

The Neurocognitive Theory of Dreams at Age 20: An Assessment and a Comparison With Four Other Theories of Dreaming

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This article assesses the neurocognitive theory of dreams on the occasion of its 20th anniversary. The theory synthesizes findings from 3 strands of dream research, which focus respectively on the neural substrate that subserves dreaming, the development of dreaming in children, and quantitative findings on adult dream content, all 3 of which are necessary ingredients in any theory in cognitive neuroscience (Ochsner & Kosslyn, 2014). The article compares the current standing of the theory with that of 4 other theories with a neural dimension: the Freudian, activation-synthesis, memory-consolidation, and threat-simulation theories of dreaming. It concludes that the neurocognitive theory differs from the other 4 in that many of its key building blocks were created and have since been replicated by independent investigators in 3 different research areas. The other theories lack a developmental dimension, and their claims sometimes do not accord with established findings on dream content. On the other hand, the neurocognitive theory has been strengthened by neuroimaging findings revealing that the neural substrate that enables dreaming is a subsystem of the default network, which supports imagination in waking; it also includes key hubs in the waking self-system, which may help explain the focus on personal concerns in dreams. This subsystem of the default network, when unconstrained and activated, leads dreamers to experience themselves as being in hypothetical scenarios that include vivid sensory environments, which also usually portray interpersonal interactions. Dreaming is an intensified and enhanced form of spontaneous thought that can be characterized as an “embodied simulation.”

Keywords: dreaming, imagination, embodied simulation, neurocognitive, default network

I first of all thank the late David Foulkes (1935–2019) for all the help he gave me with several of the key ideas while this article was being prepared. In addition, his innovative dream research and numerous laboratory discoveries over the past 57 years, and his early recognition that dreaming is a form of simulation, led the way to a fully cognitive theory of dreams (Foulkes, 1985), and then aided in the development of a neurocognitive theory of dreams (Foulkes & Domhoff, 2014). I thank a pioneering cognitive researcher in the study of both daydreaming and dreaming, John Antrobus, for insightful suggestions that greatly improved the substance of this article, and an innovative REM sleep expert, Jerry Siegel, for corrections and new additions on issues relating to REM sleep.

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The article entitled “A New Neurocognitive Theory of Dreams,” which brought together findings on the neural substrate that subserves dreaming, the development of dreaming, and adult dream content in a new synthesis, was first presented at the meetings of the Association for Psychological Science in 2000, first published in a slightly extended version in 2001, and then included in revised form as a chapter in *The Scientific Study of Dreams: Neural Networks, Cognitive Development, and Content Analysis* (Domhoff, 2000, 2001, 2003). The theory was significantly extended several years later when research demonstrated that “the neural network for dreaming” is very likely a “subsystem” of the default network, which subserves mind-wandering, daydreaming, and other forms of self-generated spontaneous thought during waking (Domhoff, 2011). Dreaming, like imagination and mind-wandering, can be understood as a form of simulation, “a particular kind or subset of thinking that involves imaginatively placing oneself in a hypothetical scenario and exploring possible outcomes” (Schacter, Addis, & Buckner, 2008, p. 42).

In addition, dreams can be characterized as “embodied” simulations in the strict psychological sense of the term as off-line cognition that is body based (Margaret Wilson, 2002, pp. 632–635), which developed from pioneering work by experimental cognitive psychologists studying categories, concepts, and language (Barsalou, 1991, 1999; Gibbs, 1994; Rosch & Mervis, 1975; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Building on that past work, embodied simulations are distinctive because they are subjectively experienced as the body in action (Bergen, 2012; Gibbs, 2006; Landau, Meier, & Keefer, 2010; Niedenthal, Winkielman, Mondillon, & Vermeulen, 2009). The defining feature of dreaming is therefore the sense of being a participant in (or observer of) an ongoing real event, which sometimes is thought of as a real experience for several seconds or minutes after awakening.

As a result of the realistic feelings that often accompany dreaming, dreams have parallels with theatrical plays because the dreamer and the other characters are usually engaged in one or another activity or social interaction within a setting, or series of settings, and sometimes express thoughts or emotions. In a study based on a normative nonlab sample containing 991 dream reports from young women and men, 86.9% of the dream reports included a social interaction or shared social activity, 6.7% included the dreamer seeing, hearing, or thinking about another dream character, 2.2% included only the dreamer and at least one animal, and 4.3% included only the dreamer engaging in an activity (Domhoff & Schneider, 2018, p. 10 Table 3, for a summary of the findings).

The theory thereby includes all three of the “distinct but interdependent levels” that are the hallmarks of all theorizing in cognitive neuroscience, as outlined in a general statement on what constitutes an adequate theory in cognitive neuroscience (Ochsner & Kosslyn, 2014, p. 2): an underlying neural substrate (which means a portion of the default network in the case of dreams), the cognitive processes it supports (embodied simulation in this case), and the “output” or “behavioral” level (verbal or written dream reports). The 20th anniversary of the first presentation of the theory seems to be a good time for an assessment. This is because “coherent groups in science generally have only comparatively brief life-spans, typically ten to fifteen years, after which they are either absorbed into mainstream science or die out,” or perhaps persist as “a field on the margins of

legitimacy,” as in the paradigmatic example of parapsychology (McClenon, 1984, p. 2). In addition to assessing the adequacy of the original and updated versions of the theory on the basis of the past 20 years of dream research, this article also compares the assessments of it with the assessments of four other contemporary theories with a neural dimension: the Freudian, activation-synthesis, memory-consolidation, and threat-simulation theories of dreaming.

The Original Theory and the Assessments of It

The first version of the theory began with a discussion of lesion studies that provide the likely outlines of the neural substrate that supports dreaming: “The new theory starts with findings from neuropsychological assessments of patients suffering brain injuries, which reveal the areas of the brain that are and are not necessary for dreaming to occur”; however, the analysis then quickly added that “these discoveries are supported by neuroimaging and sleep laboratory studies” (Domhoff, 2001, p. 14). In addition to the lesion and neuroimaging studies highlighted in the Introduction to the original article, the importance of findings from what is now called electrical brain stimulation were added later in the article in a more detailed discussion of this neural substrate: “Then, too, studies using stereotaxic electrodes to locate the sites causing seizures in epileptic patients show that the ‘dreamy state’ sometimes experienced as part of the diagnostic process is related to the temporal-limbic region” (Domhoff, 2001, p. 24). The neural dimension of the theory is therefore based on three independent lines of research, each of which uses a different methodology.

Based on these three different types of studies, it was concluded that,

Dreaming depends on the normal functioning of a relatively specific neural network located primarily in the limbic, paralimbic, and associational areas of the forebrain. If there are defects in this network, dreaming can be lost temporarily or permanently, or be impaired in some way, such as loss of visual dream imagery. (Domhoff, 2001, p. 14)

Because this substrate can be activated to varying degrees in both REM and non-REM (NREM) sleep, this theory encompasses dreaming in any stage of sleep. In terms of the frequency of dreaming, this generalization primarily means REM sleep and the increasing amount of NREM 2 dreaming in the last 2 hr of sleep (Antrobus, Kondo, Reinsel, & Fein 1995; Domhoff & Schneider, 1999, pp. 149–150; Herman, Ellman, & Roffwarg, 1978; Pivik & Foulkes, 1968; Wamsley, Hirota, Tucker, Smith, & Antrobus, 2007), to the point that there are no significant differences between REM and NREM 2 recall and content at the time of awakening (Cicogna, Natale, Occhionero, & Bosinelli, 1998). Soon thereafter, the theory was expanded to include dreaming at sleep onset (Foulkes, Spear, & Symonds, 1966; Foulkes & Vogel, 1965), and also brief episodes of dreaming during long periods of drifting waking thought, when individual participants are left alone in a room for upward of 30 min, with their waking state monitored by an electroencephalogram (EEG; Domhoff, 2003, pp. 20, 31–32; Foulkes & Fleisher, 1975; Foulkes & Scott, 1973).

The article then added a developmental dimension to the theory based on the unexpected and counterintuitive findings on the dreams of children ages 3–15,

which were discovered in longitudinal and cross-sectional studies in a laboratory setting (Foulkes, 1982, 1999, for a summary and synthesis; Foulkes, Hollifield, Sullivan, Bradley, & Terry, 1990). These findings were included and defended as a crucial building block in a neurocognitive theory of dreaming at a time when they were often still ignored or rejected, usually on the basis of what proved to be unfounded methodological criticisms concerning the comfort level of young children in a sleep-laboratory setting or the inability of the children to adequately convey their dream experiences after an abrupt night awakening (Hunt, 1989; Resnick, Stickgold, Rittenhouse, & Hobson, 1994; Weinstein, Schwartz, & Arkin, 1991).

The theory then incorporated the large body of findings on dream content, mostly studied with the Hall and Van de Castle (1966) coding system, leading to the conclusion that the “output” of the neural network for dream generation is “generally continuous with waking conceptions and contains a great deal of previously unrealized repetition in characters, social interactions, misfortunes, negative emotions, and themes” (Domhoff, 2001, p. 14). Based on the evidence that cognitive dream theorists had accumulated to suggest that dreaming did not have any adaptive function, or at least any adaptive function that had been proposed up to that point (Antrobus, 1993; Blagrove, 1992, 1996, 2000; Foulkes, 1985, 1993), the theory claimed that dreams are most likely “the accidental by-product of two great evolutionary adaptations, sleep and consciousness,” but noted that “many societies have invented cultural uses for dreams, usually in conjunction with religious ceremonies and medicinal practices” (Domhoff, 2001, p. 15).

