Exaptation of an entropy generator from foraging to decision making domains

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Core concept

- Humans posses an evolved psychological mechanism, hypothesized as an “Entropy-Generator” ($E_{generator}$), which produces structured (non-random) behavioral stochasticity ($E_{behavioral}$)
- Evolutionary trajectory and function: I propose exaptation of $E_{generator} \rightarrow F_{foraging}$ (optimal foraging) to $E_{generator} \rightarrow F_{foraging} \rightarrow F_{DM}$ (information foraging)

Main model

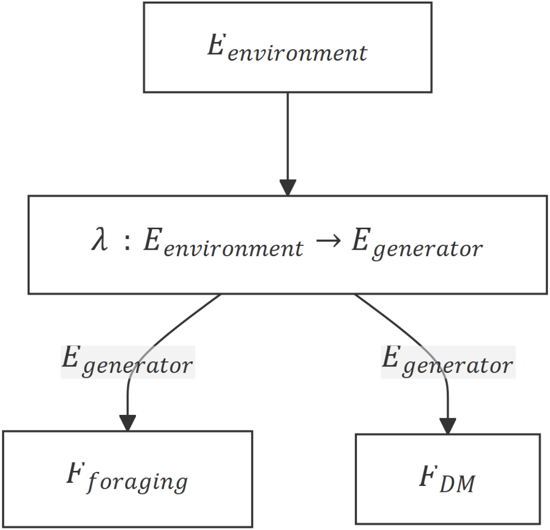


Figure 1: Proposed logical flow

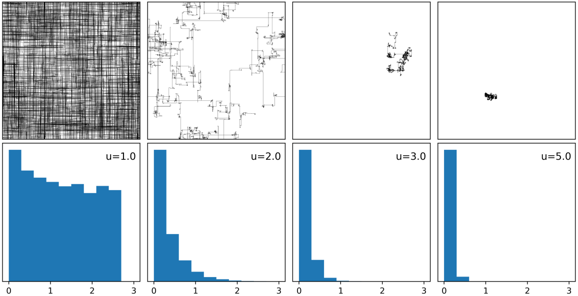
Theory

- Part (I): show that there's an optimal foraging function that is generated by a $E_{generator}$
- Part (II): proposed exaptation as useful conceptual tool
- Part (III): show that decision-making solves the same problems as foraging

Theory (I): Lévy-Flight search theory

- Lévy distributions describe typical foraging patterns across multiple species
- $1 < \mu < 3$, describes the specific "diffusive" pattern empirical observed

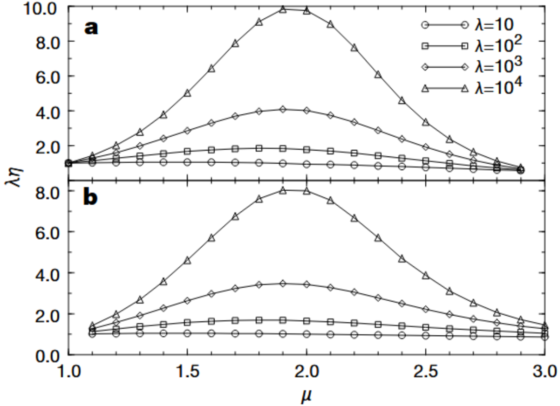
$$P(l) \sim l^{-\mu}$$



(Campeau, Simons, and Stevens 2022)

Theory (I): Adaptive search stochasticity

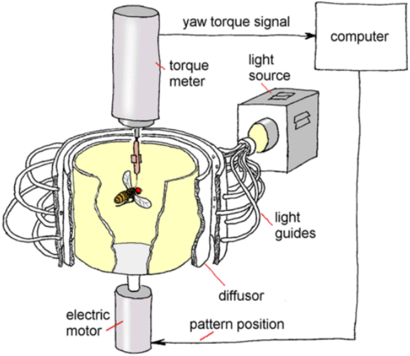
- Simulations show that with sparse and patchy environments $\lambda = 10^4$, foraging efficiency η is optimized
- Lévy-like patterns are optimal for expected environments



(Viswanathan et al. 1999)

