Mind wandering and attention during focused meditation: a fine-grained temporal analysis of fluctuating cognitive states

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**Headline**

**Default Mode Network**
Research has shown that a distributed neural network is active during the rest periods of neuroimaging experiments, known as the default mode network (DMN). This is made up of dorsal and ventral medial prefrontal cortex (PFC), posterior cingulate cortex and precuneus, posterior inferior parietal regions, lateral temporal cortex, and the hippocampal formation including the para-hippocampus. Several reports have implicated the DMN specifically in mind wandering, a mental state that has been studied during undirected cognition, or intermittently during periods of sustained attention. Studies have found that people with a greater tendency to mind wander have higher activity in DMN regions during repetitive tasks, however, relatively little is known about the underlying neural mechanics of mind wandering.

**Attention Network**
Research also suggests that there is an area of the brain active when we engage in attention-demanding tasks focused on the external environment. This is made up of the lateral PFC, premotor cortex, lateral parietal regions, occipital regions, anterior cingulate cortex (ACC), and insula. Previous research has found that the DMN and attentional networks work together in a regular pattern at opposing functions. For example, mind wandering often occurs at rest, but often interrupts tasks requiring continued attention, suggesting fluctuations between DMN and attention network activity affecting the cognitive states.

**Meditation**
There is a lot of previous research into the attentional mechanisms behind meditation and interdisciplinary scientific discussion has recently started about possible cognitive and physiological mechanisms of meditation and its potential benefits for physical and mental health, for example, as a means of understanding and possibly enhancing attention. When meditating, the aim is to help the practitioner improve awareness of his/her cognitive states while developing attentional control. When attempting to focus on a subject, such as the breath, an individual inevitably experiences mind wandering. At some time during mind wandering, the practitioner becomes aware that his/her mind is
not on the subject, at which point he/she disengages from the current train of thought and shifts attention back to the object, where it stays focused again for some period of time.

The model in this article proposes that during focused attention meditation, individuals’ subjective experience follows this structure and the researchers have named each of the phases MW (for when mind wandering occurs), Aware (the awareness of mind wandering), Shift (changing from mind wandering back to focussing) and Focus (for the times when attention is firmly on the original, intended subject). Focused attention meditation involves a type of multitasking, or voluntary task switching between MW and Focus.

**Method**

14 right handed meditation practitioners were asked to meditate, focussing on their breathing for 20 minutes in the fMRI scanner, with their eyes closed. Participants were all familiar with basic breath-focus meditation, readily understanding and performing the task. They pressed a button whenever they realised their mind had wandered away from focussing on their breathing. The researchers constructed a cognitively defined baseline and three 3-second intervals based on participants’ self-report of perceived time to become aware of mind wandering and return the focus to the breath. The 3 seconds interval containing the button press made up the Aware phase, corresponding to awareness of mind wandering. The two intervals before the Aware phase were cognitively defined as MW and were treated as baseline in the general linear model. The two intervals after the Aware phase made up the Shift phase and finally, the two intervals following the Shift phase made up the Focus phase, representing maintenance of focused attention on the breath.

To investigate whether practice time was associated with brain activity during the meditation task, the number of hours for each subject was entered as a covariate in an ANCOVA for each phase.

**Results**

The average number of button presses during the meditation task was 15.5 representing an average of one reported mind wandering event every 80 s over the 20-minute meditation session. The number of button presses did not correlate significantly with practice time.

All in all, the research detected activity in brain regions associated with the task-positive attention network during Aware, Shift and Focus phases and activity during MW in brain regions frequently associated with the DMN.

During the Aware phase, a cluster in the left inferior temporal gyrus was positively associated with practice time, indicating that more meditation experience was associated with more activity in this area.

**Conclusions**

A better understanding of the dynamics between mind wandering and attention would have importance for numerous clinical populations in which these processes and associated networks are disregulated. Results of this study suggest that repeated meditation practice may alter relevant brain networks. This study also provides a method in which first person subjective information can be used in fMRI paradigms to reveal a finely detailed picture of cognitive states as they fluctuate in real time.