# Researchers find that the unexpected is a key to human learning

March 13 2009

The human brain's sensitivity to unexpected outcomes plays a fundamental role in the ability to adapt and learn new behaviors, according to a new study by a team of psychologists and neuroscientists from the University of Pennsylvania.

Using a computer-based card game and microelectrodes to observe neuronal activity of the brain, the Penn study, published this week in the journal *Science*, suggests that neurons in the human substantia nigra, or SN, play a central role in reward-based learning, modulating learning based on the discrepancy between the expected and the realized outcome.

"This is the first study to directly record neural activity underlying this learning process in humans, confirming the hypothesized role of the basal ganglia, which includes the SN, in models of reinforcement including learning, addiction and other disorders involving reward-seeking behavior," said lead author Kareem Zaghloul, postdoctoral fellow in neurosurgery at Penn's School off Medicine. "By responding to unexpected financial rewards, these cells encode information that seems to help participants maximize reward in the probabilistic learning task."

Learning, previously studied in animal models, seems to occur when dopaminergic neurons, which drive a larger basal ganglia circuit, are activated in response to unexpected rewards and depressed after the unexpected omission of reward. Put simply, a lucky win seems to be retained better than a probable loss.

Similar to an economic theory, where efficient markets respond to unexpected events and expected events have no effect, we found that the dopaminergic system of the human brain seems to be wired in a similar rational manner -- tuned to learn whenever anything unexpected happens but not when things are predictable," said Michael J. Kahana, senior author and professor of psychology at Penn's School of Arts and Sciences.

Zaghloul worked with Kahana and Gordon Baltuch, associate professor of neurosurgery, in a unique collaboration among departments of psychology, neurosurgery and bioengineering. They used microelectrode recordings obtained during deep brain stimulation surgery of Parkinson's patients to study neuronal activity in the SN, the midbrain structure that plays an important role in movement, as well as reward and addiction. Patients with Parkinson's disease show impaired learning from both positive and negative feedback in cognitive tasks due to the degenerative nature of their disease and the decreased number of dopaminergic neurons.

The recordings were analyzed to determine whether responses were affected by reward expectation. Participants were asked to choose between red and blue decks of cards presented on a computer screen, one of which carried a higher probability of yielding a financial reward than the other. If the draw of a card yielded a reward, a stack of gold coins was displayed along with an audible ring of a cash register and a counter showing accumulated virtual earnings. If the draw did not yield a reward or if no choice was made, the screen turned blank and participants heard a buzz.

"This new way to measure dopaminergic neuron activity has helped us gain a greater understanding of fundamental cognitive activity," said Baltuch, director of the Penn Medicine Center for Functional and Restorative Neurosurgery.