

# 41 Dreaming is Imagination Roaming Freely, Based On Embodied Simulation, and Subserved by an Unconstrained Default Network

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Dreaming is based on the cognitive process of simulation, which can be usefully defined for the purposes of this chapter as “a particular kind or subset of thinking that involves imaginatively placing oneself in a hypothetical scenario and exploring possible outcomes” (Schacter, Addis, and Buckner, 2008: 42). Moreover, dreaming often includes a vivid sensory environment, interpersonal interactions, and emotions. It is subjectively “felt” as the experienced body in action, and sometimes unfolds over a period of 15–30 minutes. Dreaming is therefore an exemplary example of “embodied simulation” in which there is not only some degree of imaginative narrative flow, but also an activation of secondary sensorimotor and visual areas of the cortex when imagining different actions or events. For example, somatosensory areas of the brain are more active when people are making aesthetic judgments of dance movements. (Domhoff, 2018: 3–4, 92; Gibbs, 2014: 27–29, for overviews and examples).

In terms of their content, most dreams can be understood as dramatized presentations of personal conceptions and concerns that are embedded within larger cognitive networks of scripts, schemas, and general knowledge. Dreams have several parallels with theatrical plays, which also contain settings and a cast of characters. The dreamer and the other characters are engaged in one or another activity (e.g. watching, swimming, running) or a social interaction (e.g. helping, arguing, kissing) in 86.7 percent of dream reports (another 6.7 percent involve the dreamer only observing or thinking about other people, 2.2 percent include only the dreamer and one or more animals, and 4.3 percent include only the dreamer) (Domhoff and Schneider, 2018). Dreaming is distinguished from other forms of thinking and imagining by the sense of being an actual, embodied participant in (or observer of) an event that seems upon awakening as if it had been “real” while it lasted.

Although dreaming most frequently occurs during REM sleep, it also can occur during NREM Stage 2 sleep, especially in the last two hours of the sleep period, when the brain is returning to a daytime level of activation (Cicogna et al., 1998; Pivik and Foulkes, 1968). Auditory waking thresholds and cerebral blood flow,

which are indicators of levels of brain activation, are very similar in REM and NREM 2, and unlike those found in slow-wave sleep (Madsen et al., 1991; Zimmerman, 1970). Dreaming can also occur during the sleep-onset process, before there are any signs of the standard indicators of sleep (Foulkes and Vogel, 1965; Hori, Hayashi, and Morikawa, 1994). Moreover, brief episodes of dreaming are reported after about 20 percent of the probes during long periods of drifting waking thought when a participant is alone in a laboratory setting, with wakefulness monitored by the polysomnograph. One person, for example, dreamed she was back in her hometown, another was pressing on a vein to try to stop it from bleeding, and another was watching a judge who was wearing an old-fashioned powdered wig (Foulkes, 1985: 72). In another 20 percent of the probes the participants were mind-wandering, in 22 percent they were lost in deep thought, and in 38 percent they were fully aware of what they were doing and where they were (Foulkes and Fleisher, 1975: 72).

Based on these findings, dreaming is a unique mental state that is not dependent upon sleep. Contrary to clinical lore, neuroimaging and studies based on experiential reports show that dreaming has little in common with hallucinations, psychotic states, drug states, or hypnotic states (Abraham, 2016: 4206–4207; Pace-Schott, 2003; Sacks, 2013). Combining what is known from laboratory dream studies and neurocognitive studies, it seems likely that the neural substrate that subserves dreaming becomes operative when the following five conditions are met:

- (1) There is a mature neural network for dreaming, a qualification that allows for its gradual development, which does not reach adultlike status in terms of dream content until ages 12–13;
- (2) An adequate level of cortical activation is present, which is provided by sub-cortical ascending pathways and crucial regions in the hypothalamus;
- (3) There is an occlusion of external stimuli, which likely involves the posterior thalamus and may include some neurochemical dampening in primary sensorimotor areas;
- (4) There is a cognitively mature imagination system, a necessity indicated by the near absence of dreaming in preschoolers and its infrequency and lack of cognitive complexity until ages 9–11; and
- (5) There is a loss of conscious self-control, which may be neurologically mediated, as the final step in a complex process, by the decoupling of the frontoparietal and dorsal attentional control networks from the two functional subsystems of the default network that remain activated during dreaming.

