Translational Issues in Psychological Science
2015, Vol. 1, No. 1, 97–105

2332-2136/15/$12.00 http://dx.doi.org/10.1037/tps0000018

Dreaming and Waking Cognition

Yvette M. Graveline
University of Massachusetts,
Amherst and Furman University

Erin J. Wamsley
Furman University

Dreams are often believed to be “symbolic” and thus categorically distinct from the “ordinary” thoughts of waking cognition. But to the contrary, emerging evidence suggests that dreams and waking cognition share a common origin at the neurobiological level, which is reflected in similarity of form, content, and function at the phenomenological level. In both dreams and daydreams, memories of the past form the basis of novel imaginary scenarios. Neural networks that support remembering the past, imagining the future, and creating fictitious scenes remain active across conscious states of wake and sleep. Taken together, this evidence suggests that dreaming is a natural extension of waking conscious experience. This empirically supported conception of dreaming has important clinical applications concerning the “interpretability” of dreams in the therapeutic setting.

Keywords: dreams, mental imagery, memory, imagination, consciousness

The idea that dreams are distinct from waking cognition has been expressed in myriad forms throughout history. In ancient times, dreams were considered to be symbolic messages from the gods. In the early 20th century, Freudian and Jungian approaches considered dreams to be symbolic messages from an equally powerful and enigmatic unconscious. In each of these historical views of dreaming, dream images are elevated to a more “profound” and “meaningful” level than waking cognition. But is this assumption justified?

Even some more modern dream theories have presumed that dreams require special treatment relative to waking thought. In direct opposition to Freudian dream analysis is Alan Hobson’s highly influential “activation synthesis” model of dreaming (Hobson & McCarley, 1977). In this view, dreams are “hallucinations” produced from random neural firings in the brainstem during REM sleep. The cortex then “interprets” these random neural firings *after the fact*, as best as it can. Although still highly influential, this model has largely fallen out of favor as a result of evidence that dreams are also experienced throughout all stages of sleep, including the deepest stages of non-REM (NREM) sleep (Foulkes, 1962; Wamsley, 2014). But it is worth noting that activation synthesis maintained the assumption that dreams are unique from waking cognition. Here, dreams are considered to be highly chaotic, emotional, and bizarre, relative to waking thought (Hobson, Pace-Schott, & Stickgold, 2000). Thus, even in the first neurobiological theories of dreaming, dream content is considered to be categorically unique from waking cognition.

Yet recent research highlights fundamental similarities between dreaming and waking cognition at the phenomenological and neurobiological levels (Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013; Wamsley, 2014; Wamsley & Stickgold, 2010, 2011). At the phenomenological level, memories of waking experience are incorporated into dream content (Stickgold et al., 2000; Wamsley, Perry, et al., 2010; Wamsley, Tucker, et al., 2010). But dreams do not merely “replay” past experiences in original form. In both dreams and waking daydreams, recent and remote memory fragments combine to form novel imaginary scenar-

Yvette M. Graveline, Department of Psychology, University of Massachusetts, Amherstm, and Department of Psychology and Program in Neuroscience, Furman University; Erin J. Wamsley, Department of Psychology and Program in Neuroscience, Furman University.

Correspondence concerning this article should be addressed to Erin J. Wamsley, Furman University, Johns Hall 206K, Greenville, SC 29613. E-mail: erin.wamsley@furman.edu

ios, never before experienced by the dreamer (Stenstrom, Fox, Solomonova, & Nielsen, 2012; Wamsley, Perry, Djonlagic, Reaven, et al., 2010). As we will argue below, this spontaneous combining of recent and remote memory fragments into novel dream scenarios could be a direct reflection of ongoing memory processing during sleep (Wamsley, 2014; Wamsley & Stickgold, 2010, 2011).

There is also overlap between wake and sleep at the neurobiological level. Patterns of regional brain activity are strongly similar during waking rest and sleep. In wake and sleep, the activity of medial temporal and medial frontal memory networks, in concert with reduced executive control, allows the reactivation of past memory, as well as the creation of novel imaginative scenarios (Fox et al., 2013; Nir & Tononi, 2010; Wamsley, 2014; Wamsley & Stickgold, 2010). Such activity extends into sleep, and is therefore hypothesized to form the neural basis of novel dream scenarios (Domhoff, 2011; Fox et al., 2013; Nir & Tononi, 2010; Pace-Schott, 2013; Wamsley, 2014; Wamsley & Stickgold, 2010, 2011).

