Mushroom body output neuron 02 regulates the transition from goal-directed actions to habits in *Drosophila*

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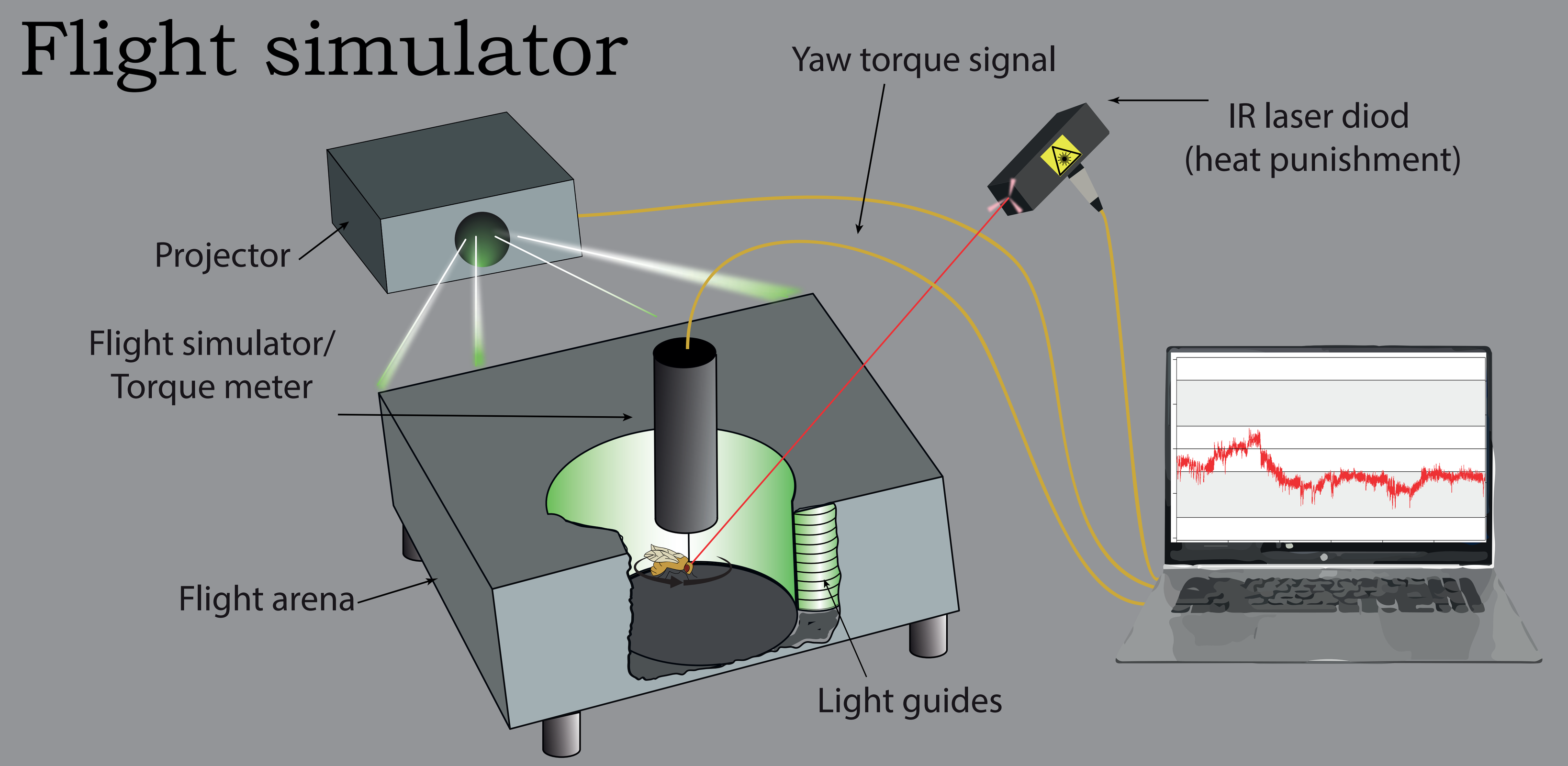