### The Nature of Dream Content

Dreaming is seldom influenced by specific stimuli introduced shortly before going to bed or during dreaming in sleep-dream laboratories. On the few occasions when stimuli seem to be incorporated, “the narrative seems to determine the fate of the stimulus, rather than the stimulus determining the fate of the narrative” (Foulkes

and Domhoff, 2014: 168). Nor do significant events of the previous day very often have an effect on dream content (e.g. Roussy et al., 1996, 2000). A study using ten-day dream diaries concluded that incorporation “is dependent on the salience or personal importance of waking life events” (van Rijn et al., 2015: 107).

The largest study of adult REM dream content in the sleep-dream laboratory, based on 635 dream reports collected “for a variety of experimental purposes” in several different investigations over a period of years, concluded that “dreaming consciousness” is a “remarkably faithful replica of waking life” (Snyder, 1970: 133). Nor are there many differences between dream reports collected in sleep-dream labs and those collected in non-lab settings from the same participants, except for aggression indicators (Domhoff and Schneider, 1999; Weisz and Foulkes, 1970). Emotions are absent from at least 25–30 percent of dream reports in both lab and non-lab settings (e.g. Domhoff, 2018: 61; Fosse, Stickgold, and Hobson, 2001; Strauch and Meier, 1996). There are virtually no episodic memories (Baylor and Cavallero, 2001; Fosse, Hobson, and Stickgold, 2003), and there are only rare indications of possible symbolism (Domhoff, 2003: 33–36, 128–133; 2015, 12–16, 21). Recurrent dreams, which many people claim they experience, are less than 2 percent of all dreams (Desjardins and Zadra, 2006). Typical dreams, which are dreams many people report they have experienced, are less than 1 percent of all dreams for any type of typical dream in both lab and non-lab studies (Domhoff, 1996; Snyder, 1970; Strauch and Meier, 1996). The appearance of everyday issues such as politics, economics, and religion is very infrequent (e.g. Hall, 1951).

Although dreams are often thought of as bizarre and disjointed, laboratory studies reveal they are far more coherent and faithful to waking life than is widely believed. In a detailed lab study of unusual and anomalous elements in dream reports, the researchers concluded their results “emphasize the rarity of the bizarre in dreams” (Dorus, Dorus, and Rechtschaffen, 1971: 367). Similar findings on the relative infrequency of bizarre elements in dreams were reported in other lab and non-lab studies (e.g. Revonsuo and Salmivalli, 1995; Snyder, 1970; Strauch and Meier, 1996).

A study comparing REM dream reports to streams of waking thought reported by individual participants alone in a darkened room found that there were more abrupt topic changes or scene changes (“discontinuities”) in the waking sample than in REM reports. In addition, there were as many “improbable combinations,” such as unusual juxtapositions of objects, in waking as in REM. The REM dream reports were higher only on “improbable identities,” such as metamorphoses and blended characters (Reinsel, Antrobus, and Wollman, 1992: 169–170, 173). This study shows that discontinuities cannot be used to study alleged bizarreness in dreams, which is one of several problems with the few studies claiming frequent bizarreness in dreams (Domhoff, 2018: 220–223, for a detailed critique).

Systematic studies of adult dream content reveal that there is considerable psychological meaning in dream content in terms of correspondences with waking demographic variables, such as nationality, gender, and age, but there are more similarities than differences (Domhoff, 1996, 2003; Pesant and Zadra, 2006). There also have been numerous quantitative studies of individual dream series

written in dream diaries by a small but diverse set of individuals for their own reasons, which never have to do with psychotherapy or an interest in dream theories, nor with any intention of later offering them to dream researchers.