As might be expected, the reactions of cognitively oriented dream researchers to the new theory were mostly positive (Foulkes, 2017; Wamsley & Antrobus, 2006). However, a Freudian-oriented research psychologist, who focused on personality studies, found the theory wanting in the level of detail on neuroimaging, “premature” in placing an emphasis on Foulkes’s (1982, 1999) laboratory findings on children in the light of what he considered to be good evidence from home-collected reports and clinical case studies, and further stated that the presentation was too readily dismissive concerning “the effects on dreams of subliminal informational inputs” (Holt, 2004, pp. 405, 408). Still, he did write that the theory builds on “convincing evidence that relatively specific areas of the brain are necessary for dreaming” and added that it is surprising how much can be learned from content analysis (Holt, 2004, p. 404).

The most critical reviewer, although agreeing that “forebrain activation is essential to dreaming,” that dream content can be studied scientifically, that the Hall/Van de Castle coding system is “good at catching” dream content, and that dreams “reflect an individual’s personality, concerns, feelings, and conflicts,” also argued that “the theory neglects the voluminous work emerging from both the new discipline of cognitive neuroscience and its traditional counterpart, neuropsychology,” downplays the role of “REM sleep physiology” in explaining key aspects of dreaming and dream content, and thus overstates the similarities of dreaming and waking thought while ignoring the unusual formal features of dreaming (Hobson, 2003, pp. 188–189). In his view, it also neglects the issue of why so few dreams are recalled and underestimates the frequency of bizarreness and emotions in dream content (Hobson, 2003, pp. 190–191).

The early versions of the new neurocognitive theory received attention in part due to the favorable treatment of them in a comparison with Freudian theory (Freud, 1900; Solms, 1997, 2000a) and activation-synthesis theory (Hobson, 1988; Hobson & McCarley, 1977). This article, written by coauthors who studied consciousness, with little or no previous involvement in dream studies, concluded that “dream consciousness is remarkably similar to waking consciousness, even allowing for the differences in ‘volition, self-awareness and reflection, affect, and memory . . . ,’” an assertion that runs contrary to the other two theories they discussed; they went on to say that “Converging evidence from multiple fields” suggests that dreaming may be “closely related to imagination, where brain activity presumably flows in a ‘top-down’ manner” (Nir & Tononi, 2010, p. 97). This assessment also included a detailed table, which provided very useful comparisons of the three theories, and made clear how different the cognitive view is from the other two theories (Nir & Tononi, 2010, Table 1, p. 93).

Although the original article from 2001 had been cited over 50 times by late 2019 by other authors, and the updated article from 2011 almost as often, most of those mentions were made in passing, and seldom supported, criticized, or made use of the theory. However, two different groups of researchers noted that their neuroimaging findings supported the theory’s claims concerning the neural substrate that enables dreaming (Eichenlaub et al., 2014; Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013). The theory has not died out, but it has not been “absorbed into mainstream science” either (McClenon, 1984, p. 2).

The Fate of Predictions Based on the Theory

Drawing on several suggestive findings in earlier research studies, the new neurocognitive theory presented two hypotheses that were later supported, one concerning likely future findings on lucid dreaming, the other concerning the degree and valence of emotionality in dreams. In the case of lucid dreaming, it was suggested that the neural substrate that enables dreaming is very likely augmented when this rare phenomenon occurs: “lucid dreaming may be a product of a dream state in which the higher-order neural patterns that give us ‘core consciousness’ and an ‘autobiographical self’ are more active than usual” (Domhoff, 2001, p. 18). It did so on the basis of a study reporting that “higher levels of alpha activity during REM are related to lucid dream reports” (Tyson, Ogilvie, & Hunt, 1984, p. 442) and a second one (Shapiro et al., 1995), reporting,

a greater sense of control in an exploratory PET-scan study of 12 male participants when the medial frontal cortex and rectal orbital gyrus were more active, and a greater sense of things being out of control when the amygdala was most active. (Domhoff, 2001, p. 18)

The hypothesis drawn from these two studies receives preliminary support in two separate studies that need to be replicated due to their small sample sizes, which together produced only five possible instances of self-aware dreaming in four out of 10 practiced lucid dreamers during 21 nights in a sleep lab. The first study reported, based on one instance each from three of six student participants, that the results showed a “hybrid state” with “wake-like inter-scalp networking, including high-frequency bands,” which were “most pronounced in frontal and frontolateral

coherences” (Voss, Holzmann, Tuin, & Hobson, 2009, pp. 1191–1192, 1195, 1196). In the second study, four adult males between ages 27 and 32, who had been training themselves to achieve self-reflectiveness during dreaming for 4 or more years, spent a collective total of 15 nights in which they were scanned with a functional MRI; one of them reported two instances of lucidity, which were accompanied by “a reactivation of several areas normally deactivated during REM sleep,” which were for the most part regions in the frontoparietal control network, such as the frontopolar cortex and the dorsolateral prefrontal cortex (Dresler et al., 2012, p. 1020).

Research on patients who had suffered damage to the amygdala (Adolphs, Tranel, & Damasio, 1998; Damasio, 1999) led to the hypothesis that such patients “might be ideal candidates for future defect studies because they have lost their capacity for fear in waking life and express predominantly positive emotions” (Domhoff, 2001, p. 25). More specifically, it was claimed that they would report less emotion and “their negative emotions percent would be far lower than the 80% figure that has been found in several different studies” (Domhoff, 2001, p. 25). These predictions received strong support several years later in a study of 23 Most Recent Dreams from eight patients with damage to the basolateral amygdala (Blake, Terburg, Balchin, van Honk, & Solms, 2019).

The original statement of the theory also suggested a tentative hypothesis that did not prove to be fruitful. Although the article warned that “very little progress has been made” in the study of symbolism in dreams, and later added that it “needs to be stressed that there is little or no systematic evidence that dreams make use of the vast system of figurative thought available in waking life to most individuals through a combination of developmental experiences and cultural heritage,” it also said that cognitive linguistics “presents new ideas for studying metaphors in dreams that provide additional starting points” (Domhoff, 2001, p. 26; Lakoff, 1993, 1997). This possibility was soon downplayed and then rejected on the basis of subsequent work (Domhoff, 2003, pp. 33–36, 128–133; 2015, pp. 33–36, 128–133). It now seems likely that the neural substrate that subserves dreaming provides insufficient cognitive capacity to support figurative thought (Domhoff, 2018a), which is a new hypothesis based on recent neuroimaging studies that reveal the brain regions involved in the comprehension and production of metaphors (Beaty, Silvia, & Benedek, 2017; Benedek et al., 2014; Holyoak & Stamenković, 2018).

Mistakes and Shortcomings

The original presentation of the theory was not without mistakes and shortcomings in terms of the presentation strategy, one or two substantive issues, and a serious omission that would have widened the scope and possible impact of the theory. First, it seemed sensible at the time to begin the discussion of the neural basis for dreaming with lesion studies, which had played a central role in neuropsychology and cognitive neuroscience, and there was more evidence concerning lesions and dreaming (Jus, Jus, Gautier, et al., 1973; Kerr & Foulkes, 1981; Kerr, Foulkes, & Jurkovic, 1978; Solms, 1997) than there was from imaging studies of REM sleep (Braun et al., 1997; Maquet et al., 1996; Nofzinger, Mintun, Wiseman, Kupfer, & Moore, 1997). However, it soon became clear that neuroimaging studies

were gaining more legitimacy and wider usage, thanks in part to the replacement of PET-scans, which require the use of radioisotopes, with the safer alternative of functional MRI (Andrews-Hanna, 2012, p. 253, Figure 1).

Neuroimaging studies of the default network therefore became the starting point for the presentation of the theory when the first major update occurred (Domhoff, 2011). Still, even though lesion studies now play second fiddle, they remain important from a neurocognitive point of view because they provide the crucial first-person testimony as to the presence, alteration, or absence of dreaming, which has led to the useful and solidly established conclusion that *only lesions inside the default network have any impact on dreaming* (Domhoff, 2018b, Chapter 5).

This update also made it possible to state the four specific conditions under which dreaming very likely occurs, namely,

- (1) an intact and fully mature neural substrate for dreaming . . . (2) an adequate level of cortical activation, which can be provided by the REM mechanism and/or generally higher brain activation at sleep onset and late in the sleep period; (3) an occlusion of external stimuli, most likely through gates in the thalamus; and (4) the loss of conscious self-control, i.e., a shutting down of the prefrontal executive systems that connect us to the external world. . . . (Domhoff, 2011, p. 1172)

Second, it proved to be both a strategic and substantive mistake to try to put the posttraumatic stress disorder (PTSD) dreams of PTSD victims, recurrent dreams reported by college students, dreams that a majority of people say via questionnaires they have experienced, and repeated themes in individual dream series along one hypothetical “repetition dimension.” This term also had unfortunate and regrettable echoes of Freud’s (1920) claim that a “repetition compulsion” was a key element in psychic life. The phrase was changed to “repetition principle” in 2003 and the idea was abandoned thereafter as a case of overreach.

On a strictly substantive level, the first presentation of the theory erred in that it too quickly concluded, based on one neuroimaging study (Maquet et al., 1996) and PTSD dreams (Hartmann, 1984; Kramer, Schoen, & Kinney, 1987), that the amygdala and other parts of the support system for emotions were regularly active during dreaming. Since that time, a meta-analysis comparing neuroimaging studies of mind-wandering and dreaming has shown that the amygdala is generally not active in either of those states (Fox et al., 2013), and a lesion study has shown that the amygdala is not necessary for dreaming to occur (Blake et al., 2019). It is now also known that parts of the amygdala are included in a perception network that detects and interprets social signals from other people and an affiliation network that promotes prosocial behavior and concern for others, as well as an aversion network, so activation of the amygdala per se is not necessarily indicative of emotions (Bickart, Dickerson, & Barrett, 2014, p. 238).

Moreover, it is now known that the prefrontal cortex in general (Dixon, Thiruchselvam, Todd, & Christoff, 2017; Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012), and perhaps the dorsolateral prefrontal cortex in particular (LeDoux, 2012, 2015, 2019), are necessary for experiencing emotions in the waking state. Even more generally, the frontoparietal control, dorsal attentional, default, and salience networks combine in slightly different ways to construct emotion states, with the salience network involved in all of the emotional states (Tourouglou, Lindquist, Dickerson, & Barrett, 2015). Because all these networks except

for the default network are relatively deactivated during both REM and NREM 2 sleep, these new findings may account for the lower levels of emotions in most dream reports than is generally assumed, a replicated finding that is discussed further at later points in this article.

