Activities (in d.p.m. g⁻¹) and activity ratios of U-series nuclides in fresh Macdonald serpentinitized basalt. U and Th isotopes were measured by high-resolution alpha spectrometry (see, for example, ref. 31). (268Ra) was measured by the 222Rn emanation method (see, for example, ref. 36). (210Pb) is the average initial activity (d.p.m. dm⁻³) in seawater collected during the 11 October 1987 eruption based on measurements made on 2 February and 23 February 1988. (230Th) is the initial activity in slick material collected during the 1 February 1989 eruption based on a single measurement made on 13 June 1989. Sr and Nd isotopic ratios were measured by thermal-ionization mass spectrometry. Th/U is the value observed in the rock and (Th/U) is the source value calculated from (230Th/232Th).

In addition to the isotopes already discussed, we measured other U-series nuclides (Table 1) which help to characterize the volcanism at Macdonald. We note that the activity ratios (232Ra/230Th) and (234U/238U) are within the range of values for other ocean island basalt (OIB) (refs 26, 27 and our unpublished data); the (232Ra) excess constrains the crustal residence time of the magma to ≈8,000 yr, and (230Th/232Th) is high and considered in this source, implies a low value of (230Th/232Th) in the source. This is more similar to values characteristic of the mid-ocean-ridge basalt (MORB) source than of the OIB source (refs 26, 28–31). On the Sr-Th isotope diagram, the Macdonald seamount data falls far above the broad array defined by oceanic rocks12, suggesting that either the Sr or Th isotopic ratios have been affected by secondary processes. Comparison of our Macdonald seamount Sr and Nd data (Table 1) with those from other nearby eastern Australia–Cook islands24,35 suggests that (Sr/Sm) is indeed high for the measured Nd isotopic composition and that the source Sr isotopic ratio may be closer to 0.7028. If this is so, the Sr-Th isotope correlation indicates that (230Th/232Th) should be close to 1.25, considerably lower than the measured value but still far above the OIB range, indicating a truly depleted source for Macdonald.

The process most likely to cause the secondary isotope shift is the incorporation of altered oceanic crustal materials, because both U concentration (and hence (230Th) and (Sr/Sr) increase during alteration. To change (Sr/Sr) from 0.7038 to 0.7073 and (230Th/232Th) from 1.25 to 1.5 would require about 14% of the Sr and 17% of the (230Th) to come from the alteration component. Similar processes have been postulated to occur at other localities (for example, Kiluaea24 and Iceland35). Furthermore, the frequent explosive magmatism, the observed release of large quantities of gas during recent eruptions, and the presence of scoriaceous spatter cones at the summit suggest that Macdonald is presently erupting highly gas-charged lavas. This implies a large increase of gas pressure over a short time interval to permit rapid gas build-up and is consistent with the effective sealing of chamber-to-surface magma conduits by seawater circulation through the crust between eruptions.

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Neural correlates of a perceptual decision

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The relationship between neuronal activity and psychophysical judgment has long been of interest to students of sensory processing. Previous analyses of this problem have compared the performance of human or animal observers in detection or discrimination tasks with the signals carried by individual neurons, but have been hampered by the small number of neurons that were not obtained at the same time and under the same conditions1–4. We have now measured the performance of monkeys and of visual cortical neurons while the animals performed a psychophysical task well matched to the properties of the neurons under study. Here we report that the reliability and sensitivity of most neurons on this task equalled or exceeded that of the monkeys. We therefore suggest that under our conditions, psychophysical judgments could be based on the activity of a relatively small number of neurons.

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data points lying slightly to the left of the psychometric data points; in this case the neuronal threshold was slightly lower than the psychophysical one. We used a likelihood-ratio statistic to test the hypothesis that the psychometric and neurrective functions were the same. For this neuron, this hypothesis could not be rejected ($P > 0.05$).

