

THE NEUROCOGNITIVE THEORY OF DREAMING: WHERE, WHEN, HOW, WHAT, & WHY

G. William Domhoff • Dept. of Psychology • University of California, Santa Cruz

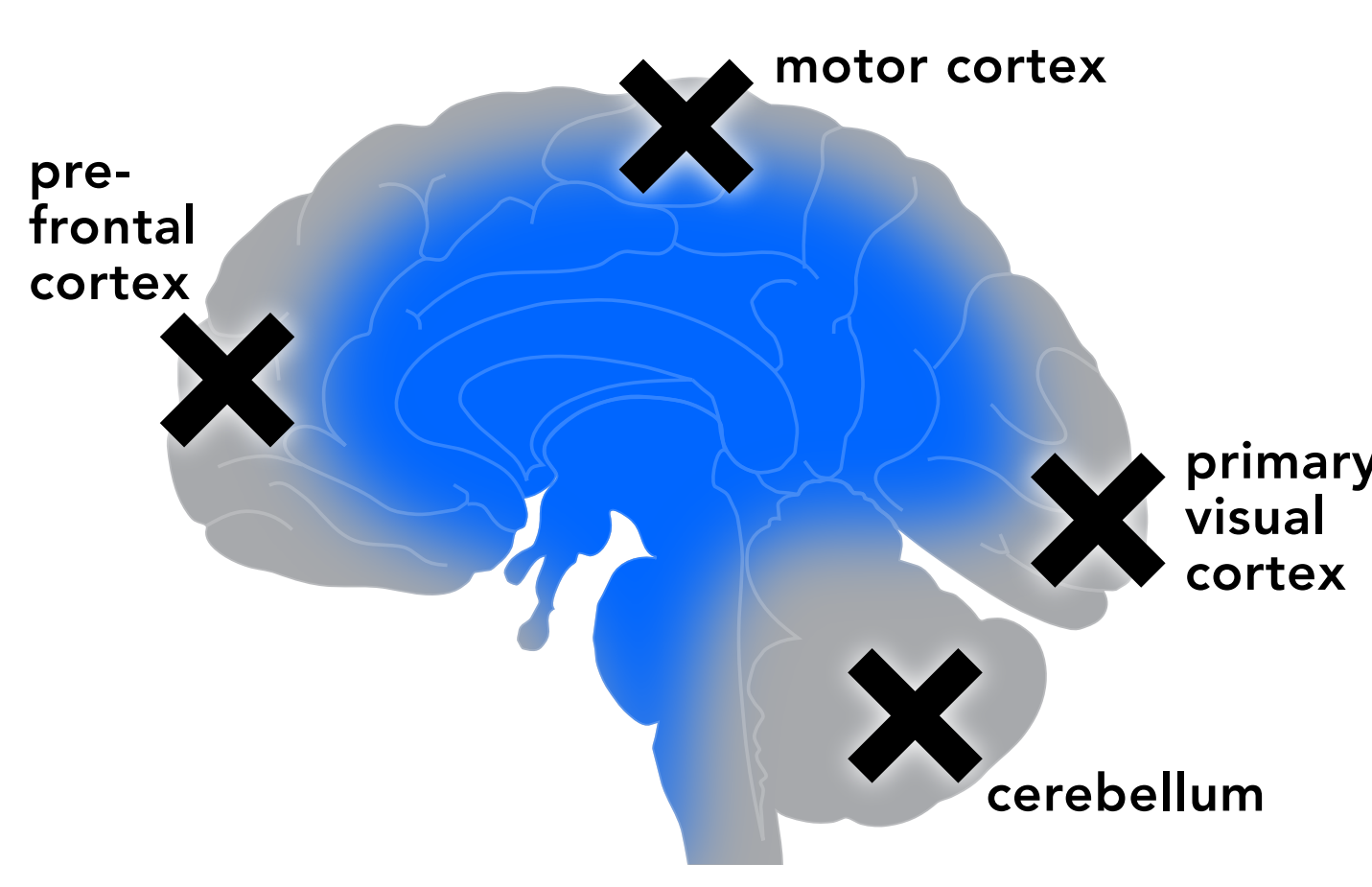
WHERE DOES DREAMING OCCUR?