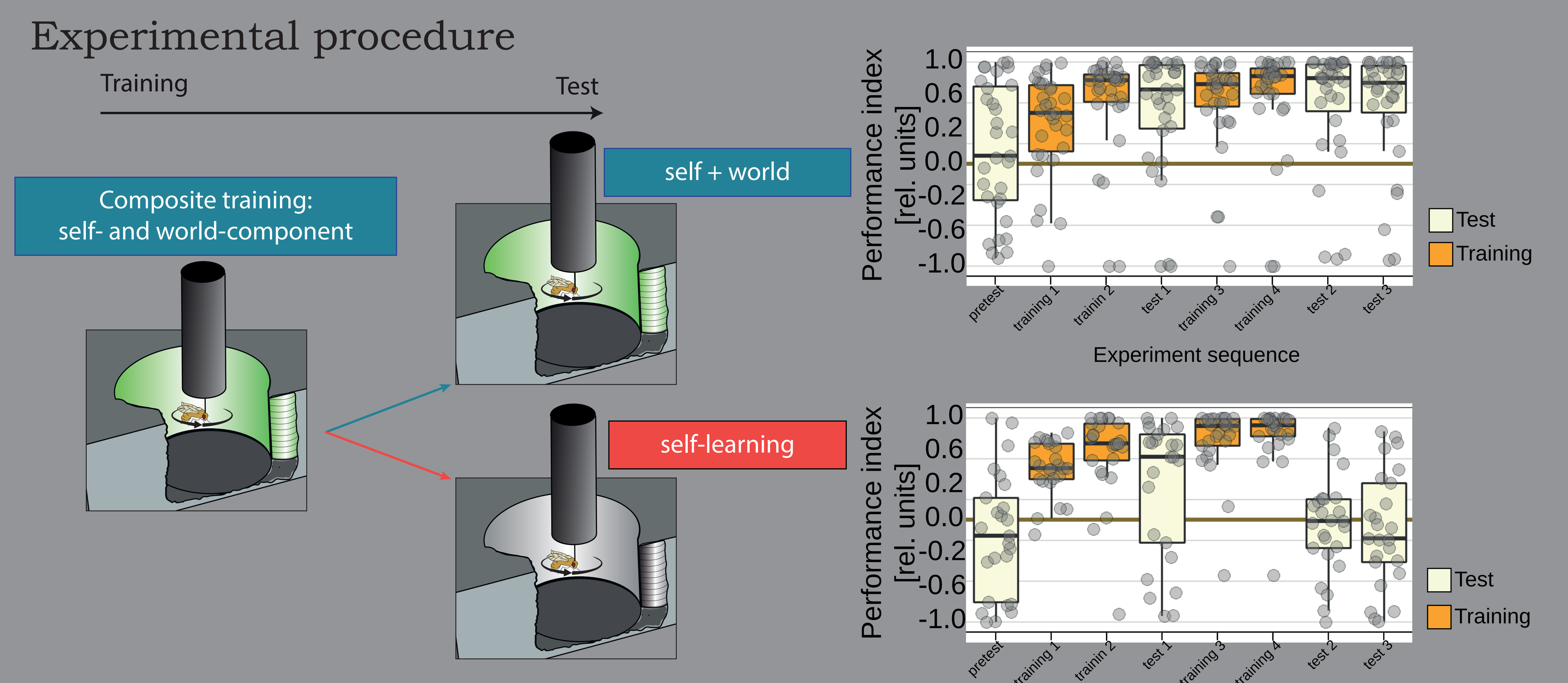
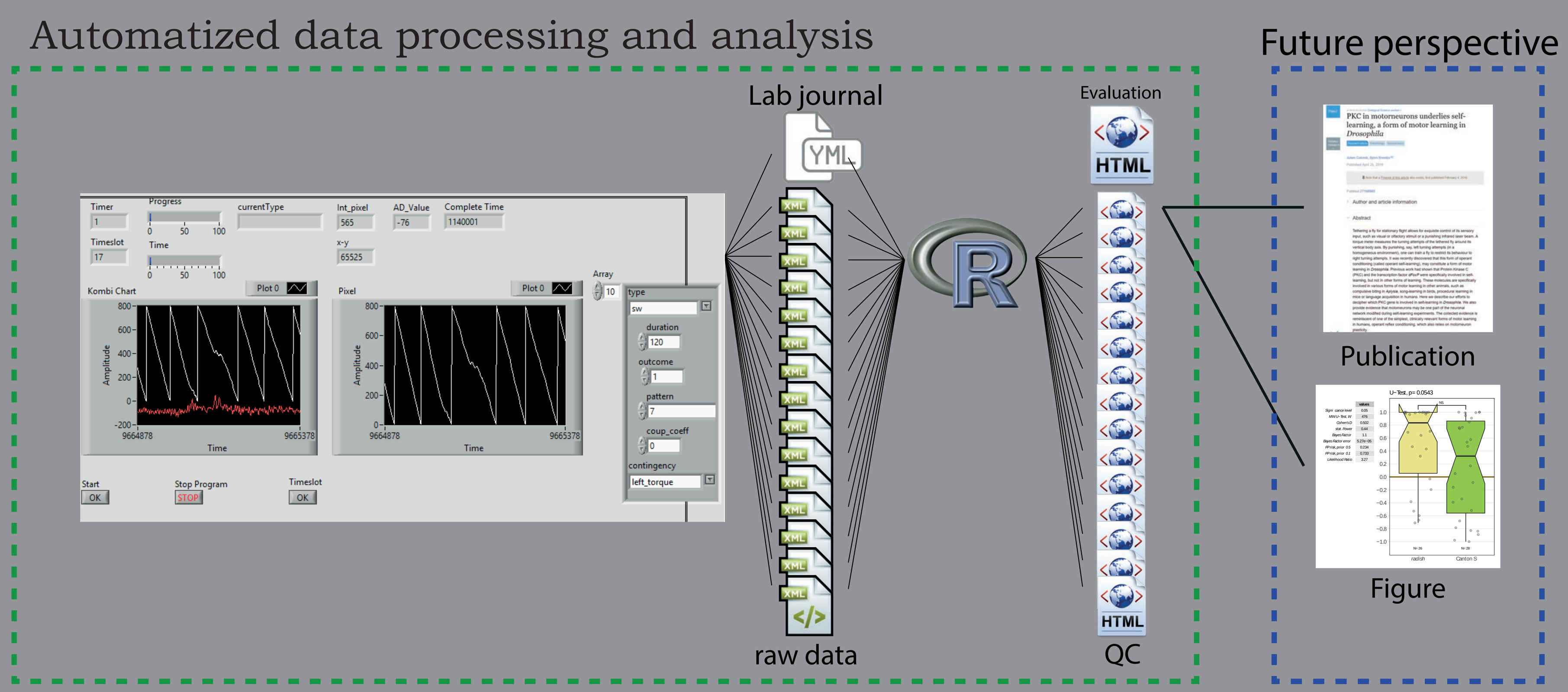
Background

