ref. 8). Experimentally, the effect has been demonstrated in the tactile system[9,10] and, as applied here, in behavioural processes in both animals[11] and humans[12] that depend on perceptive thresholds.

But Collins and co-workers[3] did not specifically search for the optimal noise intensity — the characteristic signature of stochastic resonance. So the benefits might arise from a different cause. The upright human body behaves like an inverted pendulum that is controlled by time-delayed feedback mechanisms[13]. Thus it could be that the vibrating insoles stabilize posture by introducing random, vertical vibrations[2], or by making the subjects more aware of the extent of their swaying. But neither of these possibilities is likely: first, because the insoles do not induce motion of the pivot point (the ankle and foot); and second, because the stimulus is not perceptible.

Theory aside, Collins and colleagues' observations point to a potentially valuable way of tackling a serious medical problem. Falls are the most common cause of trauma, and the largest single cause of accidental death, among the elderly. Moreover, at least in the Western world, an increasing proportion of the population is entering the elderly category. Further research and development work will be needed. But if simple and inexpensive vibratory soles could reduce falls by even a small fraction, the benefits would be considerable. ■

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Neuroscience

States of mind

Dario L. Ringach

In the brains of anaesthetized animals, neurons create spontaneous patterns of activity that resemble representations of visual stimuli. This finding may change our notions about visual perception.

Every waking moment, as we experience the world through our eyes, groups of neurons in our brain fire electrical impulses to enable us to perceive our surroundings. But what happens in our brains when our eyes are closed? In the absence of visual stimulation, the region of the brain that processes this information, the visual cortex, is not 'silent' — the neurons continue to fire. Until now, it was thought that these spontaneous patterns of activity were random, but on page 954 of this issue, Kenet et al.[1] report that this is not so. Instead, the cortex seems to show intrinsic patterns of activity that evolve over time by switching among a specific set of states. Remarkably, these states resemble the patterns of activity that are produced in response to certain visual stimuli. Studying how the intrinsic cortical states interact with incoming visual information might bring us closer to understanding perception.

Activity in the visual cortex depends not only on the nature of a visual stimulus, but also on the state of the cortex at the time of stimulation[2]. This, in turn, depends on several factors, including the sequence of the preceding stimuli, the behavioural state (for example, levels of alertness or expectation) and the background pattern of brain activity that occurs in the absence of stimulation — the so-called spontaneous or ongoing activity. Classical studies of brain function aim to measure the average behaviour of a neuron in response to a particular stimulus. In such experiments, the spontaneous activity in the
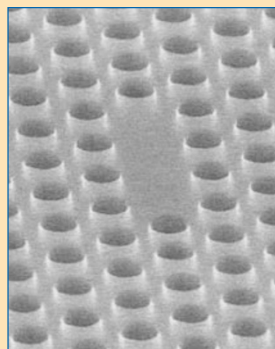

Photonics

Defective quality

In most areas of technology, defects are rarely welcome. For instance, in the semiconductor material inside a computer chip, defects might trap electrons and block the flow of current. But in photonic crystals, introducing precisely engineered defects could hold the key to a range of applications, including telecommunications and quantum computing. A new principle for the design of such defects is presented in this issue, by Susumu Noda and colleagues (*Nature* **425,** 944–947; 2003).

The periodic structure of a photonic crystal forms a 'bandgap', which forbids the propagation of light within a well-defined range of wavelengths. Making defects in the structure can then capture and

confine light, creating a photonic cavity that can control light in ways that are not possible with conventional optics.

The photonic crystal investigated by Noda *et al.* consists of a thin slab of dielectric material, such as silicon, with a two-dimensional array of sub-micrometre-sized holes cut into it. There is a variety of ways to create defects in this structure, such as making one or more of the holes bigger or smaller, or removing them completely. Previous attempts at confining light in a photonic crystal have generally concentrated on the size or number of defects, or the manner in which light is coupled in and out of them. These authors, however, have investigated the

properties not of the defect holes themselves, but of those surrounding them.

First they introduced a defect in the photonic crystal with the absence of three adjacent holes (pictured). Without further

modification, this makes an abrupt interface between the defect and the surrounding array, the severity of which allows trapped light to leak out. But by shifting the position of the holes on each side of the defect, Noda *et al.* found that they could soften this interface and reduce light leakage. And by doing so by just the right amount, the confinement efficiency, or quality factor, of the defects improves by as much as 100-fold, compared with previous studies.

This approach, which the authors refer to as "confining light gently to confine it strongly", should improve the performance not only of similar two-dimensional systems but of photonic crystals in general. **Ed Gerstner**

cortex at the time of stimulation is considered a nuisance — a source of noise that contributes to trial-to-trial variability[2,3]. It is gradually becoming clear, however, that we might better understand how the cortex processes visual information if we knew what this spontaneous activity represents and how it interacts with incoming signals to generate a 'real-time' response[2,4–6]. Kenet et al.[1] have taken a step in this direction by studying spontaneous activity in the visual cortex in the absence of any incoming visual stimulation.

To visualize spontaneous brain activity, the authors injected fluorescent dyes into the cortex of anaesthetized cats. The dyes are sensitive to the changes in voltage that occur when neurons are stimulated, so the intensity of the fluorescence provides a read-out of brain activity. This technique enables the average activity of thousands of neurons in a large patch of cortex (around 10 mm^2) to be visualized with relatively high temporal resolution.

