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0521810442 - Sleep and Dreaming: Scientific Advances and Reconsiderations

Edited by Edward F. Pace-Schott, Mark Solms, Mark Blagrove and Stevan Harnad

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## Sleep and Dreaming

How and why does the sleeping brain generate dreams?

Though the question is old, a paradigm shift is now occurring in the science of sleep and dreaming that is making room for new answers. From brainstem-based models of sleep cycle control, research is moving toward combined brainstem/forebrain models of sleep cognition itself. Furthermore, advances in philosophy, psychiatry, psychology, artificial intelligence, neural network modeling, psychophysiology, neurobiology, and clinical medicine make this a propitious time to review and bridge the gaps among these fields as they relate to sleep and dream research.

This book presents five papers by leading scientists at the center of the current firmament and more than seventy-five commentaries on those papers by nearly all the other leading authorities in the field. Topics include mechanisms of dreaming and REM sleep, memory consolidation in REM sleep, and an evolutionary hypothesis of the function of dreaming. The papers and commentaries, together with the authors' rejoinders, represent a huge leap forward in our understanding of the sleeping and dreaming brain, ultimately offering new and unique views of consciousness and cognition. They help provide new answers to both old and new questions, based on the latest findings in modern brain research. The book's multidisciplinary perspective will appeal to students and researchers in neuroscience, cognitive science, and psychology.

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**Sleep and Dreaming**  
*Scientific advances  
and reconsiderations*

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# Preface

For centuries there have been theories about how and why sleep occurs. Since the discovery of REM sleep in 1953, science has also asked how and why the individual stages of sleep, such as REM sleep and slow wave sleep, occur and what relationship they have with dreaming. The relationship of dreaming to brain physiology and neurochemistry, and the possible functions, or lack of functions, of REM sleep and of dreaming have also been addressed. This book highlights the current debates, disagreements, and understandings among many of the world's leading researchers, from many different disciplines, on these questions, including both theoretical and experimental work. The book comprises a collection of target chapters, commentaries, and replies to commentaries that were first published as a special issue on sleep and dreaming of the journal *Behavioral and Brain Sciences* in December 2000.

These are currently areas of great ferment. Fifty years ago dreams seemed to occur almost exclusively in REM sleep, a few years later dreams were also shown to occur in non-REM sleep, and the debate continues today about whether these stages of sleep result in different types of dreams or whether dreaming can occur in all stages of sleep and how closely characteristics of dreaming, such as the illogicality of some dreams or the ease with which they are forgotten, are tied to the physiology and neurochemistry of the brain. Theories of the function of dreams have abounded, from the clearing out of memories to the linking and forming of memories to creative problem-solving. There have also been theories of the function of REM sleep, such as of brain maturation in the newborn and the consolidation of memories at all ages. This book addresses

theories of the possible functions and causes of dreaming and REM sleep, with implications not only for our knowledge of two activities that take up much of the human life span, but also for the study of the relationship of conscious experience to the brain and of the possible functions of consciousness.

The target chapters and commentaries give examples of a wide range of scientific methodologies that aim to address these issues, including the phenomenology and neuroscience of conscious states, cognitive performance testing, and the relationship of dream content to waking life events. The book makes clear the relevance of the study of dreaming to neuroscience, psychology, psychoanalysis, cognitive science, neurology, philosophy, psychiatry, and other fields, and we wish to thank all the authors and commentators from the many sciences involved for their participation in this book.

For this book version of the *Behavioral and Brain Sciences* special issue, an introduction and a postscript have been added that provide updates on relevant papers published during 2000, 2001, and 2002. The necessity for these updates shows the current rapid expansion of investigations into sleep and dreaming, along with the growth of neuroscience and the study of consciousness. We hope that this volume will inspire further experiments and debate concerning the relationships between dreaming and the sleeping brain and the functions of sleep and dreaming.

Edward Pace-Schott, Mark Solms,  
Mark Blagrove, & Stevan Harnad

# Introduction

**Mark Blagrove**

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The target chapters in this book address three issues in the science of sleep and dreaming: the relationship of dreaming to brain physiology and neurochemistry and the possible functions, or lack of functions, of REM sleep and of dreaming. The target chapters provide detailed summaries of previous work and a background to these current issues. This introduction aims to summarize the main claims of each of the target chapters and to cite recent papers of relevance to those chapters that appeared around the same time as or after the production of the *BBS* special issue. A further update, by Edward Pace-Schott, specifically on the neuroscience of sleep and dreaming, is provided at the end of the book.

