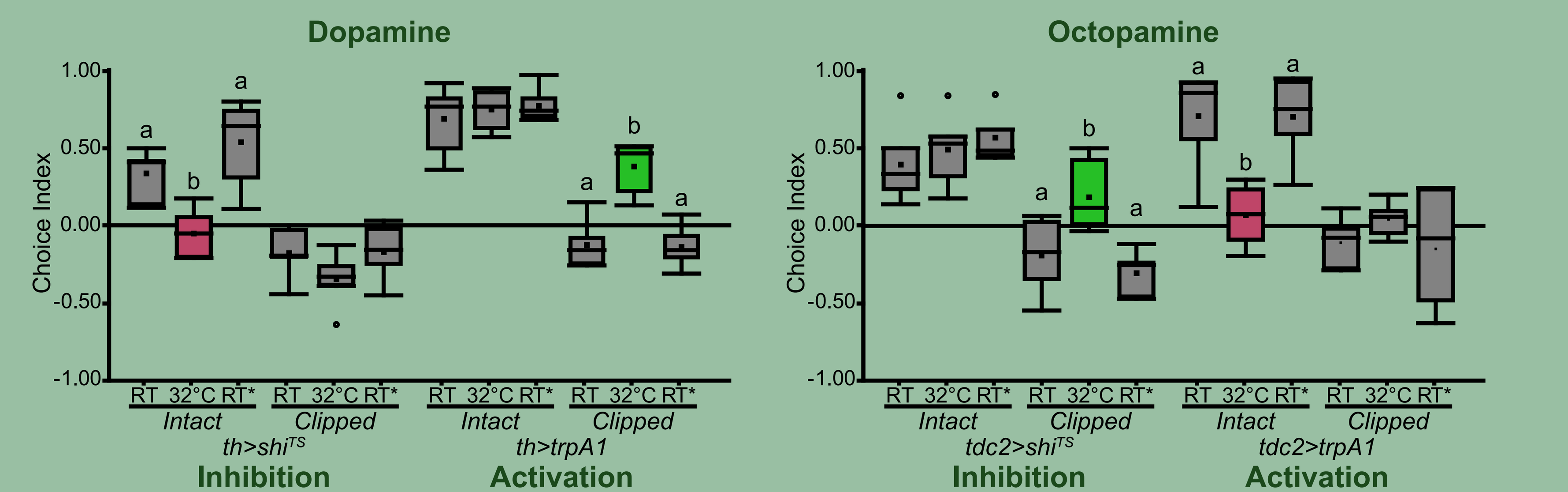
Double dissociation of octopamine and dopamine on choice behavior in Drosophila

E. Axel Gorostiza, Bianca Birk, Björn Brembs
University of Regensburg, Institute of Zoology – Neurogenetics, Universitätsstrasse 31, 93040 Regensburg, Germany
eagorostiza@gmail.com, http://lab.brembs.net