The neural substrate that supports dreaming is located in parts of the default network, including the lingual gyrus and the caudate nucleus, and most of all in its dorsomedial prefrontal and medial temporal lobe subsystems. Since the frontoparietal control network and the dorsal attentional network are largely deactivated during sleep, dreaming is enabled by a *highly activated portion of the default network*.

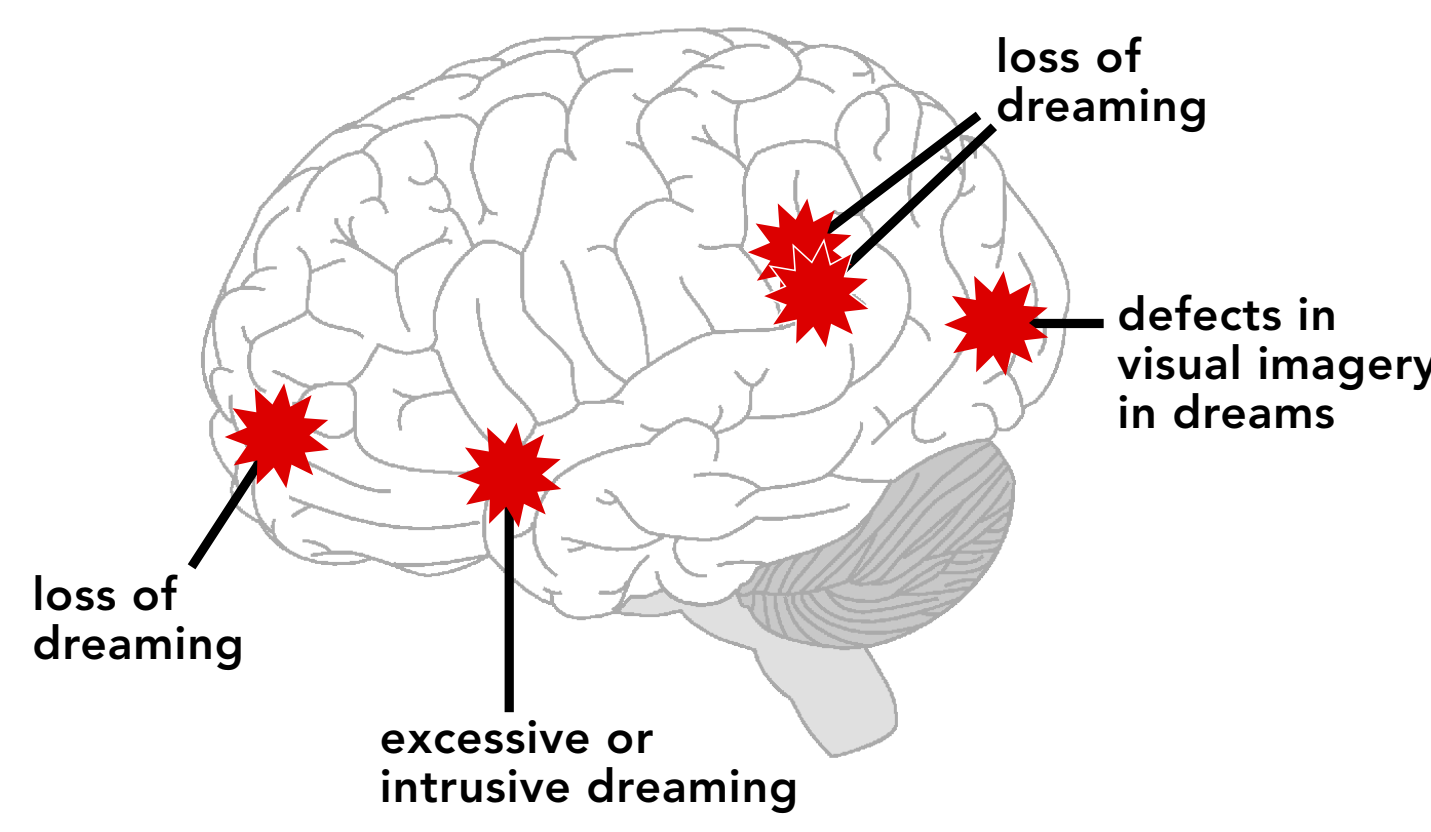
Three types of evidence support this conclusion:

1. **Neuroimaging studies** of REM sleep and the sleep-onset process, when compared with waking studies of the default network, show a large overlap;
2. **Lesion studies** reveal that lesions outside this network do not lead to reports of loss or alteration of dreaming by patients, but lesions in the ventral medial prefrontal cortex, inferior parietal lobules, or temporoparietal junction lead to reports of loss of dreaming, and lesions in areas in the secondary visual cortex lead to reports of loss of visual imagery or of alterations in visual imagery;
3. **Electrical brain stimulation** in the temporal lobe, and especially the medial temporal lobe, lead to patient reports of dreamlike mental events.

Areas of the brain NOT needed for dreaming



Effects on dreaming of lesions in various parts of the brain



WHEN DOES DREAMING OCCUR?

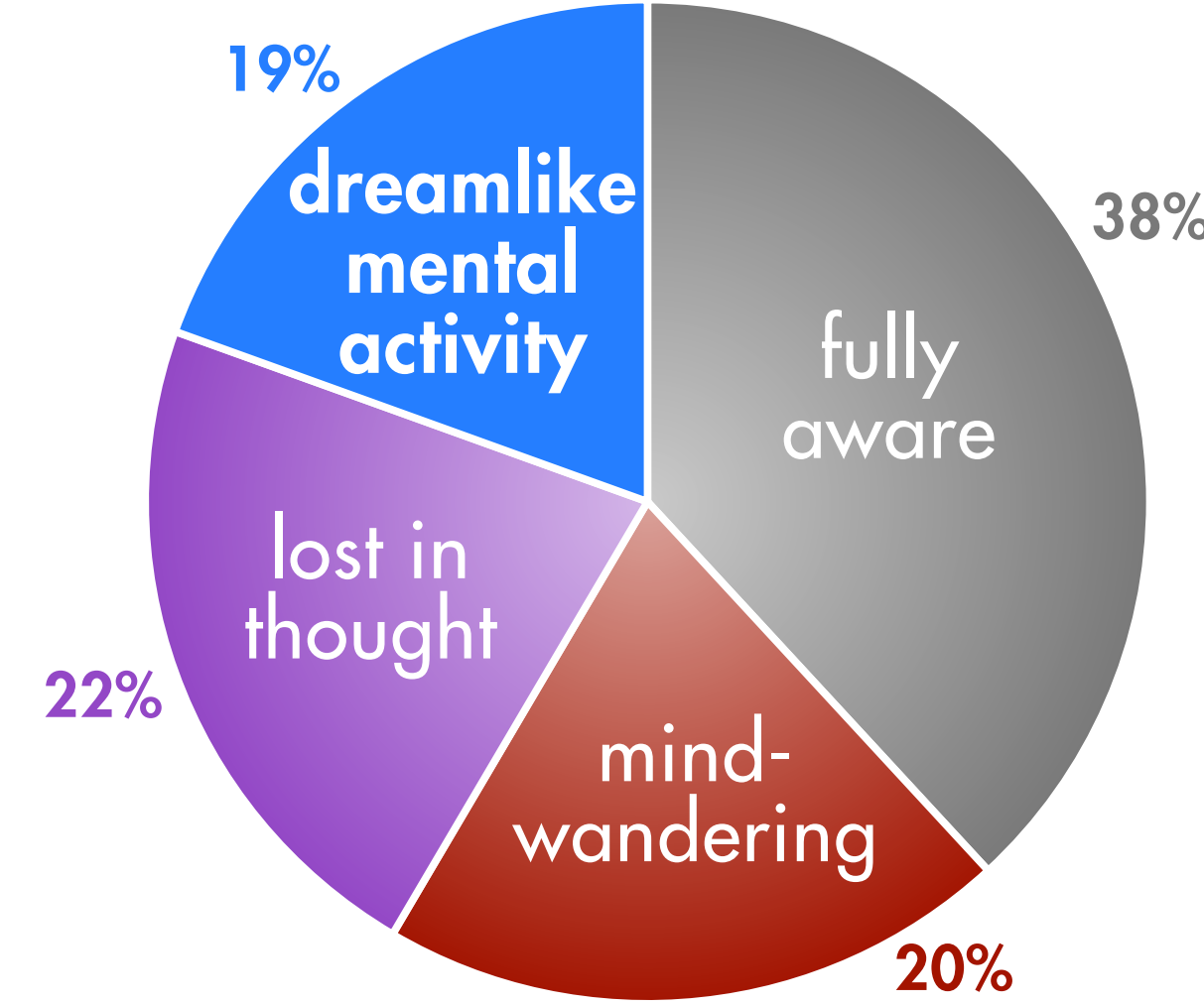
From a neurocognitive point of view, dreaming occurs under the following six conditions:

