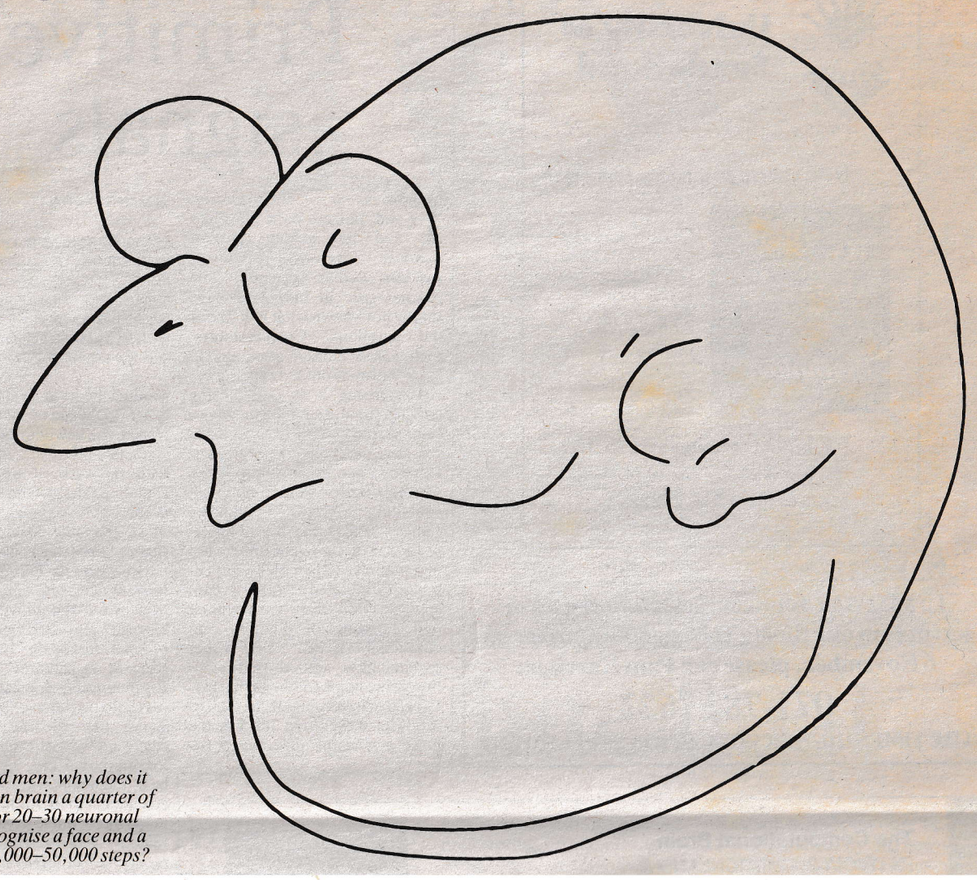
Current thinking



Of mice and men: why does it take a human brain a quarter of a second or 20–30 neuronal steps to recognise a face and a computer 3,000–50,000 steps?

BY **SUSAN BLACKMORE**

THE COMPUTATIONAL BRAIN
BY PATRICIA CHURCHLAND AND TERENCE SEJNOWSKI
MIT Press
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WHY DO we say that a slide rule is a computer but an egg beater is not? This is the sort of question that lurks under the surface of computer science but is rarely posed in technical treatises. In this comprehensive and richly illustrated book, Patricia Churchland and Terence Sejnowski have no fear of asking – or even of daring to answer – the awkward philosophical questions alongside their textbook exposition of the field of computational neuroscience.

Computational neuroscience is arguably the fastest growing and most exciting field of contemporary research. It is the coming together of the still-growing toddler of computer science with the vigorous but grown-up field of neurophysiology. At its best the knowledge we have acquired from building and using computers should help us to understand how our own nervous systems work but even though recent progress in neuroscience is, as they put it, "genuinely breathtaking and deservedly captivating" there are still enormous problems to overcome.

Churchland and Sejnowski sweep away many of the objections with disarming clarity. To those who still argue for a "ghost in the machine" they admit it is possible but not probable or interesting enough to stop the progress of materialism. The assumption that questions like "How do nervous systems represent anything?" are inevitably philosophical has, they say, simply lost its stuffing. And to those who argue that every detail of neural function has to be understood before we can proceed, they point out that progress does, and has to, go on at many levels simultaneously. A model that is too rich is just as likely to miss out on what is important as one that is too simplistic. Right now we have enough understanding to try to answer the central question "What are nervous systems doing?"

As the authors proclaim, their book is an extended elaboration of their answer; indeed of the answer of computational neuroscience as a whole. That is, nervous systems are computing with nets. There is no doubt neural nets have changed whole areas of science in a very few years. Oddly enough the general principles have been known for many decades but what has changed recently is the possibility of simulating a neural network on a digital computer and thus putting to the test the many different designs for nets that do jobs.