The major shortcoming of the article was a failure to include the literature on daydreaming, which developed in tandem with dream research from the 1960s through the 1990s, and always paid attention to and incorporated new findings from sleep-dream laboratories (Antrobus, Antrobus, & Singer, 1964; Antrobus, Singer, Goldstein, & Fortgang, 1970; Singer, 1966, 1975; Singer & McCraven, 1961). A similar strand developed in the extensive work by Eric Klinger (1971, 1990, 1999). It included a large-scale field study using random contact with the participants through the use of a pager, and in the process found that 9% of the 1,425 thought samples had “more than a trace” of dreamlike thought and another 16% had a “trace” of such thought (Klinger & Cox, 1987–1988, p. 124). Still another study, by other investigators, included a 2-week collection of daydreams from high-achieving teenagers; it documented that daydreams relate overwhelmingly to personal concerns, which is consistent with one of the major replicated findings on dream content (Domhoff, 2003; Gold & Reilly, 1985). Then, too, there is a relationship between the degree of bizarreness in daydreams and nonlab dreams in a study of the same participants in both aspects of the study (Kunzendorf, Hartmann, Cohen, & Cutler, 1997).

This oversight in the first presentation of the theory occurred even though the promulgator of the neurocognitive theory of dreams had included work on daydreaming in a book published 5 years earlier that brought together the accumulated findings based on the quantitative study of dream content (Domhoff, 1996, pp. 6–7, 211). All of this work on daydreaming fits well with the later findings on the role of the default network in mind-wandering, daydreaming, dreaming, and other forms of self-generated thought (Andrews-Hanna, Smallwood, & Spreng, 2014).

New Findings That Support the Theory

For all the initial mistakes and shortcomings, the original and updated versions of the theory have been largely supported by the accumulating evidence on all three of the theory’s dimensions. To begin with, numerous new waking neuroimaging studies provide further evidence that can be used to argue that dreaming is supported by a subsystem of the default network (Andrews-Hanna, Irving, Fox, Spreng, & Christoff, 2018; Fox, 2018; Fox et al., 2018; Fox, Foster, Kucyi, Daitch, & Parvizi, 2018; Meyer, 2019; Meyer, Hershfield, Waytz, Mildner, & Tamir, 2019; Zabelina & Andrews-Hanna, 2016). So, too, did a meta-analysis comparing neuroimaging studies of mind-wandering and REM sleep (Fox et al., 2013), and a study of neuroimaging patterns during dreaming (Eichenlaub et al., 2014). A study of the influence of psychedelics on the default network revealed that sensory substrates were augmented and the default network was relatively deactivated, which provides an important corrective to the anecdotal and clinical claim that dreaming has important commonalities with states induced by psychedelics (Fox, Girn, Parro, & Christoff, 2018).

Two further case studies provided additional evidence that lesions in posterior regions of the default network can lead to the loss of dreaming (Bischof & Bassetti, 2004; Poza & Martí Massó, 2006), and a study of the effects of electrical brain stimulation in the temporal lobe (Vignal, Maillard, McGonigal, & Chauvel, 2007) showed its importance in generating spontaneous dreamlike thought, and thereby lent further support to past studies in this tradition (Bancaud, Brunet-Bourgin, Chauvel, & Halgren, 1994; Penfield & Rasmussen, 1950, pp. 162–181). Most recently, the largest electrical brain stimulation study to date, which focused exclusively on the issue of dreaming, demonstrated that all 77 instances of a dream-like state, or a feeling of dream recall, were evoked by electrical brain stimulation in regions in the temporal lobe, and most frequently in the medial temporal lobe (Curot et al., 2018, pp. 9–10). These results are in turn consistent with waking electrical brain stimulation evidence suggesting that the medial temporal lobe is important in the initiation of any form of spontaneous thought during waking (Fox, 2018, pp. 170, 175).

Still other work, based on high-density EEG studies, provides new evidence that the brain patterns are very similar when the EEG results from NREM 2 and REM awakenings are only compared when dreams are also reported (Perogamvros et al., 2017; Siclari et al., 2017). Although this work notes that it provides some evidence that temporal and medial prefrontal areas are sometimes active, especially during REM periods (Perogamvros et al., 2017, p. 1773; Siclari et al., 2017, pp. 873, 875), it nonetheless emphasizes the importance of posterior regions. Therefore, as one of these two new contributions also states (Perogamvros et al., 2017, p. 1773), this work is limited to some extent by the absence of neuroimaging data. Based on the evidence from the neuroimaging, lesion, and electrical brain stimulation studies cited in the previous two paragraphs, this useful new work understates the importance of temporal and frontal areas of the neural substrate that subserves dreaming. This emphasis on neural networks in constructing a neurocognitive theory of dreaming is consistent with the current general focus in the cognitive neurosciences: “Network science, combined with non-invasive functional imaging, has generated unprecedented insights regarding the adult brain’s functional organization, and promises to help elucidate the development of functional architectures supporting complex behavior” (Grayson & Fair, 2017, p. 15).

There also has been new work that supports and extends the developmental dimension of the theory (Domhoff, 2018b, pp. 175–180, for a summary of the evidence that follows in this paragraph). At the neural level, there is now cross-sectional evidence that the default network does not become somewhat adultlike until ages 9–11 (Fair et al., 2008, 2009; Gordon et al., 2011; Sato et al., 2014; Supekar et al., 2010). These findings are supported in an equally important longitudinal neuroimaging study of children ages 10 and 13 (Sherman et al., 2014).

These new findings on the maturation of the default network are complemented by new work concerning the frequency of dream reporting and the substance of dream content in preadolescents and adolescents from a sleep lab at the University of Zurich (Strauch, 2004, 2005; Strauch & Lederbogen, 1999). This 5-year longitudinal study of dreaming in 24 children (12 boys, 12 girls) from ages 9–15 supports the earlier finding that dreaming is adultlike in its scope and complexity at ages 9–11; it also shows that emotion comes into dreams gradually and that most of the dream elements present in adult dreams also appear in the

dreams of preteens and teenagers (Foulkes, 1982; Strauch, 2005, pp. 160–161, 163, 167). In terms of new findings, this study discovered that teenagers dream more frequently of their peers as they mature, are more likely to be criticized or punished by adults, especially men, and are more likely to be aggressors than victims in interacting with their peers, all of which can be understood in terms of the neurocognitive theory of dreams as likely enactments of their view of themselves and their roles in waking life (Strauch, 2005, p. 160).

Then, too, the original developmental studies of dreaming are also supported by the accumulating evidence showing that preschool children are largely lacking in the waking cognitive capacities that are also very likely necessary for dreaming: generating mental imagery, organizing experience in a narrative form, imagining past and future scenarios, and developing an autobiographical self (Domhoff, 2018b, pp. 154–162 for a literature review and synthesis; Foulkes, 2017). To begin with, one large-scale study of mental imagery during waking showed that the preschool group did only half as well as the 8-year-olds in generating a simple visual image, and the 8-year-olds did only half as well as the 14-year-olds; in the case of mental rotation tests, the gap became increasingly large as the difficulty of the task increased (Kosslyn, Margolis, Barrett, Goldknopf, & Daly, 1990, p. 1000, Figure 1, p. 1007, Figure 4). These findings are consistent with the mental imagery tests used in conjunction with the cross-sectional dream study of children 5 through 8, which did not detect sufficient capacity to create mental imagery at age 5, and led to the conclusion that “the possibility of kinematic imaging emerges somewhere between 5 and 8 years of age” (Foulkes, Sullivan, Hollifield, & Bradley, 1989, p. 450).

Other studies reveal that only half of young children’s waking statements about an event are narratives by age 3, but by age 5 or 6 many children can tell a story that contains a beginning, middle, and end (Reese, 2013, pp. 197–198; Taylor, 2013, p. 803), although this ability is not fully developed until early adolescence (Bauer, 2013, p. 522; Bauer, Burch, Scholin, & Güler, 2007). Similarly, participants in the cross-sectional dream study were able to produce only simple narrative scenes, without chronology or sequence, at ages 5–7, but at age 8 they were able to generate a narrative with continuity in two temporal units, along with evidence of causality (Foulkes et al., 1990, pp. 456, 461). Waking studies suggest that children do not have the ability to engage in “pretend dramatic play” until they are age 4 or 5, even in stimulating preschool environments (Nelson, 2007, p. 170). In the cross-sectional laboratory dream study of children 5 through 8, the ability to produce complex imaginative stories in response to story prompts significantly correlated with the participants’ overall rate of dream recall when age was held constant (Foulkes et al., 1990, p. 458).

Finally, preschool children do not seem to have much awareness of a spontaneous inner mental life (Eisbach, 2013, for a review and synthesis), and personal (autobiographical, autonoetic) memories only gradually develop and become organized into an autobiographical self around age 6 (Bauer, 2013, pp. 521–522; Gopnik, 2009, Chapter 5), all of which suggests that children do not have “the basics of autobiographical memory” and “a roughly adult understanding of consciousness” until they are around the age of 6 (Gopnik, 2009, p. 156). Similarly, in dream studies, “self-involvement in dream scenarios reliably appeared only later (age 7+) than a first stage (age 5+) in which simple dream actions were performed by others” (Foulkes, 2017, p. 4). Generally speaking, then, the various 21st century

waking findings summarized in this and the previous four paragraphs support an assertion in the first version of the neurocognitive theory; “Dreaming is a cognitive achievement that develops gradually over the first 8 or 9 years of life” (Domhoff, 2001, p. 14).

