Where do our minds wander? Brain waves can point the way

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Anyone who has tried and failed to meditate knows that our minds are rarely still. But where do they roam? New research led by UC Berkeley has come up with a way to track the flow of our internal thought processes and signal whether our minds are focused, fixated or wandering.

Using an electroencephalogram (EEG) to measure brain activity while people performed mundane attention tasks, researchers identified brain signals that reveal when the mind is not focused on the task at hand or aimlessly wandering, especially after concentrating on an assignment.

Specifically, increased alpha brain waves were detected in the prefrontal cortex of more than two dozen study participants when their thoughts jumped from one topic to another, providing an electrophysiological signature for unconstrained, spontaneous thought. Alpha waves are slow brain rhythms whose frequency ranges from 9 to 14 cycles per second.

Meanwhile, weaker brain signals known as P3 were observed in the parietal cortex, further offering a neural marker for when people are not paying attention to the task at hand.

"For the first time, we have neurophysiological evidence that distinguishes different patterns of internal thought, allowing us to understand the varieties of thought central to human cognition and to compare between healthy and disordered thinking," said study senior author Robert Knight, a UC Berkeley professor of psychology and neuroscience.

The findings, published this week in the *Proceedings of the National Academy of Sciences* journal, suggest that tuning out our external environment and allowing our internal thoughts to move freely and creatively are a necessary function of the brain and can promote relaxation and exploration.

Moreover, EEG markers of how our thoughts flow when our brains are at rest can help researchers and clinicians detect certain patterns of thinking, even before patients are aware of where their minds are wandering.

"This could help detect thought patterns linked to a spectrum of psychiatric and attention disorders and may help diagnose them," said study lead author Julia Kam, an assistant professor of psychology at the University of Calgary. She launched the study as a postdoctoral researcher in Knight's cognitive neuroscience lab at UC Berkeley.

Another co-author on the paper is Zachary Irving, an assistant professor of philosophy at the University of Virginia who explored the psychological and philosophical underpinnings of mind-wandering as a postdoctoral scholar at UC Berkeley.

"If you focus all the time on your goals, you can miss important information. And so, having a free-association thought process that randomly generates memories and imaginative experiences can lead you to new ideas and insights," said Irving, whose philosophical theory of mind-wandering shaped the study's methodology.

Irving worked with Alison Gopnik, a UC Berkeley developmental psychologist and philosophy scholar who is also a co-author of the study.

"Babies and young children's minds seem to wander constantly, and so we wondered what functions that might serve," Gopnik said. "Our paper suggests mind-wandering is as much a positive feature of cognition as a quirk and explains something we all experience."

To prepare for the study, 39 adults were taught the difference between four different categories of thinking: task-related, freely moving, deliberately constrained and automatically constrained.

Next, while wearing electrodes on their heads that measured their brain activity, they sat at a computer screen and tapped left or right arrow keys to correspond with left and right arrows appearing in random sequences on the screen.

When they finished a sequence, they were asked to rate on a scale of one to seven—whether their thoughts during the task had been related to the task, freely moving, deliberately constrained or automatically constrained.

One example of thoughts unrelated to the task and freely moving would be if a student, instead of studying for an upcoming exam, found herself thinking about whether she had received a good grade on an assignment, then realized she had not yet prepared dinner, and then wondered if she should exercise more, and ended up reminiscing about her last vacation, Kam said.

The responses to the questions about thought processes were then divided into the four groups and matched against the recorded brain activity.

When study participants reported having thoughts that moved freely from topic to topic, they showed increased alpha wave activity in the brain's frontal cortex, a pattern linked to the generation of creative ideas. Researchers also found evidence of lesser P3 brain signals during off-task thoughts.

"The ability to detect our thought patterns through brain activity is an important step toward generating potential strategies for regulating how our thoughts unfold over time, a strategy useful for healthy and disordered minds alike," Kam said.

More information: Julia W. Y. Kam et al, Distinct electrophysiological signatures of task-unrelated and dynamic thoughts, *PNAS* January 26, 2021 118 (4) e2011796118; doi.org/10.1073/pnas.2011796118