

The Neurobiology of Consciousness: Lucid Dreaming Wakes Up

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Neurobiologists and cognitive scientists are engaged in new efforts to establish the brain basis of consciousness. Progress in brain imaging, quantitative EEG recording in humans and in unit recording in animals, have all contributed to our present knowledge. However, progress has been limited by the relative poverty of the paradigms used in these studies, many of which do not take subjective experience into account. One promising, though problematical, paradigm lucid dreaming, has recently been employed and preliminary results are encouraging and complimentary. It is the purpose of this paper to consider the pros and cons of this approach and to interpret the results of the new findings.

1. Definition

Lucid dreaming is the rare but robust awareness that we are dreaming and that we are not really awake (cf. Gackenbach & LaBerge, 1988). Lucid dreaming is thus paradoxical, even at a subjective level, in containing elements of both waking and dreaming consciousness. In fact, lucid dreaming is an example of dissociation, one of the most fundamental features of normal and abnormal psychology. The spontaneous occurrence of lucid dreaming varies across individuals and it also varies with age within individuals. It is notably susceptible to pre-sleep autosuggestion. That is to say, the relatively rare spontaneous incidence of lucid dreaming can be increased by training. Young subjects may not only learn to become lucid but can also perform intentional self-awakenings, and even institute plot control by introducing voluntary decision making into the normally involuntary dream experience. This plasticity makes lucid dreaming significant to our clinical efforts to change the minds of our patients. Lucid dreaming can thus be viewed as a model for psychopathology and for the mechanism of hypnosis. The results are also of relevance to philosophy and to science in suggesting that consciousness can be split into two parts: an actor (the dreamer) and an observer (the waker).

Aside from its powerful psychedelic, therapeutic and entertainment value, lucid dreaming is thus an attractive phenomenon for scientific investigation within the area of consciousness studies. Lucid dreamers often claim that they can watch their dreams evolve and then alter their course as they see fit. If one believes these claims, and we will give our reasons for doing so below, it can be concluded that the

human mind is capable of being in two states, waking and dreaming, at one time. For the experimentalist, this means that it may be possible to measure the physiological correlates of three conscious states, waking, non-lucid dreaming and lucid dreaming in the laboratory. Since the three states are psychologically distinct, they should be physiologically distinct. If detectable, those physiological distinctions might be enlightening.

2. Historical Background

One reason for taking the claims of contemporary lucid dreamers seriously is the distinguished company in which they find themselves.

The first scholar to document lucidity extensively was the French aristocrat, Hervey de Saint Denys, whose very credible and well-written book, "Dreams and the Means of Directing Them", has recently been translated into English, (Saint-Denys, 1982). Saint-Denys was a distinguished China scholar and a member of the Academie Française. Like many of his contemporary Parisian colleagues, he was experimentally inclined and concerned with the mechanism of dreaming, (which he thought of as "clichés souvenirs", or snapshot memories, in keeping with the development of photography in 19th century France by Joseph Niepce and Louis Daguerre). He was also concerned about the moral implications of a state of mind, i.e. dreaming, that was apparently involuntary. Saint Denys wondered how a person could be held legally accountable for his dreams.

Mary Arnold-Forster was an English gentlewoman who described her own experiments in her book, "Studies in Dreams", published in 1921, and containing a foreword by the distinguished Boston psychologist, Morton Prince. Apparently unaware of the earlier work of Saint Denis, Arnold-Forster, niece of the famous English novelist, E.M. Forster, was principally concerned with determining what she could and could not do when dreaming lucidly. Like many other lucid dreamers, she taught herself to fly and thus to enter, at will, all of the rooms of her house; she particularly enjoyed flying down her stairs.

Early experimental studies established the scientific validity of these charming accounts (Fox, 1962; Moers-Messmer, 1939; van Eeden, 1913). The phenomenological tradition of description and self-experimentation has recently been taken up and described by Janice Brooks and Jay Vogelsong in their website volume, "Exploring Dream Consciousness" (Brooks & Vogelsong, 2000).

I myself became a lucid dreamer after reading Mary Arnold-Foster's book in 1962. At that time I was doing all-night sleep recordings in the laboratory of Frederick Snyder at the NIMH in Bethesda, Maryland. In the morning, I made rounds on the Schizophrenia Research Unit of Seymour Kety, for which I had medical responsibility. By the time I got to bed

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at home, it was often 11 am, the time of the peak occurrence of REM in sleep. All that summer, I was so exhausted that I slept on top of the covers with the window shades up. Even the sirens of fire engines couldn't keep me awake.

But I was alert enough to give myself the pre-sleep auto-suggestion specified by Mary Arnold-Forster in her book: "When you observe that times, places and persons change without notice, bizarre events which never occur in waking, you will know that you are dreaming".

Sure enough, I was soon dreaming and aware that I was dreaming; I was lucid. I could observe and even direct my dreams, just like Hervey de Saint-Denis. Also, like Mary Arnold-Forster, I could fly. I could make love to whom ever I pleased; a practice that became very popular in the early 1960's. I could even wake myself up, the better to recall my exotic dream adventures, and then go right back to the same or some more preferable dream behavior. This experience helped to convince me that dream science was not only possible but extremely promising. I didn't maintain my lucidity and never gave much thought to working on it. Only recently, has it become clear how promising lucid dreaming is to the study of consciousness.

