

# Snooze control

23 February 2002 by [Michael Brooks](#)

AH, THE joys of a good night's sleep. Eight hours of blissful, uninterrupted shut-eye. Except it never happens.

None of us just hits the pillow and lies comatose till morning. Even a normal, healthy sleeper will wake up between 15 and 35 times each night. That's not usually a problem. Healthy sleepers hardly notice they've woken up before their bodies pull them back to sleep. But, for some people, trying to sleep is a waking nightmare. As many as 10 per cent of the adult population suffer from more extreme sleep-wake disturbances, which leave them constantly tired.

Compared with other branches of medicine, our understanding of sleep is pretty basic, and treating sleep problems is a slow process. Night after night, at sleep clinics like the one run by Thomas Penzel and Jörg-Hermann Peter at the University of Marburg, researchers record and analyse the sleep habits and the vital signs—such as blood pressure, heart rate, breathing rates and so on—of people with sleep problems, hoping to see something that will help them diagnose a particular ailment.

Occasionally, though, they have a happier task: logging the vital signs of people who sleep soundly. Penzel and Peter used to work out the proportion of the night these healthy sleepers would spend asleep and awake, and use that as a control against which to measure the problems of their patients. But that simple view came to an end a couple of years ago, when Penzel met Plamen Ivanov, a Boston University physicist.

Ivanov works in a research group that has an almost unhealthy obsession with details. Its members are experts in signal analysis, looking for hidden patterns in just about every place they can think of:

the heart, the Earth's crust, financial markets. You name it, and they'll find the pattern in its behaviour.

Between them, Ivanov and Penzel began to think there might be undiscovered patterns in the way we sleep at night, and that they might provide a new way of diagnosing and treating sleeping disorders. They and their colleagues have encapsulated these ideas in a paper published in *Europhysics Letters* this month.

To Ivanov, sleep is made up of events whose frequency you can plot mathematically, just as you can plot the severity of earthquakes. You can take all the earthquakes on the planet for one year, for example, and plot the frequency for each magnitude of earthquake against the magnitude itself. The result is a curve that shows the exact relationship between the size and how often it occurs. With earthquakes, the kind of curve you get is called a power law: the frequency of the quakes falls off in inverse proportion to their magnitude raised to some power. Movements on the stock market behave the same way. But with other phenomena, such as the intervals between signals in human neurons, the frequency decays exponentially instead.

It sounds like an obscure distinction, but it is actually profound. Exponential curves have an inbuilt scale factor: the size jump over which the frequency falls by half is the same no matter where you take your starting point. For power laws this doesn't apply.

This kind of analysis could be just the thing to sort out the problem of a bad night's sleep. Graduate student Chung Chuan Lo got the job of analysing Penzel's sound sleepers. He looked at the length and number of waking periods through the night, and plotted their frequency against how long they lasted. Then he did the same for periods of sleep.

Lo discovered that the waking periods followed a power-law relationship, while the sleep times are exponential. To his colleagues,

that was absolutely amazing. In all their years of analysis, the Boston researchers had never before come across a case in which both patterns arise in one system. Normally it's always one or the other. Having discovered this intriguing behaviour, they felt compelled to find out what was at the root of it, and what it might reveal about how sleep works. So they began to build a model.

Scans of brainwave patterns indicate that there are certain distinct sleep states: REM sleep, which usually coincides with dreaming, two other light sleeping states, and two deep states. So they divided the slumber spectrum into a few sleep "microstates". It also seems reasonable that there are many different degrees of waking, from barely conscious to fully alert, so they put a whole set of different waking microstates into the model.

The next stage was based on the latest biological thinking about sleep. A collaboration between Swiss and French neurobiologists published a couple of years ago found that sleep is essentially a battle in the brain between sleep-promoting and wake-inducing neurons (Nature, vol 404, p 6781). For their model, the Boston researchers assumed that the result of this complex chemical battle is a kind of random walk: one step towards awake, three steps back towards sleep, another couple of steps back towards wakefulness, and so on in a random pattern.

And that nightly tug of war must be one-sided—a stronger force pulls healthy sleepers back to the land of nod than pulls them awake. So it is common to hit the deepest limit of sleep, but rare that the random walk will fully wake you. "Each time the brain enters the wake state, it is pulled back to sleep quickly," Lo says.

The researchers incorporated all this in an equation and looked to see if it modelled the way people drift in and out of sleep. As they had hoped, it produced the same sleep patterns as the doctors saw in real people—including the all-important mixture of power law and exponential distribution. To the Boston researchers, this is a sign that

their model reflects the processes behind sleep.

## Night dreaming

But it's not proof. Peretz Lavie, a sleep researcher at Technion in Israel, says that the Boston model is not the only approach that could explain the strange dynamics. He thinks that alternatives might concentrate on the transition from and to REM sleep, which occurs roughly every 90 minutes and is where most of our brief awakenings are clustered.

The Boston team admit that their model is crude and that it will be hard to test the assumptions it's based on, but they still believe it is going to be extremely useful. "It's a toy model," says Ivanov. "But it is the first one to give a rough idea and explanation for a very complex and intriguing phenomenon." And it might have some strange implications.

If sleep really is a random walk, there can be no link between the length of one sleeping period and the length of the waking period that follows. There would also be no correlation between the length of one wake period and the next, or one sleep period and the next. It could explain why you sometimes wake up for no apparent reason, and why people's sleep behaviour is so varied. Light sleepers presumably have too weak a team of sleep neurons. Those who quickly drift off again even after being shaken awake might be blessed with a beefier bunch.

The Boston model is already providing a new set of tools for sleep researchers. The team has looked at sleep apnoea, in which patients have breathing problems that cause them to wake up frequently. Not surprisingly, they saw more short waking periods than normal, but there were also fewer long waking periods. This kind of shift may provide a new way to characterise sleep apnoea, and may also help researchers find out more about how the body responds to such problems. The pattern might indicate, for example, that the sleep neurons tug harder to compensate for the frequent waking.

Back at the Marburg clinic, psychiatrist and neuroscientist Martin Huber is interested in using the analysis to diagnose disorders such as depression that affect moods and feelings. "A disorder of sleep structure is very common in affective disorders," he says. Huber hopes eventually to match different sleep patterns with particular diseases. That might even allow doctors to diagnose diseases before other symptoms show up.

Ivanov is collaborating with Huber to look at how drugs affect sleep patterns. They believe some drugs may limit the number of available wake microstates. It's possible that you may hit your peak wakefulness during a night's sleep, shifting your wake state away from power-law behaviour. Looking for such a shift might provide a way to monitor the side-effects of medications.

All these efforts will, in turn, help refine the Boston researchers' model of sleep. Once a disease or a drug can be linked to a particular sleep pattern, whatever is known about that disease or drug's effects on our bodies should suggest ways to alter the model and faithfully reproduce the altered sleep patterns. As the model improves, it might be possible to see how other, subtle physiological changes affect our sleep.

The researchers are confident they have found an important new path into the relatively unexplored field of sleep. They have certainly made one thing clear: sleep is more than a welcome switch-off at the end of each day. It is a game of chance, a means of diagnosing illness, and a strange new phenomenon in physics. Really, it's enough to keep you awake at night.

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