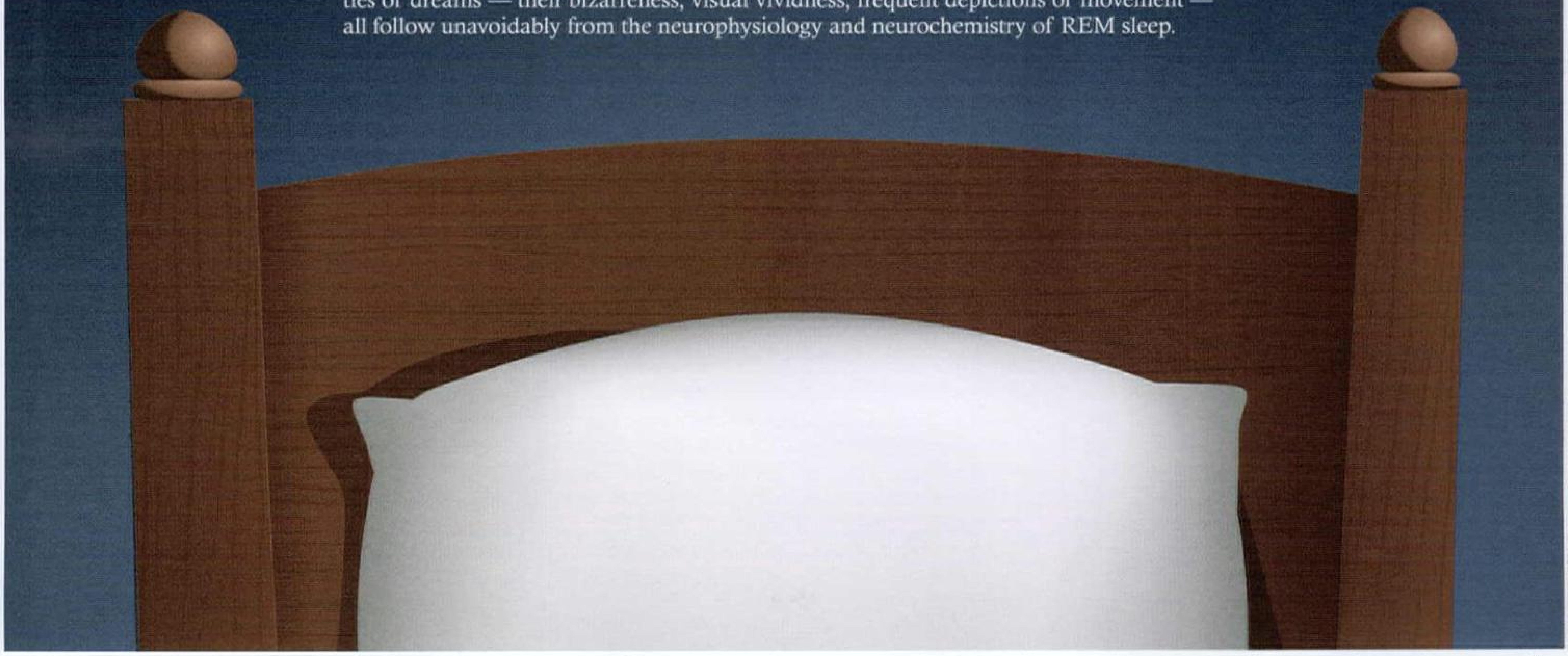
The Function of Dreaming

By Robert Stickgold

The search for the meaning of dreams dates at least to the biblical story of Joseph and *The Iliad* of Homer. The Book of Genesis quotes Joseph as saying, "The dreams of Pharaoh are one and the same. God has revealed to Pharaoh what he is about to do." The ancient Greek poet describes how Jove sent a lying dream to King Agamemnon, telling it to "say to him word to word as I now bid you." This view of dreams as messages from the deities held sway for at least 4,000 years.

Sigmund Freud's *The Interpretation of Dreams*, published in 1899, upended this assumption. For Freud, the father of psychoanalysis, dreams were a "safety valve" for the release of unconscious excitation that would otherwise awaken the individual. But his book made its mark less for how he thought dreams worked and more for what he thought they signified: disguised reflections of forbidden desires. His theory of dream interpretation captured the imagination of a sexually repressed Europe and became a metaphor for the dark side of human nature. Indeed, Freud's take permeated Western culture and wound up the dominant explanation for dreaming and a favorite trope in the arts.

