FUNDAMENTALS OF NEUROSCIENCE IN PSYCHIATRY:

Default Mode Network: the Basics for Psychiatrists

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OVERVIEW

You've heard the words "Default Mode Network" and know it has something to do with the brain, but what exactly is it? Why is the default mode network important and what's the clinical relevance? This review provides a conceptual introduction to the default mode network (DMN) through a brief vignette. Further details about how the brain's structure and function is mapped (Box 1) and the discovery of the DMN (Box 2) may be found in the pop-out boxes.

THE WANDERING MIND

We've all been there: a busy day at work, looming deadlines, family obligations... you are pulled in what seems to be a thousand different directions. You can't concentrate and you find yourself thinking: I just need to step outside for a minute to clear my head. You sneak out to the park across from your office. It's a beautiful day and you lie down on the soft grass for a moment and close your eyes to relax. But your mind doesn't stop. Instead, it shifts through scenes from earlier in the day: making dinner plans with a friend you bumped into, your overflowing inbox, a looming grant deadline, and a meeting with your Chair to discuss the grant... Each thought leads to more thoughts and then to more questions: What am I going to make for dinner? How should I respond to that email? What will I say to the Chairman? Will our grant be ready for submission? With every new question you become more aware of your inability to relax.

This scenario isn't unique. We've all had some version of this in our lives. But what accounts for this mind wandering process? Why does it happen?

The simplified answer is the default mode network (DMN). The DMN is a brain system responsible for your self-referential inner monologue or wandering mind. The DMN is thought to recruit memories, associations, and recent events to help you plan for the future. Melding these together allows you to rehearse information and plan by detaching you from what's going on around you at that moment. While the DMN is active, your brain literally ignores external stimuli, leading to what some call being "spaced out". While it may be annoying to friends and family when you're not responding to them, it's not harmful and is actually a healthy, normal process. During these times, your brain's attention has merely re-directed its focus on your internal dialogue instead of the outside world [Weissman et al., 2006]. Left with no other required tasks, your brain will gravitate towards the DMN. Indeed, the DMN is so-called because it's the brain's default pattern.

While occasional episodes of a wandering mind are normal and relatively harmless, longer periods can cause problems. Scientists have demonstrated that the more active your DMN (i.e. the more your mind is wandering) the less likely you are to remember a string of words [Buckner et al., 2008]. Additionally, an overactive DMN has been associated with several brain diseases such as depression, Alzheimer's dementia, and schizophrenia [Buckner, 2012]. In these conditions, your brain inappropriately engages its own inner monologue and jumps to unrelated memories and plans, circumstantial mind wandering. As an example, studies have shown that during a depressive episode, someone may be unable to suppress (decrease) the DMN activity during

BOX1:

MAPPING BRAIN FUNCTION WITH STRUCTURE

Neuroscience endeavors to understand which parts of the brain drive specific behaviors and functions. For centuries, people have observed that damage to specific brain areas cause predictable types of dysfunction—such observations are how the first functional maps of the brain were produced. In the early 20th century, people discovered that different brain areas have different types of neurons, producing regional differences in brain function [Brodmann, 2006]. The development of digital neuroimaging, such as positron emission tomography (PET) and magnetic resonance imaging (MRI), allowed the brain to be studied in toto and in vivo, yielding an unprecedented ability to view brain activity. Digital neuroimaging also yielded the ability to study how individual brain regions function together as networks and showed that the brain's activity can be teased apart into a number of major networks, one of which is the DMN [Smith, 2009].

normal cognitive processes such as having a conversation [Sheline et al., 2009]. This can lead to a person being unable to break off from their inner dialogue and repetitively thinking of the same things over and over again.

To illustrate, while at dinner with friends a person experiencing a depressive episode may be unable to break from thoughts about an impending deadline. As these thoughts become more and more fixed, he may start to believe he may never finish the project (e.g. writing a grant), and, even if finished, it would have an undesirable outcome (e.g. not being funded). Such episodes, called rumination, are common in depression. Ruminative thinking results from over-activity in the DMN (e.g. caught up on the deadline) when it should have lower activity, but also reflects an under-activity of other brain areas that should be active at that time but are suppressed by the DMN (e.g. what the friends are talking about). The DMN then has an inverse relationship with areas of the brain that should be active during tasks and vice-versa. Theoretically, a key way to help would be by mitigating the hyperactivity of the DMN.

