

# **The Relationship Between Dreaming and Autooetic Consciousness: The Neurocognitive Theory of Dreaming Gains in Explanatory Power by Drawing Upon the Multistate Hierarchical Model of Consciousness**

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## **Abstract**

The neurocognitive theory of dreaming, which emphasizes portions of the default network as the most important neural substrates that support dreaming, can increase its explanatory power by drawing upon the multistate hierarchical model of consciousness (Domhoff, 2022; LeDoux, 2019). The default network's two main subsystems, the dorsal medial prefrontal cortex subsystem and the medial temporal cortex subsystem, are involved in supporting imagination and mind-wandering during waking, which suggests that dreaming is a form of spontaneous imaginative thought. The multistate hierarchical model of consciousness considers the regions that support dreaming to be part of the intermediate multimodal areas in the multistate hierarchy. In terms of self-reflective (autooetic) consciousness, the schemas developed and stored in the intermediate multimodal areas are re-represented by the higher-order networks in the anterior prefrontal cortex (the dorsal lateral and ventral lateral prefrontal cortices, and the lateral frontal pole), which are the necessary additional regions essential for autooetic consciousness to emerge. These anterior areas are relatively deactivated during all stages of sleep, which may help explain various "cognitive insufficiencies" during dreaming, such as the lack of autooetic consciousness and episodic memory, and the relative absence of figurative thinking and emotions. Dreaming produces only noetic (fact-knowing) consciousness, based on semantic memory. However, there are rare instances of self-awareness during dreaming, in which the anterior higher-order networks are atypically activated during sleep. The findings on the immaturity of the default network until ages 9-11, and the gradual development of the cognitive abilities necessary for dreaming, are consistent with this analysis.

## Introduction

This proposed extension of the theoretical understanding of the relationship between dreaming and self-reflective (auto-noetic) consciousness begins with the claim that two relatively new and recently updated theories, the neurocognitive theory of dreaming and the multistate hierarchical model of consciousness, are highly compatible (Domhoff, 2022; LeDoux, 2019; LeDoux & Lau, 2020). More specifically, the explanatory power of the neurocognitive theory of dreaming therefore can be increased by drawing upon the more encompassing and more fully delineated multistate hierarchical model of consciousness, which was developed without any focus on dreaming. Most importantly, the multistate hierarchical model can explain dreams as a facet of its intermediate multimodal areas, which includes many of the same neural substrates that are claimed to be the neural substrate for dreaming in the neurocognitive theory of dreaming. The multistate hierarchical model therefore makes it possible to explain the several differences between dreaming and auto-noetic consciousness--such as the lack of episodic memories during dreaming and the relative absence of figurative thinking and emotions-- as “cognitive insufficiencies” during dreaming. The concept of cognitive insufficiencies encompasses (1) cognitive defects due to brain lesions; (2) temporary deficiencies due to immaturity; and (3) recurring deficiencies during sleep due to the relative deactivation of neural substrates that are activated during waking, as discussed in the next section (Domhoff, 2022, pp. 55-56, 160-161, 234-235, for discussions of cognitive insufficiencies during dreaming).

Drawing upon the multistate hierarchical model of consciousness and the work of other neurocognitive researchers, it also may be possible for the neurocognitive theory of dreaming to explain the rare phenomenon of self-awareness during dreaming. It does so in terms of the atypical activation during sleep of the most anterior areas of the higher-order network (the dorsal lateral and ventral lateral prefrontal cortices, and the lateral frontal pole), which are the necessary additional regions essential for auto-noetic consciousness to emerge according to the multistate model (LeDoux, 2019, pp. 359-362; 2021, p. R828, Figure 3). (The lateral frontal pole, which is the most recent and anterior portion of the human brain, is called the “rostrolateral prefrontal cortex” and the “lateral frontopolar cortex” by the other neurocognitive researchers who will be drawn upon in this article (e.g., Christoff & Gabrieli, 2000; Dixon, Fox, & Christoff, 2014a).)

More generally, the discussion of these possibilities also may serve to stimulate thinking about the compatibility of various theories of dreaming and theories of auto-noetic consciousness. Perhaps, for example, the neurocognitive theory of dreaming may be compatible with other theories of auto-noetic consciousness, or other theories of dreaming may be compatible with the multistate hierarchical model of consciousness. And, of course, other theories of dreaming may be compatible with various theories of auto-noetic consciousness, including several contemporary theories of consciousness that also discuss dreaming on the basis of empirical dream research. However, a discussion of these other contemporary theories--all of which differ from each other, and from the neurocognitive theory of dreaming and the multistate hierarchical model of consciousness-- is beyond the purview of this narrowly focused article.

