# Animal models of sleep pertaining to dream research

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Dreaming and the neurological mechanisms of sleep, as well as sleep disorders, are frequently studied independently as separate fields of research. Although many facets of the neurophysiology of sleep have been uncovered, the purpose/function of dreaming (as well as sleep-onset mentation) has remained elusive - partly due to the problem that dreams cannot be directly observed by experimenters. Although animal models have been useful for uncovering nuclei responsible for the mediation of different sleep states, these techniques are rarely viable methods for studying mentation during sleep (both because of ethical considerations, and because animals cannot report the content of their dreams). Findings from animal studies are often neglected rather than used to inform dream research conducted with human subjects. However, examining the overlap between the two fields may reveal insights that both illuminate the mechanisms underlying dreaming and provide direction/targets for future research.

Some notable examples where overlap can be found are studies of REM generation, the systems attributable to REM muscle atonia, and their dysfunction as it relates to conditions such as REM behavior disorder (RBD). Although in the absence of clinical relevance ethical considerations may not allow for animal studies to directly address sleep mentation, an examination of areas of overlap between animal models of RBD and dream generation may provide useful insights into the neurobiology of dreaming. In humans, RBD is a disorder characterized by lack of muscle atonia during REM sleep, causing sufferers to act out their dreams (often exhibiting violent or aggressive behaviors during periods of REM; Schenk, Bundlie, Ettinger, & Mahwold, 1986). In 1965, Jouvet & Delorme demonstrated that REM muscle atonia could be inhibited in cats following lesions to the sublateral-dorsal tegmental nucleus (SLD). The resulting effect was behavior during REM periods when mammals normally experience complete paralysis (REM muscle atonia). The demonstration revealed two key findings: 1) animals may share some commonality in sleep mentation with humans, since they exhibit behavior that resembles human RBD in the absence of REM paralysis, and 2) that cognitive activity during sleep as a function of the brain in felines is probably controlled by a mechanism which is independent of SLD neuron populations responsible for REM muscle atonia (since lesions yielded an absence of REM atonia, but cognitive activity during sleep appeared to persist).

Further research suggests RBD in humans is associated with neuronal cell loss in regions proximal to the pontine brainstem (Luppi et al., 2011). Additionally, distinct populations of SLD neurons with ascending/descending projections are thought to differentially control cortical activation during REM sleep and REM muscle atonia (Sakai, Crochet, & Onoe, 2001; Sakai & Koyama, 1996). Since evidence suggests cortical activity may be predictive of dream content (see Erlacher, Schredl, & Laberge, 2003; Fernandes & Paiva, 2010; Horikawa et al., 2013), it may be that ascending cholinergic SLD neuron projections mediate REM and dreaming (similarly to what was suggested by Hobson's "activation synthesis" hypothesis, 1991), but that descending SLD efferents mediate REM muscle atonia largely independently.

Further examples of overlap between animal models of sleep neurophysiology and dream research include studies of hippocampal activity during other sleep states. Louie and Wilson (2001), for example, sought to examine the patterns of hippocampal neuronal activity during sleep and waking behavior of rats. Neuronal activity in the CA1 region of the hippocampus during waking learning is followed by subsequent temporally sequenced firing during REM. Similar patterns of temporally sequenced neuronal re-activation during sleep have also been observed during slow-wave sleep (Lee & Wilson, 2002). The CA1 region of the hippocampus region is known to play a role in memory formation and consolidation, and neuronal re-activation that mimics firing patterns observed during waking-day learning. This suggests re-activation of neural traces during sleep may play a role in consolidation of newly acquired memories. Temporally sequenced firing during REM may therefore be a viable target for future research which may shed light on underlying processes associated with REM dreaming and memory.

Although animal models can provide significant insight into neurological mechanisms that may be associated with human dreaming, however, caution should be taken with regards to generalizing because of inter-species differences in neural structure and function. For example, while research suggests there is similarity in phasic muscle activity during REM sleep between species, discrepancies exist in REM-associated neurotransmission. Cholinergic agonists associated with REM sleep may have a more pronounced effect in cats than rodents (Sakai & Koyama, 1996; Mansari, Sakai, Jouvet, 1990, Luppi, Sakai, Fort, Salvert & Jouvet, 1988). Microinjection of cholinergic agonist carbachol into the posterior oral pontine nucleus (PnO) has been shown to produce REM in cats, but studies involving rats resulted

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Submitted for publication: September 2015
Accepted for publication: October 2015

either in only moderate REM activation or no effect (Bourgin, Escourrou, Gaultier & Adrien, 1995; Deurveilher, Hars & Hennevin, 1997; George, Haslett, & Jenden, 1964). Evidence therefore points to significant differences between the REM-related projections of the brainstem between cats and rodents (Luppi et al., 2011). Similarly, findings from human studies suggests that (contrary to what animal models might have suggested) brainstem lesions in humans do not significantly attenuate sleep mentation even though REM may be affected (see Solms, 2001), highlighting the need for caution in generalizing findings across species.

Regardless of the cautions necessary while generalizing findings, some findings may reflect underlying processes which are shared among humans and other species. The areas of overlap between animal models of sleep states and sleep disorders may therefore provide useful insights into the neurobiology of dreaming, and should be considered as a driving force behind future research targets.

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