

# **Training the Default Mode to Treat Psychopathology**

By

Julia Volkman<sup>1</sup>

ALM candidate in Psychology, Harvard University Extension School

## **ABSTRACT**

When we are ‘off-task,’ our brains are far from idle. A specific network of brain areas toggle on when our minds wander or when we turn our attention to planning, feeling, or considering. At the same time, our ‘on-task’ areas are suppressed. The strength of this default mode network (DMN) of brain regions is directly related to both our cognitive, emotional, and psychological health. When the DMN is weak, poorly connected with other brain regions, or unable to toggle on/off effectively, we may be faced with psychopathologies like depression, ADHD, autism, and schizophrenia. New research indicates that we can actively work to strengthen our DMN and possibly avoid or treat the potential consequences associated with atypical DMN activity.

*Key Words: Default mode network, psychopathology, meditation, attention training, cognitive training*

## **What is the Default Mode Network?**

Much of the brain research to date has focused on task or goal-oriented activity such as what happens when someone reads a word, hears a sound, or looks at emotional images. But, as it turns out, the brain regions that make up this task-positive network (TPN) are just a small part of our cerebral picture, accounting for a minimal 5% to 10% increase in the brain's energy consumption (Whitfield-Gabrieli and Ford, 2012). What's using up the rest of the brain's fuel the rest of the time? The default mode network (DMN) is a big part of the answer.

When we pause, daydream, zone out, or self reflect, an entirely distinct network of brain areas, mostly in the middle of the brain (*see Figure 1*) becomes active. These regions are called the DMN because they're what we default to when we're not doing something else (Whitfield-Gabrieli and Ford, 2012). Hans Berger, the inventor of the EEG, first suggested the possibility of a DMN back in 1929 but it wasn't until recently that the idea found strong clinical support (Raichle, 2010).

When the DMN is active, our attention is focused inward on things like considering or thinking about one's own thoughts or feelings (self-referential processing), remembering the past, planning the future, forming beliefs, or thinking about other people/what other people are thinking. When our attention is focused outward, like when you're reading the words on this page, other parts of the brain are active and the default mode areas toggle off; they become suppressed or deactivated. In a healthy DMN, the more we focus our attention on a task, the greater the degree to which we suppress DMN activity and vice versa (Immordino-Yang, Christodoulou, and Singh, 2012; Whitfield-Gabrieli and Ford, 2012).

When scientists assess how well the DMN is functioning, they look not only at activity, but also at functional connectivity. Functional connectivity refers to what other areas of the brain

are active when the DMN is active (whether or not they are directly anatomically connected). They also look at what areas are not active, those that are functionally anti-correlated with DMN activity. For example, if we are typing a note to our friend on Facebook, our motor and language areas are active and our DMN is suppressed. But, when we pause to think about how that friend might feel if we post the embarrassing picture, our DMN is active and the other areas are suppressed.

The systems for looking out and looking in work together and, in fact, regulate each other. For example, research has shown that people with a high IQ have stronger DMN connectivity (especially for long-range connections) and more efficient communication and coordination between the DMN and other regions (Immordino-Yang et al., 2012). Memory is also associated with the DMN; a greater ability to deactivate the DMN is associated with greater memory recall. A study in older adults found that when DMN connectivity increased, executive function (EF) improved (Voss et al., 2010). Moreover, the DMN extends to our ability to understand our own and other's emotions. For example, when we hear a story of maltreatment of wartime prisoners or a young mother dying of cancer, our DMN is active in interpreting these abstract social, emotional, and moral situations. So, to reach our full potential, we need to develop our ability to intentionally put our attention on both what's happening out there and on what's happening in here (Immordino-Yang et al., 2012).

### **DMN Development**

We're not born with fully developed DMNs. At first, there may be only some connectivity in posterior regions. As we grow, we develop short-term connections until, as an adult, we have a longer, more distributed and more efficient organization; in typical development, the DMN moves from local to global functional connectivity (*see Figure 2*) (Fair

et al., 2008; Immordino-Yang et al., 2012). It's interesting to note that children with ADHD have more short-range than long-range functional DM connectivity than age-matched controls (Tomasi and Volkow, 2012). Thus, it may be that childhood ADHD is a sign of delayed DMN development.