1. A **mature** neural substrate that can support the cognitive process of dreaming, a qualification that allows for neural development in childhood.
2. An **intact** neural substrate, which means there have been no lesions of the kind that lead to the loss of dreaming.
3. An adequate level of **cortical activation**, which is provided by several subcortical ascending pathways and regions within the hypothalamus.
4. The **occlusion of external stimuli** by the posterior thalamus.
5. A cognitively mature **imagination system**, based in regions within the default network, a necessity that is indicated by the relative lack of dreaming in preschoolers and its relative infrequency until ages 8–9.
6. The **loss of conscious self-control** as the frontoparietal control network becomes less activated and the dorsal attentional network and the salience network lose their functional connectivity to posterior portions of the default network.

When do these six conditions occur?

- Most often in Rapid Eye Movement sleep (REM).
- During Non-REM sleep 2 (NREM 2), which is similar to REM in terms of EEG frequencies, cerebral blood flow, and waking auditory threshold, and often leads to mind-wandering reports when dreams are not reported — which suggests the activation of the default network.
- During the eight-stage sleep-onset process, which is *not* a state of sleep.
- Briefly during long periods of drifting waking thought when alone — which suggests that dreaming can occur during a waking state.

Mental state of subjects told to “relax, but stay awake”



(Foulkes & Fleisher, 1975)

THE HOW OF DREAMING

Embodied Simulation

The key cognitive process in dreaming is “simulation,” a particular kind or subset of thinking that involves imaginatively placing oneself in a hypothetical scenario and exploring possible outcomes.

Dreaming is often based on an enhanced form of simulation, “embodied simulation,” in which people experience themselves as being in hypothetical scenarios that include a vivid sensory environment, interpersonal interactions, and emotions.

Embodied simulation is supported by the activated secondary sensory and sensorimotor areas in the default network, which support all forms of mental imagery.

Dreams may be the quintessential example of embodied simulation because they can last as long as 15-30 minutes, are experienced as “real” while they are happening, and are often remembered upon awakening, at least temporarily, as an actual experience.

Dreaming may be best described as a **simulated subjective experience in which dreamers experience themselves as embodied participants in (or embodied observers of) an event**, almost always involving characters, activities, and/or social interactions. This sense of experiential involvement in an event is what distinguishes dreaming from other forms of thinking during sleep, such as isolated imagery or repetitive thoughts, as well as distinguishing dreaming from mind-wandering, whether the mind-wandering occurs during NREM 2 or as part of waking thought when not engaged in a focused task.

