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THE WANDERING MIND: HOW THE BRAIN ALLOWS US TO MENTALLY WANDER OFF TO ANOTHER TIME AND PLACE

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REVIEWED BY:


KRISHNA
11 YEARS OLD


DARIUS
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WYATT
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8 YEARS OLD


PACEYN
7 YEARS OLD

A unique human characteristic is our ability to mind wander—these are periods of time when our attention drifts away from the task-at-hand to focus on thoughts that are unrelated to the task. Mind wandering has some benefits, such as increased creativity, but it also has some negative consequences, such as mistakes in the task we are supposed to be performing. Interestingly, we spend up to half of our waking hours mind wandering. How does the brain help us accomplish that? Research suggests that when we mind wander, our responses to information from the external world around us are disrupted. In other words, our brain's resources are shifted away from processing information from the external environment and redirected to our internal world, which allows us to mentally wander off to another time and place. Even though we pay less attention to the external world during mind wandering, our ability to detect unexpected events in our surrounding environment is preserved. This suggests that we are quite clever about what we ignore or pay attention to in the external environment, even when we mind wander.

HOW DO SCIENTISTS DEFINE MIND WANDERING?

Imagine this: you are sitting in a classroom on a sunny day as your science teacher enthusiastically tells you what our brain is capable of doing. Initially, you pay close attention to what the teacher is saying. But the sound of the words coming out of her mouth gradually fade away as you notice your stomach growling and you begin to think about that delicious ice cream you had last night. Have you ever caught yourself **mind wandering** in similar situations, where your eyes are fixed on your teacher, friends, or parents, but your mind has secretly wandered off to another time and place? You may be recalling the last sports game you watched, or fantasizing about going to the new amusement park this upcoming weekend, or humming your favorite tune that you just cannot get out of your head. This experience is what scientists call mind wandering, which is a period of time when we are focused on things that are not related to the ongoing task or what is actually going on around us (as shown in Figure 1).

MIND WANDERING

Periods of time when an individual is thinking of something that is unrelated to the task he/she is performing.

OUR TENDENCY TO MIND WANDER

Humans on average spend up to half of their waking hours mind wandering. There are differences across individuals in their tendency to mind wander and many factors that affect this tendency. For instance, older adults on average tend to mind wander less than younger adults. Also, individuals who are often sad or worried mind wander more frequently compared with individuals who are happy and have nothing to worry about. We also mind wander more when we perform tasks that we are used to doing, compared with when we perform novel and challenging tasks. There are also different types of mind wandering. For example, we may sometimes mind wander on purpose when we are bored with what we are currently doing. Other times, our mind accidentally wanders off without us noticing.

FIGURE 1

FIGURE 1

Real-world example of on-task and mind wandering states among students in a classroom. In a science class in which the teacher asks a question about the brain, some students may be focused on what is being taught, while others may be thinking about yesterday's basketball tournament, humming their favorite tune, or thinking about getting ice cream after school. The students thinking about the brain during class would be considered to be "on task," while students thinking about things unrelated to the brain would be considered to be "mind wandering."

WHAT ARE THE PROS AND CONS OF MIND WANDERING?

Since we spend so much time mind wandering, does this mean that mind wandering is good for us or not? There are certainly benefits to mind wandering. For example, one of the things the mind does when it wanders is to make plans about the future. In fact, we are more likely to make plans when we mind wander than we are to fantasize about unrealistic situations. Planning ahead is a good use of time as it allows us to efficiently carry out our day-to-day tasks, such as finishing homework, practicing soccer, and preparing for a performance. When mind wandering, we are also likely to reflect upon ourselves. This process of thinking about how we think, behave, and interact with others around us is a crucial part of our self-identity. Mind wandering has also been tied to creative problem-solving. There are times when we get stuck on a challenging math problem or feel uninspired to paint or make music, and research suggests that taking a break from thinking about these problems and letting the mind wander off to another topic may eventually lead to an "aha" moment, in which we come up with a creative solution or idea.

