The Default Network
A Review by,
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Overview
Human beings spend nearly all of their time in some kind of mental activity, and much of the time their activity consists not of ordered thought but of bits and snatches of inner experience: daydreams, reveries, wandering interior monologues, vivid imagery, and dreams. These desultory concoctions, sometimes unobtrusive but often moving, contribute a great deal to the style and flavor of being human. Their very humanness lends them great intrinsic interest; but beyond that, surely so prominent a set of activities cannot be functionless. (Klinger 1971 p. 347)

The default network is defined as a specific, anatomically defined brain system preferentially active when individuals are not focused on the external environment.
The Default Network is active when individuals are engaged in internally focused tasks including:

• autobiographical memory retrieval
• envisioning the future
• conceiving the perspectives of others

The authors hypothesize that the purpose of the default network is to facilitate flexible self-relevant mental explorations - simulations - that provide a means to anticipate and evaluate upcoming events before they happen.
History

• “When absorbed in intellectual attention we become so inattentive to outer things as to be ‘absent-minded,’ "abstracted," or ‘distracts.’ All revery or concentrated meditation is apt to throw us into this state” (W. James, 1890)

• In the 1930s, Hans Berger found that the brain is not idle when left undirected.

• In the 1970s Swedish physiologist, David Ingvar, found that frontal activity reached high levels during rest states.

• Researchers doing PET scans in the 1990s found that certain brain regions were more active in the passive conditions (down regulation of sensory regions and activation of dmPFC, PCC, and retrosplenial cortex).

Blue regions represent areas most active in passive conditions (Shulman et al. 2007, PET studies, n=132)
Anatomy

Core Regions Associated with the Brain’s Default Network

- Ventromedial Prefrontal Cortex (vmPFC)
- Posterior Cingulate (PCC)/retrospenial cortex (Rsp)
- Inferior Parietal Lobule (IPL)
- Lateral temporal cortex (LTC)
- Dorsal Medial Prefrontal Cortex (dmPFC)
- Hippocampal Formation (HF)

Across 18 data sets, the MPFC, PCC/Rsp, and IPL show nearly complete convergence.
The default network comprises multiple interacting hubs and subsystems.

The structure of the default network has a core set of regions (red) that are all correlated with each other. LTC is distant because of its weaker correlation with the other structures. The medial temporal lobe subsystem (blue) includes both the hippocampal formation (HF) and parahippocampal cortex (PHC). This subsystem is correlated with key hubs of the default network including PCC/Rsp, vMPFC, and IPL. The dMPFC is negatively correlated with the medial temporal lobe subsystem suggesting functional dissociation. Graph analytic visualization provided by Alexander Cohen and Steven Petersen.

The Default Network and the Hippocampus

- HF forms a subsystem that is distinct from other major components of default network including the dmPFC.
- Both are strongly linked to the core hubs of the default network but not to each other
- A current question is about why the correlated strengths associated with the MTL are generally weaker than those observed in the neocortical regions
- Infants don’t show interactions between default regions, indicated that the network develops in toddlers or children

Map of the default network as generated from intrinsic functional correlations with the hippocampal formation in 4 independent data sets
Spontaneous Cognition

- Stimulus-Independent Thoughts
  - thoughts about something other than events originating from the environment
- Momentary Lapses in Attention
  - during lapses of attention, activity within the default network was increased in the PCC/Rsp
  - In a memory encoding study, increases in the PCC/Rsp and IPL predicted which words would later be forgotten (Otten & Rugg, 2001)

The default network is most active in individuals who report frequent mind-wandering, suggesting a functional role in spontaneous cognition.

Functions

- The Sentinel Hypothesis
- Monitoring the External Environment
- The Internal Mentation Hypothesis
- Constructing Alternative Perspectives
- Competitive Functional Interactions
The Internal Mentation Hypothesis and the Hippocampus

- Self-reflective thought and judgments that depend on inferred social and emotional content robustly activate MPFC regions within the default network.

- The default network also includes connections with the HF and overlaps with regions active during episodic remembering, particularly with autobiographical memories (Andreason et al., 1995; Maguire, 2001; Cabeza and St Jacques, 2007).

- Autobiographical memory retrieval activated the major extent of the default network.

**FIGURE 14.** Posterior regions within the default network overlap regions that are active during successful episodic memory retrieval. (left) Image of the default network subsystem correlated with the hippocampal formation. These data represent the surface projection of data from Figure 3B. Adapted from Vincent et al. (2006). (middle) Image of successful episodic memory retrieval. This image shows regions with high levels of activity during episodic recollection as compared to familiarity-based recognition. Adapted from Wagner et al. (2005). (right) Regions of convergence across the two maps extend to the PCC/Par, IPL, and portions of MPFC.
Relevance to Brain Disease

- Autism
  - several regions within the default network exhibit a relative increase in grey matter volume compared to controls
  - significantly less activity in default network, esp. in vmPFC, show a lack of self-referential processing
  - Theory - underutilized default network

- Schizophrenia
  - overactive default network, blurring the boundaries of imagined and external scenarios

- Alzheimer's
  - severe disruption in the default network, esp. MTL regions. Atrophy in PCC/Rsp also present in preclinical stages of the disease

Conclusions

- Within this hypothesis, the default network thus comprises at least two distinct interacting subsystems:
  - one subsystem functions to provide information from memory;
  - the second participates to derive self-relevant mental simulations.
- the dMPFC and medial temporal lobe are not intrinsically correlated with one another, suggesting some level of functional separation.
- Certain situations draw heavily on both subsystems such as elicited during autobiographical memory tasks and when thinking about the future.
  - One possibility: dMPFC subsystem interacts with the medial temporal lobe subsystem to the degree that past episodic information is an important constraint on the mental simulation being derived.
  - The convergence of the two subsystems on common hubs, in particular PCC, may serve to prepare the system for these critical interactions.
Using memories and associations from past experiences as its building blocks, the default network participates in constructing self-relevant mental simulations that are exploited by a wide range of functions including remembering, thinking about the future, and inferring the perspectives and thoughts of other people.

“scene construction,” a term emphasizing that mental simulation often unfolds in one’s mind as an imagined scene with rich visual and spatial content (Hassabis et al. 2007).

Vogeley and colleagues (2004) have also noted that regions within the default network are differentially active depending on the perspective taken when imaging a scene. The default network is most active when one takes a first-person perspective centered upon one’s own body as opposed to a third-person perspective.