**“Dreams are true while they last.
Can we, at the best, say more of life?”**
— Havelock Ellis, *The World of Dreams*, 1916

THE WHAT OF DREAMING

Dream Content

- Dreams are mostly about everyday waking themes, and by ages 11-13 they very often dramatize personal concerns relating to important people and avocations in the dreamer’s life.
- There are developmental changes in content from childhood to adolescence.
- There are many cross-cultural similarities, such as more aggression than friendliness and more misfortunes than good fortunes, and a few predictable cross-cultural differences, such as a higher frequency of animals in the dreams of hunting-and-gathering groups.
- Based on studies of about two dozen dream series, there is consistency in dream content over months, years, and decades in terms of the major characters, avocations, and types of frustrating situations.
- Based on blind analyses of dream content in about a dozen dream series on which dreamers could provide feedback to the researchers’ inferences, there is a continuity between elements of dream content and waking conceptions and personal concerns.
- The character networks in dreams fit the definition of a “small-world” network.
- Dreams are rarely (if ever) “symbolic.”

WHY WE DREAM

An Evolutionary Adaptation?

Any evolutionarily adaptive function for dreaming is **doubtful** because:

- Patients who had orbitomedial leucotomies in the distant past and reported the loss of dreaming, nonetheless continued to sleep normally and to function in waking life, as documented in two sleep-laboratory studies in the early 1970s, although they also seemed to lack imagination and initiative in waking life. More recent patients with specific lesions that caused them to lose dreaming also continued to function.
- Pre-school children very likely do not dream. Elementary school children have infrequent and relatively simple dreams that rarely include any emotion, but children of any age sleep soundly, learn well, and interact socially. This suggests that any adaptive function that dreaming may have would have to emerge in preadolescence, but no theories propose any adaptive function that begins at that age or later.
- The consistency of dream content over months and years, and the fact that dream content changes only gradually over time, do not support the idea that dreams deal with new problems or help people plan for the future.
- Very few dreams are recalled by even the most frequent recallers, and those few dreams rarely if ever contain insights or solutions to problems. Instead, there is evidence that the insights attributed to specific dreams in anecdotal accounts are based on waking reflections about the dream.

These and other empirical findings have led to the abandonment of past theories of dream function, including those of Freud and Jung, as well as many other unrelated theories. And the problem-solving theory of dream function has fewer and fewer adherents.

Memory Consolidation? Social Rehearsal? Predictive Codes?

Memory consolidation, social rehearsal, and predictive code theories, which now receive wide attention, assume that dreaming and dreams are adaptive without any waking recall. However, they are called into question by most of the same empirical findings mentioned on the previous page.

In addition, the idea that dreaming during REM sleep acts to process the emotional content of waking events, a form of memory consolidation, is contradicted by the minimal amount of dreaming in young children and the wide range of repeated themes in the dreams of preadolescents, teenagers, and adults. Studies during the past 15 years find far more evidence of memory consolidation during NREM sleep than REM sleep, which is inconsistent with a theory of dream function focused primarily on REM sleep. Advocates of this view later found that NREM delta-wave activity in naps was strongly related to the consolidation of negative information. They concluded that the same degree of emotional memory benefit can be obtained by taking a nap, which raises serious questions about the degree of alleged memory consolidation that could occur in dreams during REM sleep, which is when a large percentage of dreams occur.

Social-rehearsal theories claim dreams are rehearsals for improving social interactions or dealing with threats, but children’s dreams have few social interactions and virtually no threats, and dream content changes too little and too late to be a reaction to new situations. More generally, the nature of dream content does not fit their claims. They are also called into question by their assumption that there can be implicit learning during dreaming and transfer of training from dreams to waking. But both of those processes are limited in scope in waking life and require focused attention, and there is no evidence that they occur during sleep or dreaming, when there is no focused attention in any case.