However, mind wandering can also have negative outcomes. For example, mind wandering in class means you miss out on what is being taught, and mind wandering while doing your homework may result in mistakes. Taken to an extreme, people who are diagnosed with depression constantly engage in their own thoughts about their problems or other negative experiences. In contrast, individuals diagnosed with attention-deficit/hyperactivity disorder who continually change their focus of attention may have a hard time completing a task. Taken together, whether mind wandering is good or bad depends on *when* we mind wander and *what* we mind wander about [1].

SCIENTIFIC MEASURES OF MIND WANDERING

If you were to conduct an experiment, how would you measure mind wandering? Scientists have come up with several methods, one of which is called **experience sampling**. As research volunteers are doing a computer task in a laboratory, or as they are doing chores in their day-to-day lives, they are asked at random intervals to report their attention state. That is, they have to stop what they are doing and ask themselves what they were thinking about in the moment: "Was I on-task?" (that is, was I paying attention to the task-at-hand) or "Was I mind wandering?" (that is, did my mind wander off to another time and place). Therefore, *experience* sampling *samples* the volunteer's in-the-moment experience, allowing scientists to understand how frequently people mind wander and how mind wandering affects the way people interact with their environments.

Scientists also study mind wandering by recording **electroencephalogram (EEG)**, a test that measures the electrical activity of the brain. This electrical

EXPERIENCE SAMPLING

A scientific method in which a person is asked to report their experience; that is, whether he or she is paying attention or mind wandering at random intervals in the laboratory setting or in the real world.

ELECTROENCEPHALOGRAM (EEG—"ELEC-TRO-EN-SEF-A-LO-GRAM")

Electrical activity of many neurons in the brain that is measured by electrodes placed on the scalp.

activity, which looks like wavy lines during an EEG recording (see Figure 2, Step 2), is observed in all parts of the brain and is present throughout the day, even when we are asleep. Measurements of the brain's electrical activity help scientists understand how the brain allows us to think, speak, move, and do all the fun and creative and challenging things that we do! In order to record EEG, scientists place special sensors called electrodes on the scalp of a volunteer (Figure 2, Step 1), with each electrode recording activity of numerous neurons (brain cells) in the area under the electrode (Figure 2, Step 2). Scientists then examine the brain's activity in response to images (such as a picture of a basketball in Figure 2) or sounds presented to the volunteer. The scientists present the same sound or picture to the volunteer multiple times and take the average of the brain's activity in response to the image or sound, because that method results in a better EEG signal. The averaged brain activity produces something called an **event-related potential (ERP)** waveform that contains several high and low points, called peaks and troughs (Figure 2, Step 3), which represent the brain's response to the image or sound over time. Some commonly seen peaks and troughs are assigned specific names as ERP components. For instance, a peak that occurs around 300 ms (only 3/10 of a second!) following the presentation of a picture or a sound is often called the **P300** ERP component. Based on decades of research, scientists have shown that these ERP components reflect our brain's response to events we see or hear. The size of the ERP components (measured in voltage) reflects how strong the response is, while the timing of these ERP components (measured in milliseconds) reflects the timing of the response. Now, PAUSE! I would like you to ask yourself, "Was I paying full attention to the previous sentence just now, or was I thinking about something else?" This is an example of experience sampling. And as you may realize now, when we are asked about our current attention state, we can quite accurately report it.

WHAT HAPPENS TO OUR INTERACTION WITH THE ENVIRONMENT WHEN WE MIND WANDER?