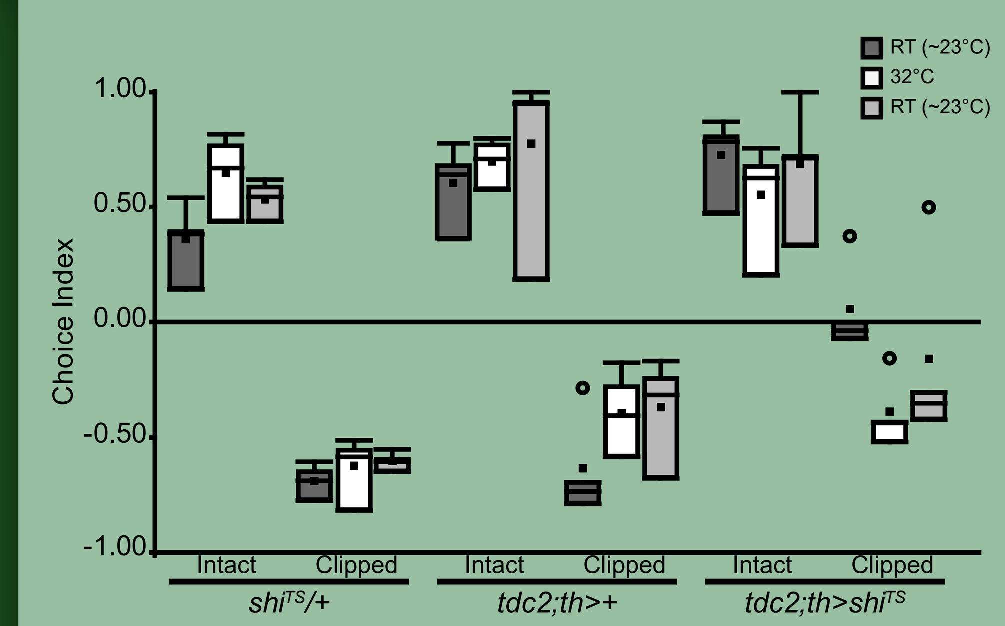
Abstract

In 1918 McEwen demonstrated that wing defects, caused by mutation or damage, profoundly affect phototaxis preferences in walking Drosophila (McEwen, 1918). We have recently described that flies are constantly monitoring their flying capability and adjust their phototactic preference accordingly. Our experiments showed that phototaxis, which appears simple and hard-wired, possess a value-driven decision-making stage, negotiating external stimuli with the animal’s internal state. Interestingly, we found that neuronal activity in circuits expressing dopamine and octopamine, respectively, is necessary and sufficient for this case of behavioral flexibility. The aim of the present work is to disentangle the neural circuit involved in this value driven decision-making process. In order to do that, we designed a screen comprising many subpopulations of dopaminergic and octopaminergic neurons, and other suitable candidates.



DA and OA differently modulate intact and wingless fly behavior. T-Maze Choice Index of intact and clipped flies before, during and after inhibition or activation of dopaminergic or octopaminergic neurons. Only experimental lines are shown. More information and the complete experiment can be found in http://dx.doi.org/10.1101/023846

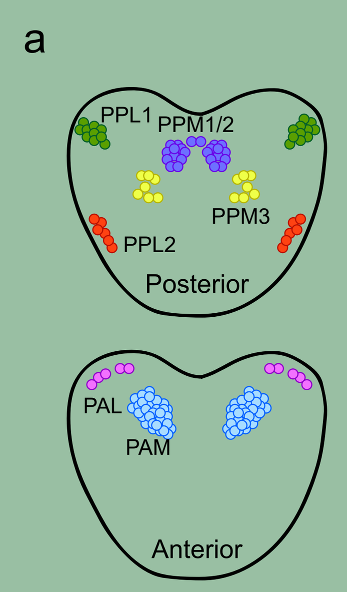
1 Simultaneous inhibition



Inhibiting dopaminergic and octopaminergic neurons simultaneously have no significant effect on phototaxis. T-Maze Choice Index of intact and clipped flies before and during simultaneous inhibition of dopaminergic and octopaminergic neurons. Kruskal-Wallis, N=4, Intact: *Shi*^{TS}*/+:* p=0.0641, *tdc2;th*>+: p=0.3967, *tdc2;th*>*Shi*^{TS}: p=0.3697; clipped: *Shi*^{TS}*/+:* p=0.3822, *tdc2;th*>+: p=0.1309, *tdc2;th*>*Shi*^{TS}: p=0.0365. Box plot shows quantiles 0.25 and 0.75, extremes, median, mean (black square), and outliers (circle).

