Watching the shied core
Striking the basket, skidding across the floor,
Shows less and less of luck, and more and more
Of failure, spreading back up the arm…

Over the last century, research on improving recovery from spinal cord injury has concentrated on 'regeneration'—the concept of recapitulating developmental growth of long axons in the nervous system. Relatively little attention has been directed to the processes of plasticity by which the nervous system fine-tunes structure and function to meet the demands of the body in its environment. This is at least in part because they involve smaller-scale, shorter collateral growth and synaptic changes that are much harder to visualize and quantify. Indeed, Bareyre *et al.* have achieved something of a technical *tour de force* by combining multiple types of anterograde and retrograde staining with the available functional measures.

In the most severe types of spinal injury, involving complete transection, it seems that plasticity of existing connections would have relatively little to offer, without first regenerating some connection across the gap between brain and distal spinal cord. However, most spinal injuries are neurologically incomplete and therefore susceptible to improvements in residual connections. Similarly, it is likely that any success that we have in regeneration will also be incomplete. Therefore, plasticity is likely to be an important adjunct therapy, even if we are eventually successful in stimulating partial regeneration of the type seen in lower vertebrate spinal cord. Growth inhibitors such as Nogo and the chondroitin sulphate proteoglycans in the central nervous system, initially of interest for their potential impact on regeneration, have shown increasing evidence of parallel inhibition of spontaneous plasticity[3,10,11]. We may find that enhanced plasticity rather than regeneration is the main justification for developing blockers of growth inhibition as therapeutic agents for CNS injury.

Bareyre *et al.* have expanded our appreciation of the capacity for meaningful reorganization of spinal cord circuitry. Their work should help to reinvigorate interest in this area, and if one were obliged to offer dinner-party advice to a current graduate in neuroscience, it would be reasonable to point to this important, fascinating and slightly mysterious area with just one word: plasticity.

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Understanding awareness: one step closer

Steven J Luck

Attention enhances neural and behavioral responses to visual objects, but how does this affect our conscious perception? Attending to an object increases our subjective experience of stimulus contrast, reports a study in this issue.

How does the biophysical machinery of the brain evoke our rich phenomenological experience of the world? This question was once thought to be beyond the range of scientific inquiry, but leading neuroscientists have begun to find interesting answers by studying the neural correlates of awareness[1,2]. Most of these experiments examine how brain activity differs when an observer reports being aware versus unaware of a given sensory input. However, these studies ignore the quality of our phenomenological experience (for example, the difference between what it's like to see blue and what it's like to see red). This approach to awareness is a bit like an art critic classifying Van Gogh's *Starry Night* as "a dark picture" and Monet's *Garden at Giverny* as "a light picture," ignoring the dimensions of color, technique, composition and expression.

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In this issue, Carrasco and colleagues[3] provide a step toward a richer and yet still rigorous description of awareness. This study addresses phenomenological experience in the context of a very old question about perception: does paying attention to an object change its appearance? Attention is often likened to a spotlight[4] or zoom lens[5] that brightens or sharpens our perception, but no one has convincingly shown that attention actually changes our phenomenological experience of the world. Many studies have shown that attending to an object amplifies and sharpens neural representations of the object[6–8], leading to an improved ability to detect the object and report its properties[9,10]. However, these studies do not show that we actually experience attended objects differently from unattended objects.

The ever-present problem in studies of awareness is that observers' reports of their experience are very easily biased by a variety of cognitive and affective factors. If observers report that an attended object seems brighter than an ignored object, it is usually impossible to know whether they really experienced it as being visually brighter. It is always possible that attention did not influence their perceptual experience, but rather that preconceptions about attention led them—intentionally or unintentionally—to report it as being brighter. Carrasco and colleagues have developed a new procedure for assessing an observer's experience that markedly reduces the influence of bias on such reports.

In this procedure (**Fig. 1**), observers were shown two oriented gratings and asked to report the orientation of the higher-contrast grating (the one with brighter brights and darker darks). Thus, the observers explicitly reported the orientation of a grating, and their decision about which grating was higher in contrast was implicit rather than explicit. Attention was manipulated by preceding one of the two gratings with a small dot that automatically attracted attention.