Dream series have long-standing methodological legitimacy in psychology as a form of unobtrusive, nonreactive archival data, because the demand characteristics and expectancy effects that can arise as subtle confounds in experimental settings do not influence them (Rosenthal and Ambady, 1995; Webb et al., 1981). Comparison studies using approximate randomization, which requires no assumptions about the independence of observations, demonstrate that dream series can be analyzed with the same statistical tests used in studies that compare samples based on numerous individuals; in addition, the possibility of autocorrelation has been ruled out as a potential confound by a study of 125 runs in four different dream series using the Wald-Wolfowitz runs test for assessing independence with nominal data (Domhoff, 2003; Domhoff and Schneider, 2008, 2015). The findings from analyses of an individual dream series can be compared with replicated norms for American men and women (Hall et al., 1982; Hall and van de Castle, 1966; Tonay, 1990/1991).

Detailed blind quantitative analyses of about two dozen different dream series, which range in length from several hundred to several thousand dream reports, demonstrate there is great consistency in what adults dream about over months, years, and decades (Domhoff, 1996, Chapter 7; 2018, chapters 3–4). Then, too, similar blind content analyses of about a dozen dream series, which led to inferences that could be accepted or rejected by the dreamer and close friends, demonstrate that there is continuity between many of the conceptions and personal concerns expressed by individuals in dreaming and waking thought. In the process, these studies revealed that the frequency of the appearance of a person or activity is a reliable index of the intensity of a personal concern. These continuities most often involve the important people in a dreamer's life and the nature of the social interactions with them. There is also good evidence for continuity with many of the dreamer's main interests and activities (Bulkeley, 2014; Domhoff, 1996, Chapter 8; 2003, Chapter 5).

Based on these studies, as many as 70–75 percent of dreams have at least one element that is continuous with waking conceptions and concerns (Domhoff, 2018, chapters 2–3). The remaining 25–30 percent of dream reports often have the flavor of adventure stories, complete with dangers (Foulkes, 1999: 136). In a study of a sample of 1,000 dream reports, 500 from 100 college women and 500 from 100 college men, the 26 percent of dreams that have *neither* familiar characters nor familiar settings have more animal characters, more acts of physical aggression, and more misfortunes than the 65 percent of the dreams that contain *both* familiar characters and familiar settings (Domhoff, 2018: 64–65).

The dream series that has been studied in the most detail consists of 4,254 dream reports written down over a forty-one-year period by a now-elderly woman. The pattern of friendly and aggressive interactions with the most frequently appearing characters in her dreams, along with the percentage of the time she initiated the friendly or aggressive interactions, provide an accurate portrait of how she regards and interacts with these people in waking life, as subsequently determined in lengthy interviews with the dreamer and four of her close women friends. For example, the elevated levels of

aggressive interactions with her mother (as determined by a comparison with the frequency of aggressive interactions with all characters in a representative sample of 250 of her dreams), along with the fact that she and her mother were equally likely to initiate both their many aggressive and fewer friendly interactions, was consistent with her waking conception of her relationship with her mother. So, too, the dreamer's even higher levels of aggressive interactions with her middle daughter, the great majority of which the dreamer initiated, fit with how she conceived of that relationship. On the other hand, she had overwhelmingly friendly interactions with her favorite brother and her closest woman friend (Domhoff, 2003: 111–128; 2018: 100–111 for a summary of all past findings as well as new findings with this series).

The findings on consistency and continuity suggest there may be a degree of lawfulness in some aspects of dreaming. This hypothesis derives from pathbreaking work, based on five dream series, ranging in length from 208 to 423 dream reports. The researchers discovered that the social networks in dreams are similar to waking social networks in that they are both “small-world” networks. Such networks are characterized by several features, including short paths to other people via shared connections, a tendency for two people who are known by another person to know each other, a strong tendency for a few characters to be more central to the overall network than others, and for a large number of characters to be connected in a large general component (Han et al., 2015).

