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Unicellular decision making: How slime mould cracks the Two-Armed-Bandit problem

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A fundamental conundrum in decision making is the exploration-exploitation tradeoff; do I exploit well-known but potentially sub-optimal options, or do I risk further exploration for potentially more rewarding ones? The problem faces casino gamblers and foraging organisms alike, but there remains no known generally optimal solution. Several studies in humans and other animals have examined the tradeoff using the 2-Armed Bandit problem, where a player aims to maximize their gain when faced with two slot machines, each with a distinct but unknown reward rate. Studies thus far have only been undertaken in organisms with brains, yet the exploration-exploitation tradeoff also applies to unicellular foragers, which must tackle the problem without the aid of neurons. Also, solutions offered by collective systems have never been investigated. We tested the slime mould *Physarum polycephalum*, which behaves as a self-organized collective system, with the 2-Armed Bandit problem by assessing the effect of sampling on foraging patch choice in a T-maze. We generate insight into the basic processes of decision making in a unicellular organism, including the use of relative vs absolute reward criteria (in both the frequency of reward, and the combination of frequency and magnitude), and the effect of static vs dynamic exploration environments - factors demonstrated to affect human decision making processes. We then propose several biologically plausible decision criteria the slime mould may be using, and use Bayesian inference to determine which of these models best explains the empirical data. These results can directly inform new models of slime mould decision making and behaviour, improving on the existing, largely biomechanical framework, by incorporating new insight into slime mould 'psychology'. Our study challenges the common view that neurological hardware is required to solve complex problems, and provides insight into basic processes of decision making, beyond phylogenetic boundaries and orders of biological organization.