analysis and pattern recognition have been found to occur, at the earliest, 150 ms after a visual stimulus is presented. After 50 ms, the primary visual areas of the brain encode continuity or vicinity (that is, are one or several separate objects processed, and how distant are they?) and other 'local' features. At about 70–100 ms, initial preconscious attentional modulation occurs (such as early processing of 'global' features, including motion, disparity, symmetry and colour). At about 100–140 ms, the contours and parts of objects (figural primitives⁴) are extracted and pattern recognition takes place. This timescale is prolonged as the length and complexity of the stimulus increase, and a similar (but even faster) processing cascade has been identified in the auditory domain.

From these discoveries, we can deduce that savants operate on the early stages of processing — they do not progress into the later, multisensory comparisons characteristic of conscious processing. Because creativity involves the formation of such multisensory interactions in widely distributed areas of the brain, access to the low-level, early processing stages is conceptually unproductive. But Snyder and Mitchell² contend that the savants' abilities are not islands of genius in an otherwise compromised brain, and that these people do not have 'better' brains for arithmetic and other talents. Instead, the authors insist that we all have the same fundamental cognitive abilities, but that savants have access to the rapid and early low-level processing owing to a functional or pathological loss of the executive brain centres.

For example, the ERPs of the 'human calculator' in Fig. 2, a computer science student who is not autistic⁵, have the same sequence of components — and, therefore, the same stages of information processing — as those of the much slower control subjects. But looking at the amplitudes, those of the human calculator are increased compared with the controls early on, indicating enhanced automatic low-level processing. In the later stages of processing, the human calculator shows smaller amplitudes, indicating less cortical activity.

Evidence from such non-savant geniuses contradicts the findings of Snyder and Mitchell², as do results from extensive training of self-perception of low-level neuro-electric phenomena in healthy controls and neurological patients⁶. Under such training conditions, a person observes his or her own changes in slow brain potentials — indicative of high or low excitability — on a computer screen, and learns to modify it by trial-and-error learning. Snyder and Mitchell believe that training and intensive learning do not open the door to the early processing that is apparent in such astonishing performances. But the human calculator in Fig. 2 began to calculate increasingly diffi-

Figure 2 Event-related brain potentials (ERPs) during mental arithmetic. The solid line shows the averaged ERPs of 13 people; the dotted line, the ERP of a 'human calculator', G.M., of the same age and general intelligence as the healthy controls. G.M. solved the multiplication problems presented at point 0 (left part of the curves) twice as quickly as the controls. The problems were presented on the screen at time 0, and remained until the subject solved them (on average, about 1,100 ms for the controls and 550 ms for G.M.). The early, positive electrocortical component (left side of the curves), reflecting fast lower-level processing, is increased in the human calculator, whereas the controls show larger late, negative components (right side of the curves), indicating higher-level 'executive' processing. (Figure courtesy of P. Pauli⁵.)

cult sequences of numbers at the age of four, and continued this mental practice for more than an hour a day until he was tested 24 years later. After many training sessions, brain-damaged patients and healthy controls can learn to control their own brain activity — which we normally cannot consciously perceive — and become sensitive to the changes that underlie the elementary, low-level processing⁶. By bringing their brain activity under voluntary control, these patients can use it to communicate from the mysterious early state of non-consciousness. The result may ultimately be that we find we all possess behavioural and physiological strategies to modify the early stages of cortical processing, with unprecedented consequences for behaviour and self-awareness. □
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1. Selfe, L. Nadia: A Case of Extraordinary Drawing Ability in Children (Academic, London, 1977).
2. Snyder, A. W. & Mitchell, D. J. *Proc. R. Soc. Lond. B* **266**, 587–592 (1999).
3. Martinez, A. et al. *Nature Neurosci.* **2**, 364–369 (1999).
4. Singer, W. in *The Mind-Brain Continuum* (eds Llinás, R. & Churchland, P. R.) 102–130 (MIT Press, Cambridge, Massachusetts, 1996).
5. Pauli, P. et al. *Psychophysiology* **33**, 522–529 (1996).
6. Birbaumer, N. et al. *Nature* **398**, 297–298 (1999).

Daedalus

Shear chemistry

On the molecular level, cutting is a very brutal process. The cutting tool forces a crack through the material, creating two highly reactive surfaces. Indeed, some quite soft materials, such as rubber and ebonite, rapidly blunt the hardest cutter. The ruptured chemical bonds of the new surfaces, dense with free radicals, combine with the cutter and erode it rapidly. Daedalus wants to improve the fundamentals.

The most efficient way to cut a material, he says, is to raise the molecules along the line of the cut into an anti-bonding excited state. The workpiece would not only lose all strength along the line of the cut; the two sides would actually repel each other. A laser beam of the right frequency should do the trick. It need not even be very intense. At any instant, it merely has to excite a single line of molecules. His prototype cutter has a stack of optic fibres which project the light in a narrow parallel beam out from its leading edge.

By itself, this simple concept would never work. As soon as the separated surfaces passed out of the micrometre-wide laser beam, they would relax back to their ground state — two dense sheets of free radicals sliding back over either side of the cutter. They would react with it aggressively. Behind its leading edge, the anti-bonding cutter will need to exude a reactive cutting lubricant, to combine with and stabilize the newly created surfaces, and give them the lowest possible friction. Fluoro-polymers have very low friction, so Daedalus is exploring cutting lubricants containing easily decomposed fluorides, such as those with xenon. Again, because only a monolayer of molecules need be supplied, very little of the expensive reagent will be needed.

Daedalus's anti-bonding cutter will be a costly, sophisticated device. Its laser wavelength and chemical cutting lubricant will need to be specially chosen for each material it has to cut. But it will then glide through the hardest and most refractory materials with wonderful ease and speed, giving optically smooth surfaces. Mated with that other sophisticated advance, the numerically controlled lathe or milling machine, it will bring new power to industry. To fund the venture, however, Daedalus is seeking military support. An anti-bonding armour-piercing smart shell or bomb would penetrate the most hardened defences as if they were not there.

David Jones