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Neural correlates of mindful self-awareness in mindfulness meditators and meditation-naïve subjects revisited

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ABSTRACT

Mindful self-awareness is central to mindfulness meditation and plays a key role in its salutary effects. It has been related to decreased activation in cortical midline structures (CMS) and amygdala, and increased activation in somatosensory regions. However, findings in untrained individuals are contradictory, and scarce in experienced meditators.

Using fMRI, we investigated experienced mindfulness meditators (LTM, $n = 21$, average 4652 practice-hours) and matched meditation-naïve participants (MNP, $n = 19$) during short periods of mindful self-awareness (FEEL) and self-referential thinking (THINK).

We report somatosensory activations and decreases in CMS during FEEL for both groups, but significantly stronger decreases in prefrontal CMS in LTM. LTM further showed decreases in language-related and amygdala regions, but the latter was not significantly different between groups. Overall, higher activations in amygdala and mid-line regions during FEEL were related to levels of depressiveness.

Neural patterns of mindful self-awareness emerge already in MNP but more pronounced in LTM. Specifically, meditation training might reduce self-reference and verbalization during mindful awareness. We further corroborate the suggested link between mindfulness and healthy self-related functions on the neural level. Longitudinal studies need to corroborate these findings.

1. Introduction

Mindfulness meditation and clinical mindfulness programs teach a non-judgmental present-moment awareness towards experiences, in particular towards sensations, feelings, and thoughts (Baer et al., 2006; Kabat-Zinn, 2006). Mindful awareness of such self-related processes can be contrasted with cognitive self-related functions, which create self-knowledge and a coherent sense of self over time (Gallagher, 2000). Indeed, most theories of different aspects of the self distinguish a present-moment, experiential self from cognitive, self-defining functions (Damasio, 1999; James, 1890; Neisser, 1988; Northoff and Bermpohl, 2004).

These forms of self-related processes are also relevant for clinical psychology. Research suggests that a strong cognitive self-focus might be related to pathological forms of self-reference, like increased negative mood (Mor and Winquist, 2002), rumination (Nolen-Hoeksema et al., 2008) and depressive symptoms (Northoff, 2007). In contrast, present-moment self-awareness has been linked to more adaptive self-processing and less rumination (Baer, 2009; Jain et al., 2007), thus illustrating a fundamental mechanism through which mindfulness training could exert its salutary effects on mental health (Gu et al., 2015).

On the neurobiological level, cognitive self-reference has been linked to brain activations in cortical mid-line structures (CMS) (Farb et al., 2007; Herwig et al., 2010; Northoff et al., 2006), and aberrant activity in these regions was related to depression in self-referential tasks (Lemogne et al., 2012) and during rest (Whitfield-Gabrieli and Ford, 2012).

There is evidence that mindfulness training changes neural correlates of self-referential processes (Brewer et al., 2011; Hölzel et al., 2011; Lutz et al., 2016; Tang et al., 2015), however this evidence builds on few studies (Tang et al., 2015). One study found that mindfulness training in the form of a 8 week mindfulness-based stress reduction program (MBSR) lead to altered neural processes during self-reference (Farb et al., 2007): MBSR participants

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showed reliably different neural activations between mindful self-awareness of general trait adjectives (experiential self) compared to cognitive self-evaluation of the same stimuli (narrative self), namely a shift away from CMS towards right sensory cortex activations during the experiential compared to the narrative self-focus. In meditation-naïve subjects, this shift was less pronounced and Farb et al. (2007) concluded that subjects without mindfulness training probably did not enter a mindful self-awareness reliably different from cognitive self-reference.

Our group studied similar states of mindful self-awareness (here called FEEL) and cognitive self-related thoughts (here called THINK) in participants without mindfulness training (Herwig et al., 2010). The design did not involve stimuli and employed shorter blocks, in order to facilitate mindful self-aware states. Results revealed reduced activations during FEEL compared to THINK in the prefrontal CMS (BA 9) and the amygdala region, along with activations in somatosensory areas. With this design, CMS deactivation in mindfulness-naïve participants seemed more robust than reported by Farb et al. (2007), and we identified somatosensory activations which were only reported after MBSR training by Farb et al. (2007). Other divergent findings in meditation-naïve participants were related to increased left DLPFC activations (Farb et al., 2007) and increased activations in left inferior frontal and pre-SMA/DMPFC (Herwig et al., 2010) (see Supplementary Material A, Table 1 for an overview of the most important findings per region). Results implicate that in meditation-naïve participants a language based testing paradigm might predispose individuals towards cognitive self-processing, whereas meditators might be less influenced by the experimental context.

