IN THE NEWS

Neuromancy

It was definitely the headline that got me reading. "Devices that read human thought now possible" reported the *San Francisco Herald* (10 November 2003), referring to studies presented at the past Society for Neuroscience meeting. Happily, my initial dismay at having missed the poster subsided when I discovered that the story was actually on brain–machine interfaces that harness neuronal activity to guide mechanical limbs. Such interfaces had already been used in monkeys, and the newspaper, prompted by preliminary results on patients with Parkinson's disease, discussed the possibility of using them in people.

Relieved by the fact that my secret thoughts will remain private for now, my attention turned to the financial twist of the story. On the one hand, Miguel Nicolelis, a leader in this field, is quoted as saying "I have no interests in any business … I want to have fun; I don't want to make money. What I am very afraid of is that people who really want to make a buck out of this will be rushing into the clinical thing." On the other, John Donaghue, another expert on this area, pointed out that he and his colleagues "realized the only way to fully exploit the technology was to form a company capable of raising the money needed to carry out very expensive clinical studies". Cyberkinetics Inc. is the result of their realization.

Regardless of whose side you are on, a growing number of neuroscientists are becoming aware of the financial implications of what they do in the lab, and spend more time with their colleagues over at the Technology Transfer Office. Although many of them are surely driven by their desire to foster technological progress, I suspect we would not need a mind-reading device to spot the phrase 'lucrative patent' in their thoughts.

Juan Carlos López

COGNITIVE NEUROSCIENCE

Cascading cognitive control

Although it is clear that the prefrontal cortex is responsible for cognitive control — ensuring that our actions are appropriate not just in light of our sensory input but also for a given context or event — the organization of the prefrontal cortex is controversial. Koechlin *et al.* propose a new model for the functioning of the lateral prefrontal cortex (LPFC) in which different areas form a hierarchy of cognitive control, from the premotor cortex to more anterior regions.

The model is best understood by considering a well-known example of cognitive control. If a phone rings, a default response would be to answer it. However, if you are at a friend's house (a different context), you would not usually answer the phone. But this contextual control can be overridden if, for example, your friend has gone out and has asked you to take any calls.

In the model proposed by Koechlin and colleagues, there are three levels of control. The premotor cortex is responsible for 'sensory control' — answering a ringing phone. More anteriorly, the caudal LPFC carries out 'contextual control' — using cues that accompany the stimulus to tell you that it is inappropriate to answer your friend's phone. And the rostral LPFC is responsible for 'episodic control', in which earlier cues (a conversation with your friend) tell you how you should respond during a given episode. In this hierarchy, signals flow from the most anterior parts of the LPFC to the more posterior parts and the premotor cortex, conveying top–down information to control our actions.

The authors tested their model using behavioural studies and functional imaging — with rather more abstract stimuli — as well as information theory for quantifying cognitive control. Subjects were given tasks in which either sensory or contextual information could be varied, either alone or with episodic information. As predicted by the model, reaction times increased with stimulus, context and episode factors, and both stimulus and context effects were additive with the episode effect.

Functional magnetic resonance imaging (fMRI) allowed the authors to see whether different types of cognitive control were reflected in increased activity in different parts of the LPFC. Consistent with the cascading, top–down nature of the model, activity in the premotor cortex showed effects of stimulus, context and episode; caudal LPFC showed effects of context and episode, but not stimulus; and rostral LPFC only showed effects of episode. To test the prediction that the effects of context and episode in more posterior areas result from top–down control from the most anterior areas, the authors used a structural equation model to investigate the effective connectivity of the LPFC. The results also supported the three-tiered model of cognitive control.

In this model, representations are distributed in the LPFC depending on their temporal structure, rather than their content or internal complexity. It joins a number of other models of prefrontal function and is unlikely to be the last, but it can also explain the pattern of results seen in a number of other studies in which rostral and caudal LPFC showed activity that depended on whether cognitive control was contextual or episodic. The story is far from over, but this study could be an important chapter.

Rachel Jones

References and links

ORIGINAL RESEARCH PAPER Koechlin, E. *et al.* The architecture of cognitive control in the human prefrontal cortex. *Science* **302**, 1181–1185 (2003)

FURTHER READING Wood, J. N. & Grafman, J. Human prefrontal cortex: processing and representational perspectives. *Nature Rev. Neurosci.* **4**, 139–147 (2003) | Duncan, J. An adaptive coding model of neural function in prefrontal cortex. *Nature Rev. Neurosci.* **2**, 820–829 (2001)