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Dreaming: Physiological Sources, Biological Functions, Psychological Implications

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Dreaming is an enigmatic phenomenon. Although research over the previous fifty years has increased our knowledge of dreaming significantly, fundamental questions lack definitive answers. This paper reviews contemporary literature to explore the physiological sources, biological functions, and psychological implications of dreaming. During rapid eye movement sleep, the brain generates stimuli. It then processes the internally generated information, organizes it, and interprets it. The result is a form of mentation called a dream. Divergent opinions exist about why we dream. It is either an epiphenomenal byproduct or an evolutionary adaptation, the purpose of which is not entirely known. Psychologically, dreaming is a cognitive phenomenon. A dream, no less than waking mentation, articulates how an individual organizes experience and expresses central psychological features. Clinically, working with dreams in psychotherapy can provide an additional opportunity for psychological development.

Keywords: dreaming, dream, psychology, interpretation

Scientists know more about DNA, atomic fission, and Loch Ness than a basic human activity: dreaming. It is not that they are uninterested. In the last fifty years, research into the nature of dreaming has increased our knowledge dramatically. Dreaming occurs four or five times every night at roughly 90 minute intervals. Dreams last for ten to 40 minutes with the last episode of dreaming being the longest; and the brain is very active while it dreams — as active as when we are awake — but in a chemically different way (Barušs, 2003; Moorcroft, 2003). Yet fundamental questions remain.

In the first section of this paper, I examine the physiology of dreaming. Brain imaging techniques, animal microstimulation experiments, and stroke victim lesion studies provide scientists an increasingly clear window through which to view the workings of the dreaming brain. Using this data, I present a physiological

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model of dreaming and describe what may happen in the brain while it dreams. In the second section, I explore possible biological explanations for why humans experience dreams during sleep. There are essentially two schools of thought: dreaming is either an epiphenomenal byproduct of a chemically-activated brain, or it is an evolutionary adaptation, the purpose of which is not entirely known. In the third section, a psychology of dreaming is presented as well as a method for analyzing dreams. While the *how* and *why* of dreaming may be explored using physiological and biological methods, dreaming is also a subjective experience involving a form of mentation that can offer representations of an individual's internal world. Thus, any study of dreaming also lends itself to psychological scrutiny and clinical application.

The paper provides a concise yet comprehensive review of contemporary literature on the nature of dreaming. Typical research into the phenomenon focuses narrowly on particular aspects. This paper integrates findings from diverse disciplines, including neurophysiology, evolutionary biology, cognitive psychology, and clinical psychology, and develops explanations that are logically related to available data. It may be of particular interest to clinical psychologists. Dreams were once considered the "royal road" in psychotherapy. In current practice, however, dreams are utilized only occasionally and most psychotherapists do not feel competent working with clients' dreams (Cartwright, 1993; Crook and Hill, 2003; Fox, 2002; Keller et al., 1995; Schredl, Bohusch, Kahl, Mader, and Somesan, 2000). This paper identifies dreams as meaningful cognitions, and argues that dream work is a valid and valuable therapeutic activity. The paper also presents an accessible method for working with dreams in psychotherapy and includes clinical examples.

Physiological Sources

In 1951, a University of Chicago physiology graduate student named Eugene Aserinsky attached electrodes to the head and eyes of his eight-year-old son, Armond, and watched him fall asleep. About 90 minutes later, Aserinsky's primitive electro-oculagraph and electroencephalograph machines sprang to life, recording his son's eye movements and brain activity. The data suggested Armond was awake, yet he was sound asleep. Eugene Aserinsky had just "discovered" rapid eye movement (REM) sleep (Brown, 2003).

While the most observable signs of REM sleep (e.g., eye twitches) were probably first noticed by a Late Pleistocene-era *homo sapien*, and certainly described by ancient Greek philosophers and Hindu poets (Stevens, 1995), Aserinsky's experiment provided neurophysiologic indicators of a particular state of sleep during which the brain seemed to be doing something. Subsequent experiments in the 1950s and 1960s demonstrated that the movements made by the eyes during REM sleep were associated with some kind of intense mental activity. Studies showed that when subjects were awakened during and after REM sleep, dreams were reported 74% to 95% of the time (Aserinsky and Kleitman, 1953; Hobson, Pace–Schott, and Stickgold, 2000). A review of 35 studies of mentation produced during sleep found a mean REM dream recall rate of 82% (Nielsen, 2000).

The discovery of REM sleep and its strong relationship with dreaming initially led to the belief that dreaming occurred *only* during REM sleep. Experiments which demonstrated mentation could occur during non-rapid eye movement (NREM) sleep challenged this hypothesis (Foulkes, 1962). Even if dreams are not the exclusive property of REM sleep, there exist qualitative differences between reports of dreams produced during REM versus NREM sleep and physiological differences between the two sleep states. These differences are significant enough that REM sleep may be considered the physiological concomitant of dreaming.

