The role of glutamate receptor-dependent signaling in the dopamine system in reinforcement learning

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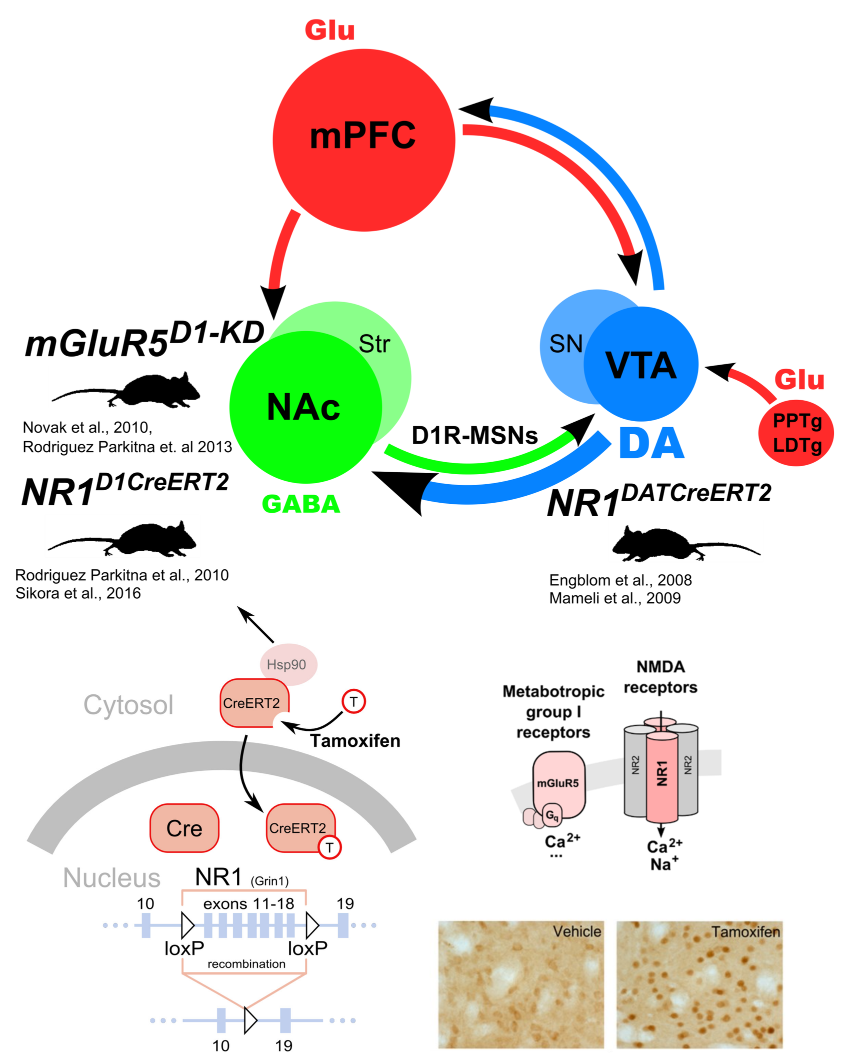
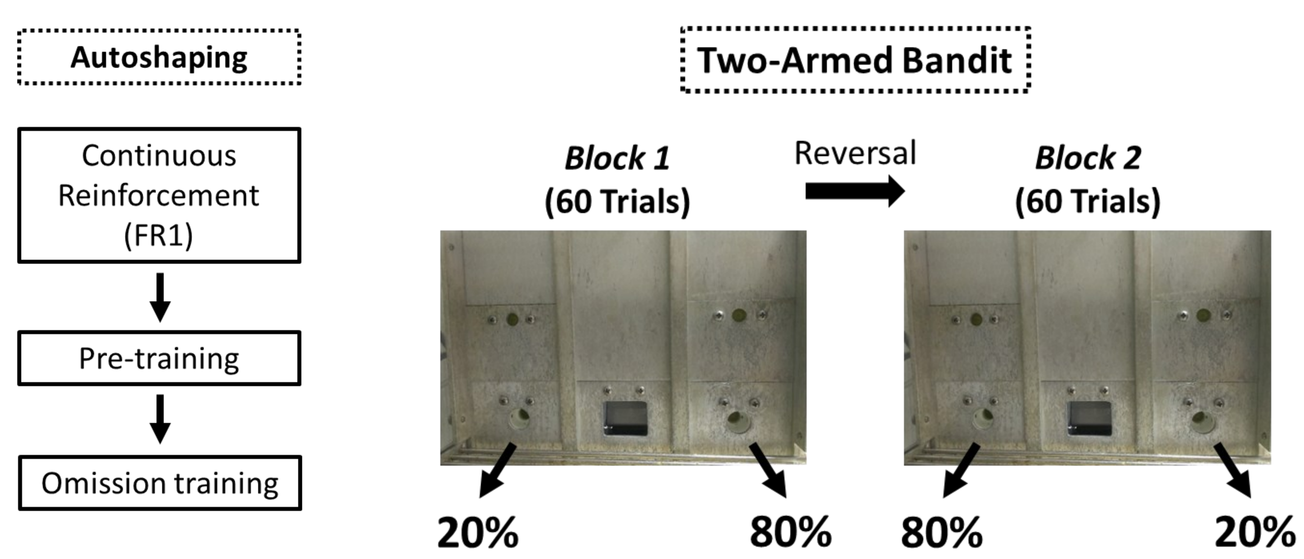
Introduction

Learning to predict rewards is crucial for adaptive decision-making. This learning