The findings with the first five dreamers were replicated and extended through a comparison of the waking social network and the network of dream characters in the series of 4,254 dream reports written down by the woman whose patterns of social interactions in her dreams with important people in her life were discussed two paragraphs ago. The results were compared with the findings from the dreamer's waking social network, which was constructed from a questionnaire in which she rated how well each possible pair of people actually knew each other in waking life and how emotionally close they were on a 1 (low) to 5 (high) scale (Han, 2014: 36). She also rated her own emotional closeness to each person on the same five-point scale.

The dream and waking social networks were similar in several ways, beginning with the “density” of the networks (Han, 2014: 47). Then, too, a measure of centrality, based on how connected a person is to other well-connected people, revealed a high correlation between the dream and waking-life networks. Suggesting once again that most dreams are about highly personal concerns, the dreamer's network of dream characters more often brought together immediate family members, other relatives, and friends than was the case in waking life (Han, 2014: 48–49). Similarly, the people who were emotionally close to the dreamer in waking life tended to appear in dreams together even though they were not in the same social networks in waking life (Han, 2014: 50).

### **Dreaming Is a Gradual Cognitive Achievement**

A longitudinal laboratory study of several dozen participants ages 3 to 15, and a cross-sectional laboratory replication with children ages 5 through 8, both

revealed that dreaming is a gradual cognitive achievement in terms of frequency, complexity, and content, as well as in the inclusion of emotions (Foulkes, 1982; Foulkes et al., 1990). Preschool and young elementary school children reported dreams after only 15–20 percent of REM awakenings, even though their verbal skills were excellent and there was every indication that they were comfortable in the laboratory setting. In addition, children’s dream reports were not adultlike in frequency, length, and form until ages 9–11, and the content did not regularly include emotions, personal concerns, and avocations in an adultlike way until ages 12–13 (Foulkes, 1982, 1999; Foulkes et al., 1990). The results for children ages 9 to 15 were later replicated in a six-year longitudinal study in Switzerland, which also included new findings on friendship patterns (Strauch, 2005; Strauch and Lederbogen, 1999).

Overall, these results suggest that there are cognitive prerequisites for dreaming. Drawing on findings in developmental cognitive psychology, as well as the cognitive testing that was carried out as part of the longitudinal and cross-sectional dream studies of children, it seems likely there are four cognitive processes that are necessary for dreaming – mental imagery, narrative skills, imagination, and an autobiographical self.

The ability to produce mental imagery, which is a significant feature of dreaming, seems to be lacking in preschool children. This conclusion is derived from numerous different types of detailed studies of visual mental imagery that are too complex to be summarized within the confines of this chapter (Domhoff, 2018: 59–162 for a literature review). Nor did the mental imagery tests used in conjunction with the cross-sectional dream study of children 5 through 8 detect sufficient capacity to create mental imagery at age 5; the investigators concluded that “the possibility of kinematic imaging emerges somewhere between 5 and 8 years of age, rather than being generally well-developed in 5-year-olds” (Foulkes et al., 1989: 450).

These findings are supported by the absence of visual imagery in people who are born blind, or lose their sight before age 5, in contrast to the continuing presence of visual imagery in the dreams of people who become blind after age 7. Taken together, these findings suggested that visual mental imagery develops somewhere between ages 5 and 7 (Foulkes, 1999: 15; Hurovitz et al., 1999; Kerr, 1993). The continuing ability of those who became blind after age 7 to generate visual imagery includes the creation of visual dream images of people they met after they became blind. It therefore seems likely that they have retained a developmentally acquired system of visual imagery that is independent of their visual-perceptual capabilities (Kerr, 1993: 30–35).