Kenet et al. find that spontaneous activity in the visual cortex is far from random. Remarkably, it fluctuates between specific states that resemble those evoked by a stimulus oriented in visual space. In other words, even without any visual input, cortical neurons fire in particular patterns, which resemble the so-called orientation maps that are produced in the cortex by looking at oriented stimuli (Fig. 1). It is known that different maps are produced by horizontal, vertical or oblique stimuli. The authors found that brain activity in the anaesthetized cats fluctuated between different orientation maps, but that the cortex spent more time 'visiting' the maps that corresponded to either horizontal or vertical orientations. This might explain why animals seem better able to recognize vertical and horizontal stimuli than oblique stimuli.

The new findings may open avenues to addressing many unsolved problems regarding cortical processing and visual perception. As the authors recognize, the next step will be to investigate whether the spontaneous cortical states have any functional significance, and what that might be. To address this issue, it will be necessary to see whether these states also occur in the brains of animals that are awake. If the findings can be replicated, we can then look at how the different spontaneous brain states interact with external stimuli to influence visual perception and performance.

One hypothesis is that the ability to recognize an oriented visual stimulus (for example, a horizontal or vertical grid) might be enhanced if the orientation of the stimulus corresponds to the spontaneous orientation map in the cortex. This could be tested by training an animal to detect different visual patterns at arbitrary orientations and measuring the cortical activity at the time the
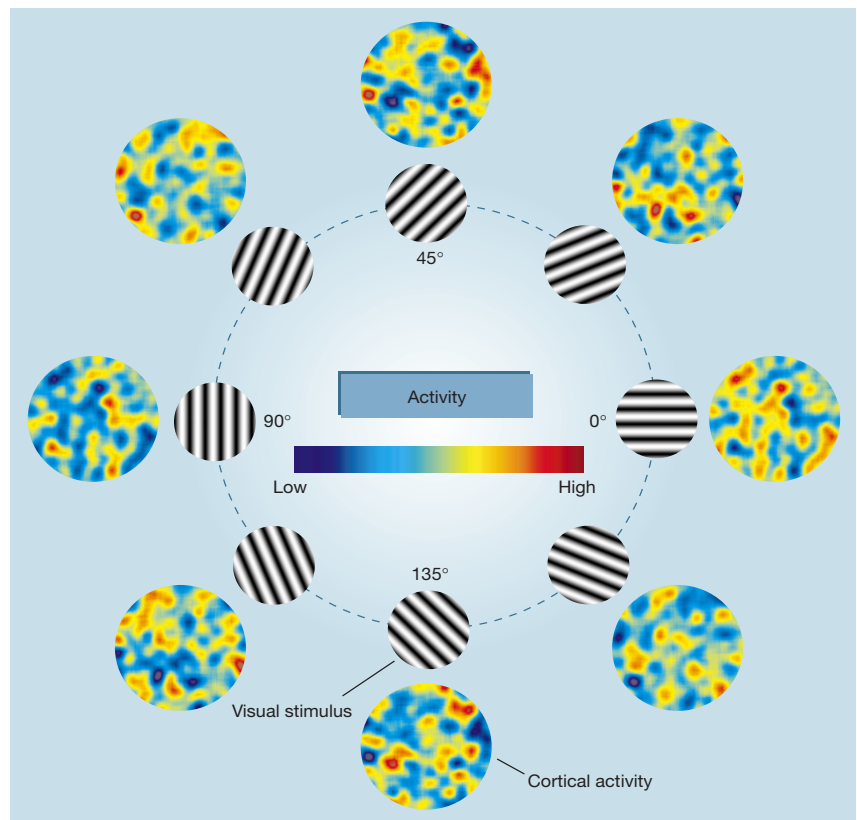
Figure 1 Mapping orientation. Each large circle shows the activity across thousands of neurons in a patch of the visual cortex of cats (the part of the brain that processes visual information) when the animals look at differently oriented stimuli. A particular 'orientation map' is produced for each different visual orientation. Kenet et al.[1] now suggest that these orientation maps are an intrinsic component of the brain, which are created spontaneously even when our eyes are closed.

visual stimulus is given. The animal's ability to recognize particular orientations could then be correlated with the spontaneous state of the cortex at the time the stimulus is presented.

If the ability to perceive oriented stimuli is found to depend on the cortical state[5,6], we can then ask a number of important questions about cortical function. Is the time the cortex spends visiting particular states a function of attention? In other words, if an animal is trained to perceive horizontal stimuli, will there be a corresponding increase in the time the cortex spends sampling the horizontal orientation map relative to the other maps? Perhaps perceptual learning has more to do with 'top-down' mechanisms (brain processes learning how to 'control' the ongoing state of the early visual cortex) rather than 'bottom-up' mechanisms (external stimuli producing dramatic and long-lasting changes in the way the visual cortex processes incoming information)[7–9]. In more general terms, one might ask if such intrinsic cortical states represent the brain's 'current hypothesis' about the state of the external world[10,11]. In this case, the purpose of the cortical machinery would be to continuously update the current hypothesis by considering new visual information.

Perception always occurs within a context. Kenet and colleagues' findings[1] show that, to understand fully how our brains allow us to perceive the world in real time, we must investigate the context in which incoming visual signals are received and how that context interacts with the signals to produce a behavioural response. ∎

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