Study suggests human brain optimally weights information during learning

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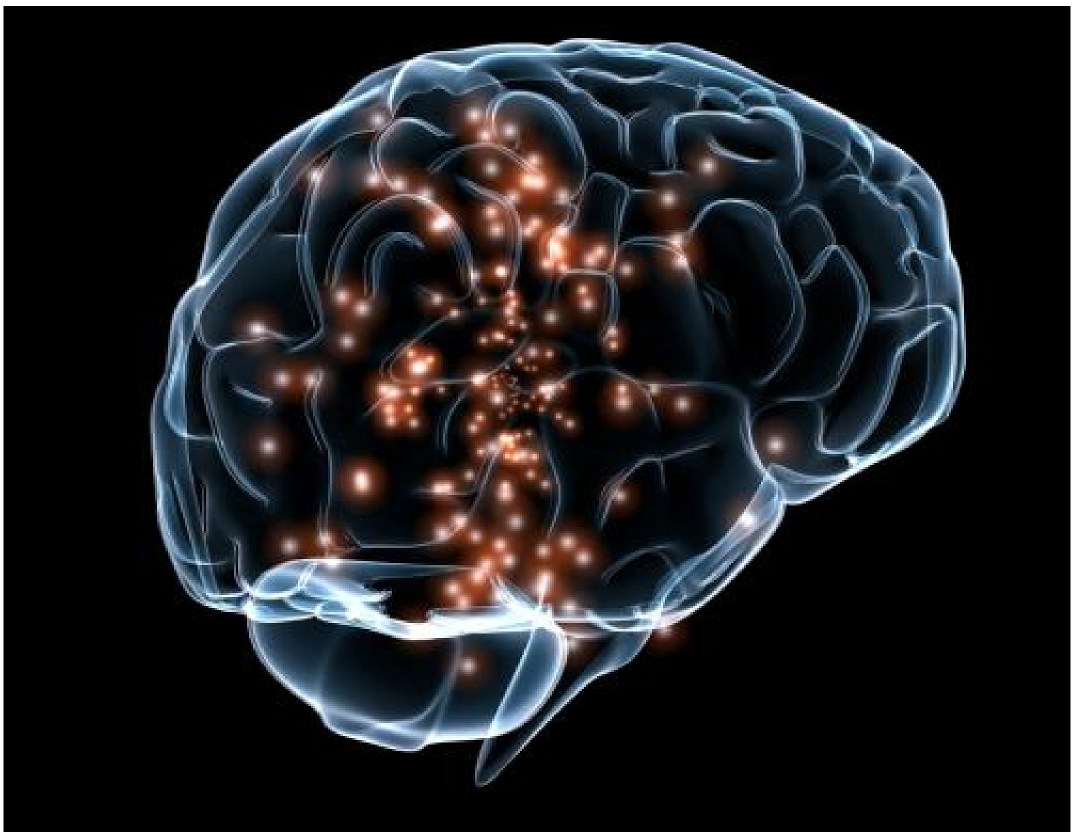

Credit: Wikimedia Commons

(Medical Xpress)—The human brain's capacity for learning is adaptable to a variety of conditions. When the environment changes repeatedly and constantly, learning is difficult, because the brain automatically seeks patterns in incoming information. This requires weighting prior knowledge and incoming data according to reliability.

Recently, two researchers in France proposed that that brain assigns levels of confidence to both new and prior pieces of information by algorithmically evaluating the reliability of knowledge, and conducted an experiment to verify it. They have published the results of their study in the *Proceedings of the National Academy of Sciences*.

Twenty-one participants conducted a learning task while the researchers scanned them via fMRI. Subjects were presented visual and auditory stimuli in alternated sessions. The subjects experienced stable periods during which the order of the stimuli was constant, and they were able to assign high levels of confidence to the likelihood that a particular stimulus would be presented next. However, at random intervals chosen to avoid lengthy stable periods, the order of stimuli changed.

The researchers paused the sequence at semi-regular intervals and asked the subjects to report their confidence on a four-point scale with a dedicated button. It's important that before the experiment, the subjects were fully informed about the task structure and the process for generating the sequences of stimuli. The performances of the subjects were compared to that of an "ideal observer," an optimised Bayseian model that optimally estimates the likelihood of the current hidden transition probabilities.

The study determined that humans possess a sense of confidence in learned material that is remarkably similar to the "ideal observer" model. The researchers write, "We propose that learning approaches optimality in humans because it shares two features of the optimal algorithm: It relies on a sense of confidence that serves as a weighting factor to balance prior estimates and new observations; and confidence is organized hierarchically, taking into account higher-order factors such as volatility."

The fMRI scans indicated that a confidence-based statistical algorithm for auditory and visual sequences is hosted in the inferior frontal sulcus. The main effect of confidence that the researchers observed were fMRI signals in this brain region that increased as confidence decreased. They also looked for fMRI effects of surprise, another important factor in the learning process. They observed these signals across several areas, but notably also in the inferior frontal sulcus.

Previous learning studies have demonstrated that environmental volatility leads to a decrease in confidence that is strikingly similar to the ideal observer algorithm. And studies have also revealed that drops in confidence boost learning, perhaps resetting the learning process altogether, priming the brain to seek new patterns. The researchers note that the study shows that "the human brain performs better than classical learning algorithms predict, and indeed makes near-optimal use of all the available evidence when updating its internal model."

More information: Brain networks for confidence weighting and hierarchical inference during probabilistic learning. *PNAS* 2017 ; published ahead of print April 24, 2017, DOI: 10.1073/pnas.1615773114

Abstract
Learning is difficult when the world fluctuates randomly and ceaselessly. Classical learning algorithms, such as the delta rule with constant learning rate, are not optimal. Mathematically, the optimal learning rule requires weighting prior knowledge and incoming evidence according to their respective reliabilities. This "confidence weighting" implies the maintenance of an accurate estimate of the reliability of what has been learned. Here, using fMRI and an ideal-observer analysis, we demonstrate that the brain's learning algorithm relies on confidence weighting. While in the fMRI scanner, human adults attempted to learn the transition probabilities underlying an auditory or visual sequence,

and reported their confidence in those estimates. They knew that these transition probabilities could change simultaneously at unpredicted moments, and therefore that the learning problem was inherently hierarchical. Subjective confidence reports tightly followed the predictions derived from the ideal observer. In particular, subjects managed to attach distinct levels of confidence to each learned transition probability, as required by Bayes-optimal inference. Distinct brain areas tracked the likelihood of new observations given current predictions, and the confidence in those predictions. Both signals were combined in the right inferior frontal gyrus, where they operated in agreement with the confidence-weighting model. This brain region also presented signatures of a hierarchical process that disentangles distinct sources of uncertainty. Together, our results provide evidence that the sense of confidence is an essential ingredient of probabilistic learning in the human brain, and that the right inferior frontal gyrus hosts a confidence-based statistical learning algorithm for auditory and visual sequences.