Functional and structural neurobiological consequences of mindfulness meditation

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Introduction

Mindfulness is a meditative technique that utilizes observation of interoceptive processes e.g., breath monitoring and open observation of thoughts.

Based on these methods employed, it has been postulated that this technique could be useful as a therapeutic intervention for some mental disorders characterized by displaced self or emotional awareness, as well as an inability to maintain focus on cognitive tasks, such as those who suffer from various forms of anxiety or drug addiction [1-4].

While a few meta-analytic studies have investigated the neural impact of various types of meditation [3,5,6], none have specifically compared and contrasted the functional and structural impacts of mindfulness techniques. Here, we sought to elucidate the functional and structural neurobiological impact of mindfulness manipulations through meta-analytic investigation using the Activation Likelihood Estimation (ALE) framework [7-9]. We hypothesized that mindfulness manipulations would enhance functional activation and gray matter volume in areas associated with attention monitoring (e.g., frontal cortex) and interoceptive processes (e.g., insula).

Methods

We conducted three separate ALE meta-analyses.

1) **Functional:** mindfulness task condition and a control condition, or long-term mindful practitioners (greater than 1 year of practice) versus novices performing any type of task.
   - 229 foci from 21 studies involving 492 participants.
2) **Structural:** increased gray matter in long-term mindfulness practitioners versus novices.
   - 27 foci from 10 studies involving 434 participants.
3) **Interoceptive:** exploratory analysis to characterize the neural correlates of specific interoceptive tasks including breath or heart rate monitoring.
   - 67 foci from 8 studies involving 124 participants.

Modeled activation for each analysis (voxel-level $p<0.005$; minimum cluster size: functional mindfulness $520mm^3$, structural mindfulness $546mm^3$, interoception $392mm^3$).

Results

1) Functional (Figure 1.A)

- Bilateral insula
- Left Superior Frontal Gyrus
- Right Middle Frontal Gyrus
- Left Parahippocampal Gyrus
- Left Inferior Frontal Gyrus
- Right Anterior Cingulate Cortex

2) Structural (Figure 1B)

- Right insula
- Bilateral Anterior Cingulate Gyrus
- Thalamus
- Fusiform Gyrus

3) Interoception (Figure 1C)

- Bilateral insula
- Right Inferior Frontal Gyrus
- Medial Frontal Gyrus
- Precentral Gyrus

