

Christoff, K., Gordon, A. M., Smallwood, J., Smith, R., & Schooler, J. W. (2009). Experience sampling during fMRI reveals default network and executive system contributions to mind wandering. *Proceedings of the National Academy of Sciences*, 106(21), 8719-8724.

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When the mind wanders off, where does the brain go? Christoff and colleagues investigated this question by scanning the brains of 15 participants (average age=22) using fMRI while they performed a long, repetitive task conducive to mind wandering. For approximately 2 hours, participants saw single digits appear every 2 seconds and were instructed to press a button each time a number appeared, except for the number "3" (which appeared infrequently, only 5% of the time). In addition to objective brain imaging methods, participants' subjective experience of mind wandering was assessed with probes interspersed at unpredictable times during the task (averaging once a minute) to catch participants mind wandering. Participants were asked "Where was your attention focused just before the probe?" and "How aware were you of where your attention was focused?" Participants reported being off-task 43% of the time, and of these times, reported being unaware of where their attention had been 45% of the time.

Concurrent experience sampling and fMRI scanning allowed researchers to tag and compare brain activity in the 10 seconds preceding on-task (when attention was focused on the numbers task) and off-task (when attention was not focused on the task at hand) reports. This comparison provided a snapshot of activity unique to the mind wandering episodes preceding off-task reports, revealing what was different about the mind wandering brain. Off-task reports were preceded by greater activity in a set of brain areas (including the medial prefrontal cortex [mPFC], precuneus, and others) known as the default network, named for its tendency to be more active when there is no external task to do - the very times mind wandering is most frequent.

In this study researchers also validated participants' reports of being off-task with objective measures. They found that task errors reflective of being on "auto-pilot" (pressing during the number 3) were, like off-task reports, preceded by increased activity in the mPFC of the default network. In addition, these errors were more likely to occur in the interval before an off-task report. The similarity in brain activity and timing of subjective and objective measures of mind wandering indicated that participants reported episodes of mind wandering accurately.

In addition to default network activity, mind wandering was also associated with greater activity in brain areas commonly active during demanding mental activity and conflict (specifically, the "executive network" which includes the dorsolateral prefrontal cortex and dorsal anterior cingulate cortex). Moreover, these areas of the executive network, along with the default network, were even more active when participants mind wandered without being aware that they were mind wandering. Researchers speculated that mind wandering can consume attention in an attempt to resolve personal concerns and conflicts, and may do so even more in the absence of awareness (however, empirical testing is required to validate such hypotheses).

These findings, for the first time, link a neural signature with online reports of mind wandering during fMRI scanning. Further, they suggest the importance of awareness in moderating the brain activity associated with mind wandering.