ISSN: 2279 - 0594

Journal of Biomedical and Pharmaceutical Research 2 (2) 2013, 50-57

REVIEW ARTICLE

Dream: from Phenomenology to Neurophysiology

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ABSTRACT

Dream is commonly used to express an unattainable ideal or a very deep and strong desire. Neurophysiological correlation of dreaming are still unclear and many questions remain unresolved, i.e. whether the images in dreams emerge randomly from the brain or they are controlled by currently known/unknown parameters and are determined by any rules; whether dreaming has any meaningful function or it just a byproduct of sleep, etc. Psychoanalytical perspective in cognitive neuroscience helps to achieve a comprehensive understanding of dreaming but it is challenging to interpret rationally. Thus, close interaction between neuroscience and psychoanalysis would probably take the dream research to a new height.

KEY WORDS: Dream, brain activity, REM sleep, NREM sleep.

INTRODUCTION:

Dream represents the conscious awareness of complex brain systems involved in the reprocessing of emotions and memories during sleep (1). Revonsuo refers dreaming to the subjective conscious experiences that we have during sleep (2). Some people rarely remember their dreams and erroneously conclude that they do not dream at all, while others experience vivid dreams with rich visual imagery and emotional content (3).

Dreaming was first investigated on an experimental level in the 19th century. Calkins published the first statistical results about dreaming and argued that some aspects of dream content could be quantified (4). According to psychological studies, visual imagery occurs more frequently in dreams than imagery of other senses (audition, olfaction, touch, and taste). Some elements of real-life events previously experienced by the dreamer often contribute to the scene of the dream and most often, the dream sequence is not within the dreamer's voluntary control. The dream report is often full of people interacting with each other (e.g. discussions, fights, pursuit, and sexuality) and finally, the dream report often contains strong emotions (5, 6).

This article is an attempt to reveal the ambiguities of different aspect of dream like the theories proposed so far to explain its mechanism; its relation with different stages of sleep; activity of different parts of brain during dreaming; content, frequency as well as speculated functions of it.

THEORIES OF DREAM:

PSYCHOANALYTICAL THEORY:

This theory, developed by the neurologist Sigmund Freud (3), proposed that a part of our mind is made up of unconscious thoughts, desires, emotions, and knowledge that influence and guide our behaviors. The dream is a highly meaningful product of unconscious mind under the circumstances of sleep. The meaning of dream is not apparent in its manifest content but in the "latent dream thoughts" some of which are unconscious and have to be uncovered by the process of free association. The latent dream thoughts includes conflicted instinctual (i.e., sexual or aggressive) wishes originating in childhood as well as day residues, thought processes typically from the previous day. The latent dream thoughts are transformed into the manifest dream by primary process mechanisms which include condensation (the combining or fusing of two or more elements into a single one), displacement (a shifting of emphasis from one element to a different one) and symbolization. The primary process mechanisms also code the expression of unconscious mind (the work of dream) and distort before they emerge in the conscious mind of the sleeping subject (manifest content of dream). As a consequence, the dreamer is not disturbed by repressed and unacceptable thoughts (latent content of the dream) and can continue sleeping. Hence, Freud debated that dreams have a meaning that can be interpreted and are considered as guardians of sleep.

ACTIVATION-SYNTHESIS HYPOTHESIS:

The activation-synthesis model of dream construction proposed by Hobson and McCarley (7) states that the phasic signals arising in the pontine brainstem during REM sleep and impinging upon the cortex and limbic forebrain led directly to the visual and motor hallucinations, emotion, and distinctively bizarre cognition that characterize dream mentation. In the activation portion of model, the authors view the brainstem as

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providing random, direct stimulation of the forebrain initiating a process of image and narrative synthesis involving associative and language regions of the brain and resulting in the construction of the dream scenarios (e.g., oculomotor, vestibular, and motor systems, accounting for the prominence of visual and movement elements in dreams). The response of forebrain to random activities initiated at the brainstem is demonstrated by PGO (pontine, lateral geniculate nucleus and occipital cortex) waves that occur during REM sleep. This explains that the random activity, or noise, emanating from the pons, passes through similar sensory-relay stations as information from the environment, and is interpreted in a way that leads to the phenomenology of dreaming. The bizarre nature of dreams is attributed to certain parts of the brain attempting to piece together a story out of what is essentially random information. The formal qualities of dreams are directly derived in this model from the properties of the brain-stem stimulation. Dreams in this view are not essentially meaningful, though some meaning may result secondarily in the forebrain's efforts to make sense of its physiologically determined stimulation. Thus, this hypothesis rejected the Freud's dream theory.