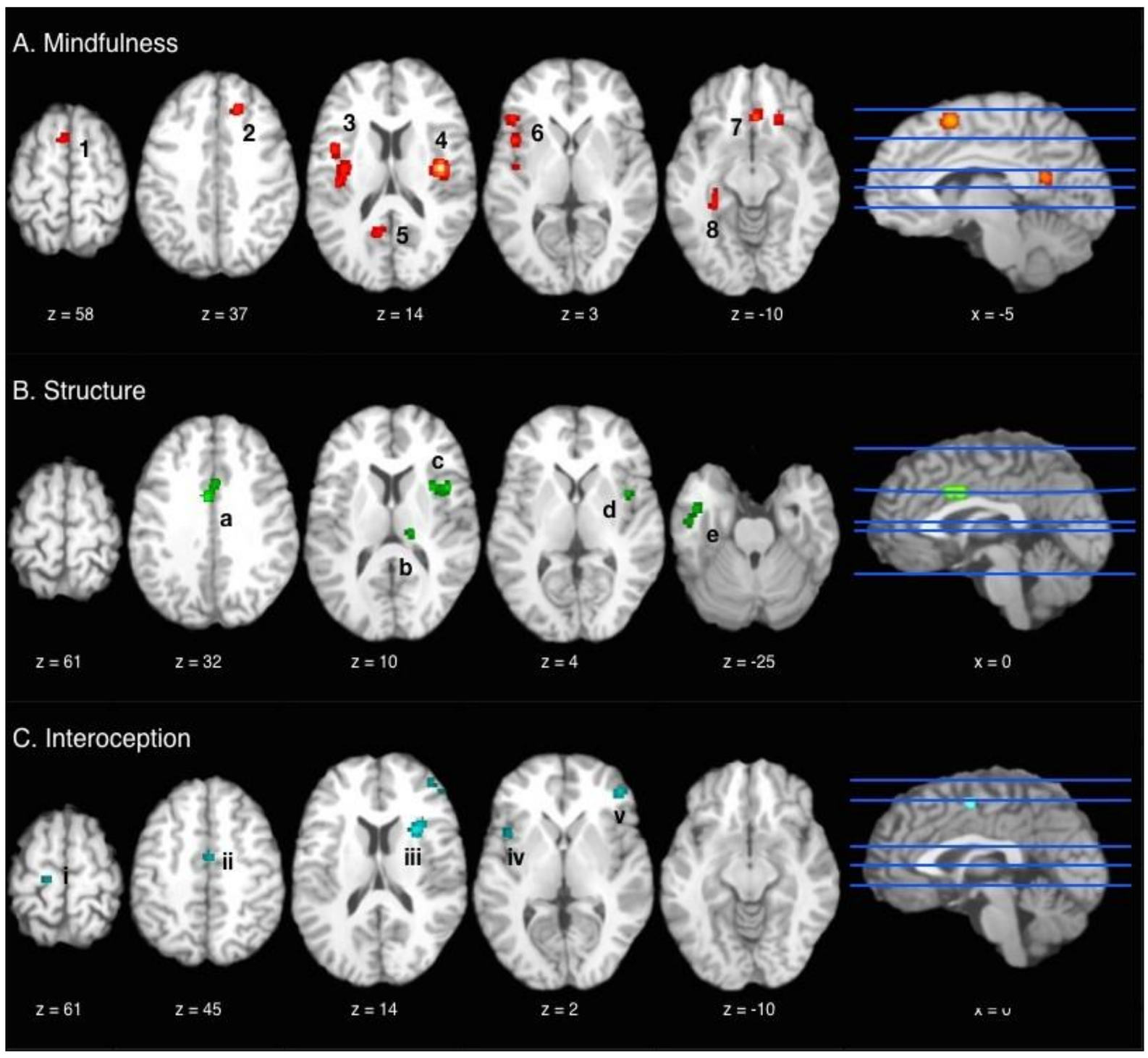

Figure 1. A. Combined analysis of experiments comparing task (mindfulness > control) and group (experienced meditators > novices). Prominent areas include: 1. Superior Frontal Gyrus, 2. Middle Frontal Gyrus, 3 & 4. Bilateral Insula, 5. Posterior Cingulate, 6. Inferior Frontal Gyrus, 7. Anterior Cingulate and 8. Parahippocampus. **B**. Analysis of structural gray matter volume increase. Prominent areas include: a. Anterior Cingulate Gyrus, b. Thalamus, c and d. right Insula and e. Fusiform Gyrus. **C**. Analysis of interoception tasks including breathing and heart rate monitoring. Prominent areas include: i. Precentral Gyrus, ii. Medial Frontal Gyrus, iii & iv. Bilateral Insula and v. Inferior Frontal Gyrus.

