Researchers show that an iron bar is capable of decision-making

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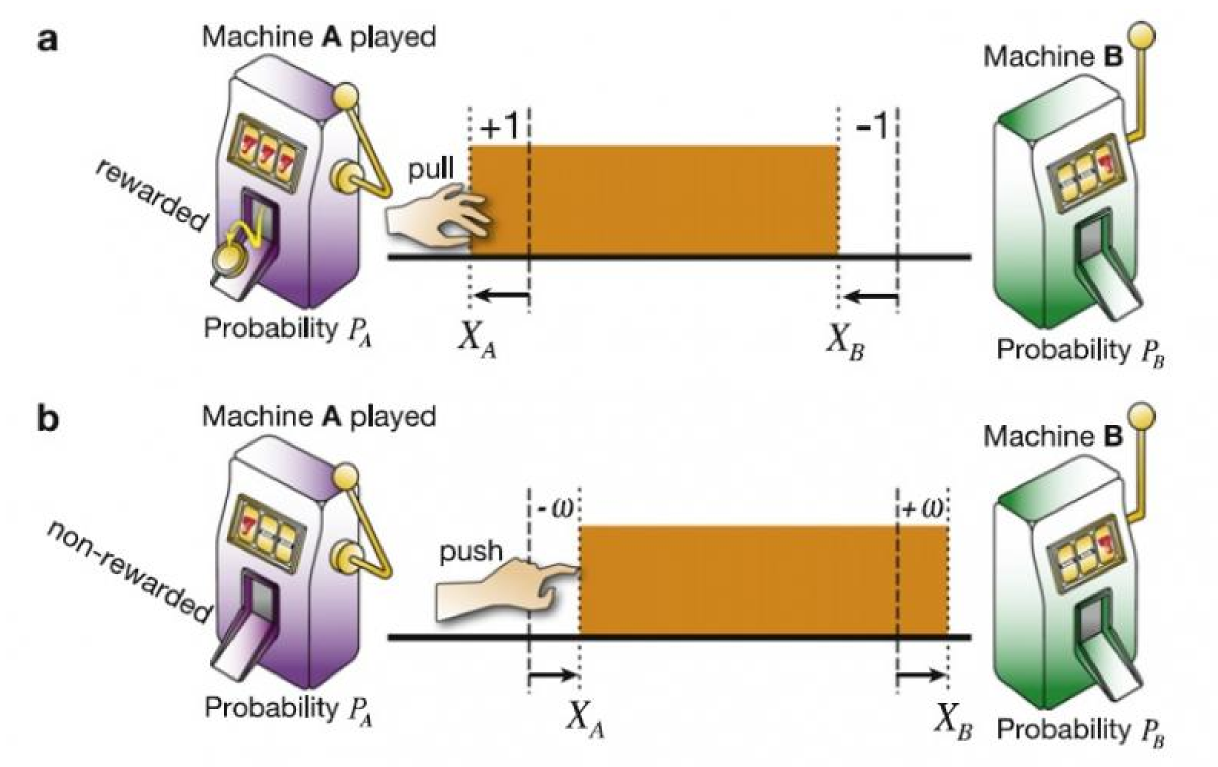

In tug-of-war dynamics, an iron bar can decide which slot machine has the higher winning probability by moving to the left for each rewarded play and to the right for each non-rewarded play of Machine A. The bar's movements are caused by physical fluctuations. Credit: Kim, et al.

(Phys.org)—Decision-making—the ability to choose one path out of several options—is generally considered a cognitive ability possessed by biological systems, but not by physical objects. Now in a new study, researchers have shown that any rigid physical (i.e., non-living) object, such as an iron bar, is capable of decision-making by gaining information from its surroundings accompanied by physical fluctuations.

The researchers, Song-Ju Kim, Masashi Aono, and Etsushi Nameda, from institutions in Japan, have published their paper on decision-making by physical objects in a recent issue of the *New Journal of Physics*.

"The most important implication that we wish to claim is that the proposed scheme will provide a new perspective for understanding the information-processing principles of certain lower forms of life," Kim, from the International Center for Materials Nanoarchitectonics' National Institute for Materials Science in Tsukuba, Ibaraki, Japan, told *Phys.org*. "These lower lifeforms exploit their underlying physics without needing any sophisticated neural systems."

As the researchers explain in their study, the only requirement for a physical object to exhibit an efficient decision-making ability is that the object must be "volume-conserving." Any rigid object, such as an iron bar, meets this requirement and therefore is subject to a volume conservation law. This means that, when exposed to fluctuations, the object may move slightly to the right or left, but its total volume is always conserved. Because this displacement resembles a tug-of-war game with a rigid object, the researchers call the method "tug-of-war (TOW) dynamics."

Here's an example of how the idea works: Say there are two slot machines A and B with different winning probabilities, and the goal is to decide which machine offers the better winning probability, and to do so as quickly as possible based on past experiences.

The researchers explain that an ordinary iron bar can make this decision. Every time the outcome of a play of machine A ends in a reward, the bar moves to the left a specific distance, and every time the outcome ends in no reward, the bar moves to the right a specific distance. The same goes for a play of machine B, but the directions of the bar movements are reversed. After enough trials, the bar's total displacement reveals which slot machine offers the better winning probability.

The researchers explain that the bar's movements occur due to physical fluctuations.

"The behavior of the physical object caused by operations in the TOW can be interpreted as a fluctuation," Kim said. "Other than this fluctuation, we added another fluctuation to our model. The important point is that fluctuations, which always exist in real physical systems, can be used to solve decision-making problems."

The researchers also showed that the TOW method implemented by physical objects can solve problems faster than other decision-making algorithms that solve similar problems. The scientists attribute the superior performance to the fact that the new method can update the probabilities on both slot machines even though it plays just one of them. This feature stems from the fact that the system knows the sum of the two reward probabilities in advance, unlike the other decision-making algorithms.

The researchers have already experimentally realized simple versions of a physical object that can make decisions using the TOW method in related work.

"The TOW is suited for physical implementations," Kim said. "In fact, we have already implemented the TOW in quantum dots, single photons, and atomic switches."

By showing that decision-making is not limited to biological systems, the new method has potential applications in artificial intelligence.

"The proposed method will introduce a new physics-based analog computing paradigm, which will include such things as 'intelligent nanodevices' and 'intelligent information networks' based on self-detection and self-judgment," Kim said. "One example is a device that can make a directional change so as to maximize its light-absorption." This ability is similar to how a young sunflower turns in the direction of the sun.

Another possibility that the researchers recently explored is an analogue computer that harnesses natural fluctuations in order to maximize the total rewards "without paying the conventionally required computational cost."

More information: Song-Ju Kim, et al. "Efficient decision-making by volume-conserving physical object." *New Journal of Physics*. DOI: 10.1088/1367-2630/17/8/083023