Children do not have good narrative skills until they near preadolescence. Only half of young children’s statements about an event are narratives by age 3, albeit limited ones, but by age 5 or 6 many children can tell a story that contains a beginning, middle, and end (Reese, 2013: 197–198). In a study of children age 7, it was found that they included only three of the eight basic elements that are part of a well-developed narrative, but by age 11 they included six of the eight. Similar insufficiencies in narrative skills were also found in the cross-sectional laboratory study of dreaming and its waking cognitive correlates. Participants aged 5–7 were

able to produce only simple narrative scenes without chronology or sequence, 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: 456, 461).

Nor do children have the ability to engage in “pretend dramatic play” until they are aged 4 or 5, even in stimulating preschool environments (Nelson, 2007: 170). Before that age they seem to lack the ability to simulate versions of past and future events, which is considered essential to imagination. Similarly, in the cross-sectional sleep-dream laboratory study of children 5 through 8, the ability to produce complex imaginative narratives in response to story prompts significantly correlated with the participants’ overall rate of dream recall when age was held constant (Foulkes et al., 1990: 458).

Finally, personal (episodic, autobiographical, autothetic) memories only gradually develop and become organized into an autobiographical self around age 6 (Bauer, 2013: 521–522; Gopnik, 2009, Chapter 5). Studies including specific questions about conscious thoughts found that preschool children do not seem to have much awareness of a spontaneous inner mental life, in contrast to those aged 6–7. Apparently due to this inability to consciously experience their own thinking, preschool children “don’t experience their lives as a single timeline stretching back into the past and forward into the future,” or “feel immersed in a constant stream of changing thoughts and feelings” (Gopnik, 2009: 153).

It therefore seems that children do not have “the basics of autobiographical memory,” along with an inner mental life and “a roughly adult understanding of consciousness,” until they are around the age of 6 (Gopnik, 2009: 156). This finding parallels the results for the longitudinal dream study of young children, which included seven boys and seven girls who were studied in the laboratory at ages 3–5, 5–7, and 7–9: “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: 4).

If the gradual independent development of mental imagery, narrative skills, imagination, and an autobiographical self in young children are considered in combination, it may help to explain why preschool children seldom dream and why the dream reports of children aged 5–7 often lack a sense of sequence, complexity, visual imagery, and a central role for the dreamer.

## The Neural Substrates That Support Dreaming

Neuroimaging, intracranial electrical brain stimulation, and lesion studies provide converging evidence suggesting that the neural substrate that enables the cognitive processes involved in dreaming is located within the default network. If future studies continue to support the evidence assembled to date for this hypothesis, then the gradual development of the default network between infancy and preadolescence may help to explain the infrequency and relative simplicity of children’s dreaming. Two cross-sectional studies of many dozens of children, preadolescents, and adolescents, aged 7 to 15, one in the United States, one in Brazil, discovered that

the default network does not approach adultlike complexity until ages 10–11 in terms of increased within-network connectivity and integration, strong connections among its major hubs, and increased segregation from other networks (Fair et al., 2008; Sato et al., 2014).

The results from the two cross-sectional studies were replicated and refined in a longitudinal study of both the default and frontoparietal control networks in forty-five participants (twenty-four girls, twenty-one boys) at ages 10 and 13. These investigators report that “by age 10, the basic functional architecture of the default mode network is in place,” and more generally conclude that the “participants’ functional networks resembled those found in mature adults in previous work” (Sherman et al., 2014: 151, 154). The fact that the default network becomes similar to the adult default network between ages 10 and 13 is consistent with the finding in lab studies that the frequency of dream recall and the content of dream reports become more adultlike during this time period.