Importantly, there is a major difference between the "spontaneous" neural activity that is part of our conception of dreaming and the "random" neural activity of Hobson & McCarley's model (1977). The spontaneous neural activity that we refer to extends across sleep as well as wake, rather than just sleep alone. In addition, such activity is expressed at the level of large-scale brain networks rather than a single region such as the brainstem. Lastly, whereas Hobson and McCarley (1977) view dream imagery as a mere byproduct of random brain signals, we propose a tight functional link between dream imagery and neural activation linked to memory consolidation during sleep. Overall, we suggest that the spontaneously arising content of our waking thoughts and dreams may be a *direct* reflection of ongoing information processing at the neurobiological level, across wake and sleep (Wamsley, 2014; Wamsley & Stickgold, 2011).

Taken together, these findings suggest that our nightly dreams are not categorically distinct from waking cognition. On the contrary, the dreaming process appears to be an extension of our waking conscious experience (Wamsley, 2014; Wamsley & Stickgold, 2010, 2011). This view of dreaming as a natural extension of waking cognition contrasts with psychoanalytic conceptions of dreams as symbolically disguised expressions of unconscious wishes. In fact, we argue below that there is no compelling evidence that dreams can be usefully "interpreted" in clinical practice. Instead, dreaming is best viewed as a transparent reflection of waking thoughts, feelings, and memories.

Waking Experience, Memory Reactivation, and Dreams

Although the popular mantra "practice makes perfect" suggests that active rehearsal is the only way to build lasting memories, there is robust evidence that spontaneous activation of experience during sleep offers an important opportunity for memory processing. Human behavioral studies demonstrate that sleep facilitates memory performance across a wide variety of domains—that is, verbal (Tucker et al., 2006), emotional (Payne, Stickgold, Swanberg, & Kensinger, 2008), perceptual (Mednick et al., 2002), motor (Walker et al., 2002), and spatial (Wamsley et al., 2010). Meanwhile, single cell recordings in rodents demonstrate that waking spatial experiences are "replayed" in slow-wave-sleep (SWS) (Ji & Wilson, 2007; Kudrimoti et al., 1999; Lee & Wilson, 2002). Memory reactivation at the neural level has yet to be explored in humans, but memory-related brain regions are reactivated during sleep (and rest) after human learning as well (Laureys et al., 2001; Tambini, Ketz, & Davachi, 2010). This converging evidence suggests that memories are processed during sleep, which has important implications for the origin of dreaming.

There is evidence to suggest that memories of waking experience form the basis of mental imagery in dreams. First, we know that presleep learning experiences are incorporated into dreams. In the 1960s and 1970s, some of the earliest studies of how waking experience is incorporated into dream content found that, while experimental materials like films and images were not often directly incorporated into dream content (Wamsley & Stickgold, 2009), the laboratory experience *itself* was a powerful influence on dream content. For example, in an analysis combining data from several prior studies, Dement, Kahn, & Roffwarg (1965) found that 22% of dreams incorporated either isolated elements (10%) of the laboratory scenario or more complex representations combining multiple laboratory elements (12%). This could suggest that dreams are influenced by experiences that are especially novel and relevant to the individual. The real-life scenario of being in a novel laboratory setting, wearing electrodes, and being awakened multiple times throughout the night may have been incorporated into dream content because it was more novel, and more important to participants, than the passive viewing of the experimental films and images.

Indeed, a number of subsequent studies demonstrated that *novel learning experiences* have a particularly powerful effect on dream content. In early studies from Howard Roffwarg's laboratory (Bowe-Anders, Herman, & Roffwarg, 1974; Tauber, Roffwarg, & Herman, 1968) subjects wore red-tinted goggles for an extended period of time during wakefulness, which led to altered perceptual qualities during dreaming. Similar effects have been seen on the dreams of subjects who wore prism goggles that invert the visual field for an extended period of time during wakefulness (e.g., Corsi-Cabrera et al., 1986).

More recently, Stickgold et al. (2000) have demonstrated an influence of engaging video games on dream content. In one study, participants played the video game Tetris before falling asleep (Stickgold et al., 2000). Multiple dream reports were obtained during early non-REM (NREM) sleep awakenings. Here, it was found that 64% of participants reported Tetris images in their dreams. Kussé et al. (2012) later replicated this same basic effect of Tetris on sleep-onset dream imagery. Virtual navigation tasks and arcade games have also been used to successfully demonstrate the incorporation of a presleep learning experience on dreaming (Wamsley, Perry, et al., 2010; Wamsley, Tucker, et al., 2010). This evidence provides further support for the idea that novel, engaging learning experiences influence dream content.