DMN connectivity declines as part of the normal aging process (Whitfield-Gabrieli and Ford, 2012). When the DMN shows a great deal of deterioration with age, it may indicate Alzheimer's Disease. In fact, the brain areas implicated in Alzheimer's match incredibly well with those associated with the DMN (Raichle, 2010).

### **Altered DMN Functionality**

As you might suspect, there is a growing list of highly prevalent conditions where the DMN doesn't work the way we expect it to (*see Table 1*). The atypical way it does work seems directly related to the symptoms of the condition. For example, in schizophrenia, the DMN doesn't quite shut down when it should. So, even though the patient is focused on external stimuli, they are simultaneously hyperfocused on internal stimuli which may be related to the inability to distinguish between thought and reality (Immordino-Yang et al., 2012).

### **Default Mode Therapies**

The big question is if we can use our knowledge about DMN abnormalities to improve health and well-being. Early signs indicate that this is exactly what the future will bring.

#### *Attention Training*

The idea of training the powers of attention is not new, dating back in spiritual traditions at least to the roots of Buddhism over 2,500 years ago and in psychology to William James in 1890 (Stevens, Lauinger, and Neville, 2009). Today, there are two types of interventions that are being shown to alter the DMN in promising ways: meditation (a form of which is referred to as

mindfulness-based activities) and task practice (designed to co-activate targeted brain regions and thereby increase desired connectivity).

Meditators are trained to put their attention on something (usually the breath), to notice when their minds wander from that thing, to let the wandering-thoughts pass without judging them, and to turn the attention back to the object of meditation. Thus, meditation gives individuals practice in toggling their DMN on and off. Imaging studies of meditators show significant decreases in DMN activity and changes in DMN functional connectivity as compared with non-meditators (Berkovich-Ohana, Glicksohn, and Goldstine, 2012; Brewer, 2011).

Not surprisingly, meditation has been shown to be effective in treating depression, panic disorder, pain management, substance-use disorders, and anxiety and to help improve well-being in otherwise healthy individuals (Brewer, 2011; Hollon and Beck, 2004). Even short-term interventions have been shown to improve attention and self-regulation (Tang et al., 2007). In children, mindfulness-based cognitive therapy (MBCT) was shown to reduce attention and behavior problems (Semple, Lee, Rosa, and Miller, 2010).

Task-based training research has reported alterations in the DMN after short-term motor skills training, long-term cardiovascular training, and problem-solving (e.g., in expert chess players) (Duan et al., 2012; Ma, Narayana, Robin, Fox, and Xiong, 2011; Voss et al., 2010). This research all points to the possibility of training the DMN through non-invasive, economical, and accessible means.

In addition, certain longstanding evidence-based therapies (such as cognitive behavioral therapy [CBT]) may work because they actively train the DMN. For example, CBT teaches patients to treat thoughts as hypotheses to be tested. This requires intentional internal focus and

self-reflection, similar to that taught in meditation. However, whether or not DMN training is the mechanism of change in CBT and other therapies has yet to be tested.

### *DMN Therapeutic Imaging*

DMN imaging may be useful in predicting clinical outcomes and may help us in choosing the right therapeutic approach for an individual patient. DMN imaging might even be used as a treatment in and of itself: real-time imaging can educate patients on regulating their internal DMN states, a process called neurofeedback. Real-time fMRI neurofeedback has been used with some success in chronic pain syndrome and chronic tinnitus (Whitfield-Gabrieli and Ford, 2012).

### **Conclusion**

All of us have times when we get lost in thought or notice our mind wandering away from the task at hand. Usually, we can simply bring our attention back to what we are doing and, thus, toggle off the DMN. But for some of us, the DMN doesn't follow this typical activity pattern. Fortunately, there is great potential for strengthening the connectivity, coordination, and toggling of the DMN both in the laboratory and in our everyday lives.

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## **ENDNOTE**

<sup>1</sup> All correspondence should be addressed to Julia Volkman, [jvolkman@fas.harvard.edu](mailto:jvolkman@fas.harvard.edu).

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## RECOMMENDED READINGS

Immordino-Yang, M.E., Christodoulou, J.A., and Singh, V. (2012). *See reference list.*

- An inspirational review of the possible role of the DMN in educational interventions

Raichle, M.E. (2010). *See reference list.*

- A lay-person summary of the DMN by the leading researcher in the field.