SOLMS'S THEORY:

Mark Solms (8), supporter of Freud's theory, argued that brain stem activation is necessary, but not sufficient, to explain the particular characteristics of dream consciousness. According to him, particular characteristics of dream consciousness can be explained by the brain activity of different regions during REM sleep like the activation of core forebrain emotion and instinctual drive mechanisms (i.e., the limbic and paralimbic brain areas: the anterior cingulate, insula, hippocampus, parahippocampal gyrus, and temporal pole); activation of posterior perceptual system (fusiform gyrus, superior, inferior and middle temporal gyrus, and angular gyrus) and the deactivation of executive dorsolateral frontal control mechanisms (dorsolateral prefrontal cortex). This concept is broadly consistent with Freud's dream theory which claims that our instinctual drive states (notably appetitive and libidinal drive system) are relatively disinhibited during sleep. Solms proposed that dreaming and REM sleep are controlled by different brain mechanisms. REM sleep is controlled by cholinergic brain stem mechanisms, whereas dreaming is mediated by forebrain mechanisms that are probably dopaminergic. This implies that dreaming can also be activated by a variety of NREM triggers.

HARTMANN'S THEORY:

This theory is based on observations on the dreams of patients following exposure to trauma and emphasizes on adaptive functions of dream. The dream utilizes an auto-associative mode in which connections are made more broadly and loosely than in directed waking thought, providing the dreamer with the opportunity to contextualize the dominant emotion in the form of an explanatory metaphor. According to this theory, purpose of dreaming is to provide the dreamer with an opportunity to deal with their dominant emotional concern which permits them to enhance their capacity for future adaptations to similar emotional conflicts (9).

RELATION BETWEEN SLEEP CYCLE AND DREAMING:

Dement and Kleitman (10) noticed that a subject awakened during REM sleep very often reported a dream. This finding led the researchers to conclude that dreaming occurs during REM sleep. Later studies on dream showed that subjects awakened during NREM sleep can also recall dreams at a high rate (11, 12) and some individuals never recall dreams, even when awakened from REM sleep (13). Therefore, many researchers have rejected the strict association between REM sleep mechanisms and dreams (14-16). Dreams obtained from REM and NREM sleep differ significantly in their quantitative and qualitative aspects and are likely to be produced by different mechanisms (17). REM dreams appear to relate to the mechanisms that are active in the production and maintenance of REM sleep. In contrast, NREM dreams appear to be associated with brief arousal intrusions out of sleep rather than with the sleep process itself. Micro-arousals during sleep occur as often as 4-26 per hour depending on the definition of arousal (18). Participants are often unaware of these arousals even though their EEGs clearly show arousal during sleep (19). Takeuchi *et al.* (17) postulate that people might incorporate some information from external surroundings into their memory during brief arousals, and later amend or reconstruct the mentation as "Dreams".

BRAIN ACTIVITY DURING DREAMING:

The researchers argued that the particular functional organization of the brain during REM sleep could explain the phenomenological characteristics of dream reports. The activity of different parts of brain during REM sleep has been studied using EEG, functional MRI and PET (20, 21). In comparison to wakefulness, brain activity during REM sleep is decreased in some brain regions (e.g., precuneus, posterior cingulate cortex, temporoparietal junction and dorsolateral prefrontal cortex) 22, 23); and increased in other regions (e.g., in the occipital, temporal and superior parietal cortex, medial prefrontal cortex, precentral and postcentral gyri, hippocampus and parahippocampus, amygdala, the anterior cingulate, thalamus and the pons) (2).

