Brain Happenings: REM Sleep and Dreaming

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The central theme of this paper deals with the phenomena of REM sleep in relation to dreaming. The physiological mechanisms of REM sleep, with primary characteristics of high brain activity and paradoxically low muscle tone, is explained. The function of REM sleep is discussed, particularly in terms of its cognitive and homeostatic functioning, but without being able to draw any final conclusion. Arguments are given to support the existence of a third state of consciousness, namely REM sleep, aside from the two commonly accepted states of 'wakefulness' and 'slow wave' sleep or non-REM sleep. REM sleep may not even belong to the domain of sleep itself, given the fact that REM sleep may occur during, or interfere with, wakefulness. Another topic discussed is the supposed relationship of REM sleep to dreaming. Based on a number of considerations, it is concluded that intense brain activity, regardless of its origin, may be the essential causal factor of dreaming. Because high brain activity always accompanies REM sleep, it looks as if there is a causal relationship between the two. This is refuted however by the occurrence of dreams during slow wave sleep, and also by the existence of hypnagogic hallucinations during naps or while falling into sleep. (Sleep and Hypnosis 2000;2:69-73)

Key words: REM sleep, dreaming, recall pardigm, information processing, activation-synthesis, consciousness

MECHANISMS OF REM SLEEP

In 1953, Aserinsky and Kleitman investigated the slow, rolling eye movements that accompanied falling into sleep. They noted that these movements continued while children were falling into sleep. After longer observation they came to the surprising conclusion that during sleep, various phases displayed another sort of eye movements: coined rapid eye movements. These quick eye movements appear to be part of a more complex phenomena involving other sorts of muscle motions. Simultaneously there is an autonomic activity in the body that not only is expressed in quick breathing, increased heartbeat and blood pressure (1), but also as in an unexpected erection in men (2). All these events are the result of a distinguishable high brain activity that is in sharp contrast with the low brain activity during slow wave sleep. The neurophysiological characteristics of rapid eye movement (REM) sleep are quite similar to those during wakefulness (3,4). Just as at wakening, the membrane voltage of many brain cells is high and close to the discharge threshold. That is the reason for the high brain activity. Under normal conditions this activity, that also extends across the motor cortex, is expressed during active behavior, but during REM sleep that is not the case because another internal mechanism insures that muscle movement deceases or is weakened (5). Humans or animals in REM sleep lay sideways, but display a wide range of muscular activities that may only be the top of an iceberg of suppressed behaviors. To mark the contrast between high brain activity versus low physical behavior, REM sleep has also been referred to as paradoxical sleep, particularly in animals (1).

The appearance of REM sleep occurred late during evolution. This phenomenon is only apparent in more highly developed mammals (6). Stemming from the fact that both animals and humans attempt to quickly make

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up for lost REM sleep at any appropriate moment, we can deduce its importance to both groups (7,8). Why is this so? This obvious question stems from the unusual characteristics of this type of sleep compared to those of non-REM sleep. Why are we outfitted with such a complex but obviously necessary mechanism that was added to our sleep evolution? Why is it necessary that normal sleep, with relatively low brain activity, be interchanged with a number of periods of high brain activity?

REM SLEEP AND DREAMS

Few discoveries have provoked so much discussion as that of Aserinsky and Kleitman (9). An immediate association was established between REM sleep and dreaming: REM sleep was supposed to be the physiological sub-layer of the psychological phenomenon of the dream. A sensation was caused when it was discovered that when people were suddenly aroused from REM sleep, they could almost always recall a vivid dream (10). It was too good to be true! On the physiological side a high brain activity, especially in that part of the brain where cognition occurs, but also of the part that controls movement, accompanied by a breaking mechanism that prevents an actual behavior such as springing out of bed during REM sleep. And on the psychological side, the dream, a clear visual event accompanied by related emotions that simulate reality. Because of the neat relationship between REM sleep and dreaming, by studying REM sleep, one could quickly solve the puzzle of the dream. Henceforth the double entities of physiological and psychological events could provide a window on the intriguing relationship between brain and mind.

It began well with the experiments of Dement and Wolpert (11), wherein a point in a dream would be tagged The researchers sprayed droplets of water on the back of REM sleeping experimental subjects. As we may recall, these stimulations were expected to be applied to an ongoing dream, and indeed, this was the case. The trick was to spurt a light stream of water on REM sleepers and tried so to match the marking points against dream reporting by experimental subjects. The researchers did find a reasonable overlap between the moment that stimulations occurred and events reported by subjects recalling their dreams. Thus, someone who was spreayed at the start of REM-sleep reported a dream in which upon going outside, it began to rain, while a person who was stimulated near the closing phase of REM sleep recalled a long story that concluded with getting wet from a leaking ceiling. These experiments systematically demonstrated that external stimulations could be easily incorporated into an ongoing dream, and that REM sleep and dreaming display a fixed time relationship.