Recent studies suggest there may, in fact, be ways to decrease the activity level of the DMN. Behaviorally, studies have shown that meditation and mindfulness can decrease the DMN's activity [Brewer et al., 2011]. Similarly, one study showed that a serotonin-norepinephrine reuptake inhibitor may appropriately decrease DMN activity during a depressive episode [Posner et al., 2013]. Additionally, stimulating the DMN with repetitive transcranial magnetic stimulation (rTMS) results in overall decreases in DMN activity [Liston et al., 2014]. It's possible that these therapies – or a combination of behavioral, pharmacologic, and procedural treatments – may result in novel ways of treating disorders involving the DMN, such as depression. It should be noted, however, that DMN dysfunction does not necessarily correlate directly with clinical (e.g. DSM) diagnoses, as similar DMN disruptions may be present in very different conditions, such as psychosis and depression. This speaks to our need, at this time, to understand DMN dysfunction more in terms that reflect brain function and organization (e.g. the Research Domain Criteria or RDoC) rather than strict clinical diagnoses [Insel et al., 2010].

AUTHOR CONTRIBUTIONS

Dr. Barron and Dr. Yarnell are from the Department of Psychiatry at the Yale School of Medicine. David Ross, MD, PhD, is the Contributing Editor for this publication. The National Neuroscience Curriculum Initiative is a collaborative effort with AADPRT and the American Psychiatric Association (APA) Council on Medical Education and Lifelong Learning and receives support from the NIH (R25 MH10107602S1)

BOX 2:

DISCOVERING THE DMN

Finding the DMN was completely unexpected. Before the DMN's discovery, studies of the brain typically involved asking a research participant to perform a particular task (e.g. wiggle your thumb) and observing where their brain activity increased during that task relative to rest. After years of performing such studies, Marcus Raichle noticed that no matter what type of task a research participant was asked to do—whether looking at checker boards, memorizing a string of numbers, or feeling the tickle of a feather—in addition to the expected increases in brain activity, decreases in activity were also observed.

What piqued Marcus's attention was that these decreases consistently occurred in the same brain regions (See Figure 1 for details), no matter what type of task was being performed. So he looked more carefully at these regions while participants were at "rest" and discovered that, indeed, these regions were more active during rest and less active when participants engaged in some task [Raichle et al., 2001]. This network, he reasoned, must be the brain's "default mode", and the name stuck.

To better tease apart the DMN, neuroscientists developed tasks that engaged "mind-wandering" activities like autobiographical thinking, envisioning the future, trying to guess what someone else is thinking, and moral decision making [Buckner et al., 2008]. These studies showed that the brain functions much like a computer network, with the DMN having smaller hubs and subsystems, a hub being a heavily involved center that controls multiple subsystems (See Figure 2 for details). To complete the analogy, the DMN is the brain's screensaver, or rather, brainsaver. When the brain is not actively performing a task the "brainsaver" comes on and, like a screensaver that pulls from your photo library, your brain focuses on autobiographical memories. Through concentrating on this internal self-talk, the DMN may represent a core component in the ancient question of what makes you who you are, a key to the so-called "self".

FIGURE 1:

Original DMN diagram. When first published, the primary areas of focus at that time were the posterior cingulate and medial prefrontal cortex (represented in red in figure above, from [Raichle et al., 2001]). Below the figures in text are x-coordinates referencing the plane of slice.