There are two distinct, functionally connected subsystems within the waking adult default network that are relevant to dreaming, the dorsal medial prefrontal cortex system and the medial temporal lobe system (Andrews-Hanna et al., 2010). Both subsystems are also active during dreaming, as found in a meta-analysis comparing studies of mind-wandering with studies of REM sleep, which is a good proxy for the neural substrate that enables dreaming (Fox et al., 2013). The dorsal medial subsystem, which is differentially activated by instructions to think about the person’s present situation or present mental state (“present self”), includes the dorsal medial prefrontal cortex, the temporoparietal junction, the lateral temporal cortex, and the temporal pole of the temporal lobe. The medial temporal lobe system, which is differentially activated by thinking about personal situations and decisions in the future (“future self”), includes the ventral medial prefrontal cortex, posterior inferior parietal lobule, retrosplenial cortex, parahippocampal cortex, and hippocampal formation (Andrews-Hanna et al., 2010: 554, 559; Andrews-Hanna, Smallwood, and Spreng, 2014; Fox et al., 2015).

The importance of the medial temporal lobe to dreaming according to neuroimaging studies is supported by an electrical brain stimulation study that had a large enough sample size to distinguish a sense of dreaming from the range of reminiscence states, such as *déjà vu*, vivid memories, and a feeling of dreaminess, reported in past intracranial brain stimulation studies (e.g. Vignal et al., 2007). This more focused analysis demonstrated that the “experiential phenomena” explicitly mentioning dreams are all evoked by electrical stimulation in regions in the temporal lobe, and most frequently in the medial temporal lobe (Curot et al., 2018: 9–10). The study is based on forty-two instances, seven from six patients in the authors’ own extensive database, and thirty-five from the neurological case-study literature concerning electrical brain stimulation in general. These results are consistent with other electrical brain stimulation evidence suggesting that the medial temporal lobe is important in the initiation of spontaneous thought in general (Fox, 2018: 170, 175).

Returning to the neuroimaging studies, it is noteworthy that the prefrontal and posterior areas that support executive functions are less active or are deactivated during dreaming. They include the dorsolateral prefrontal cortex, the orbitofrontal cortex, the rostralateral prefrontal cortex, the posterior cingulate cortex, and the precuneus (Fox

et al., 2013). Based on these findings, dreaming can be considered an enhanced form of intense daydreaming that is not constrained by sensory input or the executive and attentional control networks, which provides the neurocognitive explanation for why dreaming is imagination roaming freely. However, as a result of these deactivations, it is also noteworthy that the neural network that underlies dreaming may not be sufficient to support the generation or comprehension of metaphors, which require a combination of regions within the frontoparietal and default networks (e.g. Beaty, Silvia, and Benedek, 2017). This finding may help explain the unexpectedly few instances of symbolism in systematic, nonclinical dream research.

The neural network that subserves dreaming, located primarily within the two functional subsystems within the default network mentioned above, is supplemented by the lingual gyrus, located in the medial occipital lobe, and the caudate nucleus, located in the basal ganglia, both of which are more active during dreaming than during mind-wandering (Fox et al., 2013). This discovery is significant because the lingual gyrus supports the generation of visual imagery and the caudate nucleus supports the initiation of movement, among other functions. The two functional subsystems of the default network that are highly active during dreaming include within them the mentalizing network, which subserves the ability to infer other people's thoughts and intentions, and also the network that supports social cognition in general. Moreover, the wide range of enactments related to the past, present, and future that can arise during dreaming may be possible because there is an overlap between the neural network that mediates associative thinking and the regions in the default network that are active during dreaming. In addition, the inclusion of language areas, located in regions in the temporal lobes, is consistent with the frequency, correctness, and specificity of language use in dreams (Domhoff, 2018: 171–175, for a synthesis of the large literature on the default network that can be related to dreaming). Perhaps most significant of all, there is a greater activation of the medial prefrontal cortex, which serves as a central hub in the widely distributed waking self-system (e.g. Abraham, 2013; Jenkins and Mitchell, 2011). This finding may help explain why preadolescent, teenage, and adult dreamers are usually at the center of their dream scenarios.