The first three target chapters of this book are concerned with the relationship between dreaming and brain physiology and neurochemistry, with particular reference to the relationship of REM sleep to dreaming. Hobson, Pace-Schott, and Stickgold detail their AIM model of the mind-brain during dreaming and other states of consciousness. This model describes three dimensions of brain neuro-modulation, these being level of brain activity (A), internal or external source of stimulation for cognition (I), and mode of organization of cognition (M), which they relate to aminergic/cholinergic balance. This chapter emphasizes the importance of REM sleep to dreaming, reviews the comparison of dreaming to waking cognition [of relevance here is Kahn et al. (2000) on how character recognition occurs during dreams], and, in common with Nielsen's target chapter, reviews the history of investigations into the quantitative and qualitative differences and similarities between dreams in REM and NREM sleep. Hobson et al. then review recent studies on neuroimaging of the brain during dreaming and sleep, which indicate increased activation of limbic, diencephalon, and brain stem areas during REM sleep and the decreased activation of these areas during NREM sleep. The original activation-synthesis model of Hobson and McCarley is then updated with recent work on the relationship of cholinergic enhancement, and serotonergic and noradrenergic suppression, to REM sleep; there are also additional details from recent findings on the manner in which aminergic and cholinergic systems exert their influences on the REM-NREM cycle.

The AIM state space model that evolved from the activation-synthesis model holds that not only is the brain activated (A) with low external input (I) during REM sleep but that the modulatory factor (M) is related to the deficiencies of logic and memory found in dreams. Since the *BBS* special issue, Fosse et al. (2001a) argue that their finding of the

reciprocal variation in thoughts and hallucinations between wake, sleep onset, NREMS, and REMS indicates the need for the M factor, in addition to A and I. This method of comparing the prevalence and reciprocal covariance of different cognitive variables within each dream is also used in Fosse (2000), with a reply to the analysis by Nielsen (2000), and operationalizes the classification of different types of dreams, such as thoughtlike and hallucinatory dreams. Dream experiences have also recently been quantified in terms of four factors, Emotionality, Rationality, Activity, and Impression, using the Dream Property Scale of Takeuchi et al. (2001b), who found that EEG power in some frequencies is correlated with Rationality (the dream being more ordinary and orderly), and at other frequencies with Impression (the dream being more clear and focused), indicating some brain-mind isomorphism using a questionnaire method that is answered on awakening and is not mediated by the experimenter, nor, apparently, confounded by dream length.

Solms's target chapter details that REM sleep and dreaming are dissociable states, in that each can occur in the absence of the other; one reason for this is that, although there are average differences between NREM and REM dreams, 5–10% of NREM dreams are indistinguishable from REM dreams, in terms, for example, of their vivid and dramatic content. Using neuroanatomical studies, loss of dreaming is shown in this chapter to be associated with lesions to the ventro-mesial quadrant of the frontal lobe and to the parieto-temporal-occipital junction. The former area is known to be important for goal-seeking and appetitive behaviors, the latter area for supporting mental imagery. Solms concludes that dreaming is controlled by forebrain, probably dopaminergic, mechanisms whereas REM sleep is controlled by cholinergic brain stem mechanisms. [Gottesmann (2000) also hypothesizes that the release of dopamine results in the "psychotic-like" fantasies and irrational mental activities of dreaming.] REM sleep is therefore held to be one of many possible activators of forebrain dreaming mechanisms; others include descending stage 1 at sleep onset and the rising morning phase of the diurnal rhythm. For an update on the dopaminergic and cholinergic influences on dreaming the reader should see Solms (2002) and Cicogna & Bosinelli (2001) for more on the interaction between top-down and bottom-up components of dream mentation and for a consideration of what aspects of consciousness remain or are diminished in dreaming. Reiser (2001) suggests that top-down (psychological, psychoanalytic) and bottom-up (neuroscience) approaches to

## Blagrove: Introduction

dreaming and REM sleep are needed to account for the form and possible functions of dreams, with emotion being a bridge belonging to both domains. For example, to understand dreams one needs the top-down information derived from psychoanalysis of the dreamer's personal history and how it is incorporated into dreams together with the bottom-up PET studies of limbic areas that are activated during REM sleep.

