Deconstructing the value-based serial decision making process in *Drosophila* foraging

V.M. Corrales[1,2,3], A.A. Faisal[3,4,5], C. Ribeiro[2]

[1]Universidade Nova de Lisboa, MIT-Portugal Program, Lisbon, Portugal
[1]veronica.corrales@neuro.fchampalimaud.org
[2]Behavior and Metabolism Laboratory, Champalimaud Centre for the Unknown, Lisbon, Portugal
[2]carlos.ribeiro@neuro.fchampalimaud.org
[3]Department of Bioengineering, Imperial College London, London, United Kingdom
[4]Department of Computing, Imperial College London, London, United Kingdom
[4]a.faisal@imperial.ac.uk
[5]MRC Clinical Sciences Center, London, United Kingdom

We investigated how decision making is modulated by sensory information and internal state, by studying foraging behaviour in *Drosophila*. Flies balance yeast (main protein source) and carbohydrate intake depending on their metabolic and mating state to maximise fitness [1,2]. While proteins are required for offspring production they also reduce the lifespan of the animal. In order to understand the computations underlying this ethologically relevant value-based decision-making process, we decided to use a quantitative approach to capture the dynamics of this nutritional decision. We developed an automated machine-vision system, that records single fruit flies as they forage in a circular arena (radius = 3.3cm) containing 18 nutrient spots. Initially, 290 female flies were presented with two types of food options, 9 sucrose and 9 yeast spots. Each spot is composed of 18% food mixed with 0.75% agarose. As a control for non-food related activity, an additional group of 83 females was presented with 18 spots containing only 0.75% agarose. All flies' behaviour was recorded for 2 hours.

We first observed a characteristic speed profile that ranged between 0 to 4 mm/s, displayed only around food spots and not agarose spots. Based on this observation, we used both, distance to spot and speed, to determine the probability of engagement in a food spot at each point in time. The area below each engagement peak corresponds to the approximate duration of that engagement bout. We found that the distribution of sucrose durations follow power-laws characteristic of scale-invariant dynamics [3,4].

To assess the effect of internal state in the sequential dynamics of these decisions, we looked at the transition probabilities between spots and classified them into three types: transition to 1) a different spot of the same food type, 2) a spot of different food type or 3) the same spot (revisits). We found that mating has a very significant effect on both the sequential and temporal dynamics of these decisions resulting in a switch in nutrient preference from carbohydrates to proteins as captured by an increased total time in yeast ($p<0.001$) after mating. Currently, we are evaluating the effects of selective nutritional deprivations on these parameters.

Together these findings show that the internal state modulates the departure decision ("explore or exploit") and the arrival decision ("choose or move on") in order to achieve homeostasis. Our automated analysis makes these computational questions directly amenable to testing by genetic and neuronal manipulation.

References

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