molecular motors is one of the key issues to address next.

So much for linear motion, but how about rotary motion? Particularly promising are studies with interlocked rings (catenanes) in which circular motion can be induced[7,8]. Last year, two studies demonstrated the controlled conversion of energy into unidirectional rotation, a fundamental property of a rotary motor[9,10]. The next challenge is to control the rate of rotation to produce a motor capable of more than one speed.

Aida and co-workers[4] have found an elegant solution to this problem with a molecular system called a bisporphyrinate double-decker complex (Fig. 2). In these complexes a cerium or zirconium ion is sandwiched between two porphyrin ligands that rotate with respect to one another. The metal ion functions as a kind of ball-bearing between two rotating discs. The configuration of bulky side chains attached to the porphyrin ligands means that the metal complexes are chiral — that is, they can be mirror images of each other. This feature allows the authors to study the dynamics of the rotary motion by measuring their optical activity. (Mirror-image chiral molecules rotate polarized light in opposite directions.)

Aida and colleagues[4] found that reducing the cerium complex led to the rotation of the porphyrin ligand being accelerated more than 300-fold. Oxidation of the zirconium complex, on the other hand, decelerated it by a factor of 21 or 99, depending on the oxidation state of the complex. The change in rotary motion is attributed to a change in distance between the two porphyrin ligands. In the cerium complex, reduction of the metal centre increases the ionic radius, so the interaction between the porphyrin ligands weakens, which leads to faster rotation. In the zirconium complex, oxidation reduces the distance between the porphyrin ligands, strengthening the interaction between the ligands and slowing down the rotary motion.

The chemical control of rotation is a powerful tool to be used in more advanced molecular motors. But there are many hurdles to overcome before the structures designed by these and other groups lead to molecular machinery becoming a reality. To make their construction easier, self-assembly processes are needed. It is also not clear whether the motors described here will retain their properties when they are used as part of a more complex system. Nonetheless, we are adding important components to our toolkit for making nanomachines. ■

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Computational neuroscience

Intimate attention

Jochen Braun

If we are to perceive a visual figure, we need to direct our attention towards it. The more we discover about this ability, the more impressive it seems.

Looking at Edgar Rubin's famous image of a white vase on a dark background — or is it two dark faces on a white background? — we can alter our perception by directing our attention to either vase or face (Fig. 1). The neural basis for this ability to perceive at will some parts of a visual scene as 'figure' and others as 'background' is a hotly debated area of research. On page 196 of this issue[1], Blaser and colleagues show that, by directing our attention in this way, we can distinguish even between two intimately associated 'figures' with almost identical characteristics. Their results have profound implications for how figures are represented in the brain's visual cortex.

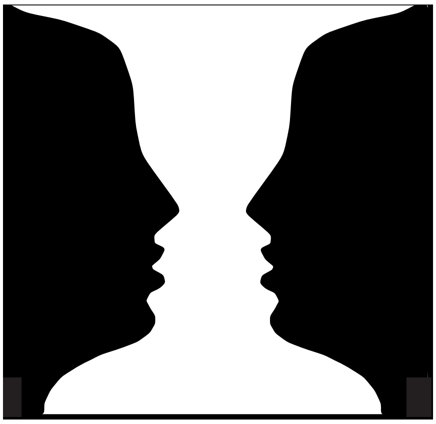

Figure 1 **Is it a vase or two faces? In Rubin's classic illustration, attention can select either object as the 'figure', thereby altering perception.**

The context of this work[1] is a debate over whether 'attention' is free to select arbitrary visual locations and attributes (any location, colour or shape of interest to the observer) as the figure, or whether it must select 'visual objects'[2,3]. Here, a visual object is defined as a cluster of locations and attributes that are linked by the Gestalt rules of visual 'completion'. What these rules mean for the visual cortex is that neuronal responses to a given visual stimulus often depend on the context — that is, on other nearby stimuli[4]. There are strong arguments that the neuronal architecture of the visual cortex must limit the selective capabilities of attention[5–8]. This is because there do not seem to be enough feedback connections to the early visual cortex to allow attention to affect arbitrary combinations of neurons.

To study how an observer divides a visual scene into 'figure' and 'background', Blaser *et al.*[1] build on their earlier work and use 'attentional tracking'[9,10]. This stratagem, which pushes attentional capabilities to the limit, involves a dynamic visual display in which two or more possible figures change beyond recognition several times. If observers can maintain attention on one particular figure (that is, 'track' it successfully while it changes), they can say which part of the final display is descended from the initial figure.

Blaser *et al.* have now constructed 'mutable objects' with three independent attributes — orientation, width of stripes, and colour saturation — that change rapidly and continually, each following an independent schedule (Fig. 2). The objects sometimes turn clockwise and sometimes anticlockwise. Stripe width sometimes increases and sometimes decreases. And the degree of colour saturation likewise sometimes increases (towards stripes of red on black) and sometimes decreases (towards stripes of light grey on black).

The authors superimposed two of these mutable objects (Fig. 2). Observers were asked to focus attention on one object, specified by its orientation, and to maintain attention on this object for ten seconds, during which time both objects changed. The impression of the observers was that, most of the time, the two objects seemed to remain perceptually distinct. At the end of the ten-second period, observers were able to report reliably which object — again specified by orientation — had descended from the initial object. In other words, observers were able to select one object as the figure, and to relegate the other to the background.