2 Dopaminergic neurons TH-subsets-G4

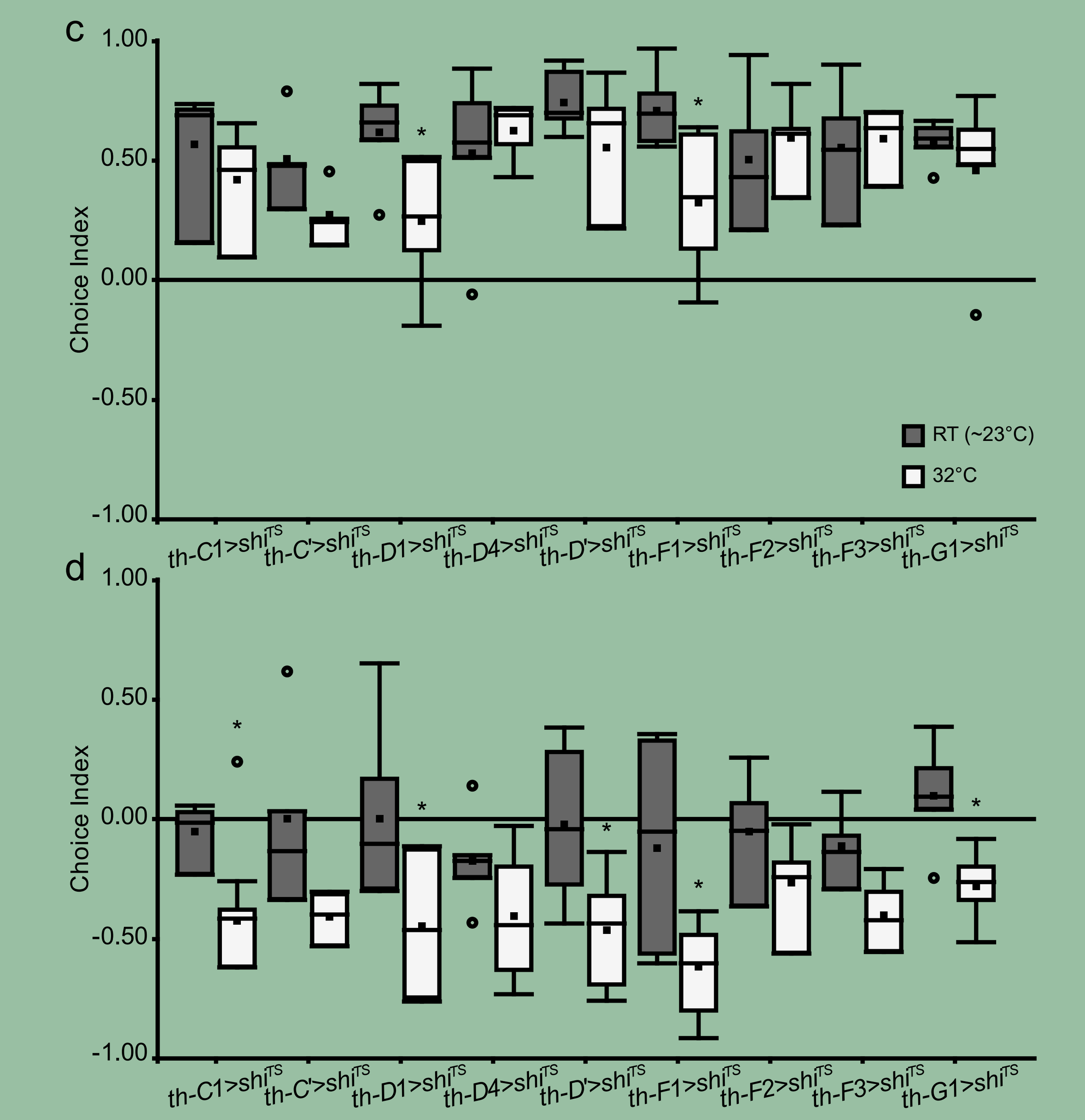
a



b

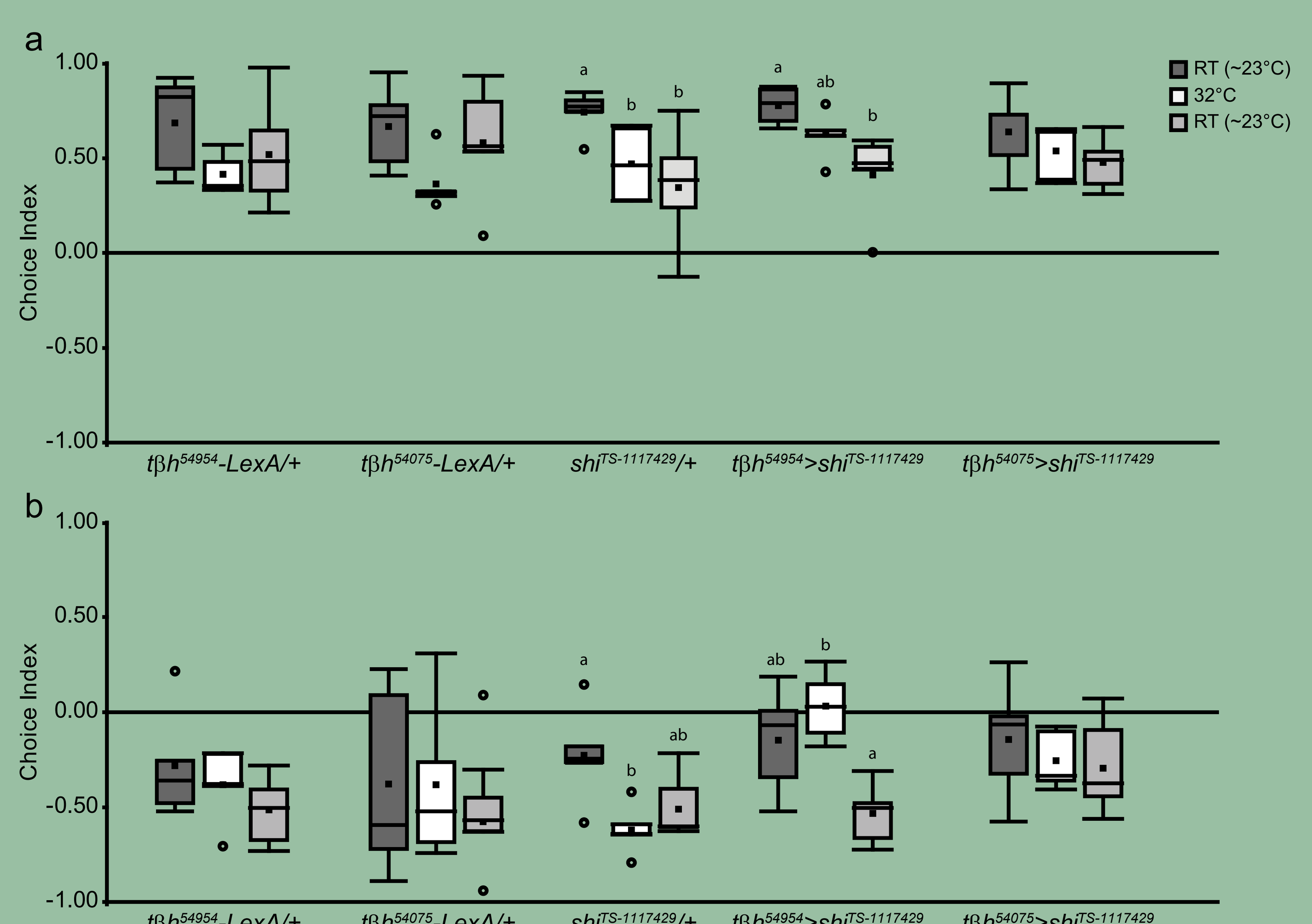
GAL4 driver

	PAM	PAL	PPM1	PPM2	PPM3	PPL1	PPL2
anti-TH +	~100	4.9	0.8	7.9	6.8	11.7	5.5
TH	8.5	5.0	4.0	8.3	7.0	11.0	6.0
TH-C’	0.3	3.0	0.5	5.4	0	0	5.9
TH-C1	10.5	2.7	1.6	6.5	0	0.6	5.6
TH-D’	0.1	1.3	0	2.7	5.8	9.8	0
TH-D1	0.3	0	0.3	3.7	6.6	10.3	0
TH-D4	0	0	0	1.6	3.4	5.6	0
TH-F1	0.1	0	0	3.7	4.6	4.5	1.1
TH-F2	0	0	0	6.8	4.4	4.4	3.6
TH-F3	0	0	0	2.5	2.5	3.8	0.5
TH-G1	10.5	0	0.2	6	6.1	5.9	2.4



Screen for specific TH positive neurons responsible for positive phototactic choice in intact flies. **a,** Representation of the major posterior and anterior clusters of dopaminergic neurons, adapted from (Liu Q, npet al 2012). **b,** Quantification of anti-TH positive neurons in each driver, taken from (Liu Q, et al 2012). **c,** T-Maze Choice Index of *th-subsets* intact flies