Home-collected dream reports also demonstrate a clear effect of waking experience on dream content. In a study by Fosse et al. (Fosse, Fosse, Hobson, & Stickgold, 2003) subjects were asked to identify waking sources of dream elements from 299 home-collected dream reports. Fragments of recent experience frequently appeared in these types of dream reports. Of the 299 dream reports, 51% were judged by subjects to contain at least one element that was directly identifiable with a recent waking event. Other studies have similarly documented the incorporation of waking episodes into home-recalled dreams (Blagrove et al., 2011; Nielsen & Powell, 1988), especially for dreams recalled from NREM sleep (Baylor & Cavallero, 2001; Cavallero, Foulkes, Hollifield, & Terry, 1990). Thus, a link between daily experience and dreaming is evident.

Of course, these are not novel proposals. It has long been suggested that dreams are related to waking experience. But importantly, the popular conception of dreams remains stubbornly rooted in the idea of dreams as a mysterious phenomenon emerging from mechanisms entirely different from those that give rise to waking thought. In contrast, we will continue to argue that mental imagery in dreams originates from the same fundamental mechanisms that produce waking thought and waking memory.

Dreaming Reflects Memory Consolidation in the Sleeping Brain

The reactivation of memory during sleep is thought to lead to consolidation and enhanced memory. If memories are indeed being "replayed" during human sleep, one might predict that the content of dreams is a reflection of this process. Indeed, several studies demonstrate that dreaming about a recent learning experience is associated with improved memory for that information later on (De Koninck et al., 1990; Fiss et al., 1977; Wamsley et al., 2012; Wamsley & Stickgold, 2010). In a study by Fiss et al. (1977) for example, participants whose dreams related to a short story read before sleep exhibited better memory for that story the following day. In an academic setting, De Koninck found that students who demonstrated better language acquisition during a 6-week French language immersion course had a higher frequency of dreams that incorporated French into dream content (De Koninck et al., 1990). More recently, Wamsley et al. demonstrated that dreaming about a virtual maze navigation task is associated with memory improvements after a nap (Wamsley & Stickgold, 2010) or a full night of sleep (Wamsley et al., 2012). Collectively, this evidence suggests that dream content may reflect offline memory consolidation. Importantly, we do not imply that dreaming is the *cause* of memory consolidation. Rather, we suggest that dreams may reflect, at the phenomenological level, memory consolidation at the neurobiological level. However, despite this preliminary evidence, the connection between memory consolidation and dreaming has not yet been definitively demonstrated, and further research is needed.

Memory and Imagination Across Wake and Dreaming

We have suggested that dreams might reflect memory consolidation during sleep. But neither dreaming nor waking thought can be described as a simple "replay" of past experience. In waking moments of rest, memory fragments form the basis of novel imaginary constructs, as we daydream about possible future scenarios, and create entirely fictitious scenes in our minds during fantasy and creativity (Fox et al., 2013; Klinger, 1971; Singer, 1966). Similarly, during dreaming, disparate memory fragments combine in unique ways to form imaginary scenes, never before experienced by the dreamer (Nielsen & Stenstrom, 2005; Wamsley, 2014). This spontaneous evolution of memory at the phenomenological level during dreaming could be a reflection of the underlying process by which memories evolve into novel forms during sleep (Wamsley & Stickgold, 2011).

Although sleep has primarily been studied as a mechanism of enhancing memory and/or stabilizing it against the effects of interference, it has become increasingly evident that sleep plays a much more complex role than to simply cement experience in its original form. For example, as new word forms are learned, they come to interfere with existing lexical knowledge only after a period of sleep, demonstrating that the integration of new knowledge into existing networks is occurring during sleep (Dumay & Gaskell, 2007). Similarly, when new *semantic* information is learned (e.g., the *meaning* of a new word), the interference of this knowledge with existing sematic information is associated with particular features of the sleep EEG (Tamminen, Lambon Ralph, & Lewis, 2013). This gradual interleaving of new information with older memory is thought to require the formation of associations between related items, so that commonalities between those items can be represented in the cortex (Kumaran & McClelland, 2012; McClelland, 1995; Lewis & Durrant, 2011). Indeed, sleep has been demonstrated to play a role in associative memory (Tucker, Tang, Uzoh, Morgan, & Stickgold, 2011), in extracting relationships between items (Ellenbogen et al., 2006), and in facilitating generalization/gist extraction (Payne et al., 2009). Thus, sleep does not merely cement memory in its original form, but rather, facilitates the evolution of memory over time. Future research focused on the evolution of memory across offline periods of both sleep *and* resting wakefulness will be critical for understanding how memory evolves into novel forms across a continuum of conscious states (Wamsley, 2014).