All of these problems also refute the predictive codes theory.

THE DEVELOPMENT OF DREAMING

Dreaming is a *gradual* cognitive achievement

Age	Dream content
3–5	Dreaming is very rare if not non-existent; static imagery; very short
5–7	Social interactions occur, but dreamer is often not in the action
7–9	Dreamer more often has a central role in the dream; longer reports
9–11	Dreams adult-like in frequency and complexity
11–13	Dreaming becomes more adult-like in content as well as complexity

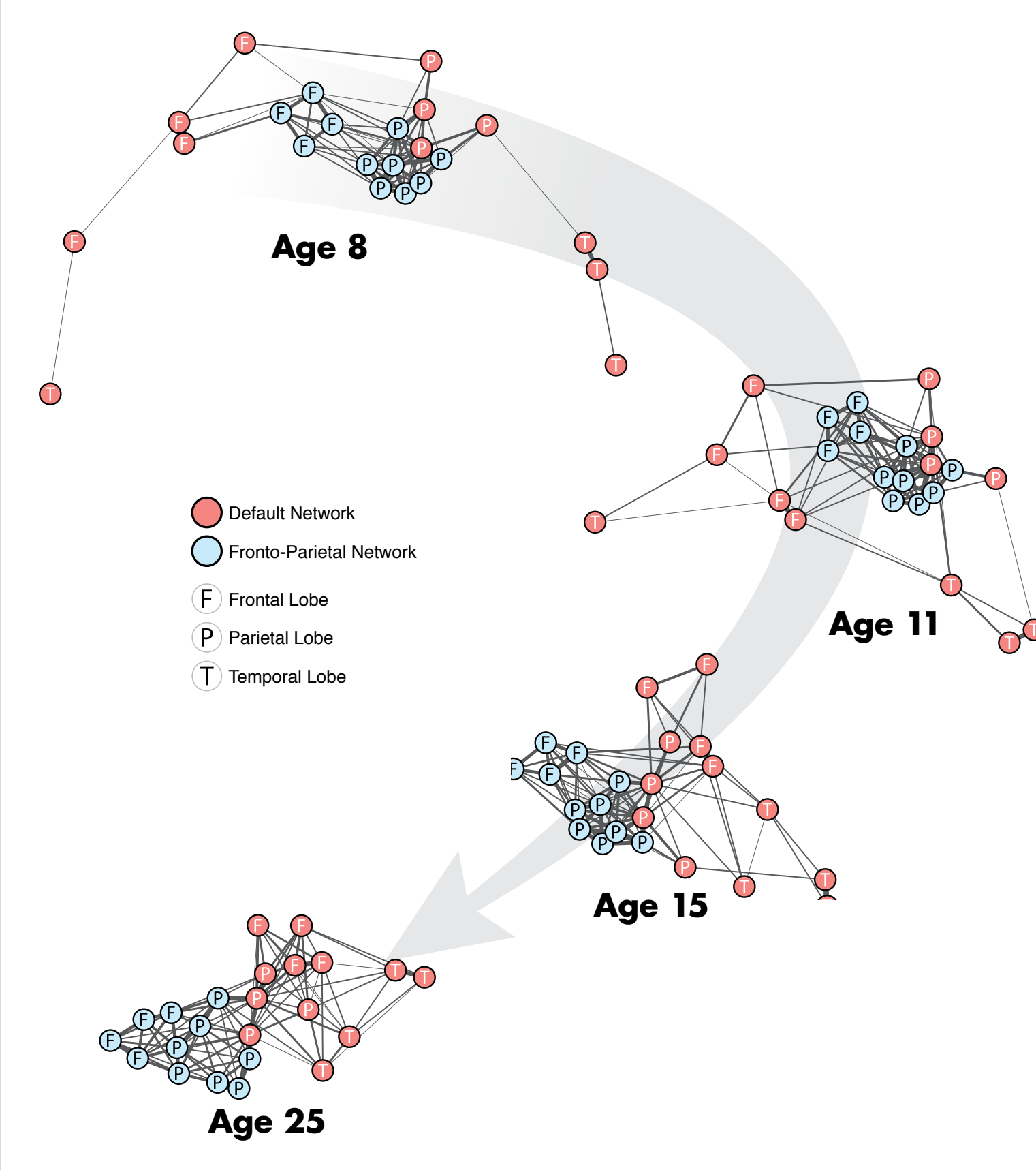
Why don’t young children dream?