Theory (I): Behavioral variability mechanism

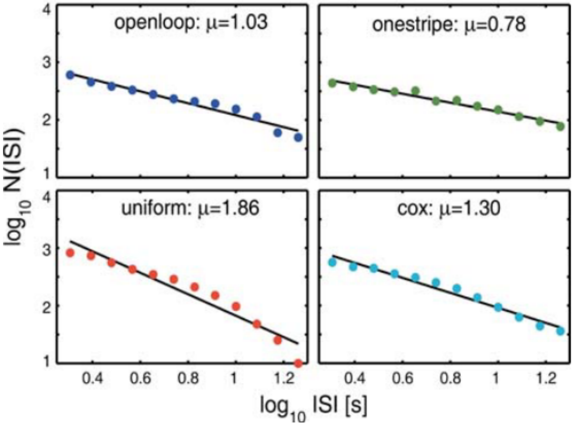
- No stimulus environment
- Why there's behavioral variability?
- What kind of behavioral variability is produced?



(Maye et al. 2007)

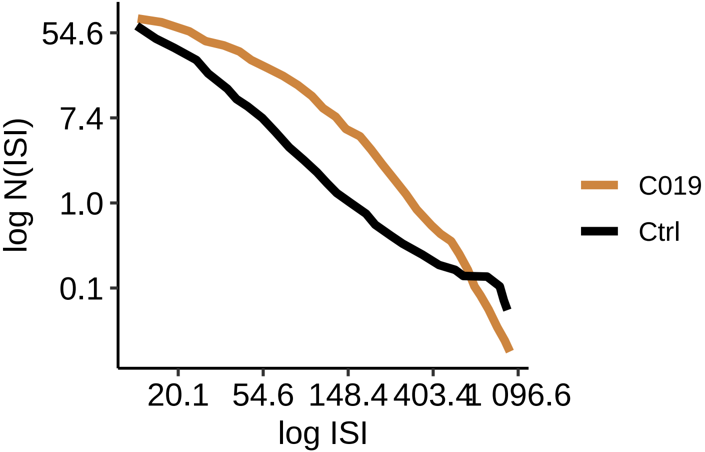
Theory (I): Behavioral variability mechanism

- Log cumulative inter-spike interval (ISI) $\sim$ log ISI
- Linear relationship shows, in general, high probability of short ISI, and low probability for long ISI
- Lévy exponent $\mu \approx \beta$, thus Lévy-flight describes spontaneous behavior



Theory (I): Behavioral variability mechanism

- Targeted synaptic blocking at the ellipsoid body
- Destroys power-law distribution (linear in log-log)



(Martin, and Ernst 2001)

Theory (II): Exaptation

- Exaptation describes a feature, that did not arise as adaptation for its present role, but was subsequently co-opted for its current function
- Highlights aquisition of new functions without needing to evolve entirely new traits de novo
- Feathers thermoregulation function $\rightarrow$ flight

(Gould 1991)

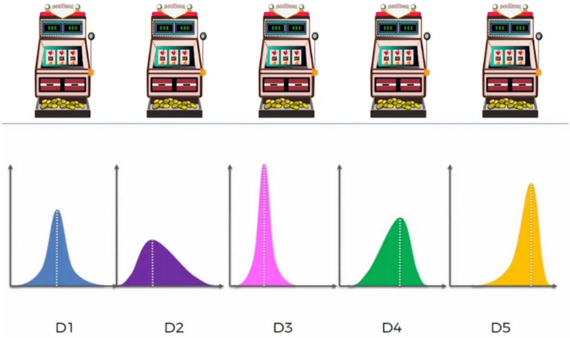
Theory (III): Information foraging

- Exploration-exploitation dilemma
- Foraging: new food source, consume food to avoid starvation
- Decision making: 'try out a new restaurant', 'chinese food'
- We can understand this as a general uncertainty-reduction problem

(Gershman 2018)