Neurobiological Overlap Between Dreaming and Wakefulness

Dreaming and waking cognition also share a common neurobiological basis. Regional activation of networks involved in both memory and imagination may play a role in the process by which memories combine into fictitious scenarios during dreaming.

The default mode network (DMN) is hypothesized to support thought processes across conscious states of wake and sleep (Domhoff, 2011; Fox et al., 2013; Nir & Tononi, 2010; Pace-Schott, 2013; Wamsley, 2014; Wamsley & Stickgold, 2010, 2011). Most active during resting wakefulness, but relatively deactivated during task engagement (Buckner et al., 2008), this system consists of memory-related regions including the hippocampus, parahippocampus, ventromedial, and dorsomedial prefrontal cortices (collectively the mPFC), posterior cingulate cortices, retrosplenial, cortices, temporal-parietal junction, lateral temporal cortex, and temporal poles (Buckner et al., 2008). Although directly linked to spontaneous cognition during wakefulness (Andrews-Hanna, Reidler, Huang, & Buckner, 2010; Mason et al., 2007), indirect evidence suggests that the DMN may be involved in dreaming as well (Domhoff, 2011; Fox et al., 2013; Wamsley, 2014). Functional imaging studies reveal that memory-related regions of the DMN, including the hippocampus, parahippocampus, and medial prefrontal cortex (mPFC), are relatively active in the human brain during sleep (Braun et al., 1997; Maquet, 2000), even during non-REM (NREM) sleep (Nofzinger et al., 2002), and at greater levels in REM sleep relative to waking levels (Braun et al., 1997; Maquet, 2000). Interestingly, these regions are part of a subsection of the DMN—the "Scene Construction Network" (SCN) – which correlates with the ability to imagine both past and fictitious scenes (Hassabis, Kumaran, Maguire, 2007; Hassabis & Maguire, 2007, 2009; Mullally & Maguire, 2014). Although mere speculation at present, it is tempting to consider the possibility that the scene construction system might provide a neural basis for the generation of novel scenes during dreaming. At the moment, it is unclear whether functional imaging activity observed in both the DMN and SCN indicates actual *activation* as opposed to *inhibition* of these areas. Still, the involvement of both the DMN and SCN across wake and sleep hints at the potential involvement of these areas in the evolution of memory into novel forms across conscious states.

Are Dreams More Symbolic Than Waking Cognition?

To date, the idea that dreams contain a different kind of content than our waking thought still strongly colors perceptions and attitudes toward dreaming everywhere. Amazon.com sells more than 300 different "dictionaries" of dream symbols, each offering to decode the meanings of specific images, objects, and themes recalled from the reader's nightly reveries. Thousands of other popular books, emerging from diverse psychoanalytic, spiritual, supernatural, psychological, and new-age perspectives, promise to reveal the secrets of effective dream "interpretation" techniques, by various methods purporting to allow the reader understanding of some deeper meaning which their dreams are attempting to communicate. That said, is it really true that dreams are any more symbolic than our waking thoughts?

Contrary to popular opinion, there is actually no evidence that dream content is any more symbolic than our waking cognition. As we argue here, there is more evidence to suggest that dream content is continuous with waking thought. Rather than containing any special symbolism, it is actually far more likely that, similar to waking cognition, dream imagery is a relatively transparent amalgam of our daily thoughts, feelings, and experiences.

Applications for Clinical Practice: Do Dreams Have a "Meaning" That Can Be Interpreted?

A major chasm exists between experimental dream research and clinical practice. More than 100 years after Freud popularized his psychoanalytic dream theory, many clinical practitioners continue to presume that dreams consist of symbolic imagery that can be "interpreted." A striking number of clinicians employ discussion and interpretation of dreams as a part of their standard treatment approach. In a recent survey, across a broad sample of psychoanalytic and nonpsychoanalytic therapists, clinicians reported using the discussion of dreams in nearly 1/3 of sessions, on average (Schredl, Bohusch, Kahl, Mader, & Somesan, 2000). Yet there is no empirical evidence that dreaming is any more symbolic than other forms of mental experience.