3. Laboratory Studies

Following the discovery of REM sleep by Aserinsky and Kleitman (1953), the objective study of lucid dreaming was undertaken in earnest by K.M. Hearne (1978), who studied Alan Worsley in his sleep lab, and by Steven LaBerge (1980), working in Bill Dement's laboratory at Stanford University (LaBerge et al., 1981). An early and still persisting problem was the difficulty that many normal subjects had in becoming lucid while sleeping in the laboratory. That meant that scientists were often tempted to study themselves or a very few others (Tholey, 1981; 1983). That fact naturally raised the suspicion of peers who demanded broader sampling. For these reasons lucid dreaming remained suspect as a phenomenon. (Tart, 1979). Is lucid dreaming real or is it just imagined? The discovery of false awakenings, when subjects remained asleep even though they were convinced that they had woken up, didn't help the credibility of the science.

LaBerge nonetheless convincingly demonstrated that lucidity always arose out of REM sleep and that subjects were able to signal that they were lucid by making a series of voluntary eye movements. LaBerge's insistence that lucid dreaming occurred within REM invited controversy from critics who felt that his subjects might be fully awake. It now appears that LaBerge and his critics were both right! Lucid dreamers are both awake and dreaming which gives the re-visitation of this fascinating phenomenon its new appeal to the emerging science of consciousness.

4. Conceptual Problems

How can the brain be in two different states at once? The answer to this question is that state dissociations are, in fact, quite commonplace as Carlos Schenck and Mark Mahowald, the discoverers of the REM Sleep Behavior Disorder, has so convincingly argued, (Schenck & Mahowald, 1996). One part of the brain may be asleep while another is awake. In the case of sleep-walking the gait-generator and navigational system of the brain stem may be fully functional while the cerebral cortex is still in Stage IV of NREM sleep. Sleep walkers, usually children or adolescents, are

notoriously difficult to arouse. Just the opposite dissociation occurs in sleep paralysis when the dreamer wakes up from REM and is unable to move because of persistent REM sleep motor inhibition.

These and other normal dissociations show that the brain-mind is not always in one, and only one, state. Such cross-state fluidity helps us to understand many normal dissociations and opens the door to new models of psychopathology as well. Instead of the all-or-none, categorical approach to mental illness taken by psychiatry from the time of Kraepelin to the present, we can now consider dimensional models such as the state space schema of AIM which was derived from animal experiments. AIM represents the cardinal syndromes of waking and sleep in a four dimensional array that easily accounts for the dissociations of normal and abnormal consciousness; the four dimensions being the independent values over time t , activation A , input-output gating I , and modulation M . (Hobson, Pace-Schott & Stickgold, 2000).

To help to make this point clear, consider hallucinosis. We know full well that dreaming is normally characterized by vivid visual percepts which, by formal definition are hallucinations. Hallucinations also occur at sleep onset (hypnogogic) and on waking up (hypnopompic). In each case, a symptom of major mental illness is experienced. But the subjects are not mentally ill. They are simply evincing normal state changes which are dissociative because such variables as A , I , and M do not change simultaneously. To hallucinate with our eyes open, we have only to run the REM sleep dream image generator in waking. When we hallucinate, we are in two states at once.

5. A New Approach to Lucid Dreaming

How can we be sure that an experimental subject is asleep when lucidity is signaled by a set of voluntary eye movements? How do we know that the subject has not woken up? It is helpful to note that inhibition of muscle tone persists in lucid dreaming, but a more confident answer to this question requires a stretch. It is that the subject is both awake and asleep with different parts of the brain in different states at the same time. Mistakes can be made, of course, and appropriate cautions and safeguards must be taken, but the best proof that lucid dreaming is a third state of consciousness, sandwiched in between waking and non-lucid dreaming is empirical. The results of two recent studies suggest that this is indeed the case.

5.1. Quantitative EEG Studies

Taking advantage of recent improvements in the resolving power and data analysis of the human electroencephalogram, Ursula Voss and her colleagues at the University of Frankfurt (Voss et al., 2009) have been able to show that lucid dreaming is associated with EEG power and coherence profiles that are significantly different from both non-lucid dreaming and waking. Lucid dreaming situates itself between those two states. Lucid dreaming is characterized by more 40 Hz power than non-lucid dreaming, especially in frontal regions. Since it is 40 Hz power that has been correlated with waking consciousness in previous studies, it can be suggested that enough 40 Hz power has been added to the non-lucid dreaming brain to support the increase in subjective awareness that permits lucidity but not enough to cause full awakening.

It is very significant that an EEG correlate of lucidity is frontal. Many independent lines of evidence point to the frontal brain as the seat of working memory, self-reflective awareness, and volition, just those psychological dimensions that appear to be absent in dreaming and those which need to be restored in order to become lucid. More specifically, as it is the dorsolateral prefrontal cortex (DLPfC) which is not activated in REM, I hypothesized that its reactivation was necessary for dreamers to become lucid when they were dreaming in REM (Hobson et al., 2000).