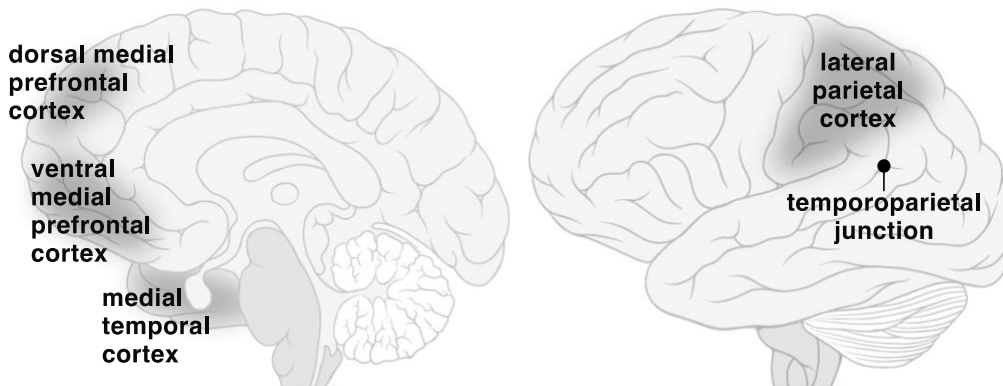
It also is necessary to emphasize what this article is not claiming. The assertion that the neurocognitive theory of dreaming is compatible with, and therefore can draw upon, the multistate hierarchical model of consciousness does not imply that either of these theories is correct. Compatibility is one issue, the adequacy of the two theories is another. Nor does the compatibility discussed in this article imply the other theories that focus on the relationship between dreaming and auto-noetic consciousness are incomplete or wrong.

### **The Neurocognitive Foundations of Dreaming**

Neuroimaging studies of sleep reveal that the neural substrates that subserve four of the five association networks active during waking thought—the frontoparietal control network, the dorsal attention network, the salience/ventral network, and the limbic network-- are relatively deactivated during sleep, as are the neural substrates that subserve the visual and sensorimotor networks (Braun et al., 1997; Braun et al., 1998; Dang-Vu, Schabus, Desseilles, Schwartz, & Maquet, 2007; Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013; Maquet et al., 1996; Nofzinger, Mintun, Wiseman, Kupfer, & Moore, 1997; Uitermarkt, Bruss, Hwang, & Boes, 2020). The exception is the relative activation of portions of the default network, the fifth of the association networks. More precisely, the dorsal medial prefrontal cortex subsystem and the medial temporal cortex subsystem of the default network are activated during the sleep-onset process, NREM 2 sleep, and REM sleep (Domhoff, 2011; Eichenlaub, Bertrand, & Ruby, 2014; Sämann et al., 2011; Stevner et al., 2019; Tagliazucchi et al., 2013; Tarun et al., 2021).

These two subsystems, which are the primary neural basis for dreaming, are also involved in supporting imagination and mind-wandering in waking life when the frontoparietal control network, the dorsal attention network, and the salience/ventral network are not constraining the default network to the degree they do in task-oriented contexts (Andrews-Hanna, Reidler, Sepulcre, Poulin, & Buckner, 2010; Andrews-Hanna, Smallwood, & Spreng, 2014; Chang, Liu, Chen, Liu, & Duyn, 2013; Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015; Spreng, Madore, & Schacter, 2018). Although the two subsystems of the default network are relatively activated during dreaming, the “zones of integration” (the areas in the default network that connect it to the other association networks during waking), are relatively deactivated throughout sleep. Their relative deactivation contributes to the independence of the default network at the times when it is relatively activated during sleep. Figure 1 provides an approximate indication of the locations of the main regions in the default network that are activated during dreaming. However, it does not include all of the neural substrates that are activated during dreaming. A more detailed presentation of the brain areas that support dreaming is provided in Table 1 at the end of the next section, which shows the differences between the neural networks that support auto-noetic consciousness and dreaming.

**Figure 1.** Five important regions in the Default Network that are activated during dreaming.



During the sleep-onset process, NREM 2 sleep, and REM sleep, the dorsal medial and medial temporal subsystems of the default network are augmented by the relative activation of secondary sensory cortices (including the lingual gyrus), along with secondary sensorimotor areas and the caudate nucleus, which combine to create the neural substrate that subserves dreaming (Domhoff, 2022, Chapter 2). However, the truncated nature of this neural substrate leads to the lack of several cognitive capabilities during dreaming that are enabled during waking by interactions among two or more of the five association networks: an awareness of the here and now, the ability to access episodic memories (Baylor & Cavallero, 2001; Fosse, Hobson, & Stickgold, 2003; Malinowski & Horton, 2014), the near or complete absence of figurative thought and symbolism (Domhoff, 2022, Chapter 5), and the relatively infrequent inclusion of emotions (Domhoff, 2022, Chapter 8). As noted above, dreaming therefore suffers from several cognitive insufficiencies when compared to the cognitive capabilities that are generally available during waking thought.