Returning to the adult level, the relatively few new relevant studies of dream content have continued to yield results supporting earlier findings that dream reports most frequently include the people of greatest personal concern to the dreamer in waking life, along with the avocations and issues that are of the most interest and concern in waking life (Bulkeley, 2018; Dale, Lortie-Lussier, Wong, & De Koninck, 2016; Domhoff, 2003, Chapter 5). These new findings also support earlier content-analysis findings with adult dream reports showing that there is relatively little emphasis in dreams on a person’s routine daily events, such as school or work, or on the economic and political events that are of concern to many people in waking life (Domhoff, 1996; Foulkes, 1985; Hall, 1951; Hartmann, 2000), which in turn is consistent with the activation of key hubs in the self-system during dreaming.

The most important new adult content findings, reported by mathematical psychologists, demonstrate that the social networks in dreams are very similar to those in waking life. They are small-world networks that have the same properties that are also found in studies of brain networks, memory networks, and many aspects of the social and natural worlds, which is evidence that dreams are more lawful than has previously been thought (Han, 2014; Han, Schweickert, Xi, & Viau-Quesnel, 2016). Then, too, the frequency of appearance of familiar characters in dreams is consistent with Zipf’s power law, which is further evidence for the lawfulness of dreams (Schweickert, 2007a, 2007b).

All in all, aside from the misplaced emphasis on the limbic system in the original version of the theory, its sins of omission and commission did not prove to be serious, and the theory has continued to be updated on the basis of new evidence. But if and to what extent it is viable in comparison with other contemporary theories is a separate question.

Assessments of Other Dream Theories

This section discusses the main assumptions, hypotheses, and findings with regard to four other contemporary theories of dreaming—Freudian theory, activation-synthesis theory, memory-consolidation theory, and threat-simulation theory. All of them have been subject to strong criticism by a variety of dream researchers with varying perspectives.

Freudian Dream Theory

By the 1990s, studies inside and outside of a lab setting had created strong doubts that very many, if any, aspects of Freudian dream theory had any substance, whether the issue concerns the importance of the day residue in initiating the specific contents of a dream, the origins of speech acts in dreams, the pervasiveness of wishes (which are said to be physiological in origin) as the basis for every dream,

the role of the dream-work in disguising the wishes in dreams, the pervasive role of repression in shaping dreams and causing them to be forgotten, or the functional role assigned to dreams as the guardians of sleep (Domhoff, 2003, pp. 136–143; 2018b, Chapter 7; Fisher & Greenberg, 1977, 1996, for detailed summaries of all past findings related to Freudian dream theory; Goodenough, 1991, for studies on the recall and forgetting of dreams; Loftus, Joslyn, & Polage, 1998; Loftus & Ketcham, 1994, for the experimental evidence leading to the abandonment of the concept of repression by academic research psychologists).

The usefulness of free association as a method of understanding the meaning of dreams, which provides the basic foundations for the Freudian theory of dreams, is called into question by the lack of evidence that it leads to the understanding of dream content (Fisher & Greenberg, 1977, p. 66; Foulkes, 1978), which led Foulkes (1996a, p. 617) to conclude that “extensive experience in association gathering” had convinced him “of its inherent arbitrariness.” Moreover, and contrary to Freudian claims that the method is free of any suggestive influence by the psychotherapist, there is experimental evidence that subtle suggestions from an experimenter-therapist can falsely convince many people on the basis of dream interpretations that they were once lost or abandoned as young children (Mazzoni & Loftus, 1998; Mazzoni, Loftus, Seitz, & Lynn, 1999).

These findings on the power of suggestion in a therapeutic context take on greater importance when Freud’s (1900, pp. 114–119) several reports of arguments with patients concerning the wishful basis of their dreams are taken into consideration. What Freud saw as overcoming the patients’ resistance to therapists’ insights may involve the social psychology of persuasion and self-persuasion. This does not imply that all psychoanalytic sessions are exercises in suggestion, but it does mean that the burden of proof is on Freudian researchers working in a clinical setting to demonstrate that any therapeutic data they use to make claims about dreams are not confounded by suggestion and persuasion.

In the wake of the wide-ranging critique of Freudian dream theory that had been fashioned by the late 1990s, the theory has been defended by two researchers on two different grounds. First, one research psychologist (Erdelyi, 1996, 2004) claims that at least some of the results of studies based on subliminal perception, including his own, demonstrate that unconscious processes can be influenced significantly through the presentation of psychodynamically relevant stimuli, including in the case of dreams. However, numerous carefully controlled experiments led most research psychologists to conclude that subliminal stimuli are limited to small priming effects for one or two words, with no ability to influence concepts (Avneon & Lamy, 2018; Biderman & Mudrik, 2018; Greenwald, Draine, & Abrams, 1996; Kihlstrom, 2004).

The main proponent of Freudian dream theory in the 21st century, who recast it as “neuro-psychoanalysis,” bases his claims primarily on findings on the loss or alteration of dreaming in neurological patients (Solms, 1997). Freud’s wish fulfillment theory is said to be supported by the fact that dopamine, which he assumes to be the primary neurochemical active during REM sleep, also supports the “appetitive interests” that he believes are akin to Freud’s concept of the libido (Solms, 2000a, 2002; Solms & Turnbull, 2002, pp. 116, 312). However, the highly complex neurochemistry of REM sleep primarily involves cholinergic, glutamatergic, and GABAergic neurons (Boucetta, Cissé, Mainville, Morales, & Jones, 2014),

with the role of dopamine still uncertain at best, and perhaps nonexistent (Siegel, 2017, pp. 9–10, 12).

Solms (1997, 2000a) also defends the hypothesis that dreams are the guardian of sleep, based on the claim that dreaming may involve the “backward projection” of the impulses arising in the dopaminergic system (located in the basal forebrain) to the inferior parietal lobes and visual association cortex, thereby preserving sleep. Other dream researchers quickly noted there is little or no evidence that such a mechanism is responsible for dreaming (Antrobus, 2000; Doricchi & Violani, 2000), and since then it has been refuted by the evidence that a subsystem of the default network is the neural substrate that enables dreaming (Domhoff, 2011; Eichenlaub et al., 2014; Fox et al., 2013).

In addition, Solms (1997) defended the guardian-of-sleep hypothesis based on his finding that patients who reported the cessation of dreaming more often said they had disrupted sleep than the control sample. However, those findings are not impressive in that 51% of the 101 patients with global loss of dreaming indicated that their sleep was not disrupted (Solms, 1997, pp. 164–165; Solms & Turnbull, 2002, p. 214). If dreaming is necessary to preserve sleep, then it might be expected that virtually all patients reporting the complete loss of dreaming would report an inability to sleep at all. Moreover, two studies of over a dozen lobotomized patients in a sleep lab found that they almost never recalled a dream after REM awakenings, but they had normal REM/NREM cycles and reported in the morning that they had slept well, a claim supported by the EEG records of their sleep (Jus, Jus, Gautier, et al., 1973; Jus, Jus, Villeneuve, et al., 1973).

At the same time that Solms (2000a, 2000b, 2002; Solms & Turnbull, 2002) defended and amended Freud’s theory at the neural level, he ignored the equally important findings on the cognitive process of dreaming and the content of dreams that are overviewed and referenced in an earlier section of this article, including the laboratory studies on the development of dreaming (Foulkes, 1982; Foulkes et al., 1990). These omissions are significant in terms of assessing Freudian dream theory because these findings raise serious questions about the adequacy of the theory, which lacks a development dimension and does not encompass the findings showing that most dream content collected in both lab and nonlab settings does not fit well with its claims about dream content (Domhoff, 1996, 2018b, Chapters 1–3; Dorus, Dorus, & Rechtschaffen, 1971; Snyder, 1970).

More recently, new challenges for the theory have arisen concerning its emphasis on symbolism (Freud, 1916, Chapter 10). As noted in an earlier section, there is now evidence that suggests the neural substrate that subserves dreaming may not be able to support the cognitive capacities that have been shown to be necessary to comprehend or generate metaphors in waking neuroimaging studies (Beatty et al., 2017; Benedek et al., 2014; Holyoak & Stamenković, 2018). There is also new evidence suggesting that potentially symbolic elements in dream content are very infrequent (Domhoff, 2003, pp. 33–36, 128–133; 2015).

When the shortcomings of Solms’ (2000a, 2000b, 2002; Solms & Turnbull, 2002) claims about the Freudian implications of neurological findings are combined with the lack of systematic attention to developmental and content studies, and with the new evidence suggesting that symbolism may not be an important feature of dreams, it does not bode well for Freudian dream theory finding acceptance outside of the therapeutic community.

Activation-Synthesis Theory

Activation-synthesis theory stresses the brain basis of dreaming, with cognitive processes a secondary issue. It states that dreaming is initiated by putatively random and chaotic firings that arise from the brain stem during REM sleep, and claims that dreaming is a cortical attempt to make sense of these brain stem events (Hobson, 2000; Hobson, Pace-Schott, & Stickgold, 2000a, 2000b). As a result, activation-synthesis theory focuses on seemingly unusual features that are said to be unique to dreaming, such as frequent occurrences of flying under one's own power; more specifically, the theory claims that "the individual historical components of dream plot construction" are "diluted" by "chaotic cerebral activation processes" that lead to "visuomotor hallucinations, delusional beliefs, thought impairments, emotional storms, and memory defects" (Hobson & Kahn, 2007, p. 857).

The theory originally began by locating the origins of REM periods in giant neurons in the pontine gigantocellular tegmental field (Hobson & McCarley, 1977; Hobson, McCarley, & Wyzinski, 1975; McCarley & Hobson, 1975). It further claimed that the neurochemical initiation of the REM-on system is cholinergic in nature and concluded that neurons in the locus coeruleus are responsible for turning off REM sleep (Hobson, Lydic, & Baghdoyan, 1986, pp. 378–379; Hobson & McCarley, 1977). Although the fact is not often remarked upon in the literature focused exclusively on dreaming and dream content, all of these claims were refuted within the space of a few years by sleep researchers and physiologists that specialize in the study of REM sleep.

