Neurocircuitry, meditation, and mind-wandering: Distinct fMRI connectivity approaches contribute to biological understandings of conscious thought

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Overview

Objective: To understand how meditative practices facilitate changes in neurocircuitry with implications for ongoing conscious thought.

Approach: Compare methods of fMRI connectivity analysis across resting- and focused-attention mental states.
- Study 1: Examined how meditation alters large-scale brain networks in vivo
- Study 2: Examines associations between affect dynamics, attention, and resting state connectivity as a function of MBSR

What is internally-directed cognition?

- Refers to stimulus-independent thought
- May occur with or without intention
- The nature of internally-directed cognition is directly implicated in psychopathology
- Observing internal thought processes is one of the directives of mindfulness and meditation

Examples of internally-directed cognition

- Dreaming
- Rumination
- Mind-wandering
- Problem-solving
- Collective well-being

Measuring the dynamics of internally-directed cognition

- Ecological Momentary Assessment (EMA): a method for measuring the dynamics of ongoing cognition
- How does attention to internal cognition alter the trajectory of moment-to-moment emotions?

Dynamic mode

- Affective Instability (AI)
- Fluctuations in positive/negative affect
- By the amplitude of moment-to-moment affect

Calculation

- Correlation between Attention and Arousal Instability
- Correlation between Attention and Emotional Instability

Clinical relevance

- Reduced AI: Lower cognitive load
- Reduced AI: Reduced rumination
- Reduced AI: Reduced mind-wandering
- Reduced AI: Reduced emotional reactance

Outstanding Questions

- How can we begin to relate brain networks to environmental systems (i.e., social networks)?
- How can we leverage knowledge of internally-directed cognition to promote prosocial behavior?
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Study 1. Measuring mindful brain states: Group independent component analysis

- Aim: To explore how first time exposure to mindfulness alters large-scale networks.
- Methods: fMRI data was collected while engaging in an 8-minute focused attention meditation (n = 50) or relaxation instruction (n = 50) (control).
- Results: Findings suggested that mindfulness elicited changes in large-scale networks associated with internal cognition, executive functioning, and somatosensory awareness

Relative to relaxation (control), mindfulness instruction increased intra-network connectivity within components of the Frontoparietal Control Network and Salience Network

Compared to relaxation (control), mindfulness instruction reduced functional coherence within the Default Mode Network

Study 2. Relating internally-directed cognition to brain-based mechanisms: A graph theory approach

Research questions:

- Is there an association between emotion and attention dynamics as measured through ecological momentary assessment?
- How does resting state functional connectivity indices determine who responds to mindfulness-based interventions?

What is graph theory?

- A graph theory is a mathematical approach to characterizing the properties of brain networks
- A graph theory: Networks are defined by nodes (i.e., parcellated regions) and edges (i.e., functional connections between nodes).
- Some graph theory indices include: participant coefficient (PC), degree, within-module degree (WMD), and modularity
- Modularity: The extent to which brain sub-networks are segregated (vs. integrated) from other sub-networks
- Brain network modularity has been linked to intervention-related gains.

Comparison to other network-based indices (Rahrig et al., 2022)

- A recent meta-analysis examined seed-based resting-state functional connectivity changes resulting from standard mindfulness training
- Results suggested that mindfulness-based interventions increased cross-network connectivity between the Salience Network (SN) and Default Mode Network (DMN).

Outstanding Questions

Neuroimaging

- How can dynamic resting state functional connectivity approaches contribute to our understanding of ongoing conscious thought?
- Can neural signatures of first-time exposure to meditation be used to predict outcomes of long-term meditation training?

Phenomenology

- What is the optimal sampling resolution for measuring dynamic internally-directed cognitions? What is the minimally sufficient sampling rate?
- What approaches can we use to capture context as it occurs in daily life?

Collective well-being

- Are the network-based indices described here invariant across different populations?
- How can we begin to relate brain networks to environmental systems (i.e., social networks)?

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View Appendix for further information on Study 1 and 2 methods and results