

# The brain's rose-colored glasses

Keise Izuma & Ralph Adolphs

People tend to remain overly optimistic even when faced with information about a gloomy future. A study now shows that **people are selectively worse at incorporating information about a worse-than-expected future**. It also describes the learning signals in the brain that correlate with this bias.

Most of us consistently underestimate the probability of something bad happening to us: stock market crashes, experiment failures and manuscript rejections often seem subjectively unlikely<sup>1,2</sup>. Although unrealistic, **such optimism is pervasive across societies and has implications for a wide range of domains**, from individual health to politics and finance. It was recently shown<sup>3</sup> that optimism bias correlates with the activation of brain structures such as the anterior cingulate cortex and amygdala, but the manner in which it is propagated in the face of disconfirming information has remained elusive. A study by Sharot *et al.*<sup>4</sup> now finds that **optimists' brains fail to generate a learning signal when confronted with the evidence that negative events are more likely to occur than predicted**.

Sharot *et al.*<sup>4</sup> asked people to guess the likelihood of various unpleasant future personal outcomes. The scenarios ranged from kidney stones and Alzheimer's disease to credit card fraud, a cheating spouse and death before the age of 70. After participants had made their guesses, they were given the actual probabilities that these events would occur to somebody demographically similar to them. In a subsequent second session, participants were once again asked to judge the likelihood of these events, and the difference between the two likelihood judgments was compared. As expected, people tended to underestimate the likelihood of negative outcomes in the first session, and they showed a marked asymmetry in updating their judgments in the second. The difference in likelihood judgments between the two sessions was greater when subjects had

to revise their guess toward a more positive view (their first estimate had overestimated the likelihood of a negative outcome) than when they had to revise their guess toward a more negative view (their first estimate had underestimated the likelihood of a negative outcome). To investigate the neural mechanisms behind the effect, the authors conducted both sessions while the participants underwent functional magnetic resonance imaging (fMRI), and brain activation data were collected together with their behavioral judgments.

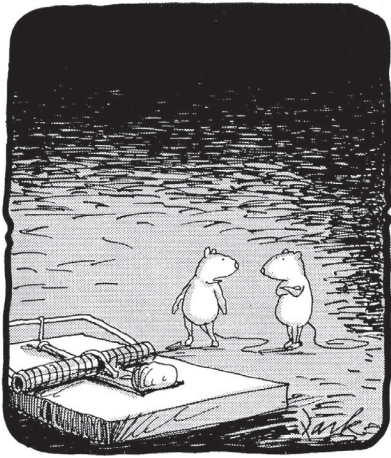
Plausible mechanisms might include differential memory for negative or positive information, differences in emotional arousal or differential familiarity from past experience. These were measured and did not account for the findings. Instead, the authors hypothesized that **a prediction error bias underlies the biased learning and that this should be reflected in the brain. Prediction errors are integral to learning theories, and the authors postulated that an analogous signal was at work here: people's belief update should depend on an estimation error, the difference between the actual probability presented and their initial estimate**. This is exactly what Sharot *et al.*<sup>4</sup> found: the greater the difference between people's initial estimate and the actual stated probability, the greater the change in estimate in the second session. However, the strength of this effect was greater when update was in an optimistic direction than in a pessimistic direction. These estimation errors, in turn, could be used as regressors in the fMRI analysis. Desirable estimation errors (that is, when the actual probability of a negative event was lower than was the initial estimate) were positively correlated with activation in several brain regions, including left inferior frontal gyrus (IFG), medial frontal cortex and cerebellum. In contrast, undesirable estimation errors (that is, when the actual probability of a negative event was higher than was the initial

estimate) were negatively correlated with the activity in right IFG. Notably, the magnitude of brain activation in these regions in the first session predicted the strength of the update in likelihood judgments in the second session.

Sectors of lateral prefrontal cortex, including the IFG, have been implicated in a host of processes that are plausibly related to those examined by Sharot *et al.*<sup>4</sup>. For example, they are engaged when learning about the probability of occurrence of future events from observations of past ones through state prediction errors<sup>5</sup>, as well as in causal learning. The left IFG participates in a network modulating the expected value of outcomes that affect us by incorporating more objective or long-term considerations, as happens when we decide to forego eating a pizza because we know it is unhealthy<sup>6</sup>, and the right IFG is known to function in response inhibition and the need to change our plans for future actions<sup>7</sup>. All of these findings are consistent with a role for lateral prefrontal regions in incorporating evidence that is discrepant with current beliefs to help us construct more accurate models of the future and plan our actions accordingly.