We performed this analysis for 45 neurons recorded from one monkey, and 15 neurons from a second. Figure 2 shows a histogram of the distribution of the ratio of neurrective to psychometric thresholds for these 60 neurons. Values of this ratio of $<1$ represent cases where the neuron's threshold was lower than the monkey's; values $>1$ represent cases where the monkey's performance was better than the neuron's. Intuitively, it might be expected that the behavioural threshold would be lower than any particular neuronal threshold but, in most cases, neuronal thresholds and perceptual thresholds were similar. Indeed in some cases, neuronal thresholds were substantially lower than perceptual thresholds. For 20 of the 60 neurons in our sample, the psychometric and neurrective functions were statistically indistinguishable ($P > 0.05$); in 18 of the 40 remaining cases, neuronal thresholds were lower than perceptual thresholds. In other words, if the monkeys were able to select and measure the discharge of some of these neurons as we did, their performance could have been better than it actually was.

An inability to select the most informative signals can be considered as a kind of perceptual uncertainty, of the kind modelled by Pelli. Obliged to monitor signals from many sources less informative than the one perfectly tuned to the visual target, the animal's perceptual performance would be degraded, because each sub-optimal source would contribute more noise than signal. Neurrective performance would then exceed psychophysical performance. Our results suggest, however, that this effect is not large. Substantial uncertainty would make the psychometric function steeper than the neurrective function, but as was the case for the example shown in Fig. 1b, the slopes of these two functions are usually similar. We thus conclude that under our conditions, the monkey's perceptual decision is not greatly affected by irrelevant signals introduced by uncertainty.

The apparent absence of uncertainty leads, however, to another question: if a perceptual decision can be based with relative certainty on the discharge of the most informative neurons, why is behavioural performance not further enhanced by using a pooled signal derived from many such informative neurons? If enough such neurons were present, such pooling would substantially improve psychophysical performance by averaging out the noise that obscures weak signals. Our data show that in most cases, the neuronal and psychophysical performances are similar, indicating that signals from many neuronal sources are not sufficient to reduce perceptual thresholds.

One way to account for the absence of either pooling or uncertainty effects is to suggest that the variability in the responses of similarly tuned neurons is correlated. Both pooling and uncertainty act as we have stated only if different neuronal signals are perturbed by independent sources of variation. If the sources are not independent, then uncertainty does no damage and pooling provides no benefit, because different neurons are carrying similar signals. The rich network of shared connections that link MT neurons with the retina might well produce correlation among neurons with related selectivities, but this possibility has not been studied. Our lack of information about the degree of shared variability makes it impossible for us to assert that the neurons whose responses we have recorded are the ones that contribute to the monkey's perceptual judgements. Nonetheless, our results show that a reasonable account of the monkey's performance can be constructed, using a simple decision rule, from signals carried by small numbers of neurons whose selectivities are well matched to the demands of the perceptual task.

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Hippocampal abnormalities in amnesic patients revealed by high-resolution magnetic resonance imaging

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THE identification of brain structures and connections involved in memory functions has depended largely on clinico-pathological studies of memory-impaired patients¹-⁴, and more recently on studies of a primate model of human amnesia⁵-⁶. But quantitative neurobehavioural data and detailed neuropathological information are rarely available for the same patients⁵-⁶. One case has demonstrated that selective bilateral damage to the hippocampus causes a circumscribed memory impairment in the absence of other intellectual deficits⁷. This finding, in conjunction with evidence from humans⁸-¹⁰ and monkeys¹¹-¹⁴, indicates that the hippocampus together with adjacent and anatomically related structures is essential for the formation of long-term memory, perhaps by virtue of

FIG. 2. Comparison of psychophysical and physiological thresholds obtained for 60 MT neurons in two rhesus monkeys. The frequency histogram shows the distribution of the ratio of the physiological threshold to the psychophysical threshold for all the neurons for which we obtained data. A value of 1 represents perfect correspondence between psychophysical and physiological thresholds; values $<1$ indicate that the physiological threshold was lower than the psychophysical threshold, whereas values $>1$ indicate the converse. The directional preferences of the 60 neurons were roughly uniformly distributed, and there was no reliable association between a neuron's direction or speed preference and its threshold relative to the perceptual threshold.