The presentation of a full statement concerning the cognitive processes supported by the neural substrates that are active during dreaming is outside the narrowly defined purpose of this theoretical article. However, it has to be added that dreaming is a form of “simulation,” which is defined as “a particular type or subset of thinking that involves imaginatively placing oneself in a hypothetical scenario and exploring possible outcomes” (Schacter, Addis, & Buckner, 2008, p. 42). Since simulation during dreaming also involves vivid mental imagery, due to the relative activation of secondary sensory and sensorimotor cortices, the enhanced simulation that enables dreaming can be characterized as “embodied simulation,” which is defined in the strict psychological sense of this term as off-line cognition that is body based. More specifically, embodied simulation occurs when “sensory and motor resources are brought to bear on mental tasks whose referents are distant in time and space *or are altogether imaginary*” (Wilson, 2002, p. 635, italics added).

Within that definition, embodied cognition includes mental imagery, imagination, figurative thinking, episodic memory, reasoning, and problem-solving, and there is ample evidence for its occurrence during waking states (e.g., Bergen, 2012; Calvo-Merino, Jones,

Haggard, & Bettina, 2017; Gibbs, 2006; Landau, Meier, & Keefer, 2010; MacDonald & Culham, 2015; Mason & Just, 2020; Wilson, 2002). It is within this framework, and the evidence for it, that dreaming can be understood as an intensified and enhanced form of mind-wandering and daydreaming, which occurs whenever the frontoparietal control network, the dorsal attention network, and the salience/ventral network are not constraining the default network to the extent that they do in task-oriented contexts during alert waking (Andrews-Hanna et al., 2010; Andrews-Hanna et al., 2014; Chang et al., 2013; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Christoff et al., 2016; Fox et al., 2015).

The emphasis on portions of the default network as the primary basis for dreaming during the sleep-onset process, NREM 2 sleep, and REM sleep is supported by studies of the impact of brain lesions on dreaming (Bischof & Basset, 2004; Jus et al., 1973; Kerr, Foulkes, & Jurkovic, 1978; Poza & Marti-Masso, 2006; Solms, 1997). These studies make use of patients with focal lesions, most of whom were studied before neural plasticity could lead to compensations for the lesions. They can be thought of as a series of inadvertent, experimentally-based tests of the neuroimaging findings. Studies of the impact of lesions in many different areas in the brain show that patients can lose dreaming due to lesions in either the medial prefrontal cortex or the temporoparietal junction, which are parts of the default network. Patients also report specific visual changes after lesions in various areas in the secondary visual cortex. On the other hand, lesions in the dorsal lateral prefrontal cortex, amygdala, primary visual cortex, primary sensorimotor cortices, hypothalamus, cerebellum, and several areas in the brainstem have no impact upon dreaming (Blake, Terburg, Balchin, van Honk, & Solms, 2019; Solms, 1997, pp. 82, 153-154, 219-223, 237). The following generalization therefore can be made on the basis of a large number of cases: lesions *outside* the neural substrates that subserve dreaming have no impact on dreaming, but lesions *within* the neural substrates that subserve dreaming have an effect on dreaming, ranging from the complete loss to dreaming to the loss of different visual aspects of dreaming (Domhoff, 2022, pp. 28-33, for the evidence for this generalization).

In combination, the neuroimaging and lesion studies circumscribe the boundaries of the neural substrates necessary for dreaming. They provide a form of convergent validity for the claim that the general contours of the neural substrate that subserves dreaming are now fairly well established, although much still remains to be learned about its inner workings. The lesion studies add first-person subjective accounts concerning the presence or absence of dreaming, and in the process eliminate many neural substrates as possible areas that might subserve dreaming. More generally, the neurocognitive theory of dreaming, by drawing upon both neuroimaging studies and lesion studies, claims that dreaming is *a property of a specific neurocognitive network*. If that network is not intact, dreaming is defective or does not occur at all.

In addition, the theory has a developmental dimension and can assimilate the many findings on dream content, which have been developed on the basis of quantitative content analyses of many thousands of dream reports collected from both children and adults inside and outside of sleep-dream laboratories (Domhoff, 1996; 2022, Chapters 3-4 and 6-8). The developmental dimension is briefly overviewed in a later section of this article because findings

on the gradual maturation of the default network, and the parallel development of dreaming and the waking cognitive capacities that are very likely necessary for dreaming, provide further support for the analysis based on adult participants in this and the following section. The findings on dream content, on the other hand, are not relevant to the focus of this article.

