PREFRONTAL CORTEX

One step at a time?

When I start to type this sentence, how does my brain represent the series of movements that are needed? Is each movement represented separately and in series, so that the representation of the movement needed to type the 't' of 'the' is followed by that for typing the 'h' and then the 'e', or does my brain 'plan ahead' and represent all of the letters in parallel? According to work by Averbeck *et al.*, the sequential movements are probably represented in parallel in my prefrontal cortex — at least, if I approach typing in the same way that a monkey approaches a serial motor task such as drawing a geometric shape.

The idea that sequences of movements are represented in parallel is not new. Fifty years ago, Lashley proposed that the serial order of movements — which must underlie many behaviours, including speech and locomotion, as well as typing — should be mediated by parallel response activation. This conclusion was based, in part, on the pattern of errors that Lashley observed in his own typing, and which will be familiar to any typist: the fingers seem to get ahead of themselves so that later letters are typed too soon (producing 'teh' rather than 'the'). Such errors indicate that serial movement patterns are represented in parallel, and sometimes 'selected' in the wrong order.

Averbeck *et al.* set out to find evidence for this idea in the monkey prefrontal cortex — an area of the brain that is important for the serial order-

ing of movement components. They recorded simultaneously from ensembles of neurons while the monkeys copied geometric shapes, such as triangles or squares, on a screen. The shapes were drawn as a sequence of segments, and the neural activity before and during each segment could be analysed. The authors were able to identify specific patterns of activity as representing each segment of the shapes. They found that all of the patterns were active before the monkey began to draw the shape, and that they all remained active during the process of drawing.

More interestingly, the strengths of the different representations evolved as the monkey drew the shape. At the beginning, the first segment was most strongly represented, but as this segment was drawn, its representation waned and the representation of the second segment became stronger. This process continued, so that each segment was the most strongly represented just before it was drawn. Presumably, this evolution of representations mediates the correct ordering of a sequence of movements.

The authors also looked at what happened when the monkeys made errors. Like humans, monkeys are most likely to make errors in the middle segments of serial tasks, rather than at the beginning or end. The first and last segments of each shape were more strongly represented than the middle segments, which might explain why the middle segments

were less likely to be drawn correctly. Furthermore, during error trials, the segment on which the monkey made the error was represented in the correct position on only 35% of trials, as opposed to 70% for correct trials. Instead, the subsequent section was more likely to be represented. Like typists, the monkey seemed to be getting ahead of itself.

The next step will be to look for similar patterns of activity in other areas of the brain. It will not be surprising if this method of representing serial order is a common feature, and it will be interesting to see how the interplay between different neural areas might contribute to the evolution of segment representations across time.

Rachel Jones

References and links

ORIGINAL RESEARCH PAPER Averbeck, B. B. *et al.* Parallel processing of serial movements in prefrontal cortex. *Proc. Natl Acad. Sci. USA* **99**, 13172–13177 (2002)

IN THE NEWS

Ecstasy danger hits the headlines

There's nothing like a good scare story for getting neuroscience into the news, and this month's item is no exception. Step forward ecstasy (MDMA), the villain of the piece. The drug has been accused of causing brain damage that could lead to Parkinson's disease.

The study, by George Ricuarte and colleagues from Johns Hopkins University, tested the effects of several doses of ecstasy on monkeys' brains, designed to mimic the amount taken by a clubber in the course of a night. After six weeks, there were significant decreases in serotonergic and dopaminergic markers. As dopaminergic innervation of the striatum declines with age, ecstasy users might be predisposed to develop Parkinson's disease later in life.

In the *Daily Telegraph* (UK, 27 September), Colin Blakemore of Oxford University says, "If dopamine cells are so dramatically affected... it's surprising that some people who have been using ecstasy for years are not already showing obvious signs of Parkinsonism. I think people would be well advised to avoid it."

However, the story is far from cut and dried. In the *Miami Herald* (5 October), Steven Kish of the Toronto Center for Addiction and Mental Health claims that "these studies are so flawed in terms of the technology used that one cannot derive any conclusion from them at all." Critics point out that the monkeys were injected with ecstasy, rather than taking it orally, and that 40% of the monkeys either died or suffered severe side effects. "How come 40% of people who are doing this drug are not dying or almost dying?" asked Rick Doblin of the Multidisciplinary Association for Psychedelic Studies.

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