Goal-directed exploration of the environment allows an animal to learn about the relationships between stimuli and how the environment responds to its actions. In this goal-directed phase, animals can flexibly apply learned relationships to other contexts. However, flexibility usually implies a cost in time, together with higher cognitive and energetic costs. In contrast, the formation of habits ensures fast and efficient behaviors. The learning mechanisms that lead to flexible and efficient behaviors, respectively, interact with each other. During the early, goal-directed phase of such composite operant learning situations, the process that mediates learning about relations in the environment (world-learning) is known to inhibit the process that renders behaviors stereotypic and efficient (self-learning), presumably in order to prevent premature habit-formation. In humans, imbalance between flexible actions and habitual responses can be linked to neuropsychiatric diseases (OCD, drug addiction). We use the fruit fly *Drosophila* to study the interactions between world- and self-learning which mediate the transition mechanisms from goal-directed actions to habitual responses. In *Drosophila* goal-directed behavior inhibits habit formation at the level of the mushroom bodies (MB), such that inhibition of the MBs results in premature habit formation. Here, we present the identification of a single mushroom body output neuron responsible for mediating this highly adaptive interaction between the two learning systems.

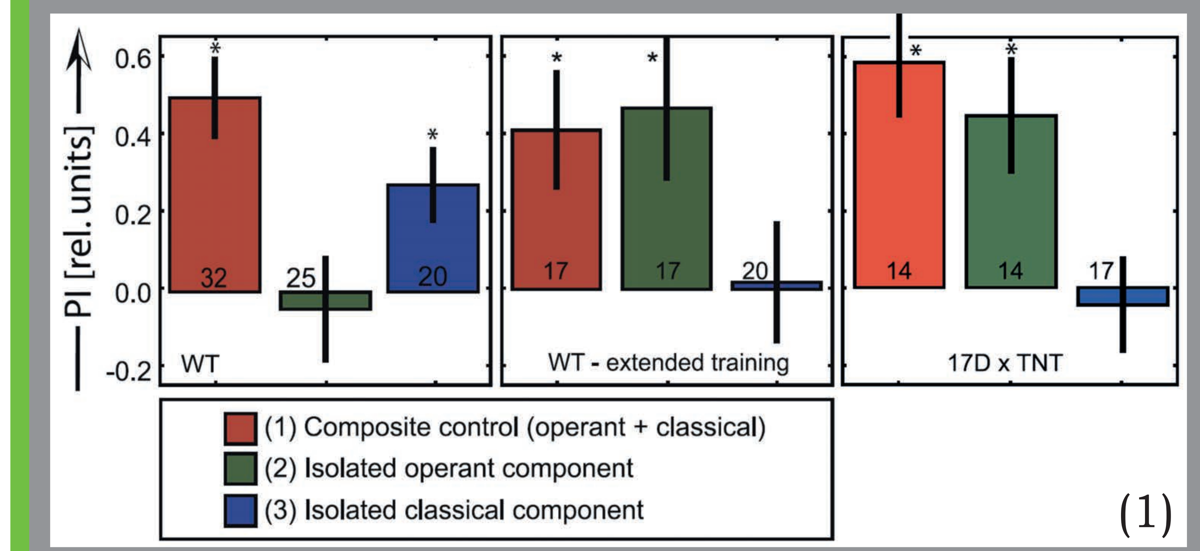
Methods

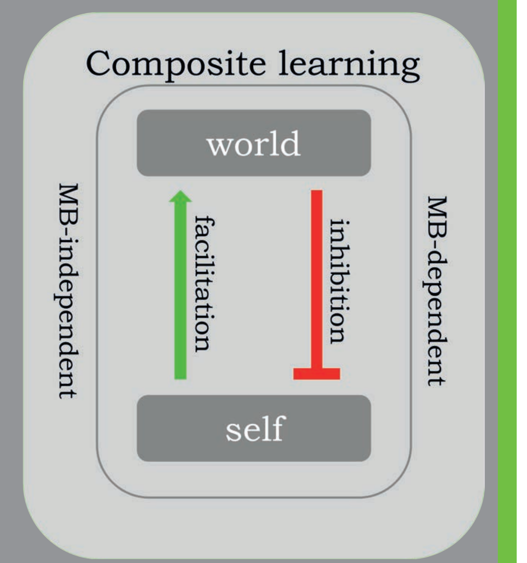




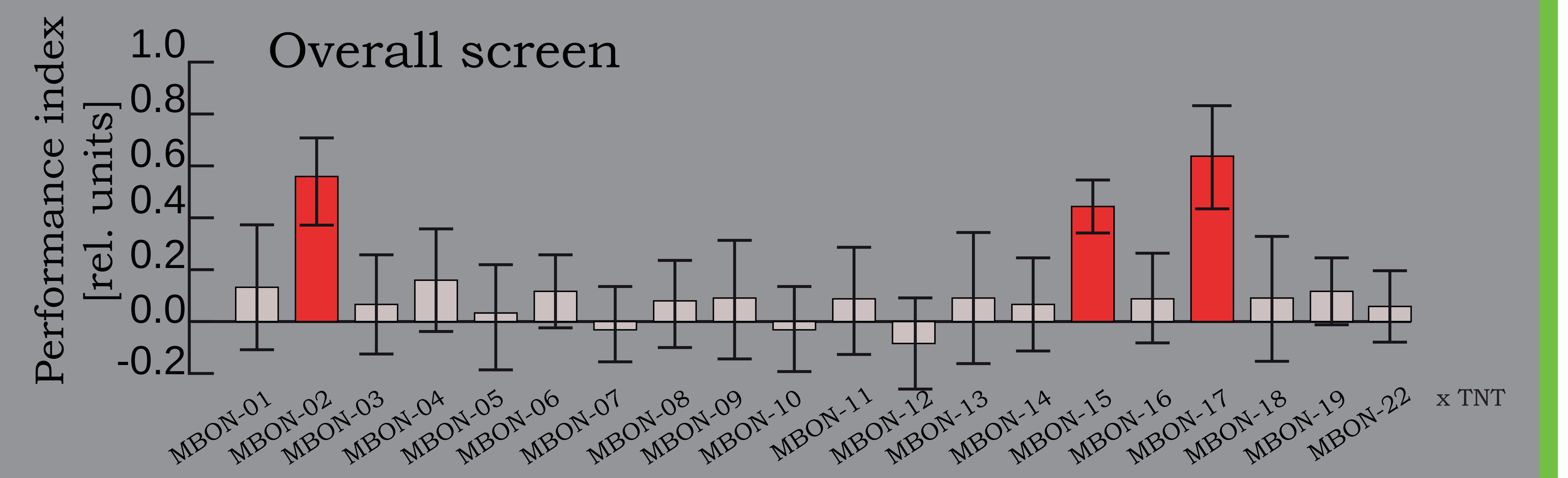


Results



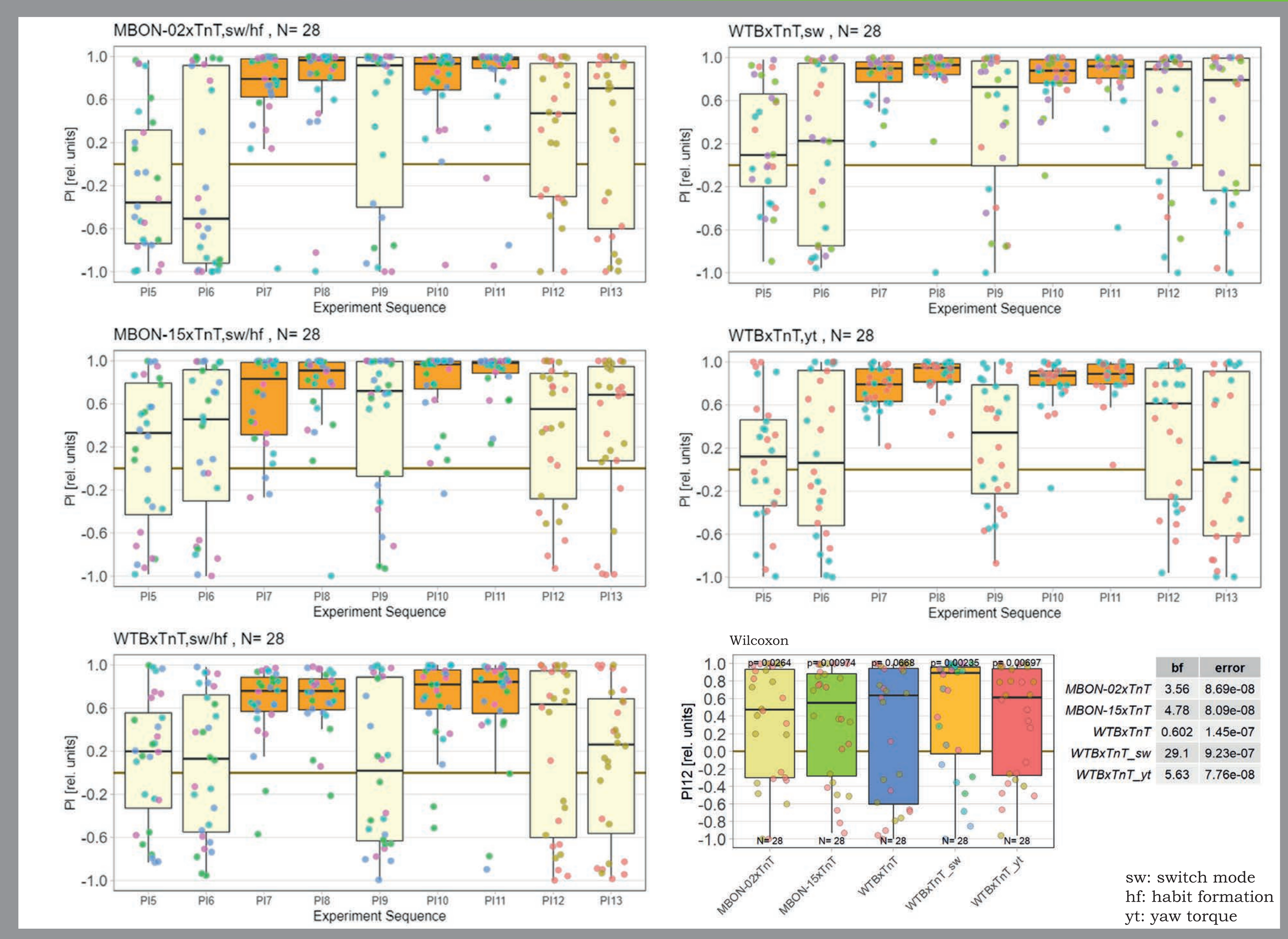


Silencing of MB α,β lobes results in premature habit formation.



data by Anders Eriksson

Silencing of three different MBONs results in premature habit formation.



Retest of candidate MBONs verifies MBON02 as potential site of memory interaction.