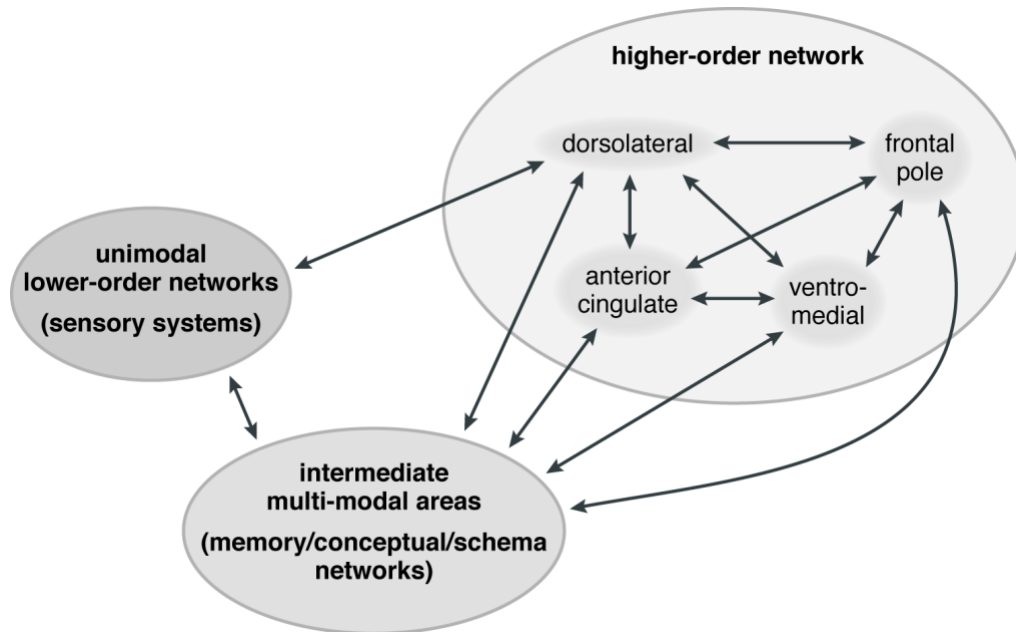
### **The Multistate Hierarchical Model of Consciousness**

The multistate hierarchical model of consciousness is based on a concept called “cortical consciousness networks.” This concept has parallels with the concept of “association networks” that is used in the neurocognitive theory of dreaming. From the perspective of the multistate hierarchical model, several of the areas that support dreaming can be understood as intermediate multimodal areas in the hierarchy that leads to auto-noetic consciousness (LeDoux, 2019, pp. 282-283, 306-308). In waking thought, these intermediate multimodal areas first all of have an important role in processing all forms of incoming sensory information from the unimodal lower-order networks and assimilating them into existing memory banks. The networks within the intermediate multimodal areas also are crucial in creating “schemas,” which are “complex collections of memories about specific things, such as situations, one’s self, and also about emotions” (LeDoux, 2021, p. R828). These areas, which include the ventral medial and dorsal medial cortices that are essential to dreaming, are thus “sources of complex cognitive representations that can, like perceptual, mnemonic, and conceptual representations, be used in the assembly of conscious experiences by the higher-order network” (LeDoux, 2019, p. 360).

The intermediate multimodal areas then connect to the higher-order network located in the most anterior portions of the prefrontal cortex. These anterior areas include the dorsal and ventral lateral prefrontal cortices and the lateral frontal pole, the latter of which is unique in its size and patterns of connectivity to the cognitively modern humans that emerged between 50,000 and 200,000 years ago (LeDoux, 2019, pp. 359-362, 373; 2021, p. R828, Figure 3). However, due to the far greater connectivity between prefrontal and parietal areas in the human brain than in other mammals, including other primates, the parietal cortex also contributes to the executive functions carried out by the higher-order network (LeDoux, 2019, pp. 258-259; 2020, pp. R2, R3). Within this context, the re-representation of the information from the intermediate multimodal networks within the higher-order network is the additional step that makes auto-noetic, self-reflective consciousness possible. The lateral frontal pole, which “only receives input from the multimodal convergence zones, and creates the most abstract conceptual presentations in the brain,” works closely with the dorsal and ventral lateral prefrontal regions in coordinating top-down control of all aspects of human thinking and action (LeDoux, 2019, pp. 252-253). Put another way, these areas “together allow executive control over both unimodal (sensory) and multimodal (conceptual) processing in posterior areas, as well as control of deliberative behavior by way of connections to the motor cortex” (LeDoux, 2019, p. 253). A schematic graphic of the three levels of the theory is presented in Figure 2, in which the two-way arrows emphasize both the complexity of the interactions among the three levels and the fact that

the higher-order network has direct pathways through which it can control the unimodal lower-order networks, as well as the multimodal memory/conceptual/schematic networks.

**Figure 2.** A Schematic Graphic of the Relationships Among The Levels in the Multistate Hierarchical Model of Consciousness: The Unimodal Lower-Order Networks, the Multi-Modal Intermediate Areas, and the Higher-Order Network.



Adapted from LeDoux (2020).

Due to the importance of the most anterior regions of the prefrontal cortex in supporting auto-noetic consciousness, both the multistate hierarchical model of consciousness and the neurocognitive theory of dreaming imply that dreaming has different properties than does auto-noetic consciousness. Unlike during waking, the higher order network is deactivated according to the multistate model, and four of the five association networks are relatively deactivated during dreaming according to the neurocognitive theory of dreaming. In addition, the primary sensory and sensorimotor networks are relatively deactivated, and incoming stimuli are gated in the thalamus (Chow, Horovitz, Picchioni, Balkin, & Braun, 2013; Picchioni et al., 2014; Tarun et al., 2021). Unlike auto-noetic consciousness, dreaming therefore does not have the perceptual inputs that represent the demands and opportunities present in the waking world, which are sent to relevant memory banks for recognition and incorporated into schemas. It also lacks the capacity to redirect thought through top-down commands-- a capacity supported by the lateral frontopolar, dorsal lateral and ventral lateral prefrontal regions (LeDoux, 2019, pp. 359-362). This emphasis on top-down commands is paralleled and supported by the findings on “cognitive control networks” by those theorists who work within the framework provided by the frontoparietal control network and the four other association networks (e.g., Christoff & Gabrieli,