Four cognitive milestones are probably required for dreaming:

1. The development of **narrative skills**
2. The development of **imagination**
3. The development of an **autobiographical Self**
4. The development of **mental imagery**

The development of the default network

The development of dreaming may depend upon the maturation of the default network, which looks very different over time, as shown in these four diagrams, drawn in fictive space (adapted from Fair et al., 2009):



DREAMING: A CULTURALLY USEFUL NON-ADAPTATION?

Not all forms and functions are a direct product of natural selection.

Dreaming may be a by-product of imaginative waking cognitive capacities that turned out to have great adaptive value. That is, it may be a by-product of evolutionary selection for the default network, which makes it possible to think about the past and prepare for the future.

More specifically, dreaming may be the accidental result of the incidental intersection in *Homo sapiens* after ages 5-7 of a large default network with one of the following: (1) the periodic activations that occur during sleep; (2) the continuing activation of the default network during the sleep-onset process; (3) the occlusion of external stimuli during long periods of drifting waking thought.

Although many people report they experience new insights or have new ideas when they awaken from sleep, empirical studies suggest that new ideas emerge *after* awakenings, whether people were dreaming or not, because the default network is more ascendant than the frontoparietal control network within that non-threatening context.

Anthropological and comparative religion studies show dreaming has psychological and cultural “uses” that were invented by human beings in the course of history, such as in religious ceremonies and healing functions, but uses created due to the imaginative capacities of the human mind are not adaptive functions based on natural selection.

Dreaming is the imagination wandering freely, powered by embodied simulation. But there’s not enough executive functioning going on during dreaming for it to be creative in the waking sense of the term.

A HISTORICAL OVERVIEW

of the (mostly accidental) discoveries leading to a Neurocognitive Theory of Dreaming

1. 1953: REM sleep is accidentally discovered: Dreams are usually reported after awakenings from this sleep state. Then an entire sleep cycle is discovered. And there is some dreaming in “Non-REM” and during the sleep-onset process. Laboratory dream research is suddenly possible. Unfortunately, replicated foundational findings are now ignored.
2. 1965-1980: Quantitative studies of non-lab dream reports reveal cross-cultural similarities and differences, consistency in what individuals dream about, and continuity with waking personal concerns.
3. Early 1970s: Waking studies in a sleep-dream lab accidentally find brief episodes of dreaming during drifting waking thought. These findings provide a bridge to the later studies of mind-wandering.
4. 1980s: Lab studies of children find dreaming develops gradually (before age 5: little or no dreaming; ages 9-11: dreams are adultlike in frequency and complexity; ages 11-13: dreams become adultlike in content, consistency, and the expression of personal concerns). Several specific cognitive abilities have to develop before dreaming can occur.
5. 1990s: Neuroimaging studies uncover the regions of the brain active during dreaming; there’s a specific neural substrate that supports dreaming. We don’t dream with the whole brain, as had been assumed.
6. 1990s: Lesion studies of neurological patients verify this brain substrate. Certain brain lesions lead to complete loss of dreaming. Other lesions lead to loss of visual imagery during dreaming; Brain injuries outside the neural network for dreaming have no impact.
7. 2000-2009: The serendipitous discovery of the neural basis for mind-wandering and daydreaming during waking changes everything in the few years between 2010 and 2018.