Outlook

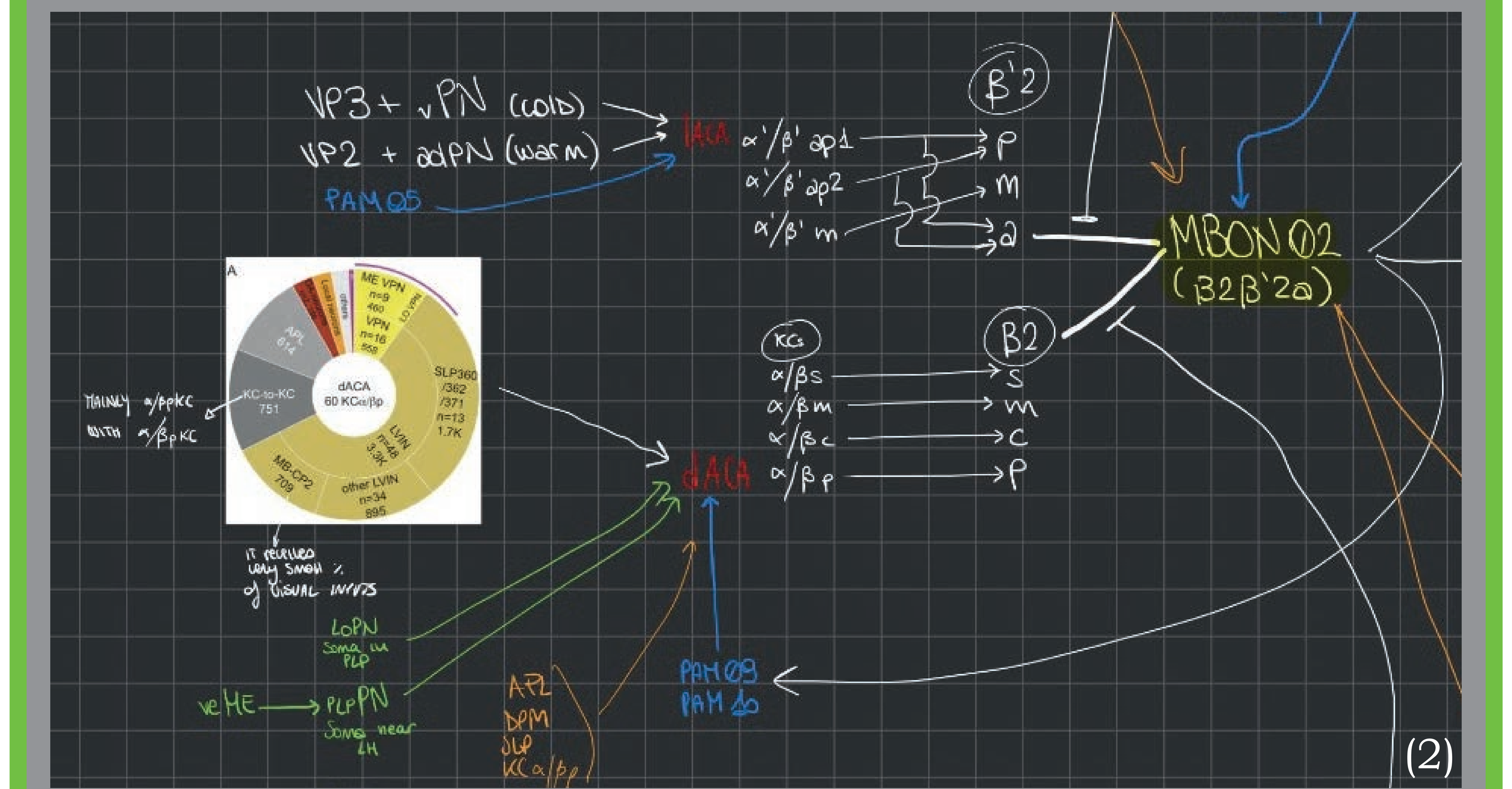


image by Silvia Marcato

Does MBON02 act as a coincidence detector?

Are both, β (visual) and β´ (thermosensory) input necessary and/or sufficient for inhibiting premature habit formation?

Does dopaminergic signaling modulate the transition from goal-directed actions to habit formation?

Are dopaminergic neurons a site of interaction between memory types?

References

(1) Brembs (2009) Mushroom Bodies Regulate Habit Formation in *Drosophila*, Current Biology19, 1351–1355. DOI: 10.1016/j.cub.2009.06.014

(2) Li et al. (2020) The connectome of the adult *Drosophila* mushroom body provides insights into function, eLife 9:e62576. DOI: https://-doi.org/10.7554/eLife.62576

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