2000; Christoff et al., 2016; Christoff et al., 2001; Dixon et al., 2014a; Dixon, Fox, & Christoff, 2014b). By cognitive control these theorists mean “the process by which PFC [i.e., prefrontal cortex] selectively biases currently relevant representations in other parts of the brain, thereby helping focus attention on currently relevant stimuli while diminishing attention toward other competing stimuli” (Christoff, 2014, p. 319).

Since dreaming is entirely self-generated and receives no external feedback, it depends on the semantic memories and the schemas at the intermediate multimodal level to generate imaginative embodied simulations. These embodied simulations often (but not always) focus on the concerns of the self-system, which is enabled in large measure by regions within the default network (Abraham, 2013; D’Argembeau, 2020; Domhoff, 2022, Chapters 2-3). To provide a contrast with daydreaming-- the spontaneous mental state that appears to be most similar to dreaming-- people can “realize” (reflect upon) the fact that they are daydreaming (Andrews-Hanna et al., 2014; Christoff et al., 2016; Fox, Andrews-Hanna, & Christoff, 2016). A somewhat simplified comparison of the brain networks that subservise autothetic consciousness during waking, and dreaming during NREM 2 sleep, and REM sleep, is provided in Table 1.

**Table 1.** A Comparison of the Main Neural Substrates that Support Autothetic Consciousness and Dreaming.

Brain Region	Consciousness Network	Dreaming Network
Frontal pole/Rostrolateral PFC	activated	relatively deactivated
Dorsolateral PFC	activated	relatively deactivated
Ventrolateral PFC	activated	relatively deactivated
Orbital PFC	activated	relatively deactivated
Ventromedial PFC	activated	activated
Dorsomedial PFC	activated	activated
Episodic memory network	activated	relatively deactivated
Semantic memory network	activated	activated
Lingual gyrus (visual processing)	activated	activated
Secondary visual areas	activated	activated
Primary visual cortex	activated	relatively deactivated

NOTE: This table is based on the discussions and graphics in Domhoff (2022, Chapter 2, with special reference to Table 2.2), and in LeDoux (2019, Chapter 57, especially Figures 57.1 and 57.2).

### Self-Awareness During Dreaming in a Hybrid Sleep State

As one team of neurocognitive researchers notes, “humans typically lack awareness that they are dreaming while dreaming” and “most individuals experience lucid dreams [dreams during which self-awareness occurs] rarely” (Baird, Castelnuovo, Gosseries, & Tononi, 2018, p. 1).

Nevertheless, self-awareness during dreaming is of interest in terms of this theoretical article



because it is a dream state, however rare, that includes self-awareness. This self-awareness occurs occasionally for some people after returning to bed following an early-morning trip to the bathroom, or shortly before their spontaneous morning awakening, which suggests that the brain may be more generally activated when self-awareness during dreaming occurs. But little is known about those who experience self-awareness during dreaming more frequently, or why they do so. Some reports by or about frequent “lucid dreamers,” as they call themselves, suggest that self-awareness during dreaming may begin because of frightening night experiences as a child, which make falling asleep anxiety-arousing to think about, and thereby cause sleep to be fitful. For others, self-awareness during dreaming begins while dealing with insomnia, or with the discontinuance of the ingestion of psychedelic drugs (Lucidity Newsletter, 1986; Rolston, 2013).

According to one systematic waking-state fMRI neuroimaging study, there may be neurological differences between those who do and do not report having experienced self-awareness during dreams with a high frequency. These differences could be caused by one or more of several factors, including genetic predispositions, the development of atypical cognitive capacities, or some of the events mentioned in the previous paragraph. The study compared 14 participants who reported they had 3 or more instances of self-aware dreaming per week with a control group of similar size, whose members reported they had 1 or fewer self-awareness dreams per year. The researchers concluded that self-awareness during dreaming may be “associated with increased functional connectivity between aPFC [the anterior prefrontal cortex] and temporoparietal association areas, regions normally deactivated during sleep” (Baird et al., 2018, p. 1). This finding is consistent with the emphasis in the neurocognitive theory of dreaming on the relative deactivation of these areas during normative dreaming.