When the two gratings differed greatly in contrast, the attention-capturing dot had no effect: observers simply reported the orientation of the higher-contrast grating. When the two gratings had similar contrasts, however, observers tended to report the orientation of the grating that was preceded by the dot. Thus, the attention-capturing dot changed the appearance of the subsequent grating, increasing its apparent contrast and leading the observers to report its orientation. This finding fits perfectly with previous studies indicating that attention increases neural[6–8] and behavioral[9,10] measures of contrast sensitivity. However, these new results allow us to make the stronger conclusion that attention changes the actual phenomenological experience of contrast, making brights appear brighter and darks appear darker.

The innovative aspect of this procedure is that the observers were not directly asked about their perception of contrast, minimizing the possibility of bias. Instead, their perception of contrast was used to determine which of the two orientations should be reported. Consequently, the observers were led to believe that orientation perception, rather than contrast perception, was the focus of the experiment. Although this should have minimized any biases, it is still possible that the attention-capturing dot biased subjects to report the orientation of the grating on the same side of the dot without any change in the appearance of that grating. To rule out this possibility, the authors ran a control experiment, taking advantage of previous findings that the appearance of a dot captures attention for only a brief period of time. In the main experiment, the grating appeared 120 ms after the dot, while attention was still focused. In the control experiment, this interval was increased to 500 ms, allowing attention to fade away before the grating appeared. Although the same top-down bias factors should have been operating at this interval, observers showed no tendency to report the orientation of the grating that was preceded by the dot. This provides strong evidence that changes in sensory processing—and not top-down bias effects—were responsible for the results of the main experiment.

By showing that the focusing of attention in space leads to a change in phenomenological experience, this study confirms the common-sense assertion of William James[11] that attention and awareness are intertwined. Much research over the past few decades has been devoted to assessing the neural substrates of attention[12,13], and it may be possible to use the results of this research to help understand the neural substrates of awareness. However, it would be easy to fall prey to the oversimplification of assuming a 1:1 relationship between attention and awareness. For example, given that attention seems to increase contrast sensitivity in area V4 of the primate visual system[7], it would be tempting to conclude that neural activity in V4 is directly related to awareness. However, an attention-related change in V4 activity could easily lead to changes in downstream activity that are more directly related to awareness. Moreover, recent evidence suggests that attention and awareness may be dissociable under some conditions[14]. Thus, although it may be possible to use our growing knowledge of the neural substrates of attention as leverage when studying the neural substrates of awareness, this research will require a sophisticated understanding of both attention and awareness.

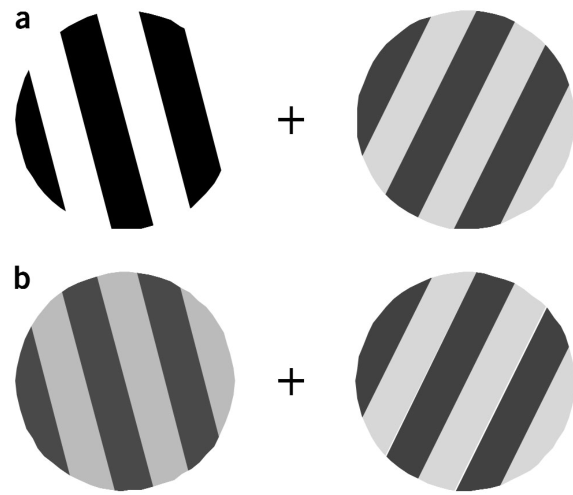

Figure 1 In the task used by Carrasco and colleagues[3], observers were presented with two oriented gratings on each trial, and they were instructed to report the orientation (left or right) of the grating with higher contrast. On some trials (**a**), one grating had much higher contrast than the other (here the left grating has much higher contrast). On other trials (**b**), the contrasts were very similar (here the right grating has slightly higher contrast). One of the two gratings was preceded by a small dot, which automatically attracted attention to that grating.

Will the present work of Carrasco and colleagues[3] change the minds of those philosophers and neuroscientists who believe that we will never be able to measure an individual's subjective experience? Probably not. No single study will change their minds, and this is appropriate given the difficulty of measuring subjective experience. However, if the new approach stands up under further scrutiny and can be used to address other questions about phenomenological experience, then it may become possible to objectively study subjective experience. Even then, we will not be at the point where we can measure the rich subjective experience evoked by viewing *Starry Night* or *Garden at Giverny*, much less understand the neural circuitry that gives rise to this experience. But we will have taken the first step in that direction.

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