Experimental lesion studies soon showed that the activation of the giant cells in the pons was not specific to REM sleep; instead, these neurons were related to movement, as indicated by their very high levels of activity in waking, a relationship the activation-synthesis missed because they used a head restraint while making their recordings (Siegel & McGinty, 1977; Siegel, McGinty, & Breedlove, 1977). Nor did the destruction of the entire gigantocellular tegmental region have any effect on REM sleep (Drucker-Colin & Pedraza, 1983; Friedman & Jones, 1984a, 1984b; Jones, 1979; Sakai, Petitjean, & Jouvet, 1976; Sastre, Sakai, & Jouvet, 1981; Vertes, 1977, 1979). Moreover, "histochemical and pharmacological data" showed that the neurochemistry of REM was not cholinergic in nature (Jones, 1986, p. 410). Still another lesion study demonstrated that the neurons in the locus coeruleus do not play any essential role in the cyclic appearance of REM and NREM sleep (Jones, Harper, & Halaris, 1977). The new evidence was succinctly synthesized as follows:

The lateral pons is the brain region critical for REM sleep. Medial pontine regions, including the gigantocellular tegmental field neurons, are not critical for REM sleep generation. . . . the neurons whose interaction is critical for REM sleep constitute only a small percentage of the cells within the lateral pontine region. (Siegel & McGinty, 1986, p. 421, italics in the original)

Physiologist Barbara Jones (2000, p. 956) later concluded that she did "not know of any physiological evidence that the cortex has no control over the brain stem or over the central activity of dreams," and added that "cortico-fugal outputs reach the entire brain stem as well as the spinal cord, influencing the very neurons shown to be critical for the initiation and maintenance of REM sleep in the pontine

reticular formation.” Subsequent evidence confirms the large degree of forebrain control of the REM generator, especially through the hypothalamus (Luppi, Clément, & Fort, 2013). The highly complex nature of this system was demonstrated in the aforementioned study using new methods of histochemical neuronal identification, which reveal that cholinergic, glutamatergic, and GABAergic types of neurons are active in varying degrees within three functional subgroups in the part of the brain stem that earlier had been implicated in the production of REM sleep; in addition, many cells previously thought to be cholinergic because of their discharge activity were found to be either GABAergic or glutamatergic through definitive histochemical identification (Boucetta et al., 2014).

By the early 21st century, the widely accepted model of REM sleep had nothing in common with the claims by the activation-synthesis theorists (Siegel, 2017, for a concise presentation and synthesis of the past several decades of studies, along with reminders of how much remains to be understood). At the same time, activation-synthesis theorists came to agree that “the apparent REM discharge selectivity of the large paramedian reticular cells was a function of the head restraint required to allow long-term recording,” and added that “the original attribution of cholinergic neuromodulation to the REM-on cells of the pontine reticular formation was incorrect” (Hobson, 2007, p. 75). They made some alterations in their neural model, but continued to make their same claims about the hallucinatory, delusional, and highly unusual nature of dream content, the details of which are discussed shortly (Hobson, 2007; Hobson & Kahn, 2007, p. 857).

By the turn of the 21st century, activation-synthesis theorists fully recognized that every aspect of their theory is challenged by the longitudinal and cross-sectional laboratory studies of children frequently cited throughout this article (Foulkes, 1982; Foulkes et al., 1990). In response, they asserted that they could imagine dreaming even in neonates:

Similarly, we specifically suggest that the human neonate, spending as it does more than 50% of its time in REM sleep, is having indescribable but nevertheless real oneiric experiences . . . For us, it is not at all difficult to imagine that an infant might be experiencing hallucinosis, emotions, and fictive kinesthetic sensations during REM sleep. (Hobson et al., 2000b, p. 803)

This claim ignores the likelihood that dreaming depends upon the same cognitive capacities (mental imagery, narrative skills, imagination, and an autobiographical self) that make daydreams and many other waking cognitive processes possible, none of which has been found to be very well developed until ages 5 to 8, as briefly summarized earlier in this article (Domhoff, 2018b, pp. 154–162, for a more detailed summary of the developmental psychology literature on these cognitive capacities).

The strong claims by the activation-synthesis theorists are based on their analysis of a word-of-mouth sample gathered from friends and friends-of-friends in the Boston/Cape Cod area, which consisted of eight children ages 4–5 (five boys, three girls) and six children ages 8–10 (five boys, one girl; Resnick et al., 1994, p. 32). The dream reports were collected on 13 consecutive days by the parents of the young participants. The collection period began with reports after spontaneous awakenings for five mornings. Then, for the next five nights, the children had to repeat “I will remember my dreams’ three times out loud just before going to

sleep,” and the next morning they were awakened 15 min before their usual time of waking (Resnick et al., 1994, p. 33). For these days, “parents were explicitly instructed to elicit as much detail as possible by guiding their children through the *who, what, when, where, why* questions and thereafter to base their questions on the children’s reports,” but were also “reminded that it was important not to ask leading questions and to wait until the child finished a statement before asking another question” (Resnick et al., 1994, p. 33, italics in the original). In the final phase, the morning awakenings were supplemented through awakenings by their parents after 3 and 6 hr of sleep. These night awakenings led to very few dream reports, which were not included in the analysis because “in many of these attempts the parent was unable to rouse the child sufficiently to get any response and hence reflect a failure to awaken rather than a failure to recall” (Resnick et al., 1994, p. 40).

As discovered in numerous waking experimental studies concerning the influence of the nature of the questions on children’s responses, this type of questioning invariably leads to compliant answers, especially when the same questions are repeated (Ceci, Bruck, & Battin, 2000; Foley, 2013; Lamb, Hershkowitz, Orbach, & Esplin, 2008, pp. 50–57, for a summary). Thus, the likely confounds, and the very strong demand characteristics, that are present in every aspect of this study, despite the warning to parents about asking leading questions, raise doubts about the results. These doubts begin with the fact that their sample was in effect primed to please the investigators and the parents of the participants, followed by the social persuasion and social pressure implied by repeated parental questioning. The implicit expectation that the children would do a good job of remembering and reporting their dreams was reinforced on five of the days by the admonition to improve their recall through the presleep repetition of a vow to remember their dreams. Based on this questionable set of procedures, dreams were reported after 85 of 131 morning awakenings (64.9%), which is well above the lab figures. The investigators then concluded that the morning dream reports revealed “remarkable similarities to those of adults in terms of length, number of characters and settings, and the presence of dream bizarreness” (Resnick et al., 1994, p. 43).

Contrary to the activation-synthesis theorists’ findings, the best-controlled study of children’s dreams using morning awakenings by parents, a 6-week cross-sectional study of 19 boys and 21 girls ages 3 to 8.5, reported very similar results to those in the longitudinal and cross-sectional laboratory studies. The researchers first of all found a mean recall rate of only 21% and an even lower median recall rate of 15.5% from 1,680 awakenings carried out over the space of 42 mornings, along with similarities for the low frequencies of friendly and aggressive interactions (Sándor, Szakadát, Kertész, & Bódizs, 2015). The main differences occurred due to the fact that the investigators had the parents ask several leading questions in each of the morning interviews, such as “Did you see your dream as a motion picture or was it rather like a photo,” and “Did you feel for example angry, sad, happy, surprised or scared or were you just calm?” (Sándor et al., 2015, pp. 11, 13). As noted in the previous paragraph, repeated questioning of this nature very often leads to the answers the questioners want to hear (Ceci et al., 2000; Foley, 2013; Lamb et al., 2008).

In addition to presenting their questionable findings, the activation-synthesis theorists claimed that the children in the laboratory studies displayed signs of being

uncomfortable in the sleep lab, and that the investigator was a “stranger” to the children (Resnick et al., 1994, p. 31). However, these assertions are extremely doubtful because the investigator knew the children well from helping to prepare them for bed, sometimes with the assistance of their parents at ages 3–5, in the first year of the longitudinal study; moreover, these same 14 children were the participants in the second and third phases of the study at ages 5–7, and 7–9. The investigator also personally carried out every lab awakening during both the 5-year longitudinal study and the later cross-sectional study (Foulkes, 1982, pp. 27, 33–34; 1996b, p. 206).

Then, too, the investigator assessed the participants’ level of anxiety and discomfort at each session. At ages 3–5, the 14 children in the longitudinal study were rated as calm or relaxed on 79% of the nights and as extremely anxious on only 5.4% of the nights. Their median time to fall asleep was 20 min; the same children took only 12 min to fall asleep when they returned 2 years later, and the median time awake during the night was 8 min or less (Foulkes, 1982, pp. 33–34). In the cross-sectional study involving 80 children within a month of their fifth through eighth birthdays, the parents of the younger children sometimes spent the night in an adjacent bedroom, and at all ages the participants scored low on a 5-point anxiety scale that was filled out by the investigator for each visit, and on average they fell asleep 12.5–14.5 min after the lights were turned out (Foulkes et al., 1990, p. 454).

Finally, the findings that were of most concern to the activation-synthesis theorists (low recall, few mentions of movement, and the frequent absence of the dreamers from their own dreams) actually were discovered in the third year of the study, at ages 5–7, not the first year, which means that the investigator had been working with the 14 children for 2 or more years, so they already had spent numerous nights in a “now-quite-familiar laboratory” (Foulkes, 1979, for his nonlab studies of the children; Foulkes, 1996b, p. 206). Based on both the findings in the well-controlled nonlab study (Sándor et al., 2015), and the precautions that Foulkes (1982) took to ensure that his findings were as free of confounds as possible, it is highly likely that his results and conclusions are credible.

