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Sleep: Keeping One Eye Open

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Unihemispheric sleep, during which one half of the brain sleeps while the other half remains awake, is seen in some aquatic mammals and birds, particularly in risky situations. It now appears that humans sleeping in unfamiliar environments do something quite similar.

Sleep and wakefulness were once thought to be mutually exclusive states. It is now well-established that aquatic mammals, birds and possibly even reptiles [1] can sleep with one eye open and the brain hemisphere that controls it awake. In cetaceans, eared seals and manatees, unihemispheric sleep prevents drowning by allowing these aquatic mammals to continue swimming and to surface to breathe while asleep. In birds, the evolutionary value is different. During long migratory flights, unihemispheric sleep may allow birds to navigate and maintain vigilance. When ducks settle down for the night near a pond, those on the outer edge of the group are far more likely to keep their outward eye open and on the lookout, and the corresponding brain hemisphere awake, than those in the center of the group, who confidently close both eyes (Figure 1) [2]. This allows those on the outer edge to protect the flock from predators. Now, a new study by Tamaki and colleagues reported in this issue of *Current Biology* [3] shows that under conditions of potential threat humans may do something similar.

Figure 1. Ducks sleeping with one eye open.
(Photo credit: Durim Beqiraj.)

Tamaki and colleagues used the ‘first night effect’ as a model for potential threat. During the first night (or nap) in a new environment, in this case a sleep laboratory, sleep is often more elusive, shallower, and more fragmented than on subsequent nights. For this reason, many sleep studies write off the first night as an adaptation night and only use data from the subsequent nights. Rather than discarding the first night’s sleep data, this study examined how it differed from sleep on a second night in the lab, and found hemispheric asymmetries in brain activity that were present only on the first night.

To measure brain activity, the authors used both electroencephalography (EEG) and magnetoencephalogy (MEG) — a technique that measures the magnetic fields on the scalp that are generated by neuronal activity. When they compared MEG recordings of non-rapid eye movement sleep from the first two nights in the lab, they found a hemispheric asymmetry in slow wave activity only on the first night. Slow wave activity reflects the depth of sleep and on the first night it was lower in the left hemisphere than in the right hemisphere, and lower than slow wave activity in either hemisphere on the second night.

More specifically, this decrease in slow wave activity was seen in a set of functionally and structurally connected brain regions collectively known as the default network. Participants with greater slow wave asymmetry in this network took longer to fall asleep — a behavioral indication of arousal/anxiety and a key component of the first night effect. These results suggest that the left hemisphere was not sleeping as deeply on the first night and that this underlies the first night effect.

But is the left hemisphere actually more vigilant when sleeping in a new environment? To answer this question, the authors played a series of repeating tones to napping participants, with an occasional ‘oddball’ tone that was different from the others thrown in. The amplitude of the brain response to oddball tones is considered to index vigilance. During the first nap, the brain response was about three times greater to oddball tones presented to the right ear (and left hemisphere) than to the left ear (and right hemisphere), and was greater than the response to oddball tones presented to either ear during the subsequent nap. Participants were also almost six times more likely to have a brief arousal after an oddball played to the right ear than to the left during the first nap. Finally, study participants were asked to tap their fingers if they heard sounds while they were napping. On the first nap only, more subjects were awakened and responded to tones presented to their right ear than their left. There were no significant asymmetries during the second nap. These findings suggest that the left hemisphere *is* more vigilant and easily aroused when sleeping in a new environment.

The authors conclude that the shallower sleep in the default network, increased vigilance, and increased responsiveness of the left hemisphere mediate first night effects and serve to protect the sleeper in a potentially dangerous environment. While not the complete asymmetry seen in birds and other mammals, with one hemisphere awake and the other asleep, this is the first demonstration of hemispheric differences in sleep depth in humans. These findings imply that varying degrees of hemispheric asymmetry in sleep may be present throughout the animal kingdom, whenever it offers survival value.

A few puzzles remain. Why were asymmetries seen in the default network and not the attention network or other intrinsic brain networks? Functional connectivity MRI studies consistently reveal a set of distinct networks that reflect the highly organized patterns of spontaneous activity that the human brain sustains when not engaged in goal-directed behavior [4]. These intrinsic networks are defined based on correlated activity during wakeful rest, but are also observable during sleep [5]. The default network typically shows increased functional MRI activation when not engaged in an overt task and deactivation during effortful task performance. This pattern of activity supports the theory that the default network monitors the internal milieu of thoughts, feelings, memories and plans for the future, and not the external world [6]. This inner focus seems incompatible with a role as a night watch for external threats. But when the default network was first identified, it was thought to maintain continuous alertness to potential threats from the environment, except when successful task performance demanded focused attention [7], a conceptualization more compatible with keeping a vigil during sleep. But what is the functional significance of reduced slow wave activity in the default mode network? How might this help it serve as a night watch? And if the purpose of the night watch is to scan the environment for threats, why is it the left hemisphere that is more vigilant, when the right hemisphere is dominant for spatially-directed attention [8]?

Despite the apparent utility of maintaining some vigilance while asleep, there are costs as well. Aside from the most obvious consequences of a poor night of sleep (e.g., fatigue), there are impairments of normal sleep functions ranging from memory processing to immune and endocrine functions to the clearance of waste products from extracellular space in the cortex [9]. The benefits of vigilance may only outweigh the costs under circumstances involving necessity, such as sleeping at sea, or in the case of self-preservation, as seen in ducks and, apparently, us.

REFERENCES

1. Kelly, M.L., Peters, R.A., Tisdale, R.K., and Lesku, J.A. (2015). Unihemispheric sleep in crocodilians? J. Exp. Biol. *218*, 3175–3178.
2. Rattenborg, N.C., Lima, S.L., and Amlaner, C.J. (1999). Facultative control of avian unihemispheric sleep under the risk of predation. Behav. Brain Res. *105*, 163–172.
3. Tamaki, M., Bang, J.W., Watanabe, T., and Sasaki, Y. (2016). Night watch in one brain hemisphere during sleep associated with the first-night effect in humans. Curr. Biol. *26*, 1190–1194.
4. Smith, S.M., Fox, P.T., Miller, K.L., Glahn, D.C., Fox, P.M., Mackay, C.E., Filippini, N., Watkins, K.E., Toro, R., Laird, A.R., *et al.* (2009). Correspondence of the brain’s functional architecture during activation and rest. Proc. Natl. Acad. Sci. USA *106*, 13040–13045.
5. Larson-Prior, L.J., Power, J.D., Vincent, J.L., Nolan, T.S., Coalson, R.S., Zempel, J., Snyder, A.Z., Schlaggar, B.L., Raichle, M.E., and Petersen, S.E. (2011). Modulation of the brain’s functional network architecture in the transition from wake to sleep. Prog. Brain Res. *193*, 277–294.
6. Buckner, R.L., Andrews-Hanna, J.R., and Schacter, D.L. (2008). The brain’s default network: anatomy, function, and relevance to disease. Ann. N.Y. Acad. Sci. *1124*, 1–38.
7. Raichle, M.E., MacLeod, A.M., Snyder, A.Z., Powers, W.J., Gusnard, D.A., and Shulman, G.L. (2001). A default mode of brain function. Proc. Natl. Acad. Sci. USA *98*, 676–682.
8. Mesulam, M.-M. (1981). A cortical network for directed attention and unilateral neglect. Ann. Neurol. *10*, 309–325.
9. Stickgold, R.S. (2015). Sleep on it! Sci. Am. *313*, 52–57.