Whitfield-Gabrieli, S. & Ford, J.M. (2012). *See reference list.*

- A look at the DMN from the perspective of psychopathology

## TABLES

Table 1: Select pathologic conditions associated with altered DMN function (Etkin, Prater, Schatzberg, Menon, and Greicius, 2009; Immordino-Yang et al., 2012; Raichle, 2010; Whitfield-Gabrieli and Ford, 2012).

<b>Psychopathology</b>	<b>Altered DMN Function</b>
ADHD/Impulsivity	Decreased DMN connectivity and activity; impaired DMN toggling (deactivation)
Alzheimer's	Altered DMN connectivity
Anxiety disorders	Increased frontal-parietal DMN connectivity; Decreased insula-cingulate DMN connectivity
Autism	Weak, non-deactivating DMN; Decreased ability to toggle DMN off
Depression, Bipolar Disorder	Decreased ability to suppress DMN; Hyper DMN connectivity to regions related to symptoms (thalamus, cingulate, precuneus)
Schizophrenia	Hyper DMN connectivity; Heightened DMN activity; Decreased ability to toggle between task positive network (TPN) and DMN

## FIGURE CAPTIONS

Figure 1: *Overview of the main brain regions comprising the “default mode” (DM) network, with brief descriptions of associated socio-emotional functions.* The DM regions listed are relatively more active and show coordinated activity during wakeful “rest”. The regions depicted are also involved in many other functions, including various cognitive association functions and aspects of homeostatic regulation and somatosensation, especially for the milieu of the internal body (i.e. the “guts”). The left side of the image is the front of the brain; the right and left hemispheres are split apart to show the medial surface. NOTE: These brain areas cannot be said to “do” the functions listed. Instead, they are especially “associated” with these functions, and as such are thought to play important roles within the complex networks of regions underlying the functions. (reprinted from Immordino-Yang et al., 2012)

- 1. Ventromedial prefrontal cortex (vmPFC):** Induction of social emotions; nonconscious induction of somatic responses like skin sweating associated with a sense of risk; modulation of the parasympathetic branch of the autonomic nervous system (important for calming of heart rate).
- 2. Dorsomedial prefrontal cortex (dmPFC):** Representation of self in relation to others; predicting emotional outcomes of social interactions for self and close others; judging psychological and emotional qualities and traits; feeling emotions about others’ mental situations.
- 3. Anterior middle cingulate cortex (ACC):** A centrally connected “hub” of the cortex, also heavily interconnected with somatosensory regions that feel the guts and viscera; error monitoring, emotion and empathy, feeling physical and social pain, modulation of the sympathetic branch of the autonomic nervous system (important for activation of heart rate, arousal).
- 4. Posteromedial cortices (PMC):** The most centrally connected “hub” of the cortex; high-level integrative representation of the physiological condition of the visceral “gut” body; construction of a subjective sense of self awareness; activated in social emotions, moral decision-making, episodic memory retrieval. Contains dorsal posterior cingulate cortex (dPCC), involved in attention monitoring/switching, and integration of information.
- 5. Inferior parietal lobule (IPL):** Involved in successful episodic memory retrieval; empathically simulating others’ perspectives and the goals of others’ actions.
- 6. Hippocampus:** Formation and recall of long-term memories. (A seahorse-shaped structure that curls underneath the temporal lobe; not visible in these views.)

*Figure 2: The DMN develops with age.* This illustration shows the sparse, short-range (lines) connectivity among DMN regions (red dots) recorded in typically developing children (ages 7-9) and the extensive, long-range DMN connectivity seen in healthy adults (ages 21-31); only one area (thick line between superior and frontal regions) had greater connectivity in children than adults (adapted from Fair et al., 2008).

# FIGURES

Figure 1

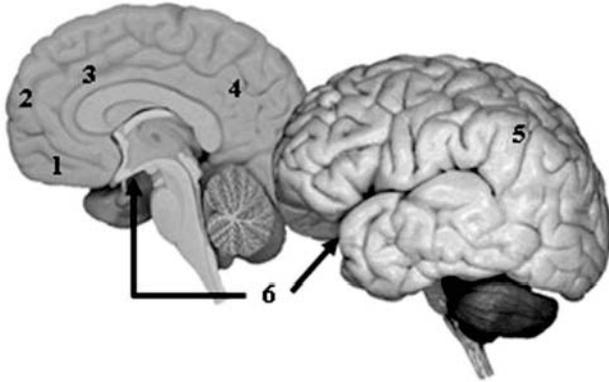


Figure 2