In addition to the brain regions that support the executive and attentional control networks, there is one other notable absence from the neural substrate that supports dreaming, the posterior cingulate cortex, which is a key connection between the default network and the dorsal attentional network. Its decoupling from the dorsal attentional network may be the final step in the complex neurocognitive process of losing conscious self-control, which begins with the gradual deactivation of the frontoparietal control network and the increasing activation of the default network (Domhoff, 2018: 194–196, for a discussion of the transition from focused thinking to mind-wandering to dreaming). Then, too, the absence of activity in the posterior cingulate cortex, which seems to be involved in retrieving past episodic memories, may help explain the rarity of episodic memories during dreaming. It is notable that the decoupling of the posterior cingulate cortex and the dorsal attentional network was also found in the largest and most detailed study of the sleep-onset process, which may be one reason why dreaming can occur during the transition to sleep (Sämman et al., 2011).

Finally, the amygdala is another prominent brain structure that is not implicated in the meta-analysis of REM sleep (Fox et al., 2013), nor in the meta-analyses of the waking default network and mind-wandering (Andrews-Hanna, Smallwood, and Spreng, 2014; Fox et al., 2015). This absence is surprising because the amygdala has long been associated primarily with fear, which is central to dreaming according to long-standing cultural beliefs (see LeDoux, 2019: 188–191, 364–367, for a refutation of this theory). This deactivation may help explain the absence of emotions from at least 25–30 percent of dream reports.

The neuroimaging findings on which areas remain activated or are deactivated during dreaming converge with and are supported by the results of lesion studies. Summarizing several studies, lesions *outside* the neural network that subserves dreaming, in regions such as the dorsolateral prefrontal cortex, the primary visual cortex, and primary sensorimotor cortices, have no impact upon dreaming (Domhoff, 2018: 187–194, for a synthesis of several studies; Solms, 1997: 82, 153, 219–223, 237 for original findings and a summary of past neurological cases). Conversely, injuries *inside* the neural network that subserves dreaming, in the ventral medial prefrontal cortex, or in the area of the temporoparietal junction, lead to a global loss of dreaming (Solms, 1997, chapters 4 and 16). In addition, injuries in regions of the secondary visual cortex lead to the loss of visual imagery in both dreaming and waking, as best shown in a study that included both waking cognitive testing and awakenings from REM sleep in a laboratory setting (Kerr, Foulkes, and Jurkovic, 1978). These experiential reports of continued dreaming, loss of dreaming, and the loss of visual imagery in dreaming provide the crucial subjective evidence that the neural network detected in neuroimaging studies is related to the cognitive process of dreaming.

The absence of amygdala activity during both mind-wandering and REM sleep in the earlier-cited meta-analytic study (Fox et al., 2013), and its consequent implications for dreaming, receives support from a study of the subjective reports of eight patients suffering from an atrophied basolateral amygdala, all of whom reported a continuance of dreaming (Blake et al., 2019). Just as in waking life, in which they experienced primarily positive emotions and a lack of fear, the content in the twenty-three dream reports they provided was “more pleasant and less unpleasant” than was the case for a control group (Blake et al., 2019: 11). This finding raises the possibility that the amygdala only becomes part of the neural network that supports dreaming when the neurocognitive system that manages anxiety breaks down (Pyszczynski and Taylor, 2016). Such a breakdown is most likely in the highly activated and agitated sleep that characterizes PTSD patients and others who suffer frequent nightmares (e.g. Germain, et al., 2013; Marquis et al., 2017).