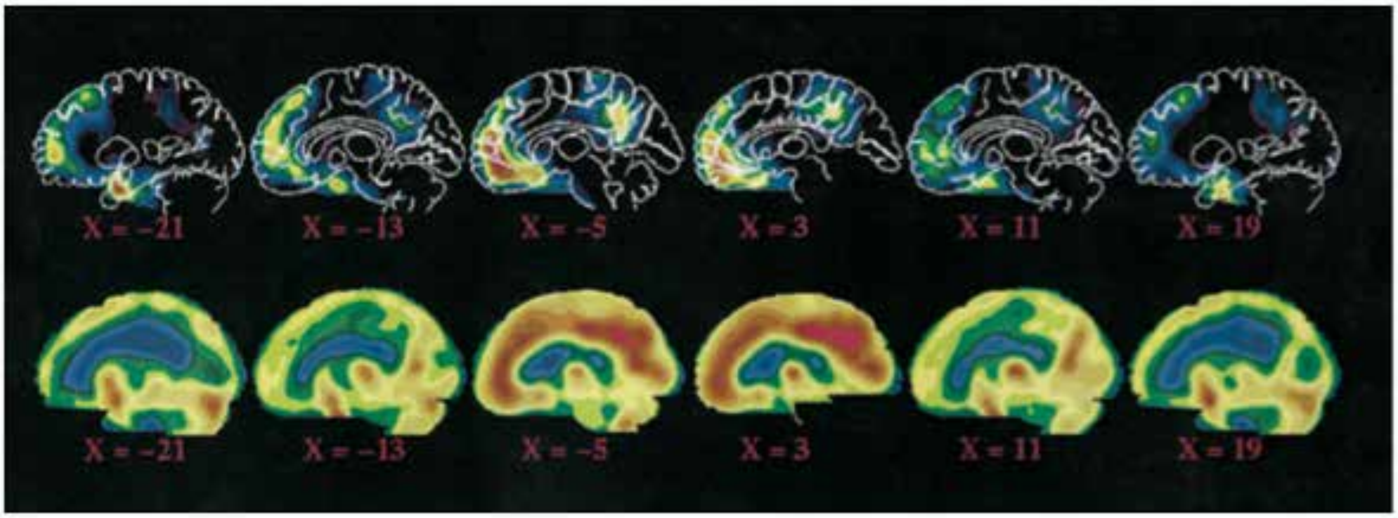
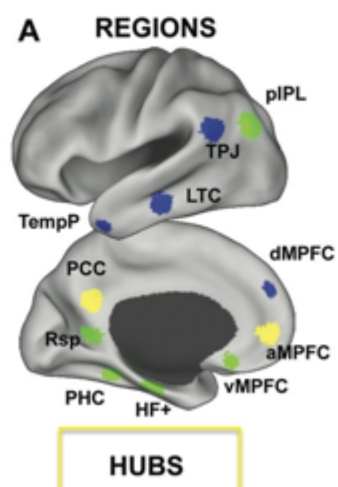


FIGURE 2:

Diagram of the DMN's main hubs and subsystems. The main DMN hubs are the posterior cingulate cortex (PCC) and the anterior medial prefrontal cortex (aMPFC; represented in yellow in figure below from [Andrews-Hanna, 2012]). These hubs communicate with two main subsystems: a medial temporal lobe subsystem (represented in green) which consists of the retrosplenial cortex (RSP), parahippocampal cortex (PHC), hippocampal formation (HF), ventral medial prefrontal cortex (vMPFC), and the posterior inferior parietal lobule (pIPL), as well as the dorsal medial prefrontal cortex subsystem (represented in blue) which consists of the temporal pole (TempP), lateral temporal cortex (LTC), temporoparietal junction (TPJ), and the dorsal medial prefrontal cortex (dMPFC).



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ADDITIONAL SOURCES

1) Magnetic Resonance Imaging for Psychiatry:
   A highly accessible, brief explanation of the basics MRI that could be helpful in understanding the basics of how imaging is used to localize and characterize brain anatomy. Available at: http://www.nncionline.org/course/magnetic-resonance-imaging-for-psychiatry/?course_type=content&course_page=1

2) TED talk by Judson Brewer:
   This is a highly accessible, basic-level introduction to the brain's autopilot mode, the so-called default mode network. A key point of this talk is that using neurofeedback to view their brains in real time, people can learn to quiet areas associated with a "wandering mind" and learn to better control their minds. A review of this video could be followed by a discussion of mindfulness, meditation, or the default mode network. Video: https://www.youtube.com/watch?v=jE1j5Om7g0U