Medical Xpress

Hedging your bets: How the brain makes decisions based on related information

September 21 2011

When making decisions based on multiple, interdependent factors, we choose based on how these factors correlate with each other, and not based on an ad hoc rule of thumb or through trial and error as was previously thought, according to research funded by the Wellcome Trust.

The study, published today in the journal *Neuron*, identifies the regions of the brain involved in tracking this correlation, which include the insula and the anterior cingulate cortex, both of which have previously been associated with decision making, emotions and awareness.

Decision-making is an extremely complex process, particularly when it involves a number of interdependent factors. How we make sense of these factors has until now been unclear. But researchers at the Wellcome Trust Centre for Neuroimaging at UCL, together with collaborators at the California Institute of Technology have now shown that our brains learn the correlation between events. This allows us to observe the outcome of just one action and then infer the outcomes of other actions without having to sample them individually.

Dr Klaus Wunderlich from the Wellcome Trust Centre for Neuroimaging explains: "Imagine our ancestors foraging for food in the woods. They could spend their time either collecting berries or hunting deer. But they have previously observed that deer eat berries. So, as they are foraging, if they notice a lack of fresh berries, they can infer that there are lots of deer around and instead focus on hunting."

The majority of the research into learning and decision-making over the past decade has focused on the direct relationship between actions and rewards. The scientific understanding was hitherto that we learn about each of a number of multiple rewards separately and then use trial and error or a rule of thumb to predict outcomes.

In the above example, this would mean that the hunter could only predict the success of hunting deer after having tried it and observed the actual outcome. In an ever-changing natural environment it is likely the case that the key correlations are more stable than the relationship between individual actions and reward. In other words, the fact that deer eat berries is always true, but the success at hunting deer can vary from year to year. Learning about the correlations therefore has immediate benefits for efficient choices.

To investigate how humans learn correlations between outcomes, the researchers scanned the brains of sixteen subjects using functional magnetic resonance imaging (fMRI), which measures activity in the brain, while the subjects performed a game involving managing resources. This involved a scenario whereby a power company generates fluctuating amounts of electricity from two renewable energy sources, a solar plant and a wind park.

The researchers instructed subjects to create an energy portfolio under a specific goal constraint which necessitated keeping the total energy output as constant as possible by adjusting weights that determined how the two resources were combined. The best performance was achievable by finding a solution that exploited knowledge of the interdependence of the resources, a task similar to a simple portfolio problem in finance. Importantly, the outcomes of the two resources co-varied with each other and this correlation between the two outcomes changed probabilistically over time, requiring subjects to continuously update their estimate of the current correlation.

The researchers found that the brain represents information about how much the two resources are correlated with each other in the insula and the anterior cingulate cortex, and uses a mechanism based on measuring how accurate the prediction was to update this information each time new information becomes available.

"It may be possible that such an evolved mechanism works best if the correlation is learnt through multiple observations, but this learning mechanism is still unable to make sense of complex statistics from tables or charts," says Dr Wunderlich. "This might explain why humans often utterly fail at making financial decisions that are based on understanding correlations."

Co-author Peter Bossaerts, a Professor of Finance at the California Institute of Technology, takes an economist's view of the research.

"When investing in more than one asset, such as stocks and bonds, it is important that one does so with the right mix, which is determined by the correlation between the returns on the assets." But how do we actually make this judgement?

"We are often presented with rough rules of thumb depending on our risk aversion – the more risk averse, the more bonds we invest in. In fact, from the point of view of financial returns, the mix between stocks and bonds should not depend on risk aversion at all, but on how correlated the two are. And, as we show in this research, in fact we do combine sources in an optimal way, taking into account explicitly how the outputs are correlated."

More information: Wunderlich, K et al. Hedging your bets by learning reward correlations in the human brain. *Neuron*; 22 September 2011