Two sleep-lab studies yielded results similar to those in the waking-state study. The first study, which used high-density EEG, involved 6 highly motivated college students who remembered 3 or more self-aware dreams each night at home. The participants each spent up to 5 nights in the sleep lab; 3 of them were able to signal 1 instance each of self-awareness during dreaming (Voss, Holzmann, Tuin, & Hobson, 2009, p. 1191). Their brain patterns were characterized by “wake-like inter-scalp networking, including high-frequency bands,” which were “most pronounced in frontal and frontolateral coherences;” the authors concluded that self-awareness during dreaming may occur during a “hybrid state” that has features of waking as well as REM sleep (Voss et al., 2009, p. 1196). These findings support the emphasis on portions of the default network as the basis for imagination and dreaming in the neurocognitive theory of dreaming, and the emphasis on the dorsal lateral prefrontal cortex, the ventral lateral prefrontal cortex, and the lateral frontal pole as the additional necessary ingredients for auto-noetic consciousness in the multistate hierarchical model of consciousness.

A nighttime combined EEG/fMRI study led to similar results. It was based on 15 nights of fMRI studies that made use of 4 adult male participants between the ages of 27 and 31, who had actively tried to have greater self-awareness during dreaming for several years or more for their own reasons. Although numerous REM periods occurred over the space of the 15 nights,

only 2 of the 4 participants were able to provide eye-movement signals in 1 instance each, which were corroborated by their post-awakening reports. These results reinforce the finding that lucid dreaming is rare even for those who strive to experience it. However, the two occurrences seemed clear enough to report “a reactivation of several areas normally deactivated during REM sleep,” and especially the dorsal lateral prefrontal cortex, ventral lateral prefrontal cortex, and lateral frontopolar cortex (Dresler et al., 2012, p. 1020). These areas are part of the higher-order network in the multistate hierarchical model of consciousness. (Here it may be useful to recall that “lateral frontopolar cortex,” “rostrolateral prefrontal cortex,” and “lateral frontal pole” are three different names for the same brain area, which makes it clear that many neurocognitive researchers agree on the important role this area plays in self-reflective awareness.)

It is also relevant in terms of the emphasis on the imaginative nature of dreams in the neurocognitive theory of dreaming that dream reports collected from individuals who report self-awareness during dreaming do not differ from other dream reports. In a comparison of 441 lucid and non-lucid dream reports collected from 10 different samples of college students and older adults over the space of several years, relatively few differences were found. There were more auditory and kinesthetic elements in self-aware dreams, and fewer characters and less happiness in the non-self-aware dreams, but the social interactions were similar, leading to the conclusion that the dream reports from the two different neurocognitive states “*are more alike than they are different*” in terms of their content (Gackenbach, 1988, pp. 192-193, italics in the original). In addition, as a comprehensive overview of the relevant literature concluded, “a majority of lucid dreams, it seems, feel very much like standard wakefulness and nonlucid dreams” (Windt, 2015, p. 118).

Based on this overview of the portions of the literature on self-awareness during dreaming that are relevant to a neurocognitive explanation for this rare phenomenon, the imaginative nature of such dreams can be explained by the relative activation of portions of the default network, secondary sensory areas, and the caudate nucleus, which provide the neural foundations for the neurocognitive theory of dreaming. The presence of self-awareness may be explained by the atypical relative activation of the dorsal lateral prefrontal cortex, the ventral lateral prefrontal cortex, and lateral frontal pole (Dresler et al., 2012, p. 1020; Voss et al., 2009), which are the additional necessary ingredients for self-awareness in the multistate hierarchical model of consciousness. However, these results need to be replicated with larger sample sizes, and the factors that allow self-awareness to be possible during dreaming without awakening remain unexplained. Put another way, the extent to which self-awareness during dreaming is similar to auto-noetic consciousness during waking remains to be fully examined.

One possibility might be that a specific network of areas in the anterior prefrontal cortex, including the lateral frontal pole/rostrolateral prefrontal cortex, serve to focus attention internally or externally (e.g., Burgess, Dumontheil, & Gilbert, 2007; Christoff, 2014; Christoff & Gabrieli, 2000; Christoff, Ream, Geddes, & Gabrieli, 2003; Henseler, Krüger, Dechent, & Gruber, 2011). In particular, a study showing that there are two subsystems within the frontoparietal control network, one that regulates the dorsal attention network during attention and action, and one that

interacts with the default network when the focus is on personal thoughts, might provide a useful starting point (Dixon et al., 2018). Two other studies support the possibility that the internally oriented portion of the frontoparietal control network may play a role in self-awareness during dreaming. First, a waking study of the lateral frontal pole/rostrolateral prefrontal cortex found that participants could gain some control of self-referential thoughts relating to that region by reflecting on their own thoughts (“meta-awareness”) (McCaig, Dixon, Keramatian, Liua, & Christoff, 2011). In addition, still another waking study found that this same internally oriented region within the frontoparietal control network interacts with regions in the default network that are concerned with self-referential information and contribute to meta-awareness (Dixon et al., 2022).