A neural net is just what it sounds like: a network of interconnected neurons that work together to carry out functions. The term is also used, however, for the hypothetical structures designed on paper or implemented in computers. One of the big questions for this book is to what extent theoretical nets can teach us about real live brain nets. Are real nervous systems doing something similar to the simulated ones, and if so how are they doing it? Or, as the authors put it, to what extent we can learn about global properties of an up-and-running "Critternet" from a computer net apparently doing the same task. The position the authors take, and vigorously defend, is that they can teach us a great deal as long as the two nets are sufficiently similar in dynamics and architecture. Indeed it is their constant and effective crossing over between brains and computers that makes this book much more than just a textbook of either neuroscience or computing.

So how can a neural net compute anything? The answer lies in the way the neurons are connected up. There are many kinds of nets, and Churchland and Sejnowski describe clearly the most important types, though not without requiring quite a lot of mathematics and technical knowledge on the part of the reader. A typical net has several input cells, several output cells and, in between, hidden layers of various complexity. For any cell that connects with another (via a synapse in the case of living systems), the connection can be stronger or weaker. The flexibility and power of nets lies in the fact that by changing the strength of connections (the "weights") the nature of the input-output relations are changed. In this way a mapping is achieved and a function can be computed. The answers to questions are, if you like, stored in the configuration of weights. The problem for any real net is how to set the weights appropriately, and this is where much of the research comes in.

Computer scientists have developed numerous ways of adjusting weights. Doing it by trying all possible combinations is uselessly slow but a method called back-propagation can be used to adjust weights according to experience and so produce nets that can actually make a desired discrimination. For example, one net was trained to discriminate between mines and rocks lying on the seabed on the basis of sonar echoes – a task that human operators take many training sessions to master. The net was given many examples as input, its output was compared to the desired answer, and the error used to adjust the weights in the net. Eventually the net could distinguish rocks from mines (including ones it had not encountered before) as well as human operators could.

This puts traditional problems in psychology into a totally new perspective. Until fairly recently it was baffling to psychology how babies could easily and efficiently learn tasks that were ludicrously slow if not blatantly impossible for traditional digital computers. Recognising faces is one. This can be done in about 200–300 milliseconds (a quarter of a second), which means there is only time for about 20–30 neuronal steps. But as conventional computer vision programs were using 3000–50,000 steps (or even more), it was clear that brains must be using something quite different – like neural nets.

It was also baffling how animals can so readily recognise a complete object from seeing only a tiny part of it. Neural nets can do the same. Because the information is distributed across the whole net, damage to part of the net will result only in a weakening of what has been learned, not its total loss. And parts of an input can be used to reconstruct the whole, if not quite perfectly. This may well explain why you are unlikly to have noticed the missing letter in this this sentence – or the extra word – though my computer spell-checker did.

The bulk of the book is taken up with details of how these recent principles are applied to real problems in neuroscience. There is nothing on the recent neural net theories of sleep and dreaming but there are detailed sections on issues in perception, such as how we perceive shape from shading, stereo and colour vision; in the psychology of memory such as brain damage, amnesia and possible mechanisms of storage; and in infant development and sensory-motor integration. With thumb-nail sketches, short-lists of relevant facts and "must-know lists", Churchland and Sejnowski map out what is known so far.

Throughout the book there is a sense of some very old mysteries giving up a few of their secrets. For example, it has long seemed enigmatic how nervous systems acquire notions of similarity. We have no hesitation in seeing the connection between a pheasant, an ostrich and Donald Duck, but how? As neural nets learn, their changing input-output relationships can be conceptualised as movement in a "state-space" or a space of similarities. It is by looking at them this way that we get some idea of how meaning emerges as nets learn.

Another example is the illustration to this review. Is this an old man or a rat? Of course there is no right answer but you can probably flip at will from seeing it as either one or the other. The old mystery here is what has changed since the picture obviously has not. This may once have seemed like evidence for a mind exerting its influence by will power but the ideas of similarity spaces and coding in nets makes that notion even less tenable. The neural network approach provides better answers and shows just how and why real biological information processing is "swift, accurate and no. mysterious".

What previously looked like very clever behaviour now seems to be the natural consequence of putting together a lot of individually stupid units. Complex behaviour and subtle discriminations can emerge in basically simple and mechanistic systems. Our human sense of coherence and unity can appear with no need for any central controller or "choir conductor".

Are you happy being no more than a collection of individually stupid units linked together into complicated neural nets? If Churchland and Sejnowski are right, the ethical issues involved go far wider than this. For with this increased understanding we may be on the verge of being able to manipulate or even replace the very things that make us what we are.

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