Scientists have proposed an idea—called the "Decoupling Hypothesis"—stating that during mind wandering, the brain's resources are shifted away

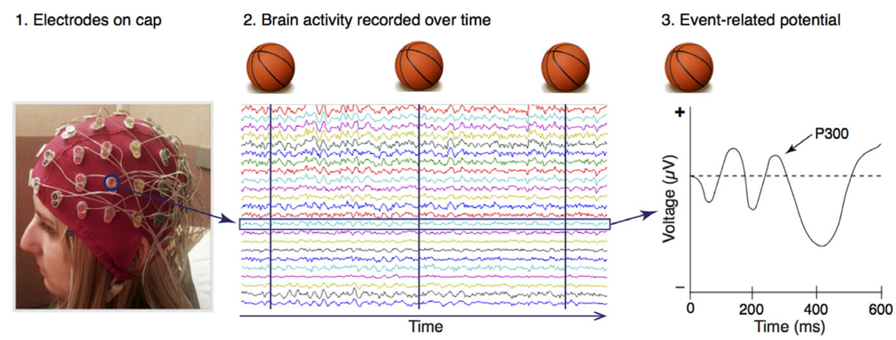

FIGURE 2

EVENT-RELATED POTENTIAL (ERPs)

Peaks or troughs in the averaged EEG signal that reflect the brain's responses to events we see or hear.

FIGURE 2

Recording electroencephalogram (EEG) in humans. Step 1. To record EEG, electrodes are attached to a cap that is placed on the scalp of a research volunteer. Step 2. Each wavy line represents the amount of activity recorded by each electrode. Research volunteers are usually presented with some images (e.g., a basketball) or sounds a number of times while their brain activity is being recorded. Step 3. Scientists calculate the average EEG activity across multiple presentations of the same picture/sound. This results in an Event-Related Potential (ERP) waveform, where time (in milliseconds) is plotted on the x-axis and the voltage (in microvolts, indicating the size of the ERP components) is plotted on the y-axis. On the x-axis, 0 indicates the time at which the stimulus (e.g., image of a basketball) was presented. The ERP waveforms contain multiple high and low points, called peaks and troughs. Some of the peaks and troughs are given specific labels. For example, the peak that occurs around 300 ms after an image is presented is often called the P300 ERP component.

from our surrounding environment and are redirected to our internal world in order to support our thoughts [2]. This hypothesis assumes that the brain has a certain amount of resources, which means that once mind wandering has used the resources it needs to focus on our thoughts, only a limited amount of brain resources remains for responding to our surrounding environment.

To test this hypothesis, scientists combined experience sampling with EEG to explore how mind wandering affects our interaction with the environment. One of the first studies to test this hypothesis asked research volunteers to categorize a series of images by responding whenever they saw rare targets (e.g., images of soccer balls) among a whole bunch of non-targets (e.g., images of basketballs). Throughout the task, EEG was recorded from the volunteers, and they were also asked at random times to report their attention state as "on task" or "mind wandering." Based on their EEGs and experience sampling reports, scientists found that the brain's response to the non-targets was reduced during periods of mind wandering compared with periods of being on task [3]. This can be seen in Figure 3A, where there is a smaller P300 ERP component during mind wandering (the green lines) compared with the P300 ERP component during the time when the volunteer was on task (the gray line). The data suggest that the brain's response to events happening in our environment is disrupted when we engage in mind wandering.

Have you ever noticed that if your mind wanders while you are doing homework, you are more likely to make mistakes? Many experiments have also shown that this happens! This led some scientists to question what is

P300

An ERP component that typically peaks around 300 ms (therefore "300") after a person sees a picture or hears a sound. It reflects the brain's processing of the information that is seen or heard. an ERP component that typically peaks around 300 ms (therefore "300") after a person sees a picture or hears a sound. It reflects the brain's processing of the information that is seen or heard.