In discussing adult dream content, activation-synthesis theorists focus on the alleged unusual features of dreaming, such as sudden scene shifts and a purported sense of constant movement, which are included along with many other aspects of dream content as “bizarreness” (Hobson & Kahn, 2007, p. 857). However, an independent investigation of this issue showed that the kinds of bizarreness most frequently reported by activation-synthesis theorists, sudden scene shifts and abrupt topic changes, are more frequent during drifting waking thought, when individual participants are left alone for up to an hour in a darkened laboratory room, than they are in a comparable set of REM dream reports; this finding suggests that scene and topic changes are an inaccurate indicator of bizarreness in dreaming (Reinsel, Antrobus, & Wollman, 1992, pp. 169–170, 173). In addition, improbable combinations, such as unusual juxtapositions of objects, are equally frequent in REM and waking reports, so only identity confusions in relation to characters, which include malformed and blended characters, along with the rare characters who undergo a metamorphosis, appear more often in the REM reports than in waking reports (Reinsel et al., 1992, pp. 169–170, 173). In effect, then, this study returned the analysis of dream bizarreness to the type of categories that were

used before the activation-synthesis theorists expanded the operational definition of the concept. Similarly, sudden scene shifts and abrupt topic changes are frequent in experimental studies of mind-wandering carried out in relation to the default network (Andrews-Hanna, Reidler, Huang, & Buckner, 2010; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Mason et al., 2007; Smallwood & Schooler, 2006).

Turning to findings by other investigators on the degree of bizarreness in adult dream content, the largest collection of REM dream reports from laboratory awakenings discovered few instances of flying under one's own power, and there were fewer instances of constant movement, such as walking or running, than there were of sitting and talking (Snyder, 1970). A detailed study of 16 young adult women, who each spent two consecutive nights in the lab and answered questions about the familiarity and likelihood of specific dream elements, after four REM awakenings per night, uncovered very little evidence for bizarreness (Dorus et al., 1971). The analysis was based on six categories of novelty, which were applied separately in relation to physical surroundings, characters, activities, and social integrations. Major distortions of waking experiences occurred in only 7.8% of instances concerning physical surroundings, 6.2% concerning characters, and 16.7% concerning either activities or social interactions (Dorus et al., 1971, p. 367). Global ratings of each dream for overall novelty found that 25.8% showed large but plausible differences from previous waking experiences, and only 8.9% were highly improbable by waking standards.

In a comparison of 120 lab and 120 nonlab dream reports collected from 12 young adult male participants, only 10% of the dream reports in either sample had one or more of the four types of bizarreness included in an Unusual Elements scale (Domhoff & Schneider, 1999, p. 142), and another lab versus nonlab comparison reported similar results (Hunt, 1982). Similar findings emerge from quantitative analyses of dream reports collected in nonlab settings (Barrett, 1991; Domhoff, 2007; Revonsuo & Salmivalli, 1995).

Due to their emphasis on chaotic signals from the brain stem during REM sleep, activation-synthesis theorists also assert that dreams are suffused with emotion. In a study of dream journals collected from students in a course on the Biopsychology of Waking, Sleeping and Dreaming at the Harvard Extension School in 1999, the activation-synthesis theorist who taught the class structured the study "as a graded class exercise which helped motivate students to comply with the complex instructions," although the students were also told they "would be given a set of dream reports if they could not recall their own dreams"; the mention of this alternative set of dream reports was meant "to discourage undesirable demand characteristics" (Kahn, Pace-Schott, & Hobson, 2002, p. 35).

Based on these instructions, 35 students provided the 320 dream reports that were used in the study. The analyses were carried out by the student dreamers themselves by reading back through each dream report on a line-by-line basis to check for the occurrence of any of eight emotions that were listed on the right-hand side of the form (anxiety/fear, anger, joy/elation, shame, sadness, surprise, and affection/eroticism, and "other," the last of which is an open-ended category that allowed the students to add any additional emotions). Aided by this list, the students reported far more emotions in their dream reports than was found in previous studies (Kahn et al., 2002, p. 44).

In stark contrast, studies by two other investigators found that emotions were absent from 25–30% of the dream reports collected from REM awakenings in studies of young adults (Foulkes, Sullivan, Kerr, & Brown, 1988; Strauch & Meier, 1996), and even more dream reports were without any emotions in two other lab studies (Domhoff, 2018b, pp. 26–27; Snyder, 1970). In a study of 104 dream reports provided to activation-synthesis theorists by a sleep lab at the University of Cincinnati, they found that only 15% of the dream reports had at least one mention of an emotion (McCarley & Hoffman, 1981, Table 1).

Most striking of all perhaps, a unique REM-awakening study by activation-synthesis theorists, which was focused exclusively on emotions, found that 26% of the dream reports did not include any emotions (Fosse, Stickgold, & Hobson, 2001, pp. 1–2), which is very similar to what was found in two of the REM-based lab studies cited in the previous paragraph (Foulkes et al., 1988; Strauch & Meier, 1996). In this study, 88 REM dream reports were collected over three consecutive nights from nine Norwegian participants in Oslo (seven women, two men), whose sleep stages were monitored in their homes with a portable EEG machine by the first author on the study, Roar Fosse. The participants were asked to write their accounts of their dreams on a standardized report form after each awakening, and then to go through the report on a line-by-line basis with the same checklist used by activation-synthesis theorists in the nonlab study discussed two paragraphs ago (Kahn et al., 2002). In addition to the absence of any emotion in 26% of the dream reports, the strength of the emotions was rated as low in 18% and medium in 28% of the dream reports, leaving only 28% of the 88 REM reports with high emotional content (Fosse et al., 2001, pp. 1–2, 4).

Adding to the evidence that there is less emotion in dream reports than claimed by activation-synthesis theorists, the meta-analysis that included six studies of REM sleep showed that three of the waking associational networks that support the construction and experiencing of emotions in waking life, the frontoparietal control, dorsal attentional, and salience networks, are relatively deactivated during dreaming (Fox et al., 2013). The relative deactivation of the dorsomedial prefrontal cortex, which is an essential part of the frontoparietal control network, may be especially important (LeDoux, 2012, 2015, 2019; Lindquist et al., 2012). Then, too, the salience network is essential to emotion states during waking (Touroutoglou et al., 2015).

These neurocognitive findings are consistent with the low levels of emotions in dreams collected from children and young adolescents in laboratory settings (Foulkes, 1982; Foulkes et al., 1990; Strauch, 2005), as well as with the numerous lab and nonlab findings in lab and nonlab studies of adults, as discussed above. As a result, the findings on the large amount of emotions in the study of dream reports collected in a graded class exercise for an extension school course, and coded for emotions by each student dreamer, do not seem credible (Kahn et al., 2002).

Finally, and also uniquely, activation-synthesis theorists report that they do not find any gender or individual differences in dreams (Hobson & Kahn, 2007). The dream reports used in this study were collected in a later offering of the same extension class that was used to collect dream reports for the emotions study. This time the dream reports were requested “as part of a class exercise” to help students learn to “appreciate the difference between the formal and content analytic approaches to dream science” (Hobson & Kahn, 2007, p. 830, p. 851). The

investigators found that their eight independent judges could not reliably match 50 dream reports with the five participants, each of whom provided 10 reports. They therefore concluded that dream content is “generic” and without significant gender or individual differences (Hobson & Kahn, 2007, p. 854). However, every study of dream content with an adequate sample size of at least 125 dream reports, which is necessary because most dream elements appear in less than half of dream reports, and the effect sizes for most dream elements are small, has revealed three or four statistically significant gender differences and a wide range of individual differences that vary in magnitude (Domhoff, 1996, Chapters 4, 7–8; 2009; Domhoff, 2018b, Chapters 2–3, for summaries of the evidence).

By the early 21st century, the neurophysiological underpinnings of activation-synthesis theory had been convincingly refuted by neurophysiologists, causing its advocates to adjust their claims about the neural basis for dreaming. Then, too, their one study of children has proven to be inadequate on methodological grounds, as best shown by a well-controlled later study by independent investigators (Sándor et al., 2015). Finally, their several studies of adult dream content have been met with skepticism on methodological grounds, and also due to the contrary findings reported by other dream researchers. There is not as much bizarreness and emotion in dreams as activation-synthesis theorists claim, and there are a few consistent gender differences as well as large individual differences. The theory is currently left without any convincing evidentiary support at the neural level, the developmental level, or the dream-content level.

The Memory-Consolidation Theory of Dreaming

The search for memory consolidation during REM sleep began in the late 1960s with an unsuccessful effort with human participants based on a REM-deprivation procedure (Feldman & Dement, 1968), followed by another study with human participants that suggested “REM sleep does not facilitate memory consolidation and that Stage 4 may be beneficial to memory” (Fowler, Sullivan, & Ekstrand, 1973, p. 302). Later work with rodents using REM-deprivation techniques seemed more promising (Fishbein & Gutwein, 1977, for a review), but there continued to be contradictory results (Shiromani, Gutwein, & Fishbein, 1979, pp. 977–978). Sleep researchers who focused primarily on human participants often reacted to these studies with skepticism and very strong criticism. In particular, they argued that the most common deprivation procedure, which deprived rodents of REM sleep by placing them on a small pedestal, from which they would fall into water if they went into REM sleep, very likely creates massive stress for a mammal that avoids light, open terrains, and places near water (Horne, 1988, pp. 272–282; Horne & McGrath, 1984).

The possibility of memory consolidation during REM sleep arose once again at the turn of the 21st century as an offshoot of activation-synthesis theory (Stickgold, 1998; Stickgold, James, & Hobson, 2000; Stickgold, Scott, Rittenhouse, & Hobson, 1999). The new examination of memory consolidation during REM originally was based in fair measure on animal studies, some of which involved depriving rodents of REM sleep by placing them on a small pedestal, surrounded by water (Smith, 1985), which is the method that had come under the most scrutiny (Horne &

McGrath, 1984). The other and more lasting animal basis for this line of theorizing focused on the tracing of hippocampal brain-wave patterns in rodents during NREM slow-wave sleep, which were similar to the brain waves that had been recorded during a spatial behavioral task in the waking state (M. Wilson & McNaughton, 1994).