REM dream reports are so qualitatively different from NREM reports that judges can easily distinguish between them (Foulkes and Schmidt, 1983; Reinsel, Antrobus, and Wollman, 1992). Antrobus (1983) found that when judges evaluated 154 REM and NREM reports, they correctly identified the sleep state in which the dream was produced 93% of the time. First, subjective reports from dreams that occur during REM sleep are more dreamlike, bizarre, and vivid than those produced during NREM sleep (Antrobus, 1983; Revonsuo and Salmivalli, 1995; Williams, Merritt, Rittenhouse, and Hobson, 1992). In Nielsen's (2000) review of 35 dream studies, 43% of NREM reports qualified as dreams, although vivid dreams occurred only 7% of the time. Next, REM dream reports are significantly longer than NREM reports, with a median length of 148 words for REM dreams compared to 21 words for NREM dreams (Stickgold, Pace–Schott, and Hobson, 1994). NREM reports are longest when they occur within 15 minutes of a REM sleep episode (Antrobus, 1983; Gordon, Frooman, and Lavie, 1982; Stickgold et al., 1994). Stickgold et al. (1994) concluded that NREM dream reports "reflect transitional periods when some aspects of REM physiology continue to exert an influence" (p. 25). That is, REM sleep processes "covertly" contribute to NREM dreaming (Nielsen, 2000).

REM sleep is physiologically different from NREM sleep. REM sleep is characterized by a low-voltage, desynchronized pattern of cerebral electrical activity, the distinctive movements of the eyes, and sporadic and spastic activity in certain groups of muscles together with an absence of tone in the large muscles of the legs, back, and neck. Also, the pulse and respiration are irregular; both male and female genitalia may become tumescent; and blood pressure, brain temperature, and cerebral metabolic rate are all raised (Moorcroft, 2003). In contrast, the body and brain behave much differently during NREM sleep. In NREM sleep, also known as "quiet" or "slow-wave" sleep, a person's breathing and heart rate are regular. Also, while neurons in the brainstem are quite active during REM sleep, they slow down or stop firing completely during NREM sleep (Siegel, 2003). Positron emission tomography (PET) studies demonstrated significant decreases in regional cerebral blood flow throughout the cortex during NREM sleep (Braun et al., 1997).

What causes a person to fall asleep, enter NREM sleep, then REM sleep, is not yet fully understood. What is clear is that the chemistry of the brain changes. By 1960, it was known that the noradrenaline and serotonin output of brainstem cells in animals changed when the animals went to sleep, and again when they entered REM sleep. Currently, it is known that noradrenaline and serotonin outputs fall by half during NREM sleep, and then shut off completely during REM sleep (Hobson, 2002).

As the brain's noradrenaline and serotonin levels fall, acetylcholine becomes the predominant neurotransmitter. During the waking state and NREM sleep, acetylcholine appears modulated and partly inhibited by noradrenaline and serotonin. Since cortical activation is maintained during REM sleep in the absence of noradrenergic and serotonergic activity, the cholinergic system appears capable of influencing the cortex. Research suggests that it may be the combined actions of acetylcholine and glutamate that contribute to cortical activation and operation during REM sleep (Perry, Walker, Grace, and Perry, 1999).

According to Perry et al. (1999), "one of the most important neurophysiologic events that trigger REM sleep or dreaming is the firing of cholinergic neurons in the pontine brainstem" (p. 276). Chemical microstimulation experiments in cats confirmed the relationship between acetylcholine, the pontine brainstem, and REM sleep: when a cholinergic drug was injected into a feline's pons, REM sleep began. If the drug was placed in the reticular formation, an area of the pontine brainstem, then the cats entered REM sleep sooner and stayed in it longer than injections into other areas of the pons (Hobson, 2002). Thus, cholinergic agents injected into the pontine brainstem seemed to produce all the activities of REM sleep, providing a possible pharmacological model of REM sleep (Steriade and Biesold, 1991; Steriade and McCarley, 1990).

The only monoaminergic neurotransmitter which continues to function during REM sleep is dopamine (Gottesman, 2007). Solms (2000) argued that a dopaminergic mechanism — distinct from the cholinergic one — is capable of producing the same quality of dreams in REM and NREM sleep. Dreaming can be artificially induced by dopaminergic agents and damage to the dopamine circuits in the ventral tegmental area of the forebrain stops dreaming completely. Solms concluded that while REM sleep may be initiated by a cholinergic-activated brainstem, dreaming may be influenced by dopaminergic-activated forebrain.

Advances in the field of brain imaging using PET technology make it possible to document localized cerebral activation patterns during REM sleep. PET studies identify the activation during dreaming of many cortical and subcortical regions. The basal ganglia, basal forebrain, and the midline anterior cerebellum and vermis are all activated. Significant activity was also evident in all regions of the brainstem, particularly in the pontine tegmentum. Dreaming is also characterized by activation of paralimbic and limbic areas, including the hippocampal formations, parahippocampal gyri, and anterior cingulate cortices (Braun et al., 1997). Prominent arousal was also found in the amygdala (Maquet et al., 1996). And despite the general deactivation of much of the parietal lobe, Maquet et al. reported activation of the right inferior parietal lobe.

Also of interest from the PET studies was information about what areas were not activated during REM sleep. Most noticeable was a vast area of the dorsolateral prefrontal cortex (Braun et al., 1997; Maquet et al., 1996). This indicates that a considerable portion of the executive cortex, active during waking, is far less active during REM sleep (Hobson et al., 2000).

A Physiological Model of Dreaming

A dream is an affect-laden, multi-dimensional, visual-motor, cognitive experience; it is full of images and emotion as the dreamer moves through three-dimensional dream “space.” How might the brain create such a phenomenon? I draw upon Hobson’s (2002) “activation–synthesis” model to integrate and conceptualize the abundant information about cerebral activation. Using this model, I describe how a dream may originate, and how such things as dream motion, emotion, and a sense of dream “space” may be created by the brain while we sleep.