But Freudian dream theory never gained any respectable scientific evidence and prevailed for a relatively brief 75 years. In 1977, Harvard psychiatrists Allan Hobson and Robert McCarley unveiled their alternative: the Activation-Synthesis model. Dreams, they postulated, arise from a "largely random and reflex process" during rapid-eye-movement (REM) sleep — the time when dreaming is most frequent and intense. Activation begins in the pontine brain stem and spreads up to the visual cortex, leading to internally generated imagery. This activation, "which is partially random and partially specific, is then compared with stored sensorimotor data in the synthesis of dream content." Thus, the properties of dreams — their bizarreness, visual vividness, frequent depictions of movement — all follow unavoidably from the neurophysiology and neurochemistry of REM sleep.



Arnel Reynon Illustration

Revolutionary shift

Hobson and McCarley attacked three key aspects of Freudian dream theory. First, they insisted that dreaming is a normal function of the sleeping brain, occurring every 90 minutes as the brain cycles in and out of REM sleep, and not an offshoot of neurosis. Second, they argued that dreams are instigated by random activations of the brain stem during REM sleep, not by a need to suppress unacceptable thoughts and desires. Third, they contended that the bizarre features of dreams are not due to any intentional obfuscation of some harbored illicitness; instead, "the forebrain may be making the best of a bad job in producing even partially coherent dream imagery from the relatively noisy signals sent up to it from the brain stem."

Hobson and McCarley also stressed that their model "does not deny meaning to dreams ... nor does it imply that they are without psychological meaning or function." Rather, psychological purpose derives from the synthesis portion of Activation-Synthesis. Therefore, in a comment particularly relevant today, "dreaming sleep may ... provide a biological model for the study of memory, [with] a functional role for dreaming sleep in promoting some aspect of the learning process."

Surprisingly, however, their evidence was circumstantial at best. The trailblazers based it on what they called "brain-mind isomorphisms" — similarities between psychological and physiological aspects of dreaming — an approach they credited to Freud. Hobson and McCarley suggest, then, that dreams of flying, for instance, ensue from the internal activation of the vestibular system during REM sleep. Like Kipling's *Just So Stories*, the logic makes sense, but the science leaves many gaps.

Nonetheless, the Activation-Synthesis model took off. In fact, the prestigious *American Journal of Psychiatry* published Hobson and McCarley's explication as a lead article. And Hobson, with whom I studied, later wrote extensively about the model, extolling the neurophysiological basis of dreaming, but focusing almost exclusively on activation. Consequently, mental health practitioners, authors of psychology and psychiatry textbooks, and their students came to believe Activation-Synthesis demonstrated that dreams were meaningless, functionless epiphenomena of the sleeping brain. This brave, new model of dreaming has largely replaced Freudian theory both in college psychology courses and among clinicians and researchers, even as Freudian dream interpretation remains an essential motif in popular culture and the arts.

Important refinement

Recent advances in cognitive neuroscience reinforce Activation-Synthesis but shift the focus from the randomness of activation to the meaningfulness of synthesis. Sleep plays a part in the off-line processing of memories, not only stabilizing and strengthening them, but also extracting their meaning, as Matthew Walker, principal investigator at the Sleep and Neuroimaging Laboratory in the Department of Psychology at University of California, Berkeley, and I reviewed in a paper published earlier this year in *Nature Neuroscience*. And in 2010 research, my Harvard colleague Erin Wamsley and I charted a strong correlation between dreaming about a recently learned skill and subsequent improvement in its performance. Examining both nocturnal dreams and waking daydreams, we have repeated these findings, and, thus, propose that "far from being a random or meaningless distraction, spontaneous cognition during states of sleep and resting wakefulness appears to serve important functions related to processing past memories and planning for the future."

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What we did in these experiments was quite simple. In the morning, students navigated a virtual 3-D maze in a computer game. We then tested how long it took them to get out of the maze from various points. That afternoon, half the subjects napped for 90 minutes while the other half watched rather boring videos. Around 5 p.m., we retested everyone. As we had expected (or at least hoped!), those who napped got through the maze about one minute faster than they had before but those who had stayed awake took about one minute longer. We also woke up the napping subjects twice to collect their dream reports. Only those who reported dreaming about the maze wound up faster at the 5 p.m. test. We also asked those who had to stay awake what had been on their minds at those same two junctures; whether they reported thinking about the task or not, they showed no improvement at the 5 p.m. test. Just 33 years after Hobson and McCarley's speculation, firm scientific evidence confirms that, for at least this one memory task, sleep enhances subjects' memories of what they recently learned, but only if they dream about it!