At the human level, the theory argues that memories of daytime experiences are reprocessed during dreams in REM sleep, especially in relation to emotional concerns, as evidenced by various changes in REM sleep parameters and REM dream reports after participants viewed either an arousing picture, such as one of a wrecked automobile, or a more neutral picture. Dreaming is said to be “simply the conscious perception of the stream of images, thoughts, and feelings evoked in the brain by one or more of the many forms of off-line learning and memory processing that occur during sleep” (Stickgold & Wamsley, 2017, p. 514). This conclusion provides the basis for the further conclusion that “the function of dreaming may be reducible to a question of the function of the sleep-dependent memory processes that result in the conscious experience of dreaming,” with an emphasis on REM dreams as aiding in emotional regulation (Stickgold & Wamsley, 2017, p. 513). As another proponent of the theory explained, “the relationship between late-night elevations in cortisol and explicit memory consolidation have important consequences for dreams: it produces fragmented dreams, gives dreams their uniquely bizarre flavor, accounts for their emotional nature, and explains not only why veridical replay of episodic memories during dreaming is rare, but also why dreams are so fleeting and difficult to remember” (Payne, 2010, p. 118).

The emphasis on emotional memory processing during REM sleep is first of all doubtful due to the continuing lack of convincing evidence for any type of memory consolidation during REM sleep. For example, one research team concluded on the basis of their own research that “Altogether, these findings indicate an importance of NonREM rather than REM sleep for the encoding of information that is independent of the emotionality of the materials” (Kaida, Niki, & Born, 2015, p. 72). These conclusions are similar to those in other research studies by the same core research group (Born & Wilhelm, 2012; Rasch & Born, 2015). Then, too, one of the researchers who did sustained work on memory consolidation, using REM-deprivation techniques with rodents (Smith, 1985), later concluded that memory consolidation during REM sleep may be limited primarily to procedural memories (Smith, 1995).

Similarly, in a review of the two decades of work on the replay during sleep of the waking brain wave patterns that accompany learning in rodents in experimental settings, the researchers concluded that the sharp-wave ripples in the hippocampal region, which are thought to indicate memory consolidation, seem to behave differently in REM than at other times. Sharp-wave ripples are frequent in slow-wave sleep and quiet wakefulness, but in REM sleep the “firing-rate correlation was not related” to the relevant learning experience during the experiment (Chen & Wilson, 2017, p. 3). Adding further complexity to the research literature on this topic, there is also evidence that some of the neurons in the hippocampus that are active during REM sleep may play a role in forgetting (Izawa et al., 2019). At the least, then, the role of REM in memory consolidation remains uncertain in animal models.

The emphasis on emotional memory consolidation during REM sleep is also called into question by studies showing that the hundreds of thousands of people who unexpectedly lost most of their REM sleep in the 1950s and 1960s, due to their use of the first generation of antidepressant medications, did not report any memory difficulties or other cognition issues; this finding is particularly striking in the case of those who took monoamine oxidase inhibitors, which all but abolish REM sleep (Schweitzer & Randgazzo, 2017; Siegel, 2001; Vertes & Eastman, 2000; Wyatt, Fram, Kupfer, & Snyder, 1971). In a study of moderately depressed patients who were given cognitive tests and then put on one or the other of two more recent antidepressant medications, which reduce REM sleep by as much as 30%, there was “no association of REM sleep diminution with decreases in memory performance or cognitive flexibility” after a 1-week trial (Göder et al., 2011, p. 544).

In addition, there is the case of a young man who lost all but a very few percent of his REM sleep due to shrapnel damage during routine military training, which permanently damaged the lateral pontine region of the brain stem, as discovered by means of CT scans after he complained of headaches (Lavie, Pratt, Scharf, Peled, & Brown, 1984). Even without REM sleep, he earned B.A. and law degrees, prepared a new crossword puzzle each week for a major newspaper, and in general led a normal life. He was examined again in greater detail 34 years later at age 68 through a full daytime neuropsychological assessment and four nights in a lab setting while being studied with EEG recordings and a CT scan; he was found to be cognitively normal and still almost devoid of REM sleep and those of REM sleep’s concomitants that could be assessed, such as increased heart rate and muscle atonia (Magidov et al., 2018). Just as two or three famous lesion cases studies refocused the study of waking memory, so, too, this unusual case perhaps should be given considerable weight in considering memory consolidation during REM.

The neuroimaging studies of the neural substrates that support emotions during the waking state, which were overviewed in the previous subsection, are also relevant to this discussion of emotions during REM dreaming. This is because the dorsomedial prefrontal cortex, which is a necessary part of the neural systems that support the experiencing of emotion in waking (LeDoux, 2012, 2015, 2019; Lindquist et al., 2012), is deactivated during both REM and NREM sleep (Fox et al., 2013). Similarly, the neuroimaging study that found the salience network to be essential to emotion states during waking (Touroutoglou et al., 2015) calls the emotion-processing theory of REM sleep into question because the salience network also was found to be relatively deactivated in the meta-analysis that included six studies of REM sleep (Fox et al., 2013).

The low levels of emotion in dream reports collected from children and adults inside and outside a laboratory setting are consistent with these neuroimaging results, and also cast doubt on the emotion-regulation theory in their own right. First, as discussed earlier in this article, there is a relative absence of emotions in the dreams of children and preadolescents, which means the theory could not likely be relevant until early adolescence (Foulkes, 1982; Foulkes et al., 1990; Strauch, 2005). Even during adolescence and adulthood, the relevance of the theory is doubtful because of the absence of emotions from at least 25–30% of the dream reports collected from REM awakenings (Domhoff, 2018b, pp. 26–27; Foulkes et al., 1988; McCarley & Hoffman, 1981; Snyder, 1970; Strauch & Meier, 1996). It is noteworthy in regard to the memory-consolidation theory that the REM-awakening study using

a portable EEG in home settings, which was also discussed in the previous subsection, not only discovered that 26% of the awakenings led to reports of no emotions, but also that the emotional intensity of the emotions was rated as low or medium in another 46% (Fosse et al., 2001, pp. 1–2, 4).

Thus, whether the relevant research literature concerns the presence of memory consolidation during REM in rodents, the cognitive unimportance of the loss of REM sleep in humans, the low levels of activation in frontoparietal, dorsal attentional, and salience networks during human dreaming, or the frequency and intensity of emotions in dream content, the theory that the function of REM dreaming involves the reprocessing and regulation of emotions remains highly unlikely, and at best inconclusive, after decades of research studies.

The Threat-Simulation Theory of Dream Function

The threat simulation theory of dreaming (Revonsuo, 2000b) is the most highly developed and visible version of the social rehearsal theories that appeared at about the same time as did the neurocognitive theory of dreaming (Breton, 2000; Franklin & Zypur, 2005). It asserts that the “biological function of dreaming is to simulate threatening events, and to rehearse threat perception and threat avoidance,” which prepare people to cope more adequately with waking threats that endanger reproductive success without necessarily being recalled (Revonsuo, 2000b, p. 793). The theory thereby assumes that there is implicit learning (incidental learning without awareness) during sleep, which threat-simulation theorists regard as the most difficult assumption in the theory to test (Revonsuo, 2000a, pp. 890, 1081; Valli & Revonsuo, 2009, p. 33).

In fact, most experimental psychologists doubt the importance of implicit learning even during waking due to its limited scope, its occurrence in only brief durations, and its relevance for only a few types of information (Ryals & Voss, 2015, pp. 44–45, for a summary of the various criticisms). Moreover, the small amount of implicit learning that does occur requires that the participant is paying attention to the main task at hand; one study reported a “significant negative correlation between mind-wandering and implicit learning” (Franklin, Smallwood, Zedelius, Broadway, & Schooler, 2016, p. 223), so implicit learning during sleep may be extremely difficult to the degree that dreaming is a form of mind-wandering that leads to inattention. In the case of implicit *sequence* learning, which seems to be the most relevant type of implicit learning in terms of the sequential, quasi-narrative nature of most dreams, a researcher who has studied the sequential-learning issue in detail concludes that it cannot be separated from explicit learning (Shanks, 2003, p. 38). Nor is there any evidence for new learning during sleep beyond two conditioning studies, which paired odors with tones to condition sniffing responses in reaction to tones (Arzi et al., 2012, 2014).

In addition to its reliance on implicit memory to learn from the very complex process of dreaming, the theory also assumes that this implicit learning can be transferred to waking situations, which is known in the psychological literature as “transfer of learning” or “transfer of training.” Once again, findings in the 21st century have led to the conclusion that the transfer of learning also seems to be limited in its scope, with little or no evidence for improvement on tasks outside of

tightly related, overlapping domains (Sala & Gobet, 2017; Sala, Tatlidil, & Gobet, 2018, for meta-analyses and overviews of very large literatures). Nor is there any evidence for transfer of learning from sleep to waking, and it is unlikely that such a complex transfer could occur. One neuroimaging study, which needs to be replicated, found that the transfer of learning involves the regions in the brain that support the central executive network, including the dorsolateral prefrontal cortex (Verghese, Garner, Mattingley, & Dux, 2016), which other studies show to be deactivated in both REM and NREM sleep (Braun et al., 1997; Dang-Vu, Schabus, Desseilles, Schwartz, & Maquet, 2007; Fox et al., 2013).

The theory does not focus on other animals, but it does suggest that “long periods of sleep” may have allowed for the simulation of threat and survival skills during the 100 million years in which early mammals “had to compete with the much larger and more numerous reptiles for resources” (Revonsuo, 2000b, p. 900, note 14). This speculation leads to the hypothesis that humans may have inherited threat scripts that are triggered by “ecologically valid cues” (Revonsuo, 2000b, p. 878). The evidence for this claim is based on the behaviors of decorticated cats, such as “hunting, stalking, running as if chasing imaginary prey,” which happen during REM periods; the fact that these behaviors also happen during waking is dismissed because “the brain in REM is most like the brain in very alert wakefulness . . .” (Revonsuo, 2000a, pp. 1070–1071). Aside from the fact that there is no reason to believe there is imagination in the brain stems of any decorticated mammals, there is no evidence that any other mammals besides humans have the mental capacities needed to dream, such as an episodic memory and an autobiographical self (Blagrove, 2000; Foulkes, 1983, pp. 317–319, 325–327, 332–333; 2017; Tulving, 2005).