Certain assumptions must necessarily be made when attempting to model any complex system. This model implies a certain progression in the development of a dream, although the flow of information between regions is probably “multidirectional with abundant feedback and feedforward loops” (Hobson et al., 2000, p. 827). Also, it is assumed that activated regions of the brain operate much as they might during waking (Antrobus and Conroy, 1999; Llinas and Pare, 1991).

Physiological data suggest that the process of dreaming may originate in the brainstem. The previously mentioned chemical change in the brainstem that may contribute to the onset of REM sleep may also act as a stimulus to dreaming. Specifically, the shift in brain chemistry from aminergic and serotonergic dominance in waking to cholinergic dominance in REM sleep appears to stimulate the pons. Braun et al. (1997) showed that when the brain enters REM sleep, the pontine tegmentum (the core area of which is occupied by the reticular formation) becomes the most active area of the brain, functioning at a level higher than it does during either NREM sleep or waking. This activity in the pons seems to start a chain reaction that the rest of the brain follows.

The now-stimulated brainstem behaves as it would during waking: it attempts to exert its effects upon the forebrain. There appear to be two major routes, or ascending arousal systems: a dorsal branch projecting into the thalamus and a ventral branch which goes to the basal forebrain and the hypothalamus (Hobson et al., 2000). Braun et al. (1997) found increased activity during REM sleep in both dorsal and ventral ascending routes, although activity in the brainstem and forebrain area was considerably elevated above waking levels while activity in the thalamus was not. This increased ventral activity is consistent with the cholinergic instigation hypothesis since the basal forebrain has widespread cholinergic projections to the neocortex and paralimbic regions of the brain. Indeed, Braun et al. argued that this "preferential activation" (p. 1185) of the ventral pathway was a distinctive feature of REM sleep, and hence, dreaming.

Since our eyes are closed while we sleep, no external visual information is transmitted to the primary visual cortex. Further, the striate cortex — the projection region for the retina in waking — is inactive. Although PET data now confirm this fact, in one study from the 1960s, the eyes of sleepers were taped open when they entered REM sleep and objects were placed before them. The sleepers were awakened several seconds later and no evidence of object recognition was found (Rechtschaffen and Foulkes, 1965). Therefore, the images that we "see" in our dreams likely originate in the brain and are based on something previously experienced (Antrobus and Conroy, 1999). PET data show that the extrastriate ventral occipital area, which creates complex structures of visual perceptions while we are awake, is active during REM sleep (Hobson et al., 2000). This appears to be the region in which basic visual dream images are created. The thalamus may also contribute to the perceptual features of dreaming by transmitting ponto-geniculo-occipital (PGO) waves to the visual cortex (Hobson et al., 2000). The activated extrastriate system in REM sleep is also associated with activation of the limbic-related projection area and parahippocampal cortices, areas that support emotional and memory processes. Thus, the dream image is constructed from memory and laden with affect (Antrobus and Conroy, 1999).

In waking, emotions are generated by the limbic and paralimbic systems: an interconnected group of cortical and subcortical structures. These are consistently found to be active in REM sleep. Braun et al.'s (1997) PET data showed "profound activation of both the paralimbic belt and limbic core" (p. 1188). In particular, the amygdala likely plays a pivotal role in the modulation of dream emotion (Maquet et al., 1996). The brainstem and forebrain may also be involved in dreams that feature primitive feelings of rage, terror, or sexual arousal. (Hobson and McCarley, 1977). Thus, most researchers believe these regions contribute to the often reported emotional quality of dreams (Domhoff, 2001; Merritt, Stickgold, Pace–Schott, Williams, and Hobson, 1994).

The basal ganglia, thalamus, and cerebellum likely play the most prominent roles in portraying dream movement. Release of acetylcholine in the basal ganglia has shown to decrease significantly during NREM and then increase to levels higher than wakefulness during REM sleep (Braun et al., 1997). The basal ganglia are a collection of neurons belonging to the forebrain; it is believed the basal ganglia are involved in complex patterns of motor activity. While a variety of names are applied to different combinations of components of the basal ganglia, usually the caudate nucleus, putamen, and globus pallidus are included. During waking, the basal ganglia are constantly informed about most aspects of cortical functioning. The putamen is probably centrally involved in most motor functions. The caudate nucleus transmits information via the globus pallidus mostly to pre-frontal areas. Next, the thalamus sits atop the brainstem and is situated between it and the cerebral cortex. In waking, the thalamus plays an important role in the sensorimotor relay system: instinctual motor commands generated by the brainstem are transmitted via the thalamus to the cortex. Finally, the cerebellum may refine dream movements with specific features.

Much of the parietal lobe is deactivated while we sleep. PET data show, however, that the right inferior parietal lobe is active (Maquet et al., 1996). This brain region is important for spatial organization and integration, and may generate the three dimensional feeling of dream "space" necessary for the total experience of dreaming. This region's importance to dreaming should not be underestimated. In Solms's (2000) lesion study, damage to the area appeared to result in the cessation of dreaming.

Waking consciousness does not exist in any particular region of the brain. During REM sleep, the influence of acetylcholine, the stimulation of the brainstem and forebrain, and the close relationship between the thalamus and the cerebral cortex may contribute to the sense of verisimilitude that exists in dreaming (Pare and Llinas, 1995). Furthermore, increased gamma wave frequencies during REM sleep indicate inter-hemispheric binding, which may be necessary to join together the internally-generated stimuli in a manner that is experienced as dream consciousness (McNamara, Nunn, Barton, Harris, and Capellini, 2007).