In part, the persistence of dream analysis in clinical practice might stem from a valid intuition that dreaming provides a useful source of information about clients' personal lives. Indeed, a strong link between dreaming and waking life has been demonstrated experimentally, as we have reviewed above. However, the nature of this link is not captured by the "interpretive" approach to dreaming, which presumes that dreams conceal a hidden meaning that must be discovered through the therapeutic process. Although we do know that memories from waking experience are reflected in dreaming, the genuinely *empirical* study of dreaming is still too far in its infancy to say much more than that at this time. Furthermore, beyond concerns about the validity of dream interpretation, there is little evidence that dream analysis is therapeutically valuable. For example, in one study comparing the effects of dream therapy, event interpretation, and unstructured therapy sessions, all three types of treatments were found to be equally as effective (Diemer, Lobell, Vivino, & Hill, 1996). This evidence suggests that dream-centered therapy is not *uniquely* therapeutic per se, but rather, that simply talking about one's memories and future concerns in general can have a therapeutic effect.

So, do dreams have "meaning"? In summary, there is little evidence to suggest that dreaming, as opposed to waking thought or fantasy, is especially rich in symbolic meaning. Although discussing dreams with a therapist (or discussing the days events, for that matter) might make a patient feel better, there is no particular reason to think that dreams are harbingers of hidden messages that require expert decoding. However, although dreams may not disguise any "hidden" meaning, in the sense that advocates of interpretation propose, this does not preclude the possibility that dreams are nonetheless "meaningful" in a very different sense of the word. Dreams are certainly not random, uninteresting, or irrelevant to our lives. In fact, as we describe above, it is well established that people routinely dream of the persons, activities, and concerns which occupy them during waking life. Dreams incorporate fragments of recent and remote personal experiences and recombine these into novel creations reflecting (in a transparent fashion) the waking thoughts, experiences, and personality of the dreamer. In this broader sense, the search for meaning in dreams is certainly not futile.

Summary and Conclusions

In this review, we offer evidence for the perspective that dreaming is an extension of waking cognition. At the phenomenological level, both dreams and waking cognition contain a mixture of spontaneously arising thoughts, memories, and concerns. Subsequently, during both dreaming and wakefulness, memories combine spontaneously to provide the basis for novel imagined scenarios. At the neurobiological level, regional patterns of brain activity linked to memory and imagination are active in both waking rest and sleep. This suggests a possible neurobiological basis for the evolution of memory into novel imaginary forms throughout a continuum of conscious states. In light of this evidence, we argue against the perspective that dreams are "enigmatic" or "symbolic," thereby requiring special treatment in relation to waking cognition. On the contrary, we suggest that dreams are best viewed as a transparent reflection of our waking thoughts, memories, and concerns. In conclusion, we offer an evidence-based view of dreaming, that although devoid of the assumption that dreams are especially symbolic, still maintains that dreams, like our waking thoughts, are nonetheless relevant to the dreamer's life.

References

Andrews-Hanna, J. R., Reidler, J. S., Huang, C., & Buckner, R. L. (2010). Evidence for the default network's role in spontaneous cognition. *Journal of Neurophysiology, 104,* 322–335.

Baylor, G. W., & Cavallero, C. (2001). Memory sources associated with REM and NREM dream reports throughout the night: A new look at the data. *Sleep, 24,* 165–170.

Blagrove, M., Fouquet, N. C., Henley-Einion, J. A., Pace-Schott, E. F., Davies, A. C., Neuschaffer, J. L., & Turnbull, O. H. (2011). Assessing the dream-lag effect for REM and NREM stage 2 dreams. *PLoS ONE, 6,* e26708. http://dx.doi.org/10.1371/journal.pone.0026708

Bowe-Anders, C., Herman, J. H., & Roffwarg, H. P. (1974). Effects of goggle-altered color perception on sleep. *Perceptual and Motor Skills, 38,* 191–198. http://dx.doi.org/10.2466/pms.1974.38.1.191

Braun, A. R., Balkin, T. J., Wesenten, N. J., Carson, R. E., Varga, M., Baldwin, P., . . . Herscovitch, P. (1997). Regional cerebral blood flow throughout the sleep-wake cycle. An H2(15)O PET study. *Brain: A Journal of Neurology, 120,* 1173–1197. http://dx.doi.org/10.1093/brain/120.7.1173

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network: Anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences, 1124,* 1–38. http://dx.doi.org/10.1196/annals.1440.011

Cavallero, C., Foulkes, D., Hollifield, M., & Terry, R. (1990). Memory sources of REM and NREM dreams. *Sleep: Journal of Sleep Research & Sleep Medicine, 13,* 449–455.