Threat simulation during dreaming is said to work well in children “as soon as their perceptual and motor skills are at a level that enables threat recognition and avoidance in the waking state” (Revonsuo, 2000b, p. 899, note 5). This assertion ignores issues concerning both waking and sleeping cognitive capacity in children; it is primarily based on an inadequate and out-of-date earlier study of children’s dream reports. Those results, which were collected by parents and teachers with minimal controls of any kind, were the best that were available at the time, but they greatly overstated the degree of aggression in children’s dreams, as subsequent research showed, even though the results for adults in that study held up much better (Hall & Domhoff, 1963). On the other hand, the findings in laboratory studies show that the few bland dream reports from preschool children contain no aggression, misfortune, or failure, and that the dreams of elementary schoolchildren very rarely contain these negative elements (Foulkes, 1982; Foulkes et al., 1990). However, these laboratory findings were not factored into the theory because “these data do not show that such experiences are not possible, at least occasionally or in specific subgroups of children who are living in less safe environments or who otherwise have been exposed to various threatening events” (Revonsuo, 2000b, p. 899, note 5).

The theory also assumes that traumatic events lead to a more rapid development of the capacity to dream in children (Revonsuo, 2000b, p. 889, Note 5), but this claim seems doubtful in terms of what is known about the gradual sequential unfolding of neural and cognitive development, as summarized earlier in this article and as shown in detail in other sources (Domhoff, 2018b, Chapters 4–5; Fair et al.,

2008, 2009; Nelson, 2005). The strong assertions on this issue by threat-simulation theorists were later altered to claim that threat-simulation dreams are possible at age 6 and thereafter (Valli & Revonsuo, 2009, p. 33), which also remains unlikely in terms of the findings on the immaturity of the default network until ages 9–11 (Fair et al., 2007, 2008), and the longitudinal and cross-sectional laboratory findings on the low frequencies of aggression, misfortune, and failure in the laboratory dream reports of children ages 6–9 (Domhoff, 1996, pp. 91–95, for an additional content analysis of the dream reports collected in the cross-sectional study; Foulkes, 1982; Foulkes et al., 1990).

The indicators of threat used to test the theory empirically in studies of dream content encompass just about everything negative that can happen in dreams. In addition to physical attacks and threats of aggressive acts, they include threats to valuable material resources, social status, and events perceived as “subjective threats,” such as mistakes and feelings of personal failure (Revonsuo & Valli, 2000, pp. 5, 23–25). Research by its proponents concludes that 60% to 77% of dream reports have threatening events (Revonsuo & Valli, 2000, 2008). This finding replicates the following Hall and Van de Castle (1966) results in their normative samples of men and women almost exactly, but overlooks some key points: 47% of men’s dream reports and 44% of women’s dream reports have at least one aggression in them, but half or less of those aggressions are physical aggressions; 36% of men’s reports and 33% of women’s reports have at least one misfortune, most of which are minor events; 15% of men’s reports and 10% of women’s reports have at least one failure; and overall, 73.8% of the men’s reports and 70.7% of the women’s have at least one of these three types of elements (Hall & Van de Castle, 1966). Similarly, when threat-simulation theorists report that dreamers are involved in a large majority of the life-threatening events (Revonsuo & Valli, 2000, p. 10), they are replicating the fact that both male and female dreamers in the Hall and Van de Castle (1966) normative findings are involved in 80% of the aggressive interactions in their dreams, but are ignoring the fact that the dreamers are the victims in the majority of the aggressive interactions, and that they seldom respond to their victimization.

At the same time, the exclusive concern with threats in this theory highlights the fact that it cannot explain the considerable percentage of dreams that do not contain threats (Zadra & Donderi, 2000). This criticism is supported by the fact that 25–30% of the dream reports in the Hall and Van de Castle (1966) normative sample do not contain the negative elements of aggression, misfortune, or failure; this large subset includes the 22.8% of the dream reports that contain a friendly interaction, but no aggressions, and a subset of 15.2% that portrays a friendly interaction, but has no aggressions *or* misfortunes.

The nonthreatening nature of many dreams is demonstrated in two studies of dream reports from students at the University of Cape Town, both of which were meant to examine threat-simulation theory. Although the university is located in the most violent and crime-ridden area in South Africa, the first study found that very few dream reports had realistic life-threatening elements, and that effective responses by dreamers to threats of direct physical harm were rare (Malcolm-Smith & Solms, 2004; Malcolm-Smith, Solms, Turnbull, & Tredoux, 2008b). The second of the two studies included a comparison with 116 dream reports from students at the University of Wales in Bangor, which is in a low-crime area in Northern Wales, but

a higher percentage of their dream reports included life-threatening events than did those from Cape Town (18.6% vs. 8.7%; [Malcolm-Smith et al., 2008b](#), pp. 1285–1286).

The weaknesses of the threat-simulation theory are also demonstrated in a study by independent investigators using 212 previously collected recurrent dreams ([Zadra, Desjardins, & Marcotte, 2006](#)), which are acknowledged by threat-simulation theorists to very often contain threat simulations ([Revonsuo, 2000a](#), p. 1076). Unlike what threat-simulation theorists would expect, the study found 8% of the instances of threats “belonged to the realm of fantasy or fiction,” or would be “very unlikely to occur in the subject’s waking life”; furthermore, a great majority of the recurrent dreams with a threat of any kind in them ended with the threat being fulfilled (40%), the participant awakening (37%), or the imminence of the threat changing “abruptly” (17%), so only 17% of the recurrent dreams with a threat in them had a positive outcome ([Zadra et al., 2006](#), p. 457). In responding to these various studies that refute their theory, threat-simulation theorists discount the findings because the setting and circumstances in which the dream reports were collected allegedly did not include ecologically valid cues ([Revonsuo, 2000a](#), pp. 1071–1073; [Revonsuo & Valli, 2008](#)), which suggests that the theory verges on being unfalsifiable by studies of dream content according to threat-simulation theorists’ reasoning ([Desjardins & Zadra, 2006](#); [Malcolm-Smith, Solms, Turnbull, & Tredoux, 2008a](#)).

Although threat-simulation theorists dismiss all of the contradictory empirical findings on dream content, their theory is nevertheless subject to rejection if any one of its four main underlying assumptions are judged to be unlikely by members of the scientific community—dreaming during REM sleep in the human ancestral line 200,000 or more years ago, implicit learning during sleep, the transfer of implicit learning to waking situations, and complex threat-simulation dreams in young children between ages 6 and 9. In addition to overcoming the strong doubts that can be raised concerning all four of these assumptions, the theory’s proponents would also have to deal with the finding that as many as 30% of dream reports do not contain a threat, whether physical or subjective, in order for it to remain at all viable.

Conclusion

As shown in the previous section, none of the four theories that is compared with the neurocognitive theory of dreams has been adopted as yet by researchers outside the original theory group, which is usually a sign after 10–15 years that the theory is not likely to be accepted by the larger scientific community ([Griffith & Mullins, 1972](#); [McClenon, 1984](#)). Then, too, there are only a few instances of findings being replicated. Further, all four of these theories have been subjected to strong criticisms that have not been answered well by their proponents.

Although the neurocognitive theory has not been adopted by other researchers either, as noted in an earlier section, it does differ from the other four because many of its key building blocks were created by investigators who were not part of the construction of the theory, and its most important foundational studies have been replicated by independent investigators in regard to its neural, developmental,

and content levels. The theory also has led to a plausible, low-budget research agenda, based on studies that could be carried out inside or outside of laboratory settings (Domhoff, 2018b, Chapter 9).

As noted at the outset of this assessment of the neurocognitive theory of dreaming at age 20, it begins with a highly plausible neural substrate that enables dreaming, which brings dreaming into the same realm as daydreaming and mind-wandering as a type of spontaneous, self-generated thought (Andrews-Hanna et al., 2018; Fox et al., 2018). In its updated version, it incorporates the findings on the gradual development of dreaming into the larger context of waking cognitive developmental psychology and encompasses the full range of replicated findings from laboratory and nonlaboratory studies concerning adult dream content. It therefore includes the three levels that are necessary for a fully adequate neurocognitive theory—an underlying neural substrate, the cognitive processes that neural substrate supports, and the behavioral level in the form of verbal reports (Ochsner & Kosslyn, 2014).

Moreover, the neurocognitive theory does not necessitate unsubstantiated assumptions about repressed wishes that arise during sleep, allegedly random firings in the brain stem during REM sleep, emotional memory consolidation during REM sleep, implicit learning during sleep, or the transfer of implicit learning to waking life. Nor does it include an adaptive function for dreaming in the face of strong empirical evidence to the contrary, including, but not limited to, the unlikelihood of implicit learning during dreaming and its transfer to waking states, lesion studies showing that adults can lose dreaming without losing basic cognitive functions, and the likely absence of dreaming during the preschool years and its infrequency and lack of complexity until ages 9–11.

On the other hand, the other four contemporary dream theories discussed in this article lack a sound neural basis that is grounded in neuroimaging studies, ignore or reject the replicated findings on the gradual cognitive development of dreaming, often build upon inadequate samples of actual dream content, or make assumptions about the adaptive functions of dreaming that have not been supported by empirical studies.

If theories should be judged by their capacity to explain the widest range of findings about a phenomenon, their basis in solidly grounded replicated findings, their compatibility with established generalizations in closely related fields of inquiry, and their ability to provide ideas for further studies that potentially could add nuance to the theory, or refute it, then the updated version of the neurocognitive theory of dreams still appears to be promising. Due to the various updates, its statute of limitations can be extended to 2030 before it expires.

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