before and during silencing of candidate neurons. T-Test, *th-C1>Shi*^{TS}: N=4, p=0.4505; *th-C’>Shi*^{TS}: N=4, p=0.0982; *th-D1>Shi*^{TS}: N=6, p=0.0209; *th-D4>Shi*^{TS}: N=5, p=0.5950; *th-D’>Shi*^{TS}: N=6, p=0.1567; *th-F1>Shi*^{TS}: N=7, p=0.0045; *th-F2>Shi*^{TS}: N=4, p=0.6564; *th-F3>Shi*^{TS}: N=4, p=0.8370; *th-G1>Shi*^{TS}: N=5, p=0.5069. **d,** T-Maze Choice Index of *th-subsets* clipped flies before and during silencing of candidate neurons. T-Test, *th-C1>Shi*^{TS}: N=4, p=0.0092; *th-C’>Shi*^{TS}: N=4, p=0.1230; *th-D1>Shi*^{TS}: N=6, p=0.0428; *th-D4>Shi*^{TS}: N=5, p=0.1830; *th-D’>Shi*^{TS}: N=6, p=0.0263; *th-F1>Shi*^{TS}: N=7, p=0.0146; *th-F2>Shi*^{TS}: N=4, p=0.2698; *th-F3>Shi*^{TS}: N=4, p=0.0597; *th-G1>Shi*^{TS} N=5, p=0.0177. * indicates significant differences. Box plot show quantiles 0.25 and 0.75, extremes, median, mean (black square), and outliers (circle).