Nielsen lists further examples where dreaming can occur in NREM sleep, such as when there is external sensory stimulation. He proposes that there are many levels of cognitive activity during sleep, from vivid intense dreams to thinking and fragmentary impressions to preconscious cognition, with the more complex or dramatic types of dreams more likely to occur in REM sleep. He shows that the liberalization (from around 1962) of what was accepted by dream researchers as a "dream" resulted in higher rates of dream recall being recorded from REM and NREM sleep and a diminution of the differences found between the dreams of the two states. The main purpose of the chapter is to review and reconcile evidence for the 1-generator view of dreaming, where similar processes of dream production are assumed to be occurring in REM and NREM sleep (but with the possibility that memory source activation and memory of dreams could be different in REM from NREM sleep), and the 2-generator view, where there are quantitative or qualitative differences between dreams from the two states. That the more vivid and even lucid types of dreams occur far more often in REM sleep is given as evidence for the 2-generator model.

Nielsen discusses, as do Hobson et al., the current debate about whether length of report should be controlled for in comparing dreams from REM and NREM sleep; such control has been found to eliminate almost all differences between dreams from the two states, but this statistical method is contentious because dream length may itself be a result of real differences in the characteristics of dreams from the two states. To explain why many dreams from NREM sleep are indistinguishable from REM sleep dreams, Nielsen then proposes that components of REM sleep can occur during NREM sleep but remain hidden ("covert") either because not all components are present at once, and so the sleep epoch is not scored as REM sleep, or because measures are not sensitive enough to detect the component. Nielsen proposes a probabilistic model whereby REM-like dreams can occur in NREM sleep during windows that are approximately 15 minutes prior to or following a REM period.

Of relevance to the discussion in these chapters of the comparison of dreams in REM and NREM sleep is a recent paper by Baylor and Cavallero (2001). In their reanalysis of three previously published studies they find that episodic memory sources occur significantly more often for NREM than REM dreams, and this stage effect remains even when report length is controlled for. Stickgold et al. (2001) found that dream report length increases with time in stage only for REM sleep, not for NREM sleep, and Takeuchi et al. (2001a) found that occurrence of dreams during sleep onset REM periods is related to amount of REM sleep, whereas occurrence of dreams during sleep onset NREM periods is related to number of arousals, but not to length of NREMS. However, note that Conduit et al. (2001) find that postsleep recall of events that occurred during NREM

sleep is worse than for REM sleep, and that therefore dreaming may occur equally in NREM sleep as in REM sleep, but just not be remembered. Similarly, Cicogna et al. (2000) ascribe the difference they find in REM and SWS dream recall rates to a mnemonic deficit, claiming that mental experiences may be produced almost continuously during sleep, this being a 1-generator theory. They did find a greater intensity of emotions during REM sleep, but level of self-participation and awareness did not differ between the two stages, and two significant differences between the stages, in number of characters and number of emotions, disappeared when dream length was partialled out.

The emphasis in these three chapters is on finding physiological and neurochemical correlates that explain the recall, lack of recall, and form of dreams across different brain states. For a review of psychological variables that affect individual differences in dream recall, see Blagrove & Akehurst (2000). As an indication that individual differences in length of dream reports may be a result of state-independent differences in reporting style, Stickgold et al. (2001) found intersubject differences in REM report lengths were correlated with similar differences in NREM, sleep onset, and waking report lengths.

In their target chapter Vertes and Eastman argue against REM sleep having a memory consolidation role, claiming that animal REM deprivation studies are divided equally in showing REM deprivation does or does not disrupt learning/memory. They account for REM deprivation studies that do show deficits in learning/memory as being due to the stress of the deprivation procedure, and a recent report by Spiegel et al. (1999) does find endocrine, metabolic, and stress effects of sleep restriction in humans. Vertes and Eastman claim that the majority of human REM deprivation studies find minimal or no effects on learning/memory, and they review work in humans on the suppression of REM sleep by antidepressants in which there are no, or negligible, effects on learning/memory. As a further context to their review, there has been debate over whether sleep restriction to less than 5 hrs per night, which can eliminate some REM sleep but generally leaves SWS intact, results in only minor or in large and cumulative cognitive deficits (Dinges et al. 1997; Pilcher & Huffcutt 1996). As Vertes and Eastman state in their reply to the commentaries, a recent series of experiments has compared memory after a period of early sleep (in which SWS predominates) with memory after a period of late sleep (in which REMS predominates). Readers may consult Wagner et al. (2001) for a recent example. Vertes and Eastman propose that REM sleep has a function of periodically activating the brain following each period of slow wave sleep. This view is supported by Horne's (2000) view that REM sleep tones up the sleeping cortex. Horne also accounts for the post-REM deprivation phenomenon of REM rebound, often taken as an indication of the importance of REM sleep to the organism, as instead being due to a default condition of loss of inhibition of REM sleep by non-REM sleep. Horne concludes that REM has little advantage over wakefulness in providing cerebral recovery or memory consolidation and that it can occur as a default condition when wakefulness is temporarily unnecessary to the organism, as would occur in situations of boredom or satiation.