This ability to distinguish between objects found at the same location, and assuming the same attributes at different times, reveals hitherto unsuspected capabilities of visual attention. But what does attention select as the figure — the tracked object as a whole, comprising its orientation, stripe width and colour saturation? Or does it merely select the task-relevant attribute — in this case, orientation?

Figure 2 **What does attention select as 'figure' when two objects have almost identical characteristics? To address this question, Blaser *et al.*[1] superimposed two objects, each with three attributes — orientation, stripe width, and degree of colour saturation. In the experiment, all attributes changed rapidly and continuously over time. In the snapshot shown here, object 1 has narrow stripes that are pink on black and orientated at $+45°$, whereas object 2 has broad stripes that are red on black and orientated at $-45°$. The objects were superimposed (3) and observers were asked to maintain attention on one of the objects as the attributes changed. Even after several seconds, observers were able to state which object in the changed display had descended from the initial object. Further results suggest that attention may select all three attributes of one object as 'figure', but not a single attribute or a mixture of attributes from both objects.**

To answer this question, Blaser *et al.* used a modified display of two mutable objects and asked observers to monitor either one or two attributes of the tracked object. During the tracking period, all attributes of both objects showed simultaneous, discontinuous jumps, which observers had to report. Observers were able to monitor any two attributes of the same object about as well as they monitored either attribute alone. The implication is that all attributes of the tracked object are perceived as 'figure'. (If only task-relevant attributes were perceived as figure, performance would be expected to deteriorate when more attributes are monitored.) In a control experiment, observers were asked to monitor one attribute from each object. Here, performance was far worse, showing the difficulty of tracking both objects at once.

In short, attention seems to select all the attributes of one object — even those not immediately relevant to the task in hand — as 'figure'. But it does not seem able to select one attribute of one object, or a mixture of attributes from both objects. This means that attention selects not individual attributes or locations, but rather visual objects as a whole (that is, a set of locations and attributes linked by Gestalt rules). This result is all the more striking because — unlike in some earlier studies — the deck was not stacked in favour of whole-object selection. It would clearly have been advantageous to select a single attribute or a mixture of attributes from each object had it been possible.

How might objects be selected in the visual cortex? And does the apparent restriction to selecting objects — rather than arbitrary sets of attributes — reflect the limitations of neuronal hardware? A conceptually simple scenario is that attention enhances the representation of one object's attributes while attenuating those of the other. But how can attention single out the attributes of just one object? Attributes of the other are encoded in closely overlapping neuronal populations, and the anatomy of the visual cortex seems to support only relatively coarse and unspecific attentional feedback.

Perhaps one (task-relevant) attribute is selected at first, with feedback spreading to other (non-task-relevant) attributes of the same object through the neural equivalent of Gestalt rules. Alternatively, it is possible that the initial selection is based on the location. Although superimposed, the two objects would have been large enough to allow attention initially to select a small part of one object, and then spread to other parts, again through Gestalt rules. To see this point, bear in mind that the objects stimulated, in visual cortical area V1 alone, neurons in a cortical region of some 100 mm^2 and several dozens of neuronal 'hypercolumns'.

It remains to be seen exactly how attention can distinguish between objects represented by populations of neurons that are so intimately entwined. But at the very least, the striking capabilities of visual attention revealed by Blaser *et al.*[1] give us new reasons to think hard about how objects are represented in the visual cortex. ■

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Global change

That sinking feeling

Jorge Sarmiento

The land and sea soak up much of the carbon dioxide emitted into the atmosphere. But one set of simulations suggests that global warming could greatly impair this ability.

Burning of fossil fuels and changes in land use — mainly deforestation — are resulting in more CO_2 in the atmosphere and, it seems, global warming. Much of that extra CO_2 is absorbed in 'sinks' on land and in the oceans. But what effect will future warming have on these sinks? In their paper on page 184 of this issue[1], Cox *et al.* find that in the long run they absorb carbon much less effectively. According to the authors' calculations, the result is 2.5 °C greater global warming over land by the year 2100 than the 5.5 °C predicted if the climate–carbon-cycle connection is not taken into account.

At the moment, the annual increase of CO_2 in the atmosphere is less than half of the estimated emissions[2]. The rest is absorbed by the terrestrial and ocean sinks for carbon. So climate projections have to consider not only future emissions but how those sinks will react[3,4]. It is no easy matter to couple models of climate change and the carbon cycle, but this is what Cox *et al.* have done.

In their first simulation, they projected how much carbon would be taken up by the land biosphere and ocean if climate remains constant, as in previous studies. They predefined emissions of CO_2 at the 'business-as-usual' (IS92a) emission scenario[5]. This model predicts that the land biosphere will take up 450 Pg of carbon over the coming century, and the ocean 300 Pg, a grand total of 750 Pg (P is peta, 10^{15}) (Fig. 1). At an average of 7.5 Pg C yr^{-1}, this is about 50% more per year than the estimated present uptake. The primary mechanism for the land uptake is increased photosynthesis resulting from the increase in atmospheric CO_2 (CO_2 fertilization). In the ocean, it is carbon dissolution of the excess atmospheric CO_2 in the surface waters and transport to depth.

Cox *et al.* then carried out a global warming simulation with atmospheric CO_2 predefined at the IS92a concentrations predicted by a model without climate warming[5]. The reason for doing this was to provide a baseline for how much warming their model would project if there were no feedbacks between climate and the carbon cycle. The projected warming is 5.5 °C over land. A simulation of