Corsi-Cabrera, M., Becker, J., García, L., Ibarra, R., Morales, M., & Souza, M. (1986). Dream content after using visual inverting prisms. *Perceptual and Motor Skills, 63,* 415–423. http://dx.doi.org/10.2466/pms.1986.63.2.415

De Koninck, J., Christ, G., Hébert, G., & Rinfret, N. (1990). Language learning efficiency, dreams and REM sleep. *Psychiatric Journal of the University of Ottawa, 15,* 91–92.

Dement, W. C., Kahn, E., & Roffwarg, H. P. (1965). The influence of the laboratory situation on the dreams of the experimental subject. *Journal of Nervous and Mental Disease, 140,* 119–131.

http://dx.doi.org/10.1097/00005053-196502000-00002

Diemer, R. A., Lobell, L. K., Vivino, B. L., & Hill, C. E. (1996). Comparison of dream interpretation, event, interpretation, and unstructured sessions in brief therapy. *Journal of Counseling Psychology, 43,* 99–112. http://dx.doi.org/10.1037/0022-0167.43.1.99

Domhoff, G. W. (2011). The neural substrate for dreaming: Is it a subsystem of the default network? *Consciousness and Cognition, 20,* 1163–1174. http://dx.doi.org/10.1016/j.concog.2011.03.001

Dumay, N., & Gaskell, M. G. (2007). Sleep-associated changes in the mental representation of spoken words. *Psychological Science, 18,* 35–39. http://dx.doi.org/10.1111/j.1467-9280.2007.01845.x

Ellenbogen, J. M., Hulbert, J. C., Stickgold, R., Dinges, D. F., & Thompson-Schill, S. L. (2006). Interfering with theories of sleep and memory: Sleep, declarative memory, and associative interference. *Current Biology, 16,* 1290–1294. http://dx.doi.org/10.1016/j.cub.2006.05.024

Fiss, H., Kremer, E., & Litchman, J. (1977). The mnemonic function of dreaming. *Sleep Research, 6,* 122.

Fosse, M. J., Fosse, R., Hobson, J. A., & Stickgold, R. J. (2003). Dreaming and episodic memory: A functional dissociation? *Journal of Cognitive Neuroscience, 15,* 1–9. http://dx.doi.org/10.1162/089892903321107774

Foulkes, W. D. (1962). Dream reports from different stages of sleep. *Journal of Abnormal and Social Psychology, 65,* 14–25.

Fox, K. C. R., Nijeboer, S., Solomonova, E., Domhoff, G. W., & Christoff, K. (2013). Dreaming as mind wandering: Evidence from functional neuroimaging and first-person content reports. *Frontiers in Human Neuroscience, 7,* 412. http://dx.doi.org/10.3389/fnhum.2013.00412

Hassabis, D., Kumaran, D., & Maguire, E. A. (2007). Using imagination to understand the neural basis of episodic memory. *The Journal of Neuroscience, 27,* 14365–14374. http://dx.doi.org/10.1523/JNEUROSCI.4549-07.2007

Hassabis, D., & Maguire, E. A. (2007). Deconstructing episodic memory with construction. *Trends in Cognitive Sciences, 11,* 299–306. http://dx.doi.org/10.1016/j.tics.2007.05.001

Hassabis, D., & Maguire, E. A. (2009). The construction system of the brain. *Philosophical Transactions of the Royal Society of London Series B, Biological Sciences, 364,* 1263–1271. http://dx.doi.org/10.1098/rstb.2008.0296

Hobson, J. A., & McCarley, R. W. (1977). The brain as a dream state generator: An activation-synthesis hypothesis of the dream process. *The American Journal of Psychiatry, 134,* 1335–1348.

Hobson, J. A., Pace-Schott, E. F., & Stickgold, R. (2000). Dreaming and the brain: Toward a cognitive neuroscience of conscious states. *Behavioral and Brain Sciences, 23,* 793–842. http://dx.doi.org/10.1017/S0140525X00003976

Ji, D., & Wilson, M. A. (2007). Coordinated memory replay in the visual cortex and hippocampus during sleep. *Nature Neuroscience, 10,* 100–107. http://dx.doi.org/10.1038/nn1825

Klinger, E. (1971). *Structure and functions of fantasy*. New York, NY: Wiley.