The goal of the current study was to probe if meditation-naïve subjects show qualitatively similar somatosensory activations and reductions in CMS as meditators, during mindful self-aware states, when these are not initiated by language-related stimuli. Further, we wanted to verify potential meditation-practice related changes in these networks. Our knowledge of practice-related changes is mainly based on cross-sectional results with MBSR participants. To our knowledge, no study has looked at cross-sectional differences in neural activations during these two self-modes in longer-term, regular mindfulness meditators.

Using an adapted version of Herwig et al.'s (2010) experiment, the current study assessed differential neural correlates between FEEL and THINK in meditation-naïve participants and in mid-to-long-term meditators. Importantly, we directly compared whole-brain analyses between groups to reach conclusions about statistically significant group differences. Based on the discussed previous findings, we hypothesized decreased activation in CMS and amygdala, and increased sensory cortex and posterior insula activation in both groups during the FEEL condition, while we also expected to find differences between the groups in these regions and lateral prefrontal regions, namely in DLPFC and inferior prefrontal regions. Additionally, affective ratings were acquired during the experiment to gain insights into the subjective experience during THINK and FEEL.

In follow-up analyses we assessed how group differences during FEEL might be related to differences in verbal labeling of experience. We further analyzed how depression scores in our healthy sample were related to activations during FEEL, to potentially gain translational insights into the clinical relevance of mindful awareness.

2. Materials and methods

2.1. Subjects

We recruited 22 mid-to-long-term meditation practitioners (LTM, ages: 28–67, *Mean* = 47, *SD* = 11.11, 10 female). LTM had at least 3 years of meditation experience with a minimum of 1 year in Vipassana, a current practice of at least 1 h per week and retreat experience in Vipassana (minimum duration 3 days). Meditation experience was assessed in a structured self-report screening.

We matched LTM with 22 nearly or completely meditation-naïve participants (MNP, ages: 29–64, *Mean* = 45.45, *SD* = 10.94, 8 female) for age, gender, years of education, highest degree, general field of occupation, and a short German version of an intelligence test (Mehrfachwahl-Wortschatz-Intelligenztest, Lehrl, 1977). All subjects were right-handed according to the Annett hand preference scale (Annett, 1970), with no prior or current neurological or psychiatric illnesses (self-report). Further exclusion criteria were intake of medication (except for oral contraceptives), psychotropic drugs, regular consumption of alcohol >6 units/week, cigarettes >0.5 pack/day and general contraindications against MRI examinations. The study was approved by the ethics committee of the canton of Zurich and conducted in compliance with the Declaration of Helsinki (World Medical Association, 1992). All participants gave written informed consent and received financial compensation.

Subjects with more than 1.5 mm of head movement in one direction were excluded from further analysis, resulting in 40 subjects (LTM = 21, MNP = 19). The analyzed sample still fulfilled our matching criteria. For an overview of the analyzed sample's sociodemographic data see Table 1. The included LTM had an average of 4652.33 lifetime practice hours in Vipassana or related open monitoring meditation practices (Lutz et al., 2008) (range 281–18,325). For full disclosure of meditation experience in both groups see Supplementary Material B.

2.2. Image acquisition

Scanning was performed at the University Hospital of Psychiatry (Zurich, Switzerland) using a 3-T Philips Intera whole-body MR unit equipped with an Philips SENSE head coil. For each participant, 370 echo-planar whole-brain images were acquired (repetition-time (TR)/echo-time (TE): 2000/25 ms, 30 sequential axial slices, slice thickness: 3.0 mm, gap 1.1 mm, field of view (FOV): 240 × 240 mm, matrix 80 × 80 voxel, resulting voxel size: 3 mm × 3 mm × 3 mm, SENSE-factor: 2.0). The first four scans were discarded due to T2 saturation effects. Further, we acquired a T1-weighted high-resolution image (TR/TE 6.73/3.1 ms; voxel size 1 mm × 1 mm × 1 mm, 145 slices, axial orientation).

2.3. Questionnaires

Within a week before scanning, participants completed a set of questionnaires via online investigation tool (Unipark, QuestBack).

Of particular interest for this study were *trait mindfulness* assessed by the Five Facets Mindfulness Questionnaire (Baer et al., 2006, German version: Translation by Ströhle et al., 2010, KIMS-D-Items, 2010; Michalak et al., 2008). Further, we assessed *depressive symptoms*, using the Zung Self-rating Depression Scale (SDS, Zung, 1965, German version: Zung, 2005), the ability to identify and describe emotions with the Toronto Alexithymia Scale (TAS, Taylor et al., 1985, German version, Bach et al., 1996) and participant's sociodemographics, and experience with meditation and related techniques.

Before scanning we assessed participant's affective state by administering the Positive and Negative Affect Schedule PANAS (Watson et al., 1988, German version Krohne et al., 1996). After scanning, participants were asked about general experience during scanning, how successfully they thought they completed the task and whether they experienced the FEEL condition mostly verbally (i.e. labeling their experience) or non-verbally (simply experiencing). Answers were given on a 9-point Likert scale.