By measuring the temporal correlation between frontal and occipital EEG patterns it could be demonstrated that subjects enjoyed more EEG coherence when lucid than when not and, again, less than in full waking. A reasonable interpretation of this finding is that dreaming is the result of posterior brain activation while waking requires frontal activation as well. In lucid dreaming, subjects are in between and thus on the edge of both states. That may be why lucid dreaming so often gives way to waking or is lost to non-lucid dreaming. Lucid dreaming is on the cusp of two states which are programmed to be all-or-none, winner take all, with ties improbable. That's why lucid dreaming is so rare and why it is so evanescent.

5.2. Brain Imaging

Another German group, under the leadership of Michael Czisch in Munich, has used MRI techniques to study brain regional activation in lucid dreaming subjects, (Wehrle et al., 2005; 2007). Compared to non-lucid dreaming, the brain regional activation pattern was markedly different. Lucid dreamers showed increased activation patterns of those brain regions that distinguish humans from macaque monkeys. These areas are not only frontal, as might have been predicted by the Voss et al. (2009) findings, but are temporal and even occipital as well.

One implication of these new and still preliminary MRI data is that the brain activation underlying lucidity is not only frontal but also involves parietal and temporal brain structures. These structures are activated in the frontoparietal region proposed by Vincent et al. (2007, 2008) as the substrate of consciousness. This circuit is more specifically related to consciousness than the one which Marcus Raichle and his colleagues call the "default mode".

The term "default" could be a misnomer for a circuit that has also been proposed to be a substrate of waking consciousness. When we are "on task" we may activate structures specific to each task, like the visual cortex for vision, the hand area for fist clenching, and the face area for facial recognition. Most imaging studies ask subjects to perform such tasks but when they are simply awake in the scanner and thinking about what they have just done or what they are about to do (or, perhaps, just wishing they were at the beach!) it is the so-called "default" network which is activated.

Those of us who are interested in consciousness itself have every right to consider the term "default" to be an operationally understandable, but unfortunate, one. This circuit could be a substrate of awareness, self-reflection, and decision making. As such it is the network of great interest to consciousness science. This brings home the major point about subjectivity that was raised in the introduction to this paper. It is impossible for normal subjects to stay awake and do nothing while lying in the scanner. They continue to think, to feel and to imagine. In a word, they are conscious.

Waking consciousness may consist of what Gerald Edelman has called secondary consciousness as well as primary consciousness (Edelman, 1992). Primary consciousness has recently been proposed by us to be characteristic of dreaming. Put another way, waking, by including secondary consciousness, is characterized by higher orders of insight, abstraction, and awareness of awareness, precisely those attributes which dreaming normally lacks. Dreams have strong primary consciousness elements. They include a strong sense of self, of self-as-agent, and movement of that self-agent through a perceptual space, all integrated with emotional salience. Dreaming is thus a virtual reality experience with a remarkably predictive simulation of external reality. Lucid dreamers may experience primary consciousness (the dream) and secondary consciousness (the waking) separately but simultaneously.

A question of direct relevance to the virtual reality hypothesis is whether the enactment of dream behaviors utilizes the same brain circuits as those which mediate those very behaviors in waking. A review of the lucid dreaming literature supports the identity hypothesis (Erlacher & Schredl, 2008a). This question is under active investigation using MRI for hand-clenching (Czisch et al., personal communication) and psycho-physiological techniques for autonomic measures (Erlacher & Schredl, 2008b).

It is possible that the primary-secondary consciousness distinction is dependent upon the acquisition of language by humans as suggested by Edelman. In any case, the language hypothesis is consistent with the Czisch et al findings that dream lucidity depends upon activation of brain regions which are distinctly human. As it turns out, language areas of the brain are not specifically activated in lucid dreaming but then again, neither is language. We can speak and understand words in non-lucid dreams as well as in lucid ones.

6. Summary and Conclusions

Lucid dreaming is an unusual state characterized by elements of both waking and dreaming. It is a rare but robust condition which has attracted the attention of scientists with an interest in further specifying the brain basis of consciousness. Quantitative EEG studies indicate that both 40 Hz power and fronto-occipital coherence are correlates of waking consciousness. Brain imaging research has shown that the regional activation pattern in lucid dreaming correlates with those cortical areas known to be more highly developed in humans than in monkeys. To become aware that one is dreaming, it would appear to be important to ratchet up frontal 40 Hz power and coherence in a human brain and thus to turn on a distributed network that normally mediates waking consciousness.

By means of pre-sleep autosuggestion, it could be possible to reactivate the DLPfC enough to support lucidity. This is an interpretation of earth-shaking importance to our concepts of mental health and illness. Among other things, it suggests that we may have a handle on insight and its enhancement via suggestion. If that is so, then lucid dreaming could move from its marginal and tenuous place at the fringe of psychophysiology to center stage in the emerging science of consciousness. Lucid dreaming may, in turn, help consciousness science to effect revolutionary changes in psychology.

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