Kudrimoti, H. S., Barnes, C. A., & McNaughton, B. L. (1999). Reactivation of hippocampal cell assemblies: Effects of behavioral state, experience, and EEG dynamics. *The Journal of Neuroscience, 19,* 4090–4101.

Kumaran, D., & McClelland, J. L. (2012). Generalization through the recurrent interaction of episodic memories: A model of the hippocampal system. *Psychological Review, 119,* 573–616. http://dx.doi.org/10.1037/a0028681

Kussé, C., Shaffii-LE Bourdiec, A., Schrouff, J., Matarazzo, L., & Maquet, P. (2012). Experience-dependent induction of hypnagogic images during daytime naps: A combined behavioural and EEG study. *Journal of Sleep Research, 21,* 10–20. http://dx.doi.org/10.1111/j.1365-2869.2011.00939.x

Laureys, S., Peigneux, P., Phillips, C., Fuchs, S., Degueldre, C., Aerts, J., . . . Maquet, P. (2001). Experience-dependent changes in cerebral functional connectivity during human rapid eye movement sleep. *Neuroscience, 105,* 521–525. http://dx.doi.org/10.1016/S0306-4522(01)00269-X

Lee, A. K., & Wilson, M. A. (2002). Memory of sequential experience in the hippocampus during slow wave sleep. *Neuron, 36,* 1183–1194. http://dx.doi.org/10.1016/S0896-6273(02)01096-6

Lewis, P. A., & Durrant, S. J. (2011). Overlapping memory replay during sleep builds cognitive schemata. *Trends in Cognitive Sciences, 15,* 343–351. http://dx.doi.org/10.1016/j.tics.2011.06.004

Maquet. (2000). Functional neuroimaging of normal human sleep by positron emission tomography. *Journal of Sleep Research, 9,* 207–231. http://dx.doi.org/10.1046/j.1365-2869.2000.00214.x

Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C. N. (2007). Wandering minds: The default network and stimulus-independent thought. *Science, 315,* 393–395. http://dx.doi.org/10.1126/science.1131295

McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review, 102,* 419–457. http://dx.doi.org/10.1037/0033-295X.102.3.419

Mednick, S. C., Nakayama, K., Cantero, J. L., Atienza, M., Levin, A. A., Pathak, N., & Stickgold, R. (2002). The restorative effect of naps on perceptual deterioration. *Nature Neuroscience, 5,* 677–681.

Mullally, S. L., & Maguire, E. A. (2014). Memory, imagination, and predicting the future: A common brain mechanism? *The Neuroscientist, 20,* 220–234. http://dx.doi.org/10.1177/1073858413495091

Nielsen, T. A., & Powell, R. A. (1988). Longitudinal dream incorporation: Preliminary evidence of cognitive processing with an infradian period. *Sleep Research, 17,* 112.

Nielsen, T. A., & Stenstrom, P. (2005). What are the memory sources of dreaming? *Nature, 437,* 1286–1289. http://dx.doi.org/10.1038/nature04288

Nir, Y., & Tononi, G. (2010). Dreaming and the brain: From phenomenology to neurophysiology. *Trends in Cognitive Sciences, 14,* 88–100. http://dx.doi.org/10.1016/j.tics.2009.12.001

Nofzinger, E. A., Buysse, D. J., Miewald, J. M., Meltzer, C. C., Price, J. C., Sembrat, R. C., . . . Moore, R. Y. (2002). Human regional cerebral glucose metabolism during non-rapid eye movement sleep in relation to waking. *Brain: A Journal of Neurology, 125,* 1105–1115. http://dx.doi.org/10.1093/brain/awf103

Pace-Schott, E. F. (2013). Dreaming as a story-telling instinct. *Frontiers in Psychology, 4,* 159. http://dx.doi.org/10.3389/fpsyg.2013.00159

Payne, J. D., Schacter, D. L., Propper, R. E., Huang, L.-W., Wamsley, E. J., Tucker, M. A., . . . Stickgold, R. (2009). The role of sleep in false memory formation. *Neurobiology of Learning and Memory, 92,* 327–334. http://dx.doi.org/10.1016/j.nlm.2009.03.007

Payne, J. D., Stickgold, R., Swanberg, K., & Kensinger, E. A. (2008). Sleep preferentially enhances memory for emotional components of scenes. *Psychological Science, 19,* 781–788. http://dx.doi.org/10.1111/j.1467-9280.2008.02157.x

Schredl, M., Bohusch, C., Kahl, J., Mader, A., & Somesan, A. (2000). The use of dreams in psychotherapy: A survey of psychotherapists in private practice. *Journal of Psychotherapy Practice & Research, 9,* 81–87.