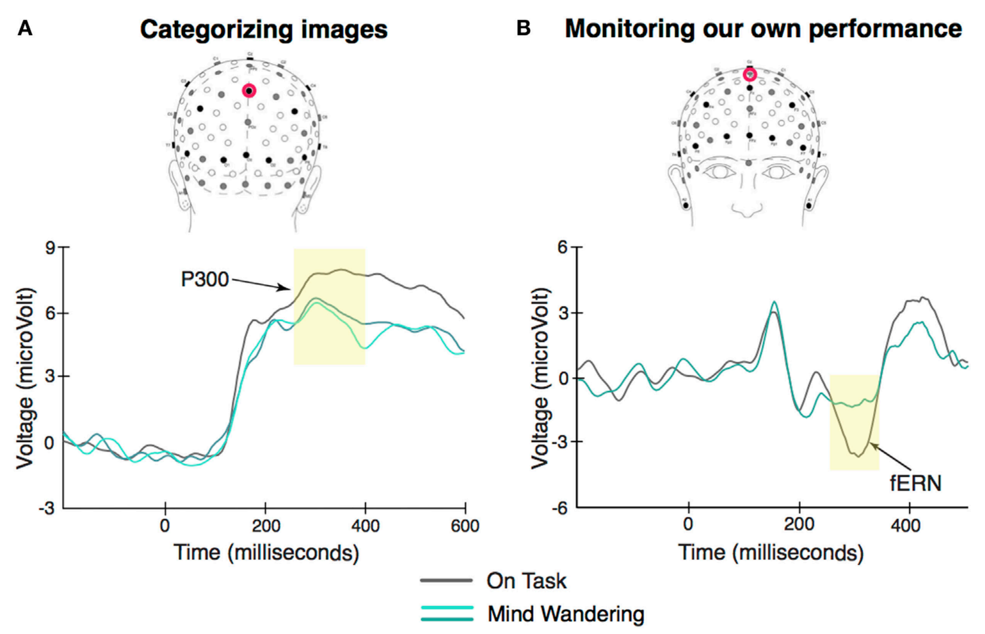

FIGURE 3

FIGURE 3

Mind wandering affects our ability to process events in the environment. **A.** The brain's processing of external events (e.g., images of basketballs and soccer balls) is reduced during periods of mind wandering. This is indicated by the smaller P300 ERP component during mind wandering (green lines) compared with on-task (gray line). The ERP waveform was recorded from the electrode site circled in red, which is located on the back of the head. **B.** Mind wandering impairs our ability to monitor our own performance, making it more likely that we will make mistakes. This is shown by the smaller feedback error-related negativity ERP component, a trough occurring around 250 ms, for mind wandering (green line) compared with on-task (gray line). The ERP waveform was recorded from the electrode site circled in red, which is located near the front of the head.

FEEDBACK ERROR-RELATED NEGATIVITY

An ERP component that reflects how much a person is monitoring the accuracy of his/her performance.

happening in the brain when we make mistakes. They specifically measured something called the **feedback error-related negativity** ERP component, which gives scientists an idea of how closely we are monitoring the accuracy of our responses when we perform a task. The scientists found that the feedback error-related negativity ERP component was reduced during mind wandering compared with on-task periods, as shown in Figure 3B. This suggests that mind wandering negatively affects our ability to monitor our performance and adjust our behavior, making it more likely that we will make mistakes [4]. All of these studies provide evidence supporting the hypothesis that when the mind wanders, our responses to what is going on in the environment around us are disrupted.

DOES MIND WANDERING IMPAIR ALL RESPONSES TO THE ENVIRONMENT?

