The Brain’s Dark Energy (Default Mode Network)

By: Marcus E. Raichle
Default Mode Network (DMN)

- Neuroscientists have long thought that the brain’s circuits are turned off when the person is at rest.

- Recent neuroimaging studies have revealed that a great deal of meaningful and persistent activity occurs in the brain when a person is sitting back and doing nothing.

- When your mind is at rest (daydreaming quietly a chair, asleep in a bed or anesthetized for surgery) different brain areas are talking to each other. These areas are called the Default Mode Network (DMN).
Default Mode Network

- The energy consumed by the DMN is about 20 times that which is used by the brain responding to an outside stimulus.

- The DMN organizes memories and prepares other systems in the brain for future events (the brain’s motor system has to be revved up and ready before any motor movements).

- The DMN plays a critical role in synchronizing all parts of the brain to be in “ready mode” before any actions occur.
In 1992 scientists started to use functional MRI for the evaluation of brain function. fMRI gauges the brain blood flow and oxygenation.

fMRI can be used to pinpoint the brain regions that give rise to a given perception or behavior.

Scientists measure brain signals while a subject is at rest and while the subject performs a task, then look for differences in activity in the different regions of the brain. Any of what is called intrinsic activity (constant activity observed both at rest and during the task) can be ignored.
1. Dark Energy

- Performing a given task increases the brain’s energy consumption by less than 5% of the underlying baseline activity.

- A large fraction of overall brain activity - 60 to 80% of all energy used by the brain - occurs in circuits unrelated to any external events. This is called Dark Energy.

- When we see our environments, the equivalent of 10 billion bits per second arrives on the retina in the back of the eye. Because the optic nerve attached to the retina has only a million output connections, just 6 million bits/sec can leave the retina, and only 10,000 bits/sec make it to the visual cortex.
2. Dark Energy

- After further processing, visual information is fed into the brain region responsible for forming our conscious perception.
- Surprisingly, the amount of information constituting conscious perception is less than 100 bits per second.
- Such a thin stream of data could not produce “perception” without help of Dark Energy that makes constant predictions about the outside environment.
- In the visual cortex, only 10% of neurons receive information from the outside world. The rest comes from internal connections inside the brain.
Discovering the DMN

- In the mid 1990s, it was noticed that certain brain regions experienced a decreased level of activity from baseline resting state when subjects carried out certain tasks.

- These areas, especially a section in the medial parietal cortex, exhibited a drop in activity when other areas were engaged in carrying out a defined task such as reading aloud. Another area in the medial prefrontal cortex has the same properties.

- These two areas are major hubs of the DMN and are responsible for the brain’s intrinsic activity.
The DMN consists of several widely separated brain areas, including those depicted below.

Inside right hemisphere

Outside left hemisphere

- Medial parietal cortex
- Medial prefrontal cortex
- Default mode network
- Lateral parietal cortex
- Lateral temporal cortex
Functional MRI (fMRI) and DMN

- The fMRI signal is usually referred to as the blood oxygen level-dependent (BOLD) signal because fMRI’s imaging method relies on changes in the level of oxygen in the human brain induced by alteration in blood flow.

- The BOLD signal from any part of the brain, when observed in a state of quiet repose, slowly fluctuates every 10 seconds (in the past, these activities were considered noise and were simply ignored).

- In 2000 Greicius et al. found that this activity (or noise) is, in fact, coming from the DMN in a resting subject and also during sleep and anesthesia.
1. Slow Cortical Potential (SCP)

- Every brain system harbors a hub related to the DMN, but the major hubs are the Medial Prefrontal and Medial Parietal Cortices.

- The DMN contains several groups of neurons that produce a slow electrical activity known as Slow Cortical Potential (SCP). These neurons fire every 10 seconds or so (identically to the fluctuations found in BOLD images).
2. Slow Cortical Potential (SCP)

- Other parts of the brain can produce electrical activities with a broad spectrum of frequencies but all of them synchronize with the oscillation or phase of SCP.

- If you consider the brain a symphony orchestra, SCP is equivalent to a conductor’s baton. SCPs ensure that the right computations occur in a coordinated fashion at exactly the correct moment.

- Each brain system has its own SCP but at the top of this hierarchy resides the DMN which acts as an uber-conductor.

- The brain is not a free-for-all among independent systems but a federation of interdependent components.
DMN function in response to outside world

- Internal DMN activity sometimes diminishes due to the demands of outside world.
- SCPs in the DMN diminish when vigilance is required because of novel or unexpected sensory inputs (e.g. you suddenly realize that you promised to pick up milk on the drive home from work).
- Internal SCP messaging revives once the need for focused attention dwindles.
- The brain continuously wrestles with the need to balance planned responses and the immediate needs of the moment.
DMN and Consciousness

❖ In 2008, a group of researchers reported that by watching the DMN, they could tell predict whether a subject was about to commit an error in a task up to 30 seconds before it actually occurred. They found that if the subject’s DMN took over and activity in areas involved with focused concentration abated, a mistake would soon follow.

❖ Our conscious interaction with the world is just small part of the brain’s activity. The DMN is critical in providing context for what we experience in our small window of conscious awareness.
DMN and Diseases

- Alzheimer’s disease: Brain areas that shrink in this disease overlap major DMN centers very closely.
- Depression: Patients with depression exhibit decreased connections between one area of the DMN and regions involved in emotions.
- Schizophrenia: Many regions of the DMN in patients with schizophrenia demonstrate increased levels of signaling. The importance of this finding is not clear yet.