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BIOLOGICAL RHYTHMS

Human sleep before the industrial era

A quantitative study of sleep patterns in three pre-industrial societies implies that our natural sleep duration is close to seven hours, and that sleep cycles are determined by environmental temperature as well as the light–dark cycle.

DERK-JAN DIJK & ANNE C. SKELDON

How much sleep do we need? What time should we start school or work so that we are in tune with our body clocks? These are topical questions, and hardly a week goes by without media reports about the importance of sleep and daily rhythms for physical and mental health. The suggestion is that our modern sleep patterns are muddled. But what are our natural sleep patterns, and how are they influenced by environmental factors? What is the benchmark for 'good' sleep? Writing in *Current Biology*, a team of sleep neuroscientists and anthropologists (Yetish *et al.*[1]) reports a study of sleep patterns in three hunter-gatherer and hunter-horticulturist groups. During the study, and as is usual for these communities, none of the participants had access to electricity, and the only sources of light, apart from the Sun and Moon, were small fires.

The study participants came from the Hadza group in Tanzania, the Ju/'hoansi San in Namibia and the Tsimane' in Bolivia. The authors monitored the participants' sleep over several days or weeks using activity and light recorders, and found that the average sleep duration across the three groups — the interval between sleep onset and sleep end — was 7.7 hours (Fig. 1). Subtracting the awakenings that occur during the night left an average total sleep time of only 6.4 hours. How does this compare with sleep in modern industrialized societies that use electricity daily? The embarrassing answer is: we don't really know, because most estimates of sleep duration are based on self reports rather than the objective measures used by Yetish and colleagues. However, the self-reported average sleep duration in modern industrialized groups is around 7–7.5 hours, and although it depends on the day of the week and the age of the individual[2,3], it differs little from that found in this study.

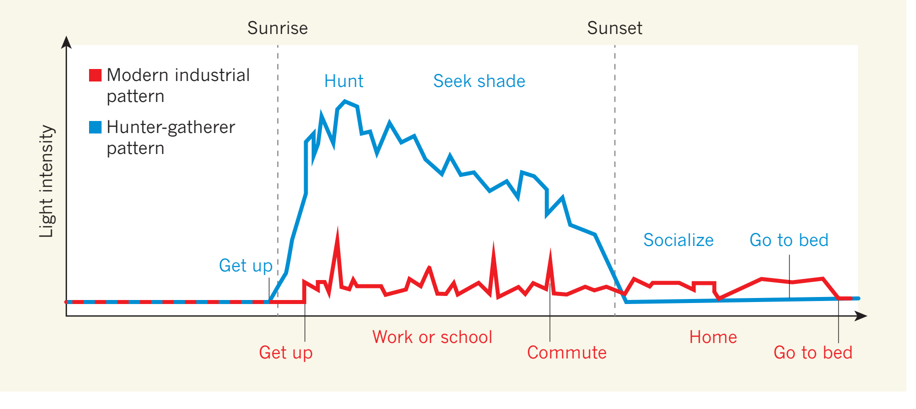

Figure 1 | Daily patterns. Yetish and colleagues' study[1] of sleep patterns in hunter-gatherer and hunter-horticulturalist groups allows a comparison between typical sleep patterns and daily activity schedules of individuals in modern but pre-industrial societies and those in modern, industrial societies[4]. In the latter societies, regular access to electricity divorces people from the natural environmental light–dark cycle, with light-exposure levels being largely self-determined and fairly uniform across waking hours. The authors' findings show that average sleep duration in the two societies is similar, but that sleep timing is more in sync with environmental cycles in pre-industrial than in industrial societies. (Schematic of light intensity derived from refs 1 and 4.)

When do the 7.7 hours of sleep recorded by Yetish *et al.* occur? No watches or electronic clocks were available to the participants, so sleep timing was determined by environmental cues and internal biological clocks. Maybe surprisingly for those of us who think that napping is natural, the authors found that few daytime naps were taken. Furthermore, sleep did not begin at the onset of darkness, but on average 3.3 hours after sunset. This average conceals a remarkable night-to-night variation in sleep onset — it seems that a regular bedtime is not a hallmark of natural sleep. By contrast, individuals in each group tended to wake at similar times, generally before sunrise. How does this compare with modern, industrialized sleep? Many people do go to sleep well after sunset, but few of us consistently rise before sunrise.