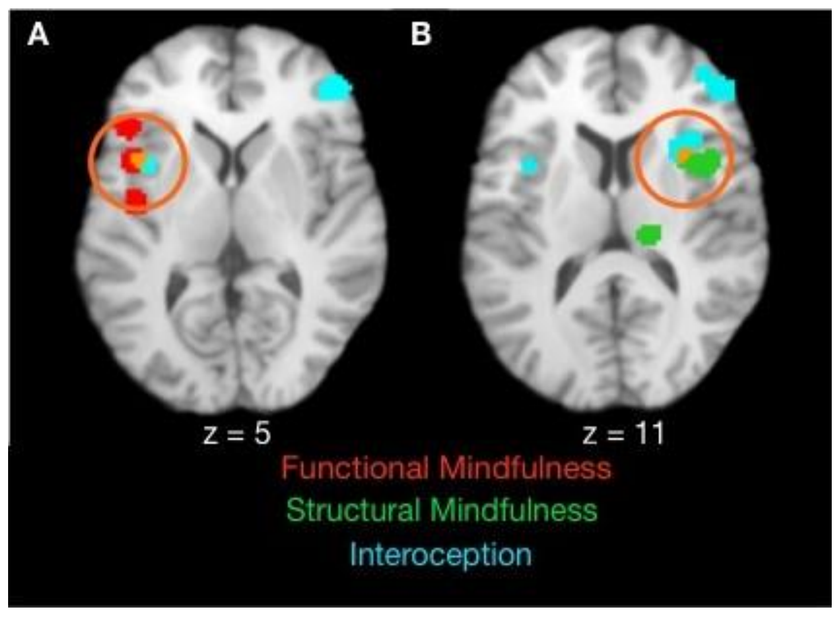

Figure 2. The results from the interception analysis overlapped with those from the functional analysis (A) in the left insula and the structural analysis (B) in the right insula.

Discussion

Mindfulness manipulations are associated with increased activity and grey matter volume in multiple dissociable brain regions. Our results support the idea that:

- Meditation augments areas previously linked with attention processes (i.e., frontal cortex) and interoceptive awareness (i.e., insula).
- Regions are also associated with a number of other psychological processes including emotion, addiction, mental as well as physical self- awareness, interpersonal experience and psychopathology[10].
- Neurobiological evidence supporting further consideration of mindfulness-based practices as a therapeutic intervention for neuropsychiatric disorders such as anxiety and drug addiction.

References

1. Baer, R.A. (2003), 'Mindfulness Training as a Clinical Intervention: A Conceptual and Empirical Review', *Clinical Psychology: Science and Practice, vol. 10, no. 2,* pp. 125-143.
2. Goldin, P.R. (2010), 'Effects of Mindfulness-Based Stress Reduction (MBSR) on Emotion Regulation in Social Anxiety Disorder', Emotion, vol. 10, no. s 1, pp. 83-91.
3. Grossman, P. (2004), 'Mindfulness-based stress reduction and health benefits: A meta-analysis', *Journal of Psychosomatic Research, vol. 51, no. 1*, pp. 35-43.
4. Brewer, J. A., Elwafi, H. M., & Davis, J. H. (2013). Craving to quit: psychological models and neurobiological mechanisms of mindfulness training as treatment for addictions. *Psychology of Addictive Behaviors: Journal of the Society of Psychologists in Addictive Behaviors*, *27*(2), 366–379. http://doi.org/10.1037/a0028490
5. Boccia, M. (2015), "The Meditative Mind: A Comprehensive Meta-Analysis of MRI Studies', *BioMed Research International, vol. 2015*, article ID 419808, 11 pages.
6. Tomasino, B. (2013), 'Meditation-related activations are modulated by the practices needed to obtain it and by the expertise: an ALE meta-analysis study', *Froniers in Human Neuroscience, vol. 6:*346.
7. Eickhoff, S.B. (2009), 'Coordinate-based activation likelihood estimation meta-analysis of neuroimaging data: A random-effects approach based on empirical estimates of spatial uncertainty', *Human Brain Mapping, vol. 30*, pp. 2907-2926.
8. Laird, A.R. (2005), 'ALE meta-analysis: controlling the false discovery rate and performing statistical contrasts', *Human Brain Mapping, vol. 25*, pp. 155-164.
9. Turkeltaub, P.E. (2002), 'Meta-analysis of the functional neuroanatomy of single-word reading: Method and validation', *Neuroimage, vol. 16*, pp. 765-780.
10. Lutz, A. (2007), 'Meditation and the neuroscience of consciousness: an introduction',*The Cambridge Handbook of Consciousness,* Cambridge University Press, Cambridge, UK, pp. 499–554.

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