The activation of many cortical and sub-cortical regions during REM sleep contrasts sharply with the prominent deactivation of the "executive" portions of the frontal cortex, particularly the dorsolateral prefrontal cortex. In waking, this area is involved in reasoning, self-reflection, directed thought, and working memory tasks. Dreams are frequently described upon waking as illogical (e.g., "I was flying"), and disorienting (e.g., "The location suddenly shifted to my childhood home"). During a dream, however, the content is typically experienced without such critical evaluation. The deactivation of prefrontal cortex areas may contribute to the uncritical acceptance of dream content as reality while we are dreaming (Hobson et al., 2000).

Biological Functions

In this section, I present multiple hypotheses concerning the function of dreaming. Possible explanations cluster around two views. One view is that dreaming serves no purpose. A dream is merely the byproduct of neurochemical transitions that occur while we sleep. The other view is that dreaming is a product of our evolution. Functions of dreaming may be deduced by understanding the environmental context within which our species evolved.

Epiphenomenon

It is possible that dreaming "was not selected for (or against) during our evolutionary history but was dragged along because the feature to which it was coupled [REM sleep] was actively selected for" (Revonsuo, 2000, p. 879). Thus, dreaming may serve no particular biological purpose. This is not a new opinion; most of Sigmund Freud's contemporaries believed dreams were "foam." Proponents of this view believe dreams are simply the incidental results of the brain's thermoregulatory chemical transitions. The cortex creates a random story from the random messages it receives from the brainstem. Thus, a dream is the best fit the cortex can provide (Moorcroft, 2003). Dreams are "noise in the machine." Because dreams have no function, the content is meaningless.

That people can remember dreams is balanced, if not outweighed, by the fact that it appears as if humans were physiologically programmed to forget their dreams. In one study, only 14% of people reported dreaming every night and 6% reported never remembering their dreams (Strauch and Meier, 1996). Poor or no dream recall by many people is a function of the abolition of memory during brain-activated phases of sleep. Neurochemical systems that are responsible for recent memory are completely turned off when the brain is activated during sleep, making recall difficult (Hobson, 2002). If dreams had a purpose, would it not be more functional and adaptive to remember rather than forget them?

Evolutionary Adaptation

Humanity's evolutionary history has taken place mostly in a Hobbesian world in which life was nasty, brutish, and short. Anthropologists speculate that a Paleolithic hominid's life expectancy would have been no more than 30 years (Fortey, 1997). Daily threats to an early human's survival included predatory animals, disease, weather, and poisonous plants. Thus, sickness, injury, and death were common and would have generated intense natural selection pressures. If dreaming serves a biological function, then it must have enhanced our species' evolutionary fitness in some way. Specifically, dreaming must have provided our ancestors with a method for surviving better in an often hostile environment. This would have increased an individual hominid's odds for surviving and more importantly, reproducing. Reproduction would have allowed the mechanisms that produced dreaming to persevere (Revonsuo, 2000). Possible evolutionary adaptations of dreaming include threat simulation, memory consolidation, memory dumping, trauma processing, and costly signaling.

Threat simulation. A biological function of dreaming may be to simulate events that might have threatened the reproductive success of our ancestors, in order to improve the probability that corresponding real events would be negotiated successfully (Revonsuo, 2000). Dreams allow us to "rehearse threat-avoidance skills in the simulated environment of dreams so as to lead to improved performance in real threat-avoidance situations in exactly the same way as mental training and implicit learning have shown to lead to improved performance on a wide variety of tasks" (Revonsuo, 2000, p. 891). It is not necessary to completely remember the dream, for the purpose of the simulations is to rehearse skills, and such rehearsal results in faster and improved skills rather than a set of explicitly accessible memories. Furthermore, due to the conditions under which dreaming evolved, it is doubtful that any biological function of dreaming could be based on remembering or reflecting upon dreams. Because most humans now live in relative safety from environmental dangers, the threat-simulating function of dreaming rarely gets activated fully. Instead, the contents of modern dreams are usually prompted by recent events that are associated to related "traumatic" emotions drawn from long-term memories (Revonsuo, 2000).

Memory consolidation. An association between dreaming and remembering is apparent in experiments on both animal and human subjects: REM sleep deprivation impairs the capacity to remember tasks from one day to the next (Stevens, 1995). Winson (1990) believed that dreaming may be a memory-processing mechanism in which information important for survival is processed during REM sleep. The clue, according to Winson (1985), lies in hippocampal theta rhythms. The brain's electrical activity can be classified into frequency bands. Waves of frequency greater than 13 cycles per second (cps) are called beta waves, those 8 to 13 cps are called alpha waves, those 4 to 7 cps are theta waves, and those less than 4 cps are called delta waves (Barušs, 2003). Experiments in most mammals have detected theta rhythms in the hippocampus on two occasions: whenever the animals performed survival-important behavior, and during REM sleep. The hippocampus is an old structure, phylogentically, and has a number of important functions, one of which is to fix experiences in memory, thus enabling an organism to learn and store new and valuable information.

