Psychophysics

Limits of visual resolution

from Graham Martin

At first sight we might expect that the limits of our ability to resolve an object in a visual scene constrains the precision with which we are able to judge the position of that object. However, psychophysical experiments suggest that this is not the case. Elsewhere in this issue, N.V. Swindale and M.S. Cynader provide an answer to this problem by measuring for the first time a physiological correlate of hyperacuity in the visual cortex (*Nature* 319, 591; 1986). Their results suggest that the mechanism underlying hyperacuity is relatively simple, perhaps based on the well-known properties of orientation sensitivity of cortical neurones.

It is easy to demonstrate that the smallest object that we are able to resolve in a scene, determined by measuring minimum separable visual acuity, subtends an

a, The type of stimulus pattern used to assess the limits of visual resolution. When using a regular grating pattern of high contrast, the smallest gap between the bars which can be detected by man subtends at the eye about 1 minute of arc. *b*, The limits of accuracy with which the position of an object in the visual scene can be assessed is measured by using a stimulus pattern consisting of two offset bars. The smallest offset in the alignment of these bars which can be discerned by man subtends only about 5 seconds of arc at the eye. Swindale and Cynader show that if such a stimulus is swept across the receptive field of a neurone in the cat's visual cortex, the response of that neurone is reduced compared with its response when a single bar of the same dimensions is used. The degree of reduction is comparable with that produced when the orientation of the single bar is changed from its optimal position, say θ (*c*) by an amount equivalent to the orientation of straight line that joins the midpoints of the two offset bars, say α (*d*).

angle at the eye of about 1 minute of arc, but we may be able to assess the position of that object in the scene (determined by measuring vernier acuity or hyperacuity) with much greater accuracy, probably about 5 seconds of arc. The reasons for this have been discussed extensively (Westheimer, G. in *Progress in Sensory Physiology* 1; Springer, Berlin, 1970) and it has been generally agreed that these two abilities and the limits on their accuracy arise from different mechanisms in the visual system.

The factors limiting visual acuity seem to lie in the eye. Here the ultimate limit on resolution is dictated by the size of the photoreceptors on which the image of the world is focused. Were photoreceptors any thinner and packed more closely together than about 2 microns, then optical cross-talk between adjacent photoreceptors would degrade the information contained in the image (Miller, W.M. in *Handbook of Sensory Physiology* VII/6A; Springer, Berlin, 1979). This sort of photoreceptor spacing, coupled with the focal length of the eye, accounts well for the measured values of maximum visual acuity in various species, including man.

The mechanisms limiting hyperacuity must, however, lie not in the eye but in the visual cortex. Theoretical explanations of hyperacuity have usually involved the idea that averaging of signals from several parts of the retina occurs within the brain, together with the notion that the visual world is represented in the cortex in a much finer grain than in the retina (Barlow, H.B. *Nature* 279, 189; 1979). (There are several hundred times as many cells in the visual cortex as there are pathways entering from the eye.)

Swindale and Cynader show that if a vernier acuity type of stimulus is moved across the receptive field of a neurone in area 17 of the cat visual cortex, the response of that cell is significantly reduced compared with its response when a single bar is used (see figure). But the size of the offset necessary to cause this reduction is considerably smaller than the spatial resolution of the same cell. Thus, a single cortical cell can show properties that seem directly analogous to the distinction between acuity and hyperacuity.

Such an apparently straightforward correlation between the properties of single cortical cells and visual performance is in itself impressive. However, perhaps the most important aspect of the work is the similarity which Swindale and Cynader find between the vernier sensitivity of a cortical cell and its orientation selectivity. The properties of a vernier stimulus can be approximated by a single bar of the same dimensions but which has an orientation the same as that of a line joining the midpoints of the two bars that make up the vernier stimulus. Thus, hyperacuity may turn out to be subverted by the same or similar mechanisms to those which underlie our ability to detect differences in the orientation of a straight line, especially its deviation from the vertical. Mechanisms involving a hypothetical fine-grained representation of the visual world within the cortex may not be necessary to explain hyperacuity. But Swindale and Cynader's explanation does require that the nervous system has the ability to interpret fine fractional changes in the firing rates of neurones. Whether this is true will require further study, but such a property would simplify our understanding of how sensitivity thresholds measured psychophysically are related to properties of neurones in the visual cortex. □

Graham Martin is in the Departments of Zoology and Comparative Physiology, and of Extramural Studies at the University of Birmingham, Birmingham B15 2TT, UK.

Space science

First results from Spacelab 2

from Eugene W. Urban

THE Spacelab 2 mission was launched on 29 July 1985 on the space shuttle Challenger, with a crew of seven consisting of the commander, pilot, three mission specialists who operated the spacelab systems and biological experiments, and two payload specialists, both of whom were solar scientists and operated many of the experiments. What follows is an account of the post-flight science meeting held on 14 and 15 November 1985 at the Marshall Space Flight Center at which the principal investigators of the experiments (see

table) described the type, quality and status of the data and their analysis.

Spacelab 2 was originally to have been launched on 12 July 1985 for 7 days at an orbital inclination of 49.5° and a circular altitude of 385 km. This date would have given a new moon in the middle of the mission, primarily for the benefit of the infrared telescope (IRT), the plasma depletion experiment and the vehicle charging and potential (VCAP) experiment, but a technical problem caused the original lift-off to be aborted.