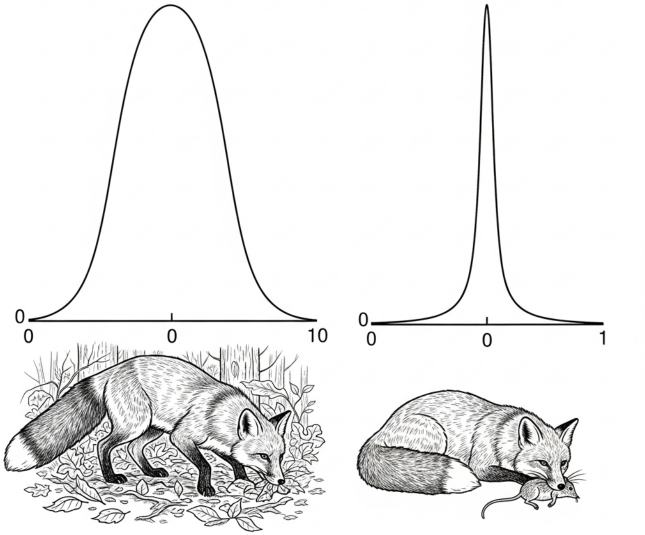
Theory (III): Formal models of decision-making

- Update a probability distribution after each decision
- Sample from each distribution and chose the one with the largest value
- Distributions with large expected value get chosen often (D5), but distribution with high uncertainty (variability) can also sample large values (D2)



(Sutton and Barto 2020)

Theory (III): Formal models of decision-making



Framework

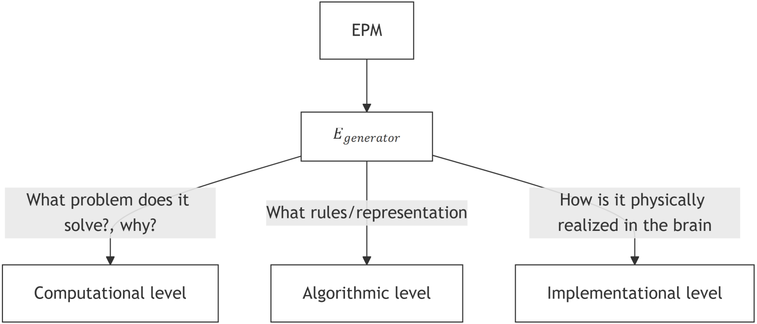


Figure 2: Proposed framework

(Tooby and Cosmides 2015; Marr 1996)

Methods

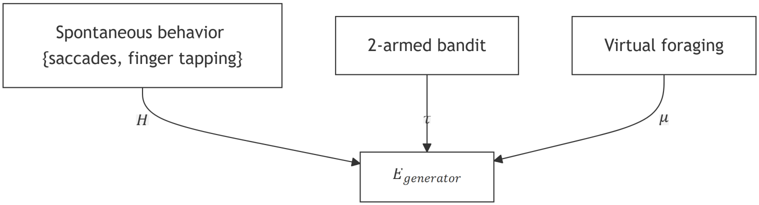


Figure 3: Proposed experiments

Hypothesis

- Environmental entropy $\rightarrow$ Entropy generator
- $corr(S_{behavior}, F_{foraging}) \neq 0$
- $corr(S_{behavior}, F_{DM}) \neq 0$
- $corr(S_{foraging}, F_{DM}) \neq 0$
- Formal model of decision-making better predicts $S_{behavior}$ (deterministic clock-like process)
- VTA/Basal-ganglia (reward-related circuits) modulation $\rightarrow$ $\theta_{spontaneous}, \theta_{foraging}, \theta_{DM}$

Thanks!

References

Campeau, Winston, Andrew M. Simons, and Brett Stevens. 2022. "The Evolutionary Maintenance of Lévy Flight Foraging." *PLOS Computational Biology* 18 (1): e1009490. https://doi.org/10.1371/journal.pcbi.1009490.

Gershman, Samuel J. 2018. "Deconstructing the Human Algorithms for Exploration." *Cognition* 173 (April): 34–42. https://doi.org/10.1016/j.cognition.2017.12.014.

Gould, Stephen Jay. 1991. "Exaptation: A Crucial Tool for an Evolutionary Psychology." *Journal of Social Issues* 47 (3): 43–65. https://doi.org/10.1111/j.1540-4560.1991.tb01822.x.

Marr, David. 1996. *Vision: a computational investigation into the human representation and processing of visual information*. 13. print. New York: Freeman.

Martin, Jean-Rene, Faure ,Philippe, and Roman and Ernst. 2001. "The Power Law Distribution for Walking-Time Intervals Correlates with the Ellipsoid-Body in Drosophila." *Journal of*