New model describes cognitive decision making as the collapse of a quantum superstate

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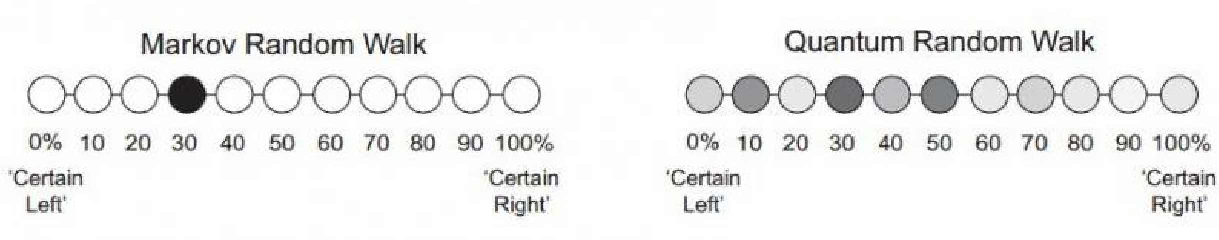

Diagram of a state representation of a Markov and a quantum random walk model. In the Markov model, evidence (shaded state) evolves over time by moving from state to state, occupying one definite evidence level at any given time. In the quantum model the decision-maker is in an indefinite evidence state, with each evidence level having a probability amplitude (shadings) at each point in time. Credit: (c) 2015 *PNAS*; doi:10.1073/pnas.1500688112

(Phys.org)—Decision making in an enormous range of tasks involves the accumulation of evidence in support of different hypotheses. One of the enduring models of evidence accumulation is the Markov random walk (MRW) theory, which assigns a probability to each hypothesis. In an MRW model of decision making, when deciding between two hypotheses, the cumulative evidence for and against each hypothesis reaches different levels at different times, moving particle-like from state to state and only occupying a single definite evidence level at any given point.

But the Markov random walk theory, based in classical probability theory, runs into problems when confronted with the emerging research consensus that preferences and beliefs are constructed, rather than revealed by judgments and decisions. An international group of psychological researchers now suggests a new model called the quantum random walk (QRW) theory that specifically posits that preferences and beliefs are constructed rather than revealed by judgments and decisions, and they have published the results of an experiment that support this theory in the *Proceedings of the National Academy of Sciences*.

By contrast with MRW, the new theory assumes that evidence develops over time in a superposition state analogous to the wave-like state of a photon, and judgements and decisions are made when this indefinite superposition state "collapses" into a definite state of evidence. It's important to note that the researchers are not suggesting that the brain is a quantum computer; they specifically note that their report uses quantum dynamics only metaphorically.

In the experiment, nine study participants completed 112 blocks of 24 trials each over five sessions, in which they viewed a random dot motion stimulus on a screen. A percentage of the dots moved coherently in a single direction. The researchers manipulated the difficulty of the test between trials. In the choice condition, participants were asked to decide whether the coherently moving dots were traveling to the left or the right. In the no-choice condition, participants were prompted by an audio tone simply to make a motor response.

Then participants were asked to rate their confidence that the coherently moving dots were traveling to the right on a scale ranging from 0 (certain left) to 100 percent (certain right). The researchers report that, on average, confidence ratings were much higher when the trajectories of the dots were highly coherent. Confidence ratings were lower in the no-choice condition than in the choice condition, providing evidence against the read-out assumption of MRW theory, which holds that confidence in the choice condition should be higher.

The QRW theory posits that evidence evolves over time, as in MRW, but that judgments and decisions create a new definite state from an indefinite, superposition-like state. "This quantum perspective reconceptualizes how we model uncertainty and formalizes a long-held hypothesis that judgments and decisions create rather than reveal preferences and beliefs," the authors write.

They conclude, "...quantum random walk theory provides a previously unexamined perspective on the nature of the evidence accumulation process that underlies both cognitive and neural theories of decision making."

More information: "Interference effects of choice on confidence: Quantum characteristics of evidence accumulation." *PNAS*, published ahead of print August 10, 2015, DOI: 10.1073/pnas.1500688112

Abstract

Decision-making relies on a process of evidence accumulation which generates support for possible hypotheses. Models of this process derived from classical stochastic theories assume that information accumulates by moving across definite levels of evidence, carving out a single trajectory across these levels over time. In contrast, quantum decision models assume that evidence develops over time in a superposition state analogous to a wavelike pattern and that judgments and decisions are constructed by a measurement process by which a definite state of evidence is created from this indefinite state. This constructive process implies that interference effects should arise when multiple responses (measurements) are elicited over time. We report

such an interference effect during a motion direction discrimination task. Decisions during the task interfered with subsequent confidence judgments, resulting in less extreme and more accurate judgments than when no decision was elicited. These results provide qualitative and quantitative support for a quantum random walk model of evidence accumulation over the popular Markov random walk model. We discuss the cognitive and neural implications of modeling evidence accumulation as a quantum dynamic system.

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