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Emergence of long time scales in a fluctuating landscape picture of animal behavior

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Animal movement exhibits multiple time scales: from the fine-scale movements of the limbs, to the behavioral sequences that result in different search strategies, all the way up to aging. Here, we hypothesize that the multiplicity of scales inherent to behavior effectively breaks ergodicity, preventing the system from reaching a steady state within experimental time scales. This motivates a phenomenological picture in which the behavioral dynamics evolve in a fluctuating potential landscape: the different wells correspond to stereotyped movements while the potential itself fluctuates reflecting slow changes in strategies or internal states. Under general assumptions for the underlying dynamics, we show that driving the potential landscape slowly and strongly enough results in the emergence of heavy-tailed first passage times, which asymptote to a power law with an exponent of -2 . Finally, we illustrate these results in the behavior of the nematode *C. elegans*, in which a slowly varying potential landscape accurately predicts the nontrivial statistical properties of the dynamics. Such inferred slow dynamics reflect underlying neuro-physiological patterns, opening up new paths for the understanding of how such internal states are generated and controlled by the organism.

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