The increased occipital cortex activity during REM sleep could explain the visual component of dream reports because neuroimaging results during wakefulness showed that visual imagery with the eyes closed activates the occipital cortex (24). The decreased activity in the temporoparietal junction during REM sleep may explain why dreams are mainly experienced in the ego-centric coordinates (25). The increased activity in the hippocampus during REM sleep could explain why dreams are often composed of known images or characters, as the hippocampus is known to be associated with the encoding and retrieval of lived events during wakefulness (26). The amygdala's activity during REM sleep could explain why emotions, especially fear, anxiety are often mentioned in dream reports; indeed, the amygdala is involved in the processing of emotional stimuli during wakefulness (27) which also suggest the involvement of REM sleep in processing of emotionally significant memories. The increased activity in the motor cortex (precentral gyrus) during REM sleep could explain the movements of characters' body in the dream because, during wakefulness, motor imagery, and the imagination of someone's action from the third-person perspective involve the precentral gyrus (28). The increased activity in the medial prefrontal cortex during REM sleep could explain the attribution of thoughts, beliefs, and emotions to the characters in the dream because during wakefulness, the medial prefrontal cortex is known to participate in mind reading (29). The decreased activity in the lateral prefrontal cortex during REM sleep could explain why dream stories lack consistency, why the dreamer's perception of time is altered, why the dream story is beyond the control of the dreamer and why the dreamer is convinced that the dream story is really happening. Indeed, during wakefulness, the lateral prefrontal cortex is involved in executive function, cognitive control, and working memory (30).

CONTENTS OF DREAM:

Substantial variability of content exists among the same individual's dreams and among the dreams of different individuals. The dreams that tend to be recalled outside the laboratory are those that are more vivid and bizarre and therefore may not be representative. Both external and internal parameters can shape or govern dream content. Few of these parameters are known but many more have to be discovered yet. For example, males report more aggression and violence in their dreams than do females (31). The stimuli given during REM sleep may be incorporated in dreams, rather in a direct or in a transformed way. Dement and Wolpert (32) found that the frequency with which subjects incorporate different kinds of stimuli given during REM sleep varies with the type of stimulus. An example of a direct incorporation was in a dream of being squirted by someone; an indirect incorporation was seen in a dream of a leaky roof. Similarly, sensory stimulus (e.g., the scent of lavender) presented to a sleeping subject without his or her knowledge could induce the incorporation of an event associated with the stimulus (e.g., holidays spent near a lavender field) into a dream, regardless of the delay between the dream and the association of stimulus/events (lavender scent/holidays). This finding led Saint-Denys (33) to conclude that the external world can influence dream content in a direct or indirect way. However, some studies have shown that external stimuli influence mentation only during NREM sleep but not REM sleep (34, 35). Takeuchi *et al.* (17) constructed the Dream Property Scale (DP scale) to characterize the dreams found that sleep onset REMP dreams as brighter, more cheerful, more comfortable, more likable, clearer, more explicit, more memorable and more vivid as well as noisier, more dynamic and more bustling compared with NREMP dreams.

Schredl and Hofmann (36) showed that the content and style of a person's life strongly influence dream content. This may be a reason why some individuals experience recurring themes, characters, or places in their dreams. Greenberg *et al.* (37) found that problems (defined as an expression of negative feeling or any situation evoking such feeling or requiring some change or adaptation) occurred very frequently in the manifestation of dream content and that these problems were nearly systematically related to the problems noted during pre-sleep wakefulness. They also observed that effective dreams (i.e., dreams that presented some solution to the individuals' problems) were followed by a waking state in which the impact of the problems was diminished, whereas ineffective dreams were followed by the persistence of the problems. Therefore, the researchers concluded that personal concerns influence dream content. Many aspects of the subject's daily life influence dream content like news events (38), musical practice (39), religious beliefs (40), chronic pain (41), mood (42), or a violent living environment (43). By contrast, congenital or acquired malformations do not seem to significantly influence dream content (44, 45). Based on these results, two opposing hypotheses were formulated: the continuity hypothesis (36) and the discontinuity hypothesis (46). The continuity hypothesis relies on the results showing that the themes of an individual's thoughts during waking life and dreaming are similar; the discontinuity hypothesis focuses on the fundamentally different structures of thoughts during waking life and dreaming. Voss *et al.* (44) argued that waking and dreaming thoughts were related but structurally independent and she argued in favor of merging the continuity and discontinuity hypothesis. However, how lived events are selected to be incorporated into dream remains unknown. Whether the representations constituting the dream emerge randomly from the brain, or there are certain parameters which bring them to surface are still to be answered.