### **Parallel Developmental Paths Support Dreaming and Autooetic Consciousness**

The findings described in the earlier sections of this article concerning the basis of normative everyday dreaming and autooetic consciousness are consistent with what has been learned about the parallel development of dreaming and autooetic consciousness in young children. The most important finding from longitudinal and cross-sectional developmental studies of dreaming is that dreaming does not occur often, if at all, before age 5, and develops only gradually in terms of its frequency and complexity between the ages of 5- 9. Dreaming then becomes somewhat more adultlike between ages 9-11 but dream content does not become similar to that of adults until ages 12-15 (Domhoff, 2022, Chapters 6-7, for a synthesis; Foulkes, 1982, 2017; Foulkes, Hollifield, Sullivan, Bradley, & Terry, 1990; Strauch, 2004, 2005; Strauch & Lederbogen, 1999, for the longitudinal and cross-sectional studies that provide the basis for this synthesis). In addition, neuroimaging studies of children and adolescents reveal that the default network matures only slowly, and it is not close to adultlike levels until ages 9-13, which is consistent with the emphasis in the neurocognitive theory of dreaming on the role of portions of the default network (Domhoff, 2022, Chapter 6, especially Figure 6.1; Fair et al., 2008; Fair et al., 2009; He et al., 2019; Moraczewski, Nketia, & Redcay, 2020; Sherman et al., 2014).

Moreover, dreaming seems to require the development of five cognitive capacities that have been systematically studied by those psychological scientists who focus on waking cognitive development. These cognitive capacities include the ability to form concepts, generate mental imagery, make use of narrative thinking, and think imaginatively, along with the acquisition of an autobiographical self. It is likely that these are the cognitive abilities that are necessary for the more general cognitive process of simulation, as will become clear as this section unfolds. The ability to form concepts develops between late infancy and 30 months (Mandler, 2008, 2012; Nelson, 2004). Children gradually develop the capacity to generate mental imagery, make use of narrative thinking, and think imaginatively between the ages of 3 and 6, but imaginative abilities only gradually become more adultlike until ages 10-12 (Coughlin, 2016, p. 22; Coughlin, Robins, & Ghetti, 2019; Foulkes et al., 1990; Nelson, 2007, pp. 170-171; Taylor, 2013). The many findings in this large waking-state literature in developmental psychology have been summarized and synthesized in the context of adding a

developmental dimension to the neurocognitive theory of dreaming (Domhoff, 2018, Chapter 4; 2022, Chapters 6-7).

With regard to the development of autooetic consciousness, it is first of all relevant that preschool children “don’t understand that your thoughts can be internally generated,” or that “thoughts can simply follow the logic of your internal experiences instead of being triggered from the outside,” until the ages of 5-6 (Gopnik, 2009, p. 152). Similarly, pre-school children do not understand that dreams are internally generated, and they sometimes think dreams are a shared experience, which may be because they do not dream very often and therefore rely on what parents and children’s books tell them about dreaming (Meyer & Shore, 2001; Woolley & Boerger, 2002; Woolley & Wellman, 1992). In addition, young children “don’t experience their lives as a single timeline stretching back into the past and forward into the future;” nor do they “feel immersed in a constant stream of changing thoughts and feelings” (Gopnik, 2009, p. 153). Furthermore, if pre-school children are asked during an idle moment what they were just thinking, they usually say “nothing,” which actually may be the case if they are not proficient at imagining and simulating. In a developmental study of children’s familiarity with mind-wandering, only 44% of children understood what mind-wandering is at ages 6–7, compared to 86% by ages 10–11. This finding raises the possibility that mind-wandering has a developmental trajectory similar to that of dreaming, which again suggests the importance of a mature default network and the cognitive ability to simulate in order to mind-wander and dream (Eisbach, 2013, Table 2).

Based on these and other findings, developmental psychologist Allison Gopnik (2009, p. 153) argues that children need to have an autobiographical self in order to experience autooetic consciousness, which according to her analysis does not develop until about age 5 and thereafter. Developmental psychologist Katherine Nelson and her colleagues have enriched the understanding of an autobiographical self through numerous studies, and report a similar developmental timeline. Their work demonstrates that there is an important narrative dimension to autooetic consciousness, which develops through pre-school children’s conversations with adults, especially their mothers, about recent past events and upcoming events (Nelson, 2005; Nelson & Fivush, 2020).

Memory researcher Endel Tulving (2005) reaches a similar conclusion about the importance of autobiographical memories in the development of autooetic consciousness after assessing the literature on the development of episodic memory in children, which manifests itself between ages 4 and 5. In his view, autooetic consciousness appears to be a necessary correlate of episodic memory, which includes a sense of subjective experience, a sense of inner existence, and a personal identity that persists and grows over time (Tulving, 2005, pp 29-34). This pioneering analysis of the relationship between episodic memory and autooesis is also considered to be essential in the multistate hierarchical model of consciousness (LeDoux, 2019, pp. 294-299; LeDoux & Lau, 2020, p. R109).