Additional findings

Actually, this idea of a link between sleep and memory processing is nothing new. The ancient Roman rhetorician and educator Quintilian noted in the first century A.D., "Things which could not be recalled on the spot are easily coordinated the next day." In modern times, the scientific study of sleep and memory only began in 1972, with the pioneering work of psychologist and academic Carlyle Smith. And it was only around the year 2000 that the field began in earnest. Since then, understanding of this link between sleep and memory processing has grown exponentially. Here are some examples.

Sleep consolidates and enhances memories. Most researchers believe that sleep reactivates memories, stabilizing and strengthening them unconsciously. For procedural memories — how to do things like ride a bicycle — subjects perform better after a night's sleep than at the end of instruction or after a period of daytime wakefulness. In 2002, colleagues and I trained people on a finger-tapping task, typing the sequence 4-1-3-2-4 over and over during 12 half-minute trials. After training them in the morning, we tested them 10 minutes after the last trial and 10 hours later, and they revealed no further improvement. But when we instead trained them in the evening and tested them the next morning after a night's sleep, they were 10 percent to 20 percent faster and made fewer mistakes. In other cases, for example verbal memory, sleep slows the rate of forgetting and makes memory more resistant to interference from newly learned material. In a 2006 study, we taught subjects a list of word pairs like "horse-track." They did somewhat better retaining the pairs when tested after a night of sleep versus after a day of wakefulness. Other subjects were additionally taught a list of competing word pairs like "horse-hay" before retesting. The new list made remembering the original pairs much harder after the day of wakefulness, but not after the night of sleep.

Your parents were right, at least when you want to hold on to what you've just learned: get a good night's sleep!

Sleep selects which memories to bolster. The sleeping brain doesn't treat all memories equally. In 2008 in my sleep laboratory, Jessica Payne, who now teaches at University of Notre Dame, and I were part of a team that showed subjects photographs of scenes with central emotional objects, such as a dead cat on an open highway, and studied the changes over time in their memories of these scenes. We found that memories of the objects and their backgrounds were forgotten equally across a day of wakefulness. But only the backgrounds had been forgotten after sleep. Memories of the central emotional objects were undiminished the next morning. Thus, it appears to be sleep-dependent memory processing that causes Boston Red Sox fans like me to remember only first baseman Bill Buckner's error from the entire 1986 World Series, and nothing else!

Ironically, this capability of sleep to enhance memories selectively can solidify false memories. In a 2009 study with Payne, we had subjects listen to several lists of words that might go together, like "bed," "night," "snooze," "pillow," and "moon." Then, after a period of wakefulness or sleep, we had them write down the words they could remember. As often as not, the subjects jotted down the word "sleep" even though we had not included it. In fact, while words from the lists were forgotten across periods of both wakefulness and sleep, these "gist" words — reflecting the essence of each list but not on any of them — were only "forgotten" after periods of wakefulness, not sleep. Such gist extraction serves as one of sleep's most valuable functions. People are inundated with massive amounts of information, and survival in the modern world depends on the human brain's ability to decide what can be discarded, what should be retained, and what details are superfluous enough to let go in favor of holding on to only the core of the matter. People do some of this filtering consciously, while awake. But it appears that this refining mostly occurs during sleep, automatically and without conscious intent.

Sleep reveals how things work. Sleep can improve people's ability to discover and use rules even when they're unable to explain them. A 2009 study by others about infants learning grammar demonstrates this. Curiously, this learning is implicit. Young children quickly gain remarkable expertise in the syntax of their native tongue: word order, subject-verb agreement, plurals, tenses, etc., without yet comprehending the terms or systems. In other words, children become proficient at these rules without being consciously aware of them, and for the mastery of such complex cognitive procedural learning (of how, not of what), sleep appears to be crucial. The same goes for college students. My own research with colleague Ina Djonlagic from 2009 showed that college students trying to learn the rules of a complex game by trial and error actually get better at it after "sleeping on it." I suspect that there is little that college students learn that wouldn't benefit from a good night of sleep afterward.

Sleep inspires insight. In an elegant 2004 study, the German sleep researchers Ullrich Wagner and Jan Born taught subjects a tedious rote method of solving some mathematical problems. The subjects were not told that a much faster and easier means existed. Over about 100 problems, few subjects discovered the shortcut. When given more problems later that day, about 25 percent of the subjects figured it out. But among subjects trained in the evening and retested the next morning, more than 60 percent had this epiphany. Thus, a night of sleep more than doubled the likelihood of their discovering an insight that they didn't even know existed! How the sleeping brain does this remains a mystery.

Further experiments

Other studies from the last dozen years provide additional support for the hypothesis that sleep-dependent memory processing affects dreaming. For example, why are dreams so weird — seeming to form a tenuous storyline, with little or no coherence? One approach to answering this question comes from looking at how the mind/brain processes information during sleep. Although scientists can't get subjects to perform cognitive tests in their sleep, studies during the transition from sleep to wakefulness offer a hint about what would have been shown. In a 1999 experiment, my coworkers and I woke subjects from either REM or nonREM sleep and, in the two or three minutes after awakening, had them conduct a "semantic priming" task (deciding whether the second item in pairs like "fish-hook" and "child-mothem" is a word). In 2002, we used the same awakening technique with a set of 32 anagrams. The two tests yielded comparable results: subjects awakened from REM sleep did better. Why the brain excels at finding unexpected and weak associations during REM sleep is unknown. But researchers have found that levels of the brain chemicals serotonin and norepinephrine, which normally help humans focus attention, drop to near zero during REM sleep. Perhaps this absence prevents the brain from getting stuck on the first associations it comes upon, making it easier to follow more fluid paths to weaker ones and anagram solutions.

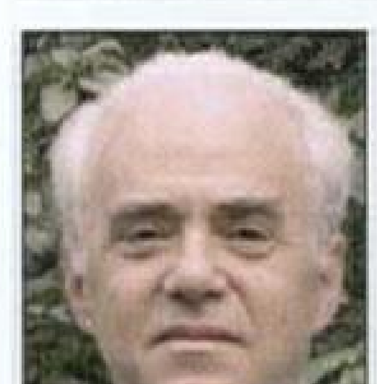
How closely does a dream match the real-life events that seem to be behind it? In a 2003 experiment, colleagues and I asked subjects to identify the waking sources of their dreams and compare the two. Turns out, dreams rarely, if ever, replay waking memories. Instead, dreams create scenes that obliquely apply to real life and that overlap primarily in terms of emotions and themes. For example, after narrowly averting a car crash during the day, I might dream about it that night. But my dream wouldn't rewind and replay my near accident; rather, the dream more likely would put me in an amusement park, riding a bumper car and feeling like doing so wasn't as much fun as it used to be. Thus, dreams seem ill-equipped to strengthen and stabilize memories. Instead, dreams excel at producing fictitious scenarios built upon the emotions and gist of waking events. Interestingly, these two elements of dream construction — extracting the gist from memories and enhancing their emotional aspects — are among the forms of memory processing at which sleep excels.

Dream away

Current research posits that dreaming simply represents the conscious experiencing of one component of sleep-dependent memory processing. I say "simply" not because I think this stance is minor or uninteresting, or indeed anything less than amazing, but because it doesn't carry the weight of forbidden angst in the older Freudian model. Instead, dreaming is part of a continuum of subjective experience that spans sleep and wakefulness and that permits people to extract the most benefit possible from the events of their lives. Wakefulness serves as a conduit for forming memories of these events. Sleeping and dreaming then help people determine what these memories mean, understand themselves and the world better, and predict how future actions might aid or hurt them the most.

Do I have any words of wisdom about dream interpretation? I generally hate that question. But I think this research does offer some suggestions. First, the themes and emotions of your dreams are probably more central to the dreaming process than are their details. Second, the odd juxtapositions of objects, characters, actions, and scenes in dreams probably reflect your brain exploring those weaker associations within its semantic networks, without any bias about whether they hold real meaning. And that's true even when the dreams are about sexual encounters, dead relatives, nightmarish situations, or whatever. After all, creativity depends on the discovery of new relationships between memories, so it's probably best to explore a lot of unlikely combinations. Third, dreams aren't trying to tell you anything. Probably 95 percent of your dreams are forgotten by the time you wake up, and whatever their function, it can't depend on your remembering them. In the end, given all of this evidence, I recommend that you respond to your dreams with a solemn nod and a little wink. They're more like advice from a friend than a gift from the gods.

Now go to bed and sleep on what you've just read. It should all make sense in the morning.



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