFC-centred network, or whether instead MT results in greater voluntary, but state-like, suppression of an otherwise undiminished mPFC-centred 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. This hypothesised cortical reorganization following MT is consistent with the notion that MT allows for a distinct experiential mode in which thoughts, feelings and bodily sensations are viewed less as being good or bad or integral to the 'self' and treated more as transient mental events that can be simply observed (Williams *et al.*, 2007). As such, the capacity to disengage temporally extended narrative and engage more momentary neural modes of self-focus has important implications for mood and anxiety disorders, with the narrative focus having been shown to increase illness vulnerability (Segal *et al.*, 2006). Conversely, a growing body of evidence suggests approaching self-experience through a more basic present-centred focus may represent a critical aspect of human well-being (Davidson, 2004).

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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).

Word	Lik	Var	Mean
Bitter	162	0.79	376
Envious	157	0.77	364
Antisocial	144	1.24	358
Productive	468	0.81	362
Lively	466	0.75	360
Delicate	467	0.78	361
Angry	169	0.9	374
Resentful	150	0.9	352
Lifeless	127	0.68	354
Mature	522	0.66	344
Decisive	427	1.03	360
Ambitious	484	1.14	378
Unhappy	203	0.98	376
Abusive	100	0.83	330
Incompetent	110	0.68	364
Sensitive	358	2.00	354
Daring	360	1.03	358
Athletic	384	0.75	385
Nervous	196	0.83	380
Cowardly	110	0.82	374
Indecisive	219	0.90	376
Powerful	357	0.87	345
Energetic	457	0.81	384
Hopeful	406	0.92	328
Foolish	140	0.83	348
Moody	182	1.36	370
Insecure	198	0.75	370
Emotional	283	1.23	376
Tolerant	461	0.91	372
Cheerful	504	0.83	372
Cruel	40	0.54	376
Pessimistic	164	1.06	376
Unkind	66	0.71	378
Independent	455	1.32	374
Talented	478	0.84	368
Fearless	366	1.12	358
Shallow	118	1.00	332
Clumsy	199	0.92	376
Unskilled	224	0.71	360
Positive	403	1.28	342
Outgoing	412	1.46	364
Sociable	429	0.85	360
Fearful	214	0.69	370
Depressed	166	1.01	370
Unreliable	104	0.93	386
Patient	478	0.70	376
Idealistic	384	1.35	350
Industrious	322	1.54	342

Lik, likability rating; Var, variance of likability ratings; Mean, meaningfulness.