The optimistic learning bias found by Sharot *et al.*<sup>4</sup> varied to some extent across individuals. To explore these individual differences further, the authors asked all of the participants to fill out a post-scanning questionnaire measuring optimism as a personality trait. People who scored high for optimism showed a weaker association between negative estimation errors and right IFG activity than did those who scored low, and the strength of the association between right IFG activation and negative estimation error was related to individual differences in how well they learned from negative information (**Fig. 1**). Such individual differences may have important implications for psychopathology; depressed people are more pessimistic<sup>8</sup>, and abnormal

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"Modern technology being what it is, there's a good chance it won't work anyway."

**Figure 1** People are biased toward unrealistically optimistic views about their own future, an effect known as the optimism bias. Figure credit: <http://www.cartoonstock.com>.

activation of the IFG has been observed in studies of bipolar disorder<sup>9</sup>.

It is well known that human preferences, beliefs and choices all feature a variety of seemingly irrational biases<sup>10</sup>, of which optimism bias and its resistance to update is just one example. For example, monetary reward can undermine people's motivation, taste preferences for wines are influenced by their price, and choices can be inconsistent depending on how the question is framed. The present set of studies<sup>3,4</sup> are in good

company with several recent investigations of the neural mechanisms behind such influences and biases<sup>11,12</sup>, and a challenge now is to begin to fit them together into a comprehensive architecture of adaptive behavior.

Finding neural correlates of optimism bias<sup>3</sup> and its resilience to learning<sup>4</sup> are one thing; explaining why we should have these biases in the first place is another<sup>13</sup>. A favored account proposes that they derive from the propensity to think and worry about our future, a burden that is thought by many to be uniquely human and that needs to be tempered when things look so gloomy that we might just give up<sup>2</sup>. Being optimistic increases positive mood and reduces stress, with concomitant benefits for health and motivation<sup>14</sup>: optimists engage in more physical activity, smoke less and eat more healthily<sup>15</sup>. Such a byproduct explanation may well be part of the story, but it is also interesting to speculate that being optimistic might be correlated with social effects, such as leadership and social dominance, an effect perhaps at work in politics, as in religion. These two possible accounts may of course interact: people's need for a rosier view of the future may be satisfied by subscribing to religious or political groups that provide reasons to believe in such a view. The observed individual differences in optimism and learning bias would be consistent with such a mixture of social roles. These considerations also point to a third extension of the two studies<sup>3,4</sup>: given sufficient information

or persuasion, can some incorrigible optimists eventually become realists? The precarious future of our species reflected in news headlines every day makes one think that elucidating the neural mechanisms for such a metacognitive ability may be more important than ever.

#### COMPETING FINANCIAL INTERESTS

The authors declare no competing financial interests.

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## EphrinBs send mixed messages

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**A new study dissects ephrinB reverse signaling and identifies separate intracellular pathways regulating dendritic and synaptic development.**

The process of synapse development is proving to be a fascinatingly complex puzzle to solve. Although many of the individual pieces have already been identified, determining how these proteins contribute to the formation of the synapse remains a challenge. In the case of the receptor tyrosine kinases EphBs and their ligands ephrinBs, solving this puzzle has been especially demanding, as the distinction between receptor and ligand is blurry. EphBs and ephrinBs are both transmembrane proteins and can each function as either ligand or

receptor. When EphB expressed on the plasma membrane of a neuron encounters ephrinB on the surface of a nearby neuron a signal can be sent in both the forward and reverse directions<sup>1</sup>. Considering that ephrinBs and EphBs are members of large families of proteins, and that ephrinBs and EphBs can be expressed both postsynaptically and presynaptically at excitatory synapses, the possibilities for signaling complexity and information flow are enormous. In this issue of *Nature Neuroscience*, Xu *et al.*<sup>2</sup> describe their use of several creative genetic techniques to identify distinct pathways that emanate from the cytoplasmic tail of ephrinBs to control the dendritic and synaptic development of a neuron.

EphrinB/EphB signaling regulates the development and function of multiple

processes in the nervous system and beyond<sup>3</sup>. One of the first challenges in studying their role at synapses was to identify their orientation with respect to pre- and postsynaptic compartments. Initial research focused on presynaptic ephrins signaling to postsynaptic EphBs to control NMDA receptor function and synaptic plasticity, as well as the formation of dendritic spines, the locations of excitatory synapses<sup>4,5</sup>. However, at the hippocampal Schaffer collateral synapse between CA3 and CA1 pyramidal neurons, this configuration is inverted: ephrinBs are strongly expressed postsynaptically in CA1 neurons and EphBs are expressed at the presynaptic CA3 terminals. Loss-of-function studies *in vitro* and *in vivo* have implicated postsynaptic

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