Learning modifies reinforcement sensitivity in honeybees via long-term changes in a dopaminergic receptor gene

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The possibility that learning induces variations in the expression of specific receptors in neuronal circuits encoding reward or punishment, thereby changing an individual’s sensitivity to such reinforcement remains unexplored. Here we studied this question in the honeybee, an insect that has a model status for the study of learning and memory. We focused on aversive and appetitive responsiveness, which we quantified by means the sting extension response (SER) to electric shocks and the proboscis extension response (PER) to sucrose solutions, respectively. We found that aversive (odor-shock) and appetitive olfactory learning (odor-sucrose) induce a long-term decrease in shock and sucrose responsiveness, respectively. In this way, learners become less sensitive to reinforcement intensities that are lower than the one they expect based on conditioning. To uncover the mechanisms mediating this decrease in sensitivity, we used laser-capture micro dissection and RT-qPCR to determine whether learning induces long-term changes in receptor-gene expression in Kenyon cells, the constitutive neurons of the mushroom bodies. We focused on octopaminergic and dopaminergic receptor genes and found that both aversive and appetitive learning promote a long-term increase in the expression of a single class of dopaminergic receptor that correlates with the long-term decrease of aversive and appetitive responsiveness. Pharmacological or RNAi-based blockade of this receptor induced an increase in responsiveness while enhancing its signaling resulted in a decrease of responsiveness. Thus, in a default state, this dopaminergic receptor represses excessive responding to reinforcement so that its blockade enhances irrelevant responsiveness. On the contrary, enhancing its expression and/or signaling renders individuals more selective in their responses. Importantly, experience with reinforcements via learning is capable of inducing the later changes, thus improving response efficiency.