The timing of natural sleep can be easily linked to what we know about our biological daily rhythms. Earth's rotation results in environmental cycles of light and dark and hot and cold, and evolution has favoured the survival of biological mechanisms that predict these daily geophysical patterns. This rhythmicity has been observed right down to the cellular and molecular level, with nearly every cell in the human body showing approximately 24-hour (circadian) oscillations in gene expression. It is thought that synchrony of these billions of individual cellular rhythms is orchestrated by the brain's master clock, and it is well established that the light–dark cycle is the most prominent environmental stimulus for synchronizing this clock with the external world. The timing of our internal clock determines when we feel sleepy.

However, since the discovery of fire, we have learnt to manipulate our exposure to light. We can extend the light period by lighting a fire, a candle, an oil lamp, an incandescent light bulb, a fluorescent lamp or a light-emitting diode, giving us behavioural control over the stimulus that synchronizes our clock. The participants in Yetish and colleagues' study have this control to only a limited extent — the dim red light emitted by their fires has less biological effect than electric light with a strong blue component, such as is emitted by electronic devices and many low-energy light bulbs[4,5].

Recent studies exploring the impact of introducing electric light to the Toba Qom people in the Argentinean Chaco region[6] or to rubber tappers in the Amazon[7] indeed demonstrate delayed bedtimes and reduced sleep duration. And evidence from a study comparing US residents in daily life and on a camping trip away from artificial light suggests that access to electric light not only shifts the circadian clock but also exaggerates the natural individual variability of sleep timing[8]. At an extreme, perhaps the owl-like tendencies of adolescents, and the resulting debate on shifting school timing to later starts, are to a considerable extent a direct result of our manipulation of our light environment.

Yetish and colleagues also point to the influence of a second environmental cycle on sleep timing: temperature. Core body temperature rises and falls over each 24 hours, with sleep generally occurring as the body temperature falls. Because we are a diurnal species, awake during the day and asleep during the night, and because environmental temperature tends to drop during the hours of darkness, the rhythm of our core body temperature tends to align with that of the environmental temperature. From an energetic perspective, this makes sense — keep the difference between environment and body temperature as small as possible and you reduce the amount of energy needed to stay warm. This link between environmental temperature, metabolic demands and the timing of the sleep–wake cycle has received attention in the animal and human sleep literature[9,10]. Yetish and colleagues found that the timing of waking is closely associated with the environmental minimum temperature; in the one group that woke after sunrise, the San, this pattern occurred only during summer, when the environmental-temperature minimum also occurred after sunrise.

We are beginning to understand the impact of our artificial world on our sleep–wake rhythms. Although we have tantalizing hints about how the light environment of our modern world affects our sleep patterns, there are few data on how we manipulate our temperature environment and the effects of such manipulation on sleep. Yetish *et al.* have provided findings that alter our assumptions about sleep in our ancestors, and have opened the door to further studies of the effects of light and temperature on sleep today. ■

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ECONOMICS

Higher costs of climate change

An attempt to reconcile the effects of temperature on economic productivity at the micro and macro levels produces predictions of global economic losses due to climate change that are much higher than previous estimates. **SEE LETTER P.235**

THOMAS STERNER

We are already experiencing the economic impacts of climate change — heatwaves, for example, are increasing health costs and employee absenteeism, as well as reducing crop yields. But attempts to calculate the costs of warmer temperatures have produced conflicting results, particularly between estimates at the micro versus the macro scale in wealthy countries. Aggregating cost estimates from many different instances of micro-scale damage to obtain a single macro-scale estimate for the whole economy is very hard. In this issue, Burke *et al.*[1] (page 235) show that these inconsistencies can be reconciled if nonlinearity in the relationship between temperature and economic productivity is taken into account at the macro scale. Furthermore, their results imply that the damages from climate change are much more serious than is generally believed.

If a cyclone hits your house, the correct cost of the damage is not what the house originally cost but the cost of the best replacement you can make that will leave you equally well