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Awake or dreaming: how brain 'noise' tells the difference

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Monitoring brain electrical activities helps us discern brain states. But understanding how we sleep is not easy. While deep dreamless sleep brings easily recognized rhythmic electrical waves, light dream sleep shows arrhythmic patterns and looks similar to wakefulness. We discover that the often-ignored background brain 'noise' can help distinguish these similar brain states.

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We spend almost one-third of our lives asleep, being disconnected from the world and seemingly 'inactive'. But sleeping is not a waste of time – it is essential for maintaining both our body and mind in good shape. Indeed, sleep is an exceptionally complex biological process, and we are far from figuring out its entire picture.

While sleeping, our body undergoes several cycles between two distinct sleep stages: deep, mostly dreamless sleep and light sleep where vivid dreams occur. As the sleep cycle is closely associated with the quality of sleep and overall mental and physical health, monitoring it provides a powerful way to diagnose health status and diseases.

Unfortunately, we cannot simply talk to a sleeping person and ask how it's going. But, the sleeping brain sends us messages alternatively. These messages are electrical activities in the brain and we can read them by recording electrical signals from the scalp using a technique called electroencephalography. We then use this information to track sleep cycles. Electrical brain activity shows two major patterns: rhythmic brain waves and arrhythmic background. Rhythmic brain waves can be easily recognized as distinct electrical signals, while the arrhythmic background signals are often considered 'noise' that provides no useful diagnostic information.

Unlike deep dreamless sleep and anesthesia that show rhythmic electric brain waves, light dream sleep brings only arrhythmic 'noise'. Strangely, the electrical brain activity during light dream sleep even looks nearly the same as that during being awake, although the person is actually sleeping! In other words, we cannot discern if he or she is awake or dreaming simply looking at electrical brain activity. Therefore, people have traditionally observed eye movements to distinguish light dream sleep from wakefulness – and this is why this sleep stage is alternatively called rapid eye movement sleep. But, is the brain 'noise' – usually discarded as meaningless background – really useless? What if this brain 'noise' contains important information about the underlying brain state, which would perhaps help us distinguish wakefulness and dream sleep?

In this study, to decode the hidden message of this 'noise', we set out to in-depth investigate the often-overlooked arrhythmic part of electrical brain activity. We recorded electroencephalography from people during wakefulness, sleeping, and general anesthesia. Besides recording the electrical signals from the scalp, we had a precious chance to perform measurements inside patients' brain, right before they underwent a planned brain surgery.

Using this approach and new analysis tools, we successfully detected noisy signals both outside and inside the brain. Notably, inside the brain, we saw intricate patterns of changing brain noise during sleep, especially in deep brain regions important for memory where the classic scalp-based method cannot reach. We found that brain noise differed depending on brain states, and importantly, the noise pattern was very different between wakefulness and all the examined unconscious brain states (anesthesia, deep sleep and dream sleep).

We thus developed a new technique to discern wakefulness from the similar-looking brain state of light dream sleep, based solely on the 'noise' in electrical brain activities. This technique may soon replace the traditional way of identifying light dream sleep based on eye movements.
Moreover, the brain noise readings could potentially be used for many clinical applications – for instance, the automation of monitoring of brain states and sleep stages during deep unconsciousness states like anesthesia and coma.

We have not yet completely understood what the brain 'noise' actually is. It possibly reflects balance in a brain's activity: an equilibrium between activation and inactivation of circuits of neurons (or nerve cells) that allow exchanging information between brain areas. This balance moves towards neural inactivation during general anesthesia or sleep and towards neural activation in wakefulness. Therefore, the different noise levels between light dream sleep and wakefulness may suggest that light dream sleep is associated with a stronger inactivation, keeping you from acting out your dreams. Testing this hypothesis will be an exciting topic for future study and perhaps open a new avenue for unraveling the mystery of sleep.