All further investigations into the hypothesized relationship between REM sleep and dreaming has yielded many new facts, both about REM sleep itself and also about dreaming. Mostly because REM sleep can be objectively verified, there was suddenly a method of collecting a large number of dream reports. Researchers needed only to awaken REM sleeping subjects and inquire about their dreams. This dream recall research has been often carried out with globally similar results (12). It thus appears that everyone undergoes several dream periods per night, and that most dreams are about normal everyday occurrences. They describe personal relationships, worries and fears, work and hobbies, and generally all events that preoccupy the person (13). It is quite notable however that during dreaming there is no form of critical awareness present. We are not surprised at uncommon or impossible events, at the easy integration of external stimuli into the ongoing dream, such as for example the call of an alarm clock, nor even less the combination of daily events that have no apparent relationship to each other. Complicating the matter of dream explanations is also the unexplained fact that our dreams near the end of night sleep have a much more fantastic or unreal character than those at the beginning. Thus upon wakening we may partially recall the latter while earlier dreams are completely forgotten.

From the earlier mentioned dream recall research, it also appears that erections have no relationship with dream content. Freudian enthusiasts, who often attend to the sexual implications of dreams, explain that these result in an erection. But whatever the content of a dream, no matter how far removed from sexual content, it is commonly accompanied by an erection. A similar sort of phenomenon occurs in women; one notes an increased blood flow to the vagina. These phenomena are now being more accepted as resulting from higher autonomic activities. Diagnosticians are making thankful use of these phenomena to differentiate between psychological and physiological causes of impotence. In the latter group no erections occur during REM sleep (14).

DISAPPOINTMENTS

With the exception of the previous example, one can mistake the connection between physiological and psychological relationships in dreams. Two important disappointments can be noted. The research literature indicates that, now and then, but indeed consistently, non-REM sleeping subjects report dreams upon sudden awakening (12,15). This is a fundamental discrepancy that confounds the fixed relationship between REM sleep and dreaming. Although this finding has been abnegated as being insignificant, it cannot be refuted or overlooked (16). Concurrently there is more criticism of the recall method. The application of this method is skating on thin ice. The critical point is that dreaming occurs

during sleep and is not directly observable by researchers. The actual dream cannot be studied, but only its reflection in the real world as told by the subject; no one can directly verify the accuracy of dream reporting. A dream is what someone describes upon awakening and researchers must infer a one to one relationship between the dream and the way it was reported. A dream report is once removed from an event or a memory. It is therefore impossible to exclude such confounding factors as poor memory, oversite, or suppression. Complicating matters further is that short memory period after awakening, in which the dream must be immediately recalled. This is witnessed by the fact that so few people recall their dreams in the morning. And why are dreams so illusory? In short, dream recall studies can be deceptive and need not always be taken too seriously.

VIEWPOINTS ON REM SLEEP

The intriguing question about the function of REM sleep, in spite of intense and ingenious research, cannot yet be answered. There is still no definite explanation about its function or meaning on the horizon. The most important commonly accepted construct is that of the information processing hypothesis (1). This construct has several variations including the viewpoint that REM sleep is involved in storing information. The long film of information that is taken up daily is run-off during the evening in order to pluck out relevant information, to store it away and discard anything superficial. The suggestion of this hypothesis is based on earlier observations by Jenkins and Dallenbach (17), that sleep has a beneficial effect on memory. Information learned in the evening is better remembered than that learned in the morning. The positive effect on memory has been attributed to REM sleep by several researchers. Herein, sleep and especially REM sleep, fulfills a role in the process of memory and forgetting. The ontogenetic theory formulated by Roffwarg, Muzio and Dement (18) makes use of the latter finding. The fact that babies undergo so much REM sleep is explained by their need to process so much information. Two methods can be employed to empirically support this information processing hypothesis. One is to force a group of human or animal subjects to experience an intensive learning period, and then to measure whether the amount or intensity of REM sleep increased. This would infer that more information than normal had been processed. A second method is to prevent experimental subjects from undergoing REM sleep after a similarly intensive learning experience. The expectation here is that the recording or storage of information would thus be confounded. These types of experiments have been frequently performed on animals, and results appear to be strongly dependent on the method used to prevent REM sleep. A thorough review of the literature to find support for this cognitive function of sleep, yields ambiguous results: some supportive, some contradictory. For many years Coenen together with van Luijtelaar and van Hulzen have carried out REM sleep deprivation studies, and personally observed the debatable, controversial experimental results of this type of research (19-22).