Since theta rhythms are involved in both dreaming and in the performance of important survival behaviors, Winson (1990) concluded that "theta rhythm reflected a neural process whereby information essential to the survival of the species — gathered during the day — was reprocessed into memory during REM sleep" (p. 44). Early mammals had to perform all their "reasoning" on the spot. In particular they had to integrate new information (sensory data) with old information (memories) immediately to work out their strategies. Winson (1985) speculated that at some point in human evolution, the brain invented a way to postpone processing sensory information by taking advantage of the hippocampus: REM sleep. Theta rhythm is the pace at which that processing happens. Instead of taking input from the sensory system, the brain takes input from memory. But the kind of processing during REM sleep is the same as during the waking state, so this REM sleep processing is merging new information with old memories. From an evolutionary point of view, REM sleep helps the brain "remember" important facts without having to add cortical tissues. A dream lets us "see" some of the processing.

Memory dumping. Crick and Mitchison (1983), based upon research on mammalian brains, hypothesized that "reverse learning" or "unlearning" took place during REM sleep when unwanted and/or useless information acquired during the awake state was removed. They argued that while we dream during REM sleep, the brain eliminates potentially unnecessary or damaging patterns of brain functioning. The brain's network of interconnected cells is so dense, so complex, and so sensitive that "unwanted or 'parasitic' modes of behavior" (p. 111) can easily take hold when the brain is disturbed either by natural growth or by external experience. To perform as well as it does, the brain must have some way of ridding itself of unwanted, unnecessary, or harmful information. Using this hypothesis, the process of dreaming makes memory space available for newer information to be encoded (Gulyani, Majumdar, and Mallick, 2000). Thus, for proponents of the memory dump hypothesis, trying to remember dreams is not encouraged since this just maintains information the brain was trying to purge.

Emotion processing. According to Hartmann (2007), dreams diffuse emotions and serve a kind of "quasi-therapeutic" function. A recent emotional experience during waking, typically one capable of disrupting an individual's emotional equilibrium (e.g., a traumatic event), is diluted through a dream. Dreaming connects the new emotional material to older memories; by weaving in a current emotional experience with older ones, the intensity of affect is spread out.

Hartmann (2007) collected numerous dream reports, over a period of months, from people who experienced traumas. This allowed him to track and assess any qualitative changes in content. Over time, the dreams followed a pattern. Initially, the trauma typically manifested as a natural disaster (e.g., tidal wave, tornado, or avalanche). According to Hartmann, such a dream produced intense feelings of helplessness, terror, and vulnerability, which facilitated verbal expression of the trauma upon waking. Within days to weeks, the dreamer's mind began to connect the traumatic experience with older memories. Connecting the trauma with older material from the dreamer's life gradually diluted its intensity and the event occupied a diminishing role in the individual's waking life and dreams. Dreams processed the intense emotions and contributed to integrating the trauma into the dreamer's waking life.

Costly signaling. Neurochemical changes, brain activation, increased cardiac and respiratory rates, and muscle twitches are metabolically "costly." McNamara, Harris, and Kookoolis (2007), using evolutionary theory, argued that these features of REM sleep and dreaming are likely to have been selected and serve a purpose that justifies the expense. In nature, certain characteristics or behaviors evolve because they signal health and strength to members of the species. The costlier the trait, "the more honest is the advertisement of 'having good genes' " (Valli and Revonsuo, 2007, p. 103). A signal that is metabolically costly serves as a "certification of honesty" (McNamara, Harris, and Kookoolis, 2007, p. 117).

Dreams, which are often emotionally charged, can influence an individual upon waking. In particular, they produce memories and feelings that are then used by the individual in social interactions. When these thoughts and feelings are conveyed either subtly or overtly to another person, they are considered "honest" and "hard to fake" signals. According to McNamara, Harris, and Kookoolis (2007), "the audience who hears the dream knows that regardless of content, the dream will convey important emotional and social information about the mind of the dreamer" (p. 118). Dreams, therefore, are a form of communication and important for our species' social behavior.

Psychological Implications

While a dream likely has physiological sources, and may have biological functions, it is also a form of mentation and an experience through which an individual has lived. Hunt (1989) wondered if it is even possible to study the activity of dreaming without recognizing it as "a lived story with rich imaginistic properties and powerfully felt meanings" (p. 18). Mancia (1999) argued that dreaming "transcends the brain and occupies an epistemological level very different from that of brain functions" (p. 1211). Thus, dreaming may be studied as an empirical, meaningful, cognitive phenomenon (Kramer, 2007; McNamara, Nunn, Barton, Harris, and Cappellini, 2007). Dreams also have clinical applications. The images in a dream are drawn from an individual's personal history and express core features of his psychology. By clarifying dream images and connecting them to the dreamer's waking life, a meaning for the dream can emerge. Such explication of a dream can lead to understanding personality dynamics and promote behavioral change.

When the brain is activated during REM sleep, it operates as it does when awake. That is, the brain processes information, organizes it, and interprets it (Fosshage, 2000; Hartmann, 2007). Since external sensations are limited during sleep, the brain focuses on internally generated stimuli. Dreams represent this process, using the cognitive abilities that are accessible to the brain in its REM state (Beck, 1969; Llinas and Pare, 1991). The result is a dream; a form of mentation that uses schemas, expresses emotions, and incorporates procedural, semantic, declarative, and episodic memories (Bucci, 1997; Domhoff, 2003).

A dream's most striking features are verisimilitude and narrative cohesion. Both the poet and the scientist capture these qualities. Edgar Allen Poe asked "Is all that we see or seem but a dream within a dream?" David Foulkes (1985) wrote "dreams are credible multimodal world analogs that are experienced as life. The simulation of what life is likely to be like is so nearly perfect, the real question may be, why shouldn't we believe this is real" (p. 37)? Because dreams feel real and usually tell a story, we often impart meaning to them and seek to understand the imagery they contain.