FREQUENCY OF DREAMING:

The four or five REM periods that people typically have in a night can be taken as a rough estimate of the number of dreams per night. These REM periods, and associated dreaming, occupy around 20% of the night in young adults. REM periods, and hence most dreams, occur in a 90-min cycle, with a period of NREM sleep followed by REM sleep. Individual REM periods may last from a few minutes to over an hour; with REM periods becoming longer the later it is in the night. The time length is closely related to the real-time length of the corresponding REM periods (10). Researchers found that dream recall (vs. no dream recall) was associated with decreased alpha (8-12 Hz) power in the EEG preceding awakening, regardless of the sleep stage (47). Recalling of dream all depends to a great extent on the timing of awakening. Majority of dreams are "forgotten" only in the sense that they have never been committed to memory. Dream report frequency can vary within subjects and varies substantially among subjects. The production, encoding and recall of dreams are influenced by numerous parameters that probably interact with each other. Some of the reported influencing parameters are:

SLEEP PARAMETERS:

Dream report frequency varies according to the sleep stage preceding awakening (10). More dream reports were obtained after an awakening during REM sleep than after an awakening during NREM sleep. These results inspired the REM sleep hypothesis of dreaming. Recall rate of dreaming drops off rapidly if the awakening is delayed until after the REM period has ended. Most dreams are lost to recall by 8 minutes (10), or even within seconds (48), after the end of the REM period. Dream report frequency increases with the number and method of awakenings during sleep (49). More the subjects awaken during sleep, the higher their dream report frequency. These results support the hypothesis of Koulack and Goodenough (50), which proposes that nocturnal awakenings facilitate the encoding of the dream in memory and thus facilitate dream recall upon awakening. Abrupt awakenings lead to more dream reports than gradual awakenings (51).

PHYSIOLOGICAL AND ENVIRONMENTAL PARAMETERS:

Kohler *et al.* (52) found that dream recall is possible from REM sleep awakenings as early as 2 years of age. However, reports of dreams are obtained much less frequently in younger children. Foulkes reported only 15% of REM sleep awakenings in children 3 to 5 years of age yielded dreams. He reported a gradual development through the 7- and 9- year-old age range in recall frequency and must be viewed in the context of child's developing cognitive capacities (53). However, dream report frequency decreases with age in later years of life and tends to be slightly higher among females than males (54). The amount of dream recall can be modulated by dopamine agonists without concomitant modification of the duration and frequency of REM sleep (55). Dream recall can be suppressed by focal brain lesions (8), although these lesions do not have any appreciable effects on REM frequency, duration, or density (56). Schredl also found that dream report frequency also varied depending on the size of the subjects' place of residence (54).

PSYCHOLOGICAL PARAMETERS:

Many psychological parameters like stress, attitude, visual imagery, creativity etc. have been found to influence the dream recall abilities. Increased professional stress or interpersonal stress results in an increase in dream report frequency (57). An interest in dreams or a positive attitude toward dreams clearly co-varies with dream report frequency (49). Researchers have found both significant positive correlation between dream report frequency and memory abilities (58, 59) as well as no significant correlation between dream report frequency and memory abilities (60). There is significant positive correlation between dream report frequency and visual imagery (61). In contrast to these findings, Okada *et al*. (62) found no significant correlation between these two variables. Dream report frequency is positively correlated with creativity (57) and intelligence scales (63). Many authors have reported a correlation between dream report frequency and personality traits. Subjects with a high dream report frequency are more likely to have a personality with thinner boundaries like people as being more open, trustworthy, vulnerable, and sensitive (49), to be more anxious (63) and to be more open to experience

(49) compared to subjects with a low dream recall frequency.

FUNCTIONS OF DREAM:

The controversy on the functional aspect of dream stretches from meaningless nonfunctional to meaningful functional dream. The following hypotheses have been generated on this context.

NO FUNCTION:

Alan Hobson proposed a theory that deprived dreaming of any function. He argued that dreaming is an epiphenomenon of REM sleep whose cognitive content is so ambiguous as to invite misleading or even erroneous interpretation (64).