### **Are Dreams Useful By-Products of Adaptive Selection for Imagination?**

The many replicated lab and non-lab findings concerning the process of dreaming, such as the regularity of nightly dreaming, along with the lack of dreaming in young children and the consistency of adult dream content over

decades, do not fit with any of the past conjectures about the possible adaptive function of dreaming (e.g. Blagrove, 2000; Domhoff, 2003, chapter 6; Foulkes, 1993, for critiques of past claims about the adaptive function of dreaming). Also, the fact that so few dreams are remembered by most people, that dreams rarely relate to recent events or to intellectual, political, or economic issues and rarely if ever contain solutions to problems, along with the replicated findings on the large percentage of dreams based on past personal failures and unsatisfactory personal relationships, contradict claims that dreams have any forward-looking, problem-solving function (Blagrove, 1992, 1996; Domhoff, 2003: 159–162). Social-rehearsal theories suffer from many of the same defects that plague problem-solving theories; they also make unsupported assumptions about the possibility of “implicit learning” during unrecalled dreams and the “transfer of learning” to waking-life situations, both of which are minor processes during waking life, and for which there is no evidence during dreaming. For example, implicit *sequence* learning, which is the most relevant type of implicit learning in terms of the sequential, quasi-narrative nature of most dreams, has not been convincingly demonstrated in waking studies. Similarly, transfer of learning is limited in its scope, and seems to require cognitive processes that are supported by the dorsolateral prefrontal cortex, which is deactivated during sleep (Domhoff, 2018: 258–275; Domhoff and Schneider, 2018: 14–19, for literature summaries and critiques of social-rehearsal theories).

However, the issue of adaptation may be approachable from a new angle if the default network has adaptive value due to the cognitive capacity it provides to rethink the past, plan imaginatively for the future, and think creatively, when working in conjunction with specific regions in the frontoparietal control network (e.g. Suddendorf and Dong, 2013). Any seeming effects of dreaming on post-awakening insight and creativity (e.g. Fiss, Ellman, and Klein, 1969; Stickgold et al., 1999) may be the result of the early-morning activation of the default network and the drifting waking thoughts that it supports. Viewed in this way, dreaming may be best understood as an accidental by-product of the selection pressures that led to a highly imaginative waking human brain. Dreaming is most likely the result of the coincidental intersection of periodic activation during sleep, which goes back to the earliest mammals, with augmented portions of the human default network after age 5.

Even though it is unlikely that dreaming has any adaptive function, the fact remains that dreams have been put to use by people in many different cultures. Dreams are occasionally so dramatic, overwhelming, and realistic, at least for some individuals, that they have often become crucial aspects of religious and healing ceremonies in many different societies. They thereby have an emergent cultural function that stands as another testimony to imaginative human inventiveness. If that is the case, the psychological meaning that can be found in many dream reports, and the cultural uses of dreams, have to be distinguished from each other and from the issue of adaptive function in order to develop an adequate understanding of dreaming and dream content.

At this juncture, the task confronting dream researchers is to grasp that dreaming is the form that the process of imagining takes under certain very specific conditions.

This realization would lead to the incorporation of dreaming into neurocognitive psychology, with a focus on self-generated and inner-directed thought, not on the rare stimulus-induced incorporations that command the attention of many dream researchers. The neural network that supports dreaming could then be studied in more detail through varying combinations of neuroimaging, electrical brain stimulation, and focal brain lesions. The development of dreaming in children and preadolescents between the ages of 7 and 13 could be studied longitudinally and cross-sectionally through studies that include both the development of the default network and the frequency, complexity, and content of dream reports. Perhaps such studies could be carried out in home settings using functional near-infrared spectroscopy (fNIRS), which is portable and tolerates motion well. In addition, the full range of dream content could be plumbed using the 25,000+ dream reports available to researchers through [dreambank.net](http://dreambank.net), including as yet unstudied dream series. Finally, the recall and content of dreams from middle childhood to old age could be studied anew with original data using simultaneous voice-recording and voice-to-text apps on smartphones, with both types of reports immediately relayed to a database center for proofreading and storage. Such studies could start with thousands of pre-selected participants, who would quickly access their smartphones upon awakening each morning to report their dream recall with an immediacy and accuracy never attained before outside a lab setting (Domhoff, 2018, Chapter 9).

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