The first known recording of a dream was found on a Babylonian clay tablet dating to 3,000 BCE (Hoffman, 2004). Stevens (1995) asserted that "every society known to anthropology has had theories about dreams and techniques for interpreting them" (p. 9). In the twentieth century, the most prominent Western approach to dream interpretation was Freud's psychoanalytic theory. According to Freud (1900), a dream was a type of unconscious thought in which the images that appeared (manifest content) represented the disguised expression of a repressed wish (latent content). Freud believed that when something occurred during the day that stimulated a libidinal or aggressive wish, it was typically repressed because awareness of the wish was too disturbing for the conscious mind. Since the wish still pushed for gratification even when repressed, it was incorporated safely into a dream in a disguised form through the defensive processes of condensation and displacement.

Freud's scientific peers paid little attention to the phenomenon of dreaming and the lay public often considered dreams to be supernatural messages. Thus, Freud's theory of dream formation, rooted firmly in the science of his day and the psychology of the dreamer, represented a significant departure that has "proved essential for our modern view of dreams and dreaming (Trosman, 1995, p. 163). Freud's insights into the psychology of dreaming also had an innovative clinical implication. By thinking freely about the manifest images in a dream and following the chain of associated thoughts, memories, and feelings, Freud believed the manifest content could eventually be connected to the latent content. Thus, dream analysis could play an important role in a process of working through conflicted emotional experiences that influenced an individual through neurotic symptoms (Da Rocha Barros, 2002; Freud, 1900).

While Freud's dream theory and clinical method were revolutionary, and elements of both endure, contemporary research has led to the revision of many core psychoanalytic tenets concerning dreams. It does not appear that dreams are deliberately disguised repressed thoughts; nor do they always represent instinctual wishes (Barrett, 2007; Bucci, 1997; Cartwright, 2006; Fosshage, 2000; Trosman, 1995). Rather, dreams are the result of the brain's cognitive processing of internally generated stimuli during REM sleep cycles. In particular, a dream's organization and content are likely due to nonverbal, figurative processing mechanisms and the loss of logic resulting from the deactivation of the dorsolateral prefrontal cortex (Bucci, 1997).

The images that end up in a dream effectively and efficiently represent the self, other people, events, and relationships, as well as ideas and feelings (Cartwright, 2006; Fosshage, 2000). While image selection likely assumes a probabilistic nature, the process is based both on the activation of memories and the use of figurative thinking. First, hippocampal and amygdalar activity during

REM sleep suggests a recent waking event likely stimulates memories because the thoughts and feelings evoked in the present are similar to those associated in memory. Since memories are linked by a shared potential to evoke similar experiences (Rovee–Collier and Cuevas, 2009), the content of a dream can draw upon numerous procedural, semantic, declarative, and episodic memories (Bucci, 1997; Da Rocha Barros, 2002).

Next, given the deactivation of the prefrontal cortex and the lack of verbal mediation, the mind visually represents content using its nonverbal, figurative thought processes, such as metaphor (association by similarity) and metonymy (association by contiguity). While metaphors and metonymies are typically considered literary devices, they are fundamental to how the mind organizes and interprets information. Through a metaphor, items that are similar in form or function can be associated. One concept or image can replace another or multiple concepts or images can be condensed into one. Through a metonymy, items that are linked temporally or connected physically can be associated. People, events, and/or objects that have been experienced closely in time can stand for the other; also, a whole can stand for a part or a part for the whole.

Metaphors and metonymies allow for textured and flexible thoughts. They "connect ostensibly separate aspects of human experience, linking body and mind, emotion and memory, past and present, unconscious and conscious" (Bornstein and Becker–Matero, 2011, p. 172). Through metaphor and metonymy, complex feelings, experiences, and concepts can be represented powerfully and efficiently by a single visual image (Domhoff, 2003; Lakoff and Johnson, 2003).

A dream, no less than waking mentation, articulates how an individual organizes experience and expresses central features of his psychology (Domhoff, 2003, Fosshage, 2000). A dream offers representations of a client's internal world, in particular, schemas of self, others, events, and relationships. Clinically, since dreams flow from emotional history, they can also lead to issues that play a central role in a client's psychological difficulties (Da Rocha Barros, 2002). Working with dreams in psychotherapy can provide an opportunity for psychological development (Cartwright, 1993; Hill, 2004).

A Cognitive–Experiential Model of Dream Analysis

When dreaming is viewed as a psychologically meaningful cognitive phenomenon, the task is to clarify, through the dreamer's associations and elaborations, the organization and meaning of the dream's images. Explication of the images leads to an understanding of the underlying schemas and the possibility of promoting change. Furthermore, the experience of talking about a dream also has therapeutic properties.

Hill (2004) developed an approach to using dreams in psychotherapy that clients found helpful and fits well with the data presented in this paper. Hill assumes that: a dream is a form of cognition; dreams involve affective, behavioral, and cognitive components; a dream's meaning is personal; dreams are a useful tool for promoting insight and change; and working with dreams is a collaborative process. Theoretically, the model is rooted in both psychodynamic and cognitive psychology. It incorporates Freudian and Jungian principles and techniques when they are consistent with contemporary knowledge concerning how the mind works during its waking and REM sleep states. For example, from Freudian psychoanalytic theory comes the idea that dream images are shaped by condensation and displacement (although not for defensive purposes). Condensation works by the metaphorical cognitive mode and displacement works by the metonymic one. From Jungian analytical psychology come the dream analysis techniques of active imagination, associating close to the image, and having a component that uses the dream to facilitate change in the client's daily life. Also, psychoanalytic object relations and Jungian archetypes are expressed as schematic representations of a client's internal world.