Singer, J. L. (1966). *Daydreaming: An introduction to the experimental study of inner experience*. New York: Random House.

Stenstrom, P., Fox, K., Solomonova, E., & Nielsen, T. (2012). Mentation during sleep onset theta bursts in a trained participant: A role for NREM stage 1 sleep in memory processing? *International Journal of Dream Research, 5,* 37–46.

Stickgold, R., Malia, A., Maguire, D., Roddenberry, D., & O'Connor, M. (2000). Replaying the game: Hypnagogic images in normals and amnesics. *Science, 290,* 350–353. http://dx.doi.org/10.1126/science.290.5490.350

Tambini, A., Ketz, N., & Davachi, L. (2010). Enhanced brain correlations during rest are related to memory for recent experiences. *Neuron, 65,* 280–290. http://dx.doi.org/10.1016/j.neuron.2010.01.001

Tamminen, J., Lambon Ralph, M. A., & Lewis, P. A. (2013). The role of sleep spindles and slow-wave activity in integrating new information in semantic memory. *The Journal of Neuroscience, 33,* 15376–15381. http://dx.doi.org/10.1523/JNEUROSCI.5093-12.2013

Tauber, E. S., Roffwarg, H. P., & Herman, J. (1968). The effects of longstanding perceptual alterations on the hallucinatory content of dreams. *Psychophysiology, 5,* 219.

Tucker, M. A., Hirota, Y., Wamsley, E. J., Lau, H., Chaklader, A., & Fishbein, W. (2006). A daytime nap containing solely non-REM sleep enhances declarative but not procedural memory. *Neurobiology of Learning and Memory, 86,* 241–247. http://dx.doi.org/10.1016/j.nlm.2006.03.005

Tucker, M. A., Tang, S. X., Uzoh, A., Morgan, A., & Stickgold, R. (2011). To sleep, to strive, or both: How best to optimize memory. *PloS One, 6,* e21737. http://dx.doi.org/10.1371/journal.pone.0021737

Walker, M. P., Brakefield, T., Morgan, A., Hobson, J. A., & Stickgold, R. (2002). Practice with sleep makes perfect: Sleep-dependent motor skill learning. *Neuron, 35,* 205–211. http://dx.doi.org/10.1016/S0896-6273(02)00746-8

Wamsley, E. J. (2014). Dreaming and offline memory consolidation. *Current Neurology and Neuroscience Reports, 14,* 433. http://dx.doi.org/10.1007/s11910-013-0433-5

Wamsley, E. J., Nguyen, N. D., Tucker, M. A., Olsen, A., & Stickgold, R. (2012). EEG correlates of overnight memory consolidation in a virtual navigation task. *Sleep, 35,* A86.

Wamsley, E. J., Perry, K., Djonlagic, I., Reaven, L. B., & Stickgold, R. (2010). Cognitive replay of visuomotor learning at sleep onset: Temporal dynamics and relationship to task performance. *Sleep: Journal of Sleep and Sleep Disorders Research, 33,* 59–68.

Wamsley, E. J., & Stickgold, R. (2009). Incorporation of waking events into dreams. In R. Stickgold & M. P. Walker (Eds.), *The neuroscience of sleep* (pp. 330–336). London, UK: Academic Press. http://dx.doi.org/10.1016/B978-0-12-375073-0.50050-6

Wamsley, E. J., & Stickgold, R. (2010). Dreaming and offline memory processing. *Current Biology, 20,* R1010–R1013. http://dx.doi.org/10.1016/j.cub.2010.10.045

Wamsley, E. J., & Stickgold, R. (2011). Memory, sleep and dreaming: Experiencing consolidation. *Sleep Medicine Clinics, 6,* 97–108. http://dx.doi.org/10.1016/j.jsmc.2010.12.008

Wamsley, E. J., Tucker, M., Payne, J. D., Benavides, J. A., & Stickgold, R. (2010). Dreaming of a learning task is associated with enhanced sleep-dependent memory consolidation. *Current Biology, 20,* 850–855. http://dx.doi.org/10.1016/j.cub.2010.03.027

Received March 31, 2014
Revision received October 28, 2014
Accepted October 29, 2014 ■