At this point, you may wonder: are *all* responses to the world around us impaired during mind wandering? This seems unlikely, because we are usually quite capable of responding to the external environment even when we mind wander. For example, even though we may mind wander a lot while walking, most of us rarely bump into things as we walk from place to place. A group of scientists asked the same question and looked specifically at whether we can still pay attention to our environment at some level even when we are mind wandering. To test this question, research volunteers were asked to read a book while they were listening to some tones unrelated to the book. Most of the tones were identical, but among these identical tones was rare and different tone that naturally grabbed the attention of the volunteers. These scientists found that the volunteers paid just as much attention to this rare tone when they were mind wandering compared to when they were on task. In other words, our minds appear to be quite smart about which attention processes to disrupt and which processes to preserve during mind wandering. Under normal circumstances, our minds ignore some of the ordinary events in our environment in order for us to maintain a train of thought. However, when an unexpected event occurs in the environment, one that is potentially dangerous, our brain knows to shift our attention to the external environment so that we can respond to the potentially dangerous event. Imagine walking down the street and thinking about the movie you want to watch this weekend. While doing this, you may not clearly perceive the noise of the car engines or the pedestrians chatting around you. However, if a car suddenly honks loudly, you will hear the honk immediately, which will snap you out of your mind wandering. Therefore, even when the mind is wandering, we are still clever about what we ignore and what we pay attention to in the external environment, allowing us to smartly respond to the unusual, or potentially dangerous, events that may require us to focus our attention back on the external environment.

CONCLUSION

In summary, the brain appears to support mind wandering by disrupting some of the brain processes that are involved in responding to our surrounding external environment. This ability is important for protecting our thoughts from external distractions and allowing us to fully engage in mind wandering. We are only beginning to understand this mysterious experience of thinking, and scientists are actively researching what goes on in the brain when we mind wander. Increasing our knowledge about mind wandering will help us better understand how to take advantage of its benefits while avoiding the problems linked to mind wandering.

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CONFLICT OF INTEREST STATEMENT: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

REVIEWED BY

KRISHNA, 11 YEARS OLD

I love science and sports. I play baseball and learn kung-fu. I love to do experiments to understand how science works. In the science—I enjoy space/astronomy and physics. I enjoy reading a lot—and hope to write lot of kids' books. (I have started on three already.) In my life, I want to invent something new and bring back to life something that is extinct—using DNA research.

DARIUS, 13 YEARS OLD

I am 13 years old and in the eighth grade. In my free time I enjoy reading, backpacking, and playing the trumpet and piano. I am passionate about the environment and community service. I am very interested in public speaking and am on my school's debate team. I enjoy learning about science, particularly neuroscience, chemistry, biology, and physics.

WYATT, 10 YEARS OLD

I am a fourth grader in Piedmont, CA, USA. I like to read, play with Legos, play Minecraft, and eat and sleep! I also love scootering, biking, hiking and building stuff. My favorite food is Ethiopian—I love the whole fried fish and the dorotibs. My favorite subjects in school right now are computer lab, P.E., library, and science. I'm looking forward to taking chemistry when I get to middle school! After college, I want to be a mechanical engineer and robotics programmer.

SCHUYLER, 11 YEARS OLD

I'm Schuyler. I live in Berkeley California, I'm 11 years old and in the seventh grade. My favorite subjects in school are writing and science. I like to write fictional pieces, and I also like to sing, act and cook. Someone that I look up to and that inspires me is my mom. I also play soccer and basketball.

SYBILLE, 8 YEARS OLD

I'm Sybille. I am 8 years old and I'm in fourth grade at Malcolm X. I live in Berkeley California and I play soccer. I like doing silly science experiments and cooking and
I am really good at math.

PACEYN, 7 YEARS OLD

I'm Paceyn. I'm 7 years old and I'm in 2nd grade at LeConte Elementary in the TWI Spanish program. My favorite subjects in school are Reading, Writing and Math.
I like doing science experiments, making art, and writing stories, especially poems and songs. I collect rocks and stuffed animals and I like skiing and cold weather. I enjoy doing gymnastics, dance and cheersport, and I have a pet guinea pig named Luna.

AUTHOR

JULIA W. Y. KAM

As a psychologist, I am intrigued by our mind's tendency to disengage from the world around us to wander off into our own musings. I want to understand how our brains support these internally oriented thoughts, which changes the way we think and feel about ourselves and others around us. When I'm not studying mind wandering, I like to physically wander off to extraordinary places around the world. *juliakam@berkeley.edu