In Hill's (2004) approach, there are three stages to analyzing a dream: exploration, insight, and action. These stages mirror the typical sequence of psychotherapy itself. That is, most clients begin therapy by exploring those issues that initially brought them to treatment. Gradually, the therapist helps a client make sense of underlying personality dynamics that generate symptoms and conflicts. Finally, therapist and client collaborate on how to do things differently and make changes in the client's life. By mirroring the broader psychotherapeutic sequence, the task of analyzing a dream fits easily within the broader process. Furthermore, clients can apply what they learn from how to work with dreams to other aspects of the therapy and their life.

Exploration stage. When a client shares a dream, it is likely that neither the client nor the therapist knows immediately what it means. Even if a therapist has some interpretive ideas, she should refrain from sharing them at this point. During this stage, description precedes judgment, interpretation, and explanation. Therapist and client identify five to 10 prominent images and explore them as they appear sequentially in the dream. A selected image can be a person, object, behavior, thought, or feeling.

To facilitate the exploratory process, the therapist uses open-ended questions to help the client describe each image. (The client describes an image as it appears in the dream, rather than how it may exist in the individual's waking life.) Detailed image description immerses the client in the dream so that experiences in the dream "become more immediate, real, and significant for the client" (Hill, 2004, p. 27). The therapist then gathers the client's associations to each image. Associations are one of the principle sources of information about the client's underlying schemas. According to Hill (2004), the therapist helps the client stay close to the image rather than free associating away from the image. Finally, since each image is connected to an issue or concern in the client's waking life, the therapist helps the client to explore what may have occurred recently to trigger the selection of a particular image.

Insight stage. Therapist and client integrate the descriptions and associations gathered in the exploration stage to formulate an understanding of the dream, which may include several possible interpretations. The goal is to generate interpretations that make sense, fitting the descriptions and associations gathered during the exploration stage with knowledge of the client's present life and past history. In general, the focus is on understanding how the dream reflects aspects of the client's waking life and personality dynamics (i.e., schemas, object relations, attachment patterns, archetypes) rather than any stereotypical or fixed interpretation (e.g., a rocket symbolizing a phallus or a spider representing the pre-oedipal mother). The meaning of each image is determined by the client's associations, and the image's connection to other images in the dream. As with the previous stage, the therapist is not an "expert" who dispenses answers; rather, the therapist asks the client for his initial impressions about what a dream may mean and then collaborates on expanding the understanding of the dream.

Dreams typically range from being fairly literal with little cryptic imagery to being very figurative and full of bizarre images. Most dreams contain rather straightforward content that includes familiar people and locations; the bizarreness ratings are surprisingly low (Domhoff, 2007). Dreams with little embellishment do not require extensive interpretation to understand because the images are relatively transparent. For example, a 25-year-old male client dreams of driving down a highway and being "cut off" by another car. The dreamer feels furious, tries to catch up, but is unable to do so. In the exploration phase, the client describes the make and model of the other car and associates it to his older brother's car. The client then remembers that the previous day he was at a family picnic. The client's brother, who he described as "a natural raconteur," dominated the event with his anecdotes and the client felt frustrated that he was not able to talk (being "cut off"). The client also reported always feeling competitive with his brother and never being able to match his accomplishments (unable to "catch up").

When dream images are more bizarre and/or cryptic, the mind's nonverbal, figurative processes are used to greater effect. Again, this is not done to deliberately disguise anything; it is just how the mind works during REM sleep. As mentioned, dreams use metaphors and metonymies to portray ideas, feelings, events, people, and relationships. The focus remains on what the images might represent in the client's waking life and how they may reflect aspects of the client's personality dynamics. For example, a 27-year-old male client dreams of flying toward Tallahassee, Florida in a "Jetson's-like" flying car. He pulls into an amphitheater. As he walks through the amphitheater, something tugs at his legs. He turns around and sees a woman wearing a skull mask trying to pull him down. The client pulls off the mask and the woman is wearing another mask;

he pulls off the second mask to reveal a third mask! Upon removing the third mask, he sees the face of a female childhood acquaintance covered in blood. The dream woke the client up and he felt confused by the images and disturbed by the bloody face.

Through exploration, the client generated satisfactory descriptions and associations to Tallahassee, the flying car, the amphitheater, the woman wearing multiple masks, and the childhood acquaintance. Furthermore, the client reported having an argument with his girlfriend the previous day and this was likely the precipitating event for the dream. The primary insights gained from the dream were: frustration with his current girlfriend (as well as a previous relationship); and difficulty expressing certain feelings, particularly anger, toward women.

Knowledge of the client's associations and the dream's meaning allows it to be "reverse engineered." That is, working backward from what the dream conveys, it can be shown why the particular images may have been selected to construct the specific narrative. The central issues for this dream were the client's frustration toward women, particularly his current girlfriend, and his difficulty expressing negative feelings toward them. The mind tries to express these thoughts and feelings using visual metaphors and metonymies drawn from the memories and schemas available to it. Why was the dream set in Tallahassee versus any other location? The client had an ex-girlfriend who lived in Tallahassee and the relationship did not end amicably. In the client's memory, there were associations via temporal contiguity (i.e., a metonymy) between Tallahassee, his ex-girlfriend, and feeling frustrated and angry. The three were so closely linked in time that Tallahassee stood in for both his ex-girlfriend and his feelings toward her. We know the client felt frustrated and angry toward his current girlfriend. Thus, in the client's mind, there was no difference between Tallahassee and his current relationship. Tallahassee effectively and efficiently represented his present circumstances; that is to say, his psychological "location." The selection of the amphitheater was due to an association via similarity (i.e., a metaphor). The dreamer's argument with his girlfriend occurred in a public place and he felt awkward about being "on display." Functionally, the amphitheater and the public place in which the argument occurred were similar in the client's mind. Thus, one replaced the other in the dream. Finally, in waking life, during the argument, the client did not say something he felt would be "mean" and hurt his girlfriend's feelings: the relationship was "bringing him down." In the dream, physically being pulled down by the female figure, the skull mask, and bloody face of a childhood acquaintance captured these sentiments through metaphors. The name of the childhood acquaintance in the dream was the same as his current girlfriend. In childhood, the girl was often subject to teasing by classmates. The skull mask and blood symbolized his girlfriend being hurt. The client feared that if he expressed his frustration and anger toward his girlfriend, then she would be hurt.

Action stage. Understanding a dream can promote psychological development when it leads to the client thinking and behaving differently. The therapist helps the client use what was learned in the insight stage to consider what changes could be made and how to implement them. If the client decides to make a change, the therapist collaborates on generating specific change tactics. In particular, the therapist explores the client's options, evaluates advantages and disadvantages, provides necessary component skills (e.g., assertiveness training), and offers encouragement. The therapist does not push the client to make a change or tell the client what to do; rather, the therapist helps the client to think about how the dream may be used to change habits and attitudes in order to foster different outcomes in his life. How a client reacts to ideas of change also permits a therapist to assess readiness and motivation for change. Some clients welcome the possibility and others are more resistant. Regardless of the client's reaction, it becomes part of the dream work and psychotherapy processes.

One way to facilitate change is to ask the client to modify particular images in the dream, alter its plot, or give it a different ending. Hill (2004) believed this helps the client feel like an active agent capable of directing his life story, rather than like a passive recipient. The therapist then identifies how changes the client made to the dream could translate to the client's waking life. For example, a 41-year-old female client dreams of floating comfortably in a swimming pool when someone tells her she needs to prepare an elaborate dinner for her family. The client does not want to spend hours cooking; she wants to do something simple like order a pizza. The client secretly orders take-out food from a fancy restaurant for her family and a pizza for herself. When she goes to pick up the food, she is nervous throughout and afraid that she will be caught for "going behind their backs." Upon exploration and insight, the client determined that she often ignored her own needs and preferences for the sake of "keeping the peace" in her family.

During the action stage, the client changed the plot of the dream: when she was told to prepare dinner, she responded by saying she was enjoying her time in the pool and when she was finished she would be happy to order a pizza for dinner tonight. If the family wanted something else, they could prepare it themselves. The therapist then translated the change in the dream to the client's waking life by helping her identify a preference (e.g., taking some time for herself), as well as how to express and pursue it without feeling exceedingly guilty.

Conclusions

Dreaming is not a disembodied phenomenon. While what causes a person to dream is not fully understood, what is known is that the chemistry of the brain changes when we enter REM sleep. A neurochemical change in the brain may act as a stimulus for dreaming. Specifically, a shift from aminergic and serotonergic dominance in waking to cholinergic and glutamatergic dominance in REM sleep seems to start a chain reaction in the brainstem that the rest of the brain follows. The activation of many sub-cortical and cortical regions may provide a neurological platform for cognition. The brain can then use those cognitive functions available to it during REM sleep to create mentation based on internally generated stimuli.

Most current hypotheses concerning the function of dreaming are either too dismissive or focus too narrowly on one purpose. First, the dream as "noisy byproduct" explanation is a poor fit for what we know about human evolution and how the brain works. Given the metabolic costs involved in dreaming, as well as its continued existence over the course of our species' evolution, the phenomenon may have facilitated our environmental adaptation. If a dream is just "noise," it is far more likely that it would make no sense at all. Revonsuo (2000) provided the example of migraine auras to demonstrate how actual "noise" in the brain manifests. Next, Barrett (2007) suggested that even if some waking thoughts focus on potential dangers, we do not assume "threat management is the sole function of thought — we tend to assume it's one of many" (p. 138). Thus, dreaming likely has multiple functions that facilitate adaptation, as does waking thought, including solving problems, simulating threats, fulfilling wishes, processing emotions, and serving as forms of communication.

The physiological sources and possible biological functions of dreaming are likely important but insufficient components of a comprehensive understanding of the phenomenon. A dream is also a form of cognition and a subjective experience. During REM sleep, the brain interprets internally generated stimuli using the cognitive abilities that are available in its REM state. The result is a dream; a form of mentation that visually represents the self, other people, events, and relationships, as well as ideas and feelings using nonverbal, figurative thought processes. Thus, a dream, no less than waking mentation, is psychologically meaningful. Because of this, dreaming also has important clinical implications. Since dreams are idiographic products of an individual's memories and schemas, they reveal how an individual organizes experience and identifies core psychological issues. Working with dreams in psychotherapy can provide a valuable contribution to a client's psychological development.

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