The emphasis on the importance of autobiographical memory in the development of autooetic consciousness has a parallel with the development of dreaming. The few and brief

accounts of dreams by preschool children rarely include the dreamer herself or himself until ages 5-6. The presence and involvement of the dreamer in the ongoing dream is still not yet fully present in dream reports at ages 7-8, which suggests that both noetic dreaming and auto-noetic consciousness gradually develop between ages 5 and 8 (Foulkes, 1999, pp. 146-150, for an account of consciousness as a developmental construction; 2017, pp. 4-5, 12, for an updated view of consciousness that draws upon Tulving's work on episodic memory and LeDoux's work on emotion; LeDoux, 2015). The overall findings in this section therefore provide further support for a conclusion drawn earlier in this article: auto-noetic consciousness during waking, and dreaming during sleep onset, NREM 2 sleep, and REM sleep, have a close relationship, but they do not have quite the same properties.

### **Implications and Conclusions**

Considering the adult and developmental findings together, the neurocognitive theory of dreaming is compatible with the multistate hierarchical model of consciousness. The multistate hierarchical model therefore can be drawn upon to augment the explanatory power of the neurocognitive theory of dreaming. From the perspective of the neurocognitive theory of dreaming, dreaming occurs during the sleep-onset process, NREM 2 sleep, and REM sleep due to the concomitant relative activation of portions of the default network and secondary sensory and sensorimotor cortices, along with the caudate nucleus. The combination of spontaneous imaginative thought, vivid mental imagery, and the sense of movement that sometimes occurs during drifting waking thought and daydreaming are transformed into an enhanced version of embodied simulation during dreaming (Domhoff & Fox, 2015; Fox et al., 2013).

Dreaming has different properties than auto-noetic consciousness does because the neural substrates that support dreaming lack the perceptual inputs that serve as guideposts for thinking during waking life, as well as the top-down capacity to redirect thought. Dreaming also lacks the neural support that enables access to episodic memory and figurative thinking, and includes emotion much less often than is generally assumed (Domhoff, 2022, Chapter 8). These cognitive insufficiencies are very likely due to the relative deactivation of the frontoparietal control network, the attention networks, and the limbic network according to the neurocognitive theory of dreaming, and to the relative deactivation of the higher-order network according to the multistate hierarchical model of consciousness. The relative deactivation of these particular networks during dreaming means that auto-noetic consciousness cannot be supported according to both the neurocognitive theory of dreaming and the multistate hierarchical model of consciousness. However, it is likely that the generally rare episodes of self-awareness during dreaming involve the relative activation of internally oriented portions of the anterior prefrontal cortex during an atypical (hybrid) sleep state (e.g., Dixon et al., 2022; Dixon et al., 2018; McCaig et al., 2011). This possibility needs to be explored in more detail in studies with larger sample sizes of self-identified lucid dreamers that include neurocognitive assessments of the participants as well as detailed life histories.

The immaturity of the default network and the gradual development of cognitive capacities until ages 9-11, including the ability to simulate, join together to explain the infrequency of dreaming and the lack of complexity and self-involvement in children's dream reports until that age period. In addition, the parallels in the development of the cognitive capacities that lead to noetic dreaming during sleep onset, NREM 2, and REM sleep, as well as auto-noetic consciousness during waking, provide further evidence that dreaming and auto-noetic consciousness have a close relationship, even though dreaming has different properties than does auto-noetic consciousness. From the perspective of the neurocognitive theory of dreaming, both dreaming and auto-noetic consciousness are the properties of specific networks. If the networks are immature or damaged in certain areas, then dreaming or auto-noetic consciousness will be defective in some way or will not occur at all.

The areas that support the noetic mental state of dreaming are important as part of the intermediate multimodal areas in the multistate hierarchical model of consciousness. In that model, the memories, concepts, and schemas from the intermediate multimodal areas are re-represented as inputs into the higher-order network, and thereby contribute to auto-noetic consciousness during waking (LeDoux, 2019, pp. 359-361). In this view, the additional necessary step that leads to auto-noetic consciousness is supported by brain areas anterior to the default network-- namely, the dorsal lateral and ventral lateral regions of the prefrontal cortex, and the lateral frontal pole. Dreaming therefore has different properties than does auto-noetic consciousness within the context of both the multistate hierarchical model of consciousness, with its emphasis on intermediate multimodal areas that produce schemas, and the neurocognitive theory of dreaming, with its emphasis on portions of the default network and the cognitive capacities those portions are able to support.

In closing, it may be useful to mention again what this article is not claiming. It is not a brief for the accuracy or usefulness of either of the two theories because it has not discussed the adequacy of the evidence that supports them, a task that has been carried out by the individual theorists in their presentations of their respective theories (Domhoff, 2020a, 2022; LeDoux, 2019, 2020; LeDoux & Lau, 2020; LeDoux, Michel, & Lau, 2020). Nor has the article anticipated and attempted to answer the likely criticisms and claims by proponents of other views, which is once again an undertaking that has been attempted in other venues (Domhoff, 2020b; 2022, Chapters 8-11; LeDoux, 2019, 2020, 2021; LeDoux & Lau, 2020). Instead, this article has focused on the increased explanatory power provided to the neurocognitive theory of dreaming by drawing upon the multistate hierarchical model of consciousness.

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