PSYCHOLOGICAL INDIVIDUALISM:

Some researchers believed that dreaming serves a vital function. They observed the appearance of complex motor actions like by sleeping cat fur licking, growling, chasing prey, mastication and fighting (called as oneiric behavior) after blocking muscular atonia during REM sleep by damaging the locus ceruleus α in its brainstem (65). These results led Jouvet to propose that dreaming plays a role in reinforcing a species' typical behavior. He hypothesized that dreams/paradoxical sleep restore neuronal circuitry that was modified during the day to preserve the expression of the genetic program that codes for psychological characteristics. This process would ensure the stability of personality across time (66). In humans, complex motor behaviors (e.g. talking, grabbing, and manipulating imaginary objects, walking and running) can also occur during REM sleep in a pathological context like Parkinson's and Alzheimer's disease, pontine neoplasms. This syndrome is called REM sleep behavior disorder (67). Motor behavior during sleep can also happen outside of REM sleep. Sleep waking and sleep terrors, which occur during NREM sleep, are usually not considered dream enactments. However, dreams can happen during NREM sleep, and many patients report dreamlike mentation after awakening from sleep waking or sleep terrors which can correspond with the sleep behavior in NREM sleep (68).

THREAT SIMULATION THEORY:

According to this theory, dreams serve as virtual training places to improve threat avoidance or threat fighting ability. This theory postulates that such nocturnal training makes the dreamer more efficient at resolving threatening situations during wakefulness (69).

EMOTIONAL REGULATION:

Cartwright *et al.* believed that dreaming is involved in emotional regulation. Her team observed that normal persons other than a depressed mood before sleep showed a pattern of decreasing negative and increasing positive affect in dreams reported from successive REM periods. These results led her team to suggest that dreaming may actively moderate mood overnight in normal subjects (42). The researchers concluded that negative dreams early in the night may reflect a within-sleep mood regulation process, whereas those that occur later may indicate a failure in the completion of this process. A variety of studies in animals have provided evidence that prolonged REM deprivation may lead to hypersexual, hyper-aggressive, and increased intracranial self-stimulation behavior which support the view that dreaming is linked to basic drives and pleasure-seeking (70).

MEMORY CONSOLIDATION:

The functional specificity such as memory consolidation and learning has been suggested during REM sleep. De Koninck found that the participants who made significant progress in learning French, their learning experiences were incorporated into their dreams (71). Studies have shown that brain activity during training is replayed during post-training sleep (23). Decreased performance during the post-training day in sleep-deprived subjects further suggested that the replay of brain activity at night contributes to memory consolidation (72). Wamsley et al. also found that the subjects who dreamed about the trained task during nap performed better than subjects who did not dream (73). Stickgold *et al.* presented data that shows frequent incorporation of imagery from a pre-sleep learning task in sleep-onset hallucination and proposed that REM sleep dreaming utilizes memory in an attempt to identify and evaluate novel cortical associations in the light of emotions (1). Animal experiments have shown that hippocampal cells which are active during a learning task while awake are reactivated in a similar pattern during REM sleep and thus related to a process of memory consolidation (74) and Maquet *et al.* reported analogous findings in human using PET imaging (23).

CONCLUSION:

Psychoanalytic theory and activation-synthesis model seem to be more relevant among the different theories put forward to explain the mechanism and role of dreaming. Though dream recall rate is higher after awakening from REM sleep, dreaming occurs both during REM and NREM sleep which are different in their characteristics and are likely to be produced by different mechanisms. The eye movements of REM sleep would allow the dreamer to scan the imaginary scene of the dream; cortical activation of different regions would allow intense cognitive activity, creating the complex stories of a dream; and the lack of muscle tone would prevent the dreamer from acting out his dreams. The intra- and inter-individual variations in dream report frequency are influenced by different sleep parameters as well as physiological, psychological along with environmental parameters. Further, the role of dream in regulation of individual's emotion, memory and its effect in psychology of the person cannot be overlooked. The advancement of neuroscience in the last few decades has helped in studying the brain activity during sleep in bit depth but further work has to be done to establish a correlation between certain patterns of brain activity and dream content in human as other species cannot provide information about mental processes during sleep, so it is difficult to conclude that whether or not animals are dreaming during sleep. Another challenge still exists for the researchers to test the strength of the link between the oneiric behaviors and dream reports in a controlled and systematic manner.

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