Revonsuo's target chapter argues that during dreaming we rehearse threat perception and threat avoidance and

that this mechanism has evolved because it increases the probability of reproductive success in threatening environments, such as those inhabited by ancestral humans. He argues that dreams may only infrequently act to solve intellectual problems (this being a current matter of debate, for example, Barrett 2001a, 2001b; Baylor 2001). He claims they do not have a function of solving emotional problems, as their function, like pain and fear, is to aid reproductive fitness rather than mental health or comfort, indeed Koethe and Pietrowsky (2001) find that nightmares induce anxiety and physical complaints.

One proposition that Revonsuo uses to arrive at his theory is that dreams are an organized and selective simulation of the perceptual world, that is, they are not random or disorganized or purely reflective of waking life. On his claim about dreams not being random, Stickgold et al. (1994) find sufficient coherence across dream reports for judges to distinguish intact from spliced reports. However, Roussy et al. (2000) demonstrate an inability of independent observers to detect a clear resemblance between participants' daily events and manifest dream content, although Revonsuo does note that in nonthreatening environments dreams may not show their threat simulation function. The evidence that dreams select for negative content is detailed in his chapter, such as the preponderance in dreams of misfortune over good fortune and the high frequency of aggressive strangers in dreams. Of relevance here is the finding of Bears et al. (2000), who, defining masochistic dreams as ones that involve negative self-representation, disappointment, loss, or lack or where the dreamer is lost, excluded, or ridiculed, report that depressed individuals tend to report masochistic dreams closer to morning than do non-depressed individuals, in whom masochistic dreams are equally distributed across the night. Revonsuo also proposes that waking threats activate the threat simulation system, and there is recent work relevant to this. The presence and intensity of the contextualizing (or central) images in dreams are higher among participants who report any abuse (physical or sexual, childhood or recent) compared to those who report no abuse (Hartmann et al. 2001). Furthermore, Zadra and Donderi (2000) found significant negative correlations between well-being and nightmare frequency and that the retrospective memory of frequency of nightmares and bad dreams greatly underestimates their frequency, in comparison to daily logs: a discussion of the directions of causality for the relationship between anxiety and disturbing dreams in adolescents is provided by Nielsen et al. (2000). Methodological problems with the assessment of emotions during dreams are described by Fosse et al. (2001b), who find that 74% of REM reports have at least one discrete emotion, and that the amount of positive or negative emotions in dreams does not change across the night.

Revonsuo then argues that stimulation of perceptual and motor skills during dreams, even when dreams are not explicitly remembered, leads to enhanced performance in waking life. On this point the theory is in accord with evidence that higher mental processes, such as those underlying social interaction, affect and evaluation, motivation and goal-setting, can occur without conscious choice or guidance (Bargh & Ferguson 2000). Revonsuo's view of the dream as an environment in which to act can be contrasted to the more metaphorical and symbolic view of dreaming (e.g., Lakoff 1993). Note, however, that Revonsuo states

that other functions may also be possible for dreams. Recent suggestions are that dreams aid attachment for people who are insecurely attached (McNamara et al. 2001) and that pleasant or moderately unpleasant dreams may be sources of personal insight during dream interpretation (Zack & Hill 1998).

The five target chapters now follow. It is hoped that the debates over the relationship between dreaming and brain physiology, and over the memory consolidation function of REM sleep and the proposed threat simulation function of dreaming, will enhance the wider fields of neuroscience and of the study of the nature of consciousness and the specific questions of how and why we dream.

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