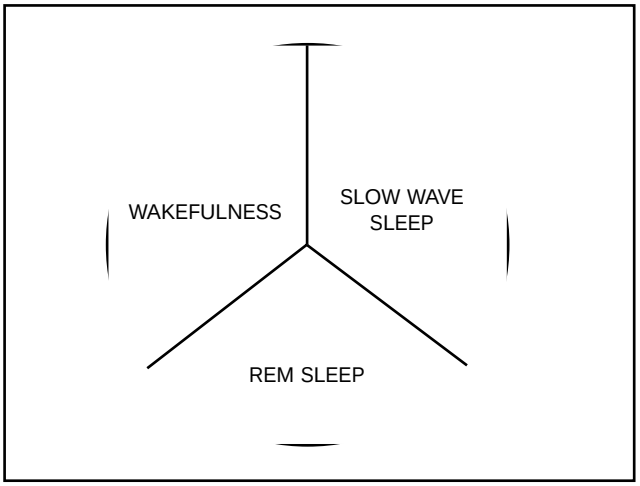
A second viewpoint is based on the assumption that REM sleep fulfills a homeostatic function (23); a viewpoint that also has several variations. The brain, during long periods of inactivity during sleep, needs to be occasionally re-activated. This endogenous stimulation is necessary for adequate behavior directly after awakening. This is analogous to a complex machine needing a warm up period after disuse, to begin properly functioning again. REM sleep is therefore necessary to maintain the neural excitability state of the brain. A related homeostatic viewpoint expressed by Vogel (24) is that brain sensitivity to external stimuli actually increases during sleep. To prevent this sensitivity from becoming excessive, REM sleep plays a decelerative role. Thus, among people in a depression, one finds brain sensitivity set too low. These people can be helped by applying REM sleep deprivation. This is a theoretical explanation of the finding that REM sleep deprivation may have an anti-depressant effect (25).

By the first of the previously mentioned cognitive (information processing) explanations of the role of REM sleep, the content of affiliated dreams might have a meaning, but for the second (homeostatic), dream interpretation plays no direct role. They are merely the mental expression of intense activity in the brain that may be important for other reasons. Hobson and McCarley (26) suggest that the cortex attempts to create a story from the random bombardment from the brainstem and a dream story is the best 'fit' the cortex could provide of this intense activity. They call this the activation-synthesis hypothesis of REM sleep. Cortical activation is, for unexplained reasons, of great importance, whereas the dream is a mere by-product. In the same sense the noise of an automobile engine is merely a by-product of its running. Nevertheless, it may be believed that dream content still has some importance to the owner. The reason is that the brain is continually being filled with information that may be (un)consciously of importance or value; and even by a non-specific activity, portions of the brain are being activated with relevant information.

IS REM SLEEP SLEEP?

Even now a number of arguments can be formulated against classifying REM sleep as a form of sleep itself. One of the main arguments for this viewpoint is that REM sleep may also occur during wakeful consciousness. Narcolepsy is a type of illness, that not only overlaps in name with epilepsy, but also in a physical form; suddenly a patient collapses (27). What follows is not really unconsciousness caused by an epileptic brain attack, but rather an involuntary setting in motion of REM sleep while the patient is physically awake and not safely prone in bed. By muscle enervation, the person collapses; rapid eye movements appear, accompanied by animated dreaming that confounds reality. For the sufferer, this convergence of fantasy with reality, accompanied by an inability to act, can be a terrifying experience. The occurrence of REM sleep not during slow wave sleep, has also been noted in babies and laboratory animals (28). The long held belief that slow wave sleep is necessary to trigger-off REM sleep is therefore put into doubt. Given the previous observations, one can increasingly come to believe that REM sleep is a separate category of consciousness. This implies that there are three definable and different states of consciousness: a) wakefulness with intense brain activity and related necessary physical behavior, b) normal, non-REM or slow wave sleep, accompanied by low brain activity and slight physical movement, and c) REM sleep with intense brain activity and a paradoxical low level of physical movement (Figure 1).

Figure 1. The three states of consciousness. 1. WAKEFULNESS with intense brain activity and intense behavioral activity. 2. SLOW WAVE or NON-REM SLEEP with low brain activity and a low level of behavior. 3. REM SLEEP with intense brain activity and, paradoxically, a low level of behavior. Arguments points towards the viewpoint that the latter category no longer falls under the exclusive state of sleep.



DREAMING AS BRAIN ACTIVITY DURING SLEEP

A defendable opinion about dreaming could be that, if there is (for whatever reason), a sufficiently high brain activity during sleep, this may produce a dream. From this perspective, dreams are not the exclusive property of REM sleep; they are only the expression of intense brain activity during sleep. Accepting this, explains the fact that an occasional dream recall during non-REM sleep can take place. High brain activity that always accompanies REM sleep is at the core of dreaming, and causes the observer to mistake dreams rather than brain activity as the essential cause of REM sleep. The various dream like phenomena that occur while one is falling into sleep, known as hypnagogic hallucinations (7), can also be declared as a mental expression of intense brain activity. This type of dream event that occurs before one dozes off is unexplainable because the persons physiological state is not comparable to the REM sleep condition. It is very likely that high mental activity before actually falling into sleep can lead to a short dream, sometimes accompanied a strong muscular movement. A shock-like brain activity may cause a directly related shocking muscle motion.

This hypothesis could be tested by a detailed comparison of recall data carefully scaled to their content of mental activity, with preceeding EEG characteristics (29). It is now possible to establish the complexity of the EEG of a given time period with methods developed in nonlinear dynamics. A positive correlation is than expected between the degree of recall and the correlation dimension of the foregoing EEG. Presumably, this correlation reveals more detailed information than classical EEG techniques and may shed some light on the malaise as noticed by Foulkes (16).

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