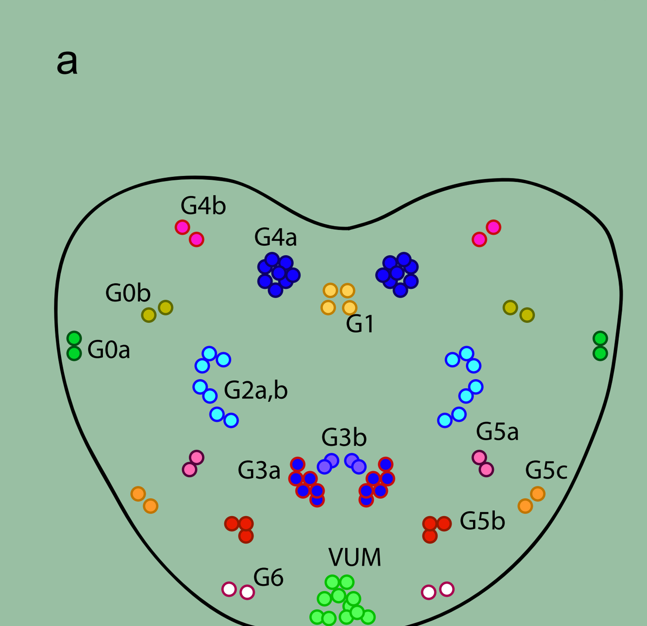
3 Octopaminergic neurons TβH-LexA drivers

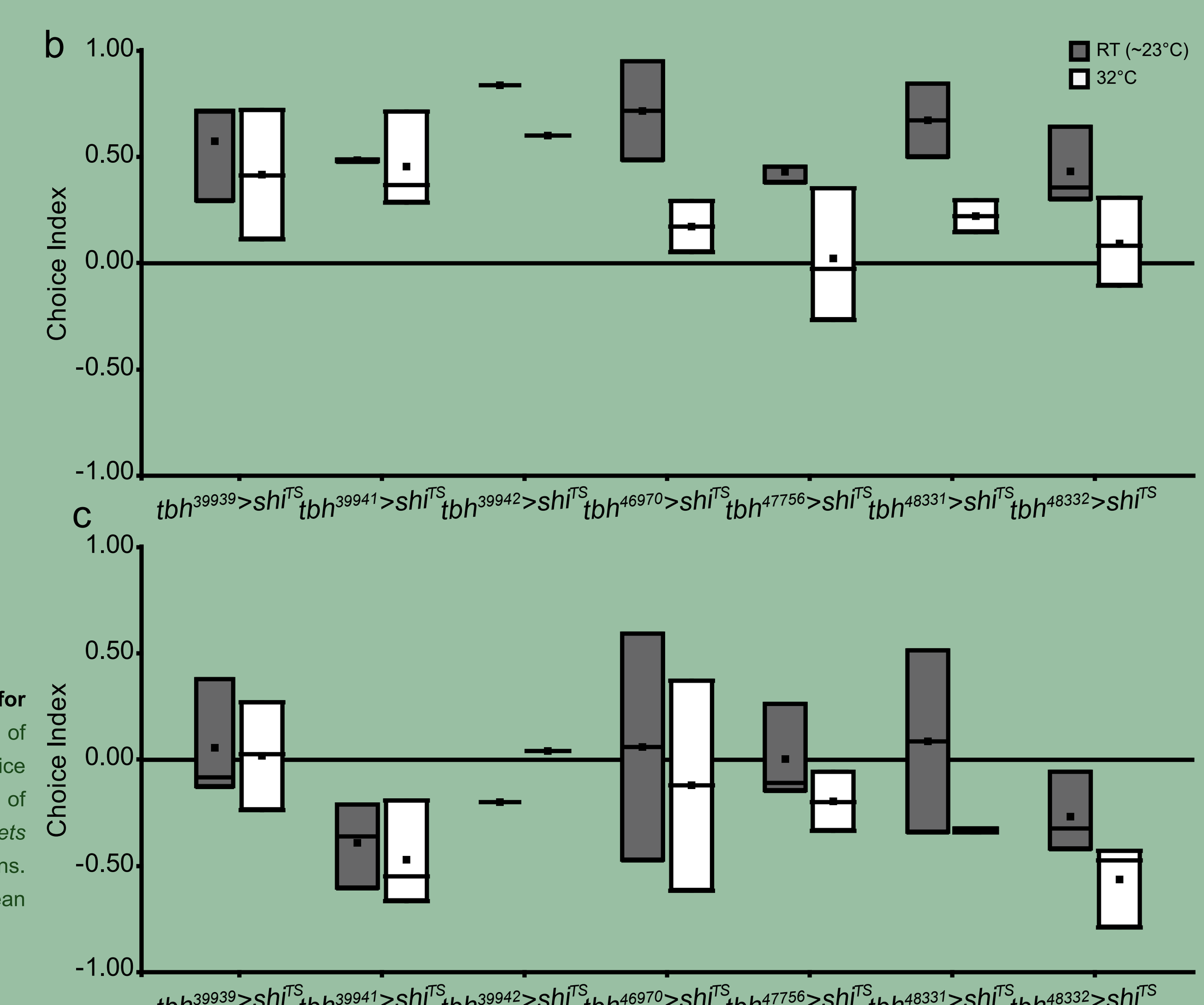


TβH positive neurons are necessary for negative phototactic choice in wing-clipped flies. Choice Index of flies before, during and after octopaminergic neurons silencing, using two different TβH-lexA lines. Kruskal-Wallis, N= 5. **a,** Intact flies: *tβh*^{54954}*-LexA*/+, p=0.2638; *tβh*^{54075}*-LexA*/+, p=0.1340; *shi*$^{ts-1117429}$/+ p=0.0342; *tβh*^{54954}>*shi*$^{ts-1117429}$, p=0.0076; *tβh*^{54075}>*shi*$^{ts-1117429}$, p=0.3289. **b,** Flies with clipped wings: *tβh*^{54954}*-LexA*/+, p=0.2808; *tβh*^{54075}*-LexA*/+, p=0.8521; *shi*$^{ts-1117429}$/+, p=0.0240; *tβh*^{54954}>*shi*$^{ts-1117429}$, p=0.0240; *tβh*^{54075}>*shi*$^{ts-1117429}$, p=0.5326. Different letters indicate significant differences between temperatures for each genotype (only shown for genotypes where the factor temperature had a statistically significant effect). Box plot shows quantiles 0.25 and 0.75, extremes, median, mean (black square), and outliers (circle).

4 Octopaminergic neurons TβH-subsets-G4

a





Screen for specific TβH positive neurons responsible for negative phototactic choice in wing-clipped flies. **a,** Sketch of octopaminergic neurons in *Drosophila* brain. **b,** T-Maze Choice Index of *tβh-subsets* intact flies before and during silencing of candidate neurons. **c,** T-Maze Choice Index of *tβh-subsets* wing-clipped flies before and during silencing of candidate neurons. Box plot shows quantiles 0.25 and 0.75, extremes, median, mean (black square), and outliers (circle).

Summary

In the present work we continue the characterization of the role of DA and OA on phototactic preference modulation. We are currently performing several screens to uncover the specific neuronal substrates. So far, we were able to identify some dopaminergic and octopaminergic GAL4-drivers that potentially comprise the relevant neurons for this behavior. However, the screens are not finished, and further experiments are needed to confirm our results.

References

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Liu Q, *et al* (2012). Two dopaminergic neurons signal to the dorsal fan-shaped body to promote wakefulness in *Drosophila*. Curr. Biol. 22, 2114–2123. doi:10.1016/j.cub.2012.09.008

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