The Default Mode Network: How the Mind Wanders

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The advent of sophisticated brain mapping techniques (magnetic resonance imaging [MRI], functional MRI [fMRI]) has given rise to the accidental discovery of a "default mode network" (DMN) in the brain, which is activated when individuals at rest are left undisturbed to think to themselves.[1] The activity associated with engagement of the DMN has been described as "mind-wandering," and has received increasing attention in the literature.[3] This rest state is involved in the "generation and manipulation of mental images, reminiscence of past experience based on episodic memory and making plans."[2(p295)]

A number of studies have revealed a distributed set of regions that make up the DMN. These include the association cortex, but not the sensory and motor cortices. The functioning of the DMN is now thought to be relevant in a number of psychiatric disorders. In this paper, we will begin by defining the DMN, and then explore two key neuroscience concepts that are important to understand its function. We then will consider the DMN in terms of its application to psychiatric disorders, as well as possible clinical applications.

Theme 1: What Is the Default Mode Network?

The DMN may be described as a brain system or network of interacting brain areas that are tightly functionally connected and distinct from other systems in the brain, and is most commonly shown to be active when a person is not focused on the outside world, such as during daydreaming and mind-wandering. According to Buckner *et al.*, DMN functions include internally focused preoccupations such as autobiographical memory retrieval and construction of self-relevant mental simulations, as well as envisioning future events.[3] Also included is reflection about one's own emotional state and the ability to conceive the perspectives of others (theory of mind). It has remained unclear whether the DMN functions as a unitary circuit or as a number of overlapping hubs with related but separate functions, and whether these functions are subject to developmental change.

Theme 2: Key Concepts

A number of concepts are key to understanding the DMN. Functional connectivity (FC) refers to the temporal correlations between the oscillatory firing of neuronal regions—otherwise put, separate brain region neurons that become activated at the same time may be considered functionally connected, even if they are not anatomically connected.[3] The DMN is characterized by temporal synchrony between functionally specific and diverse brain regions. FC is believed to increase with age and should be distinguished from frontostriatal circuits, which are anatomically connected neural pathways that connect frontal lobe regions with the basal ganglia and mediate motor, cognitive, and behavioral functions within the brain.

A second concept is the function of "anti-correlation." The DMN is described as being anti-correlated to a task-positive executive network (comprising the dorsolateral prefrontal cortex [DLPFC], inferior parietal cortex [IPC], and supplementary motor cortex [SMC]). The latter selects and maintains important task-specific information in working memory, contributing to planning and behavioral control,[4,5] while the former addresses internal issues. It has been suggested that the brain has a pattern of alternation between the DMN and the task-positive network, such that at any particular point in time there is an exclusivity of function between these two attentional orientations, leading to a pattern of "fluctuating attention, periodic lapses and associated performance variability."[5(p981)] The inattentiveness observed in attention-deficit/hyperactivity disorder (ADHD) is postulated as due to inadequate suppression of the DMN. This increased DMN activity was associated with the intrusion of thoughts unrelated to the task or daydreaming with alternation between introspective and exterospec-

tive states. Excess default mode interference in executive functions was suggested as a possible mechanism that explained response variability in ADHD.[5]

The regulation of competition between task-positive and DMN networks is not well understood. Cyclical fluctuations of attention are often regarded as pathological, though given their pervasiveness, pathology should be seen as a matter of degree. Excess task positivity (as in obsessive-compulsive disorder) may be just as detrimental as excessive mind-wandering or daydreaming. This distinction can be important in deciding whether and when to treat ADHD and raises the question of whether objective measurement is possible. Currently this decision is largely made on clinical grounds, assisted by parental and teacher rating scales. A more objective approach would be to also use measures that reflect default mode and executive fluctuations.[6]

Theme 3: Default Mode Network and Psychopathology

Autism spectrum disorder (ASD) has also been characterized by deficits in theory of mind and by hypo-connectivity between remote cortical regions with hyper-connectivity locally.[7] Children with ASD showed reduced connectivity between DMN nodes and increased local connectivity within DMN nodes and the visual and motor resting-state networks. There is also an absence of the previously described anti-correlation between the DMN and task-positive networks, which may result in a reduction in introspective thought. In children with ASD, these long-distance connections failed to develop during adolescence, suggesting developmental effects.[8]

Abnormalities in functional connectivity of the DMN have been described in schizophrenia (greater connectivity, with excessive mentalizing and environmental alertness), depression (increased affective connectivity and introspection), and Alzheimer's disease (pathology appears to form preferentially throughout the default network).[3]

Theme 4: Clinical Applications

DMN activity is most commonly measured by blood oxygen level (BOLD) measures, which reflect changes in blood oxygen levels in distinct anatomical regions. In the future, one could imagine using fMRI in clinical practice to quantify activity in the DMN and using quantified DMN activity as a diagnostic clue and measure of illness severity. Further, this could be a biomarker to track both developmental changes over time and response to treatment in conditions such as ADHD and ASD.

Activity in the DMN can also be measured using less intrusive, indirect methods, such as assessing performance on specific psychometric tests—for example, tests that measure reaction time and how reaction time may be affected by the intrusion of thoughts that are not relevant to the task at hand.[9] If these tasks can be validated as reliable measures of DMN activity, they could prove to be a preferred method for DMN evaluation in clinical settings.

Conclusion

In summary, the DMN is a promising new concept in neuroscience that has implications both for our understanding of certain psychiatric disorders and for potential utility in predicting outcomes, although future research is needed. Clinicians should be familiar with the basic functions of this network and the key concepts outlined in this paper in order to understand and respond to the clinical implications of emerging findings in this area.

Take Home Summary

A set of brain regions is active when the brain is at rest: this is called the "default mode network." A balance exists between engagement of the default mode network and task-positive brain regions. Future work may allow the assessment of default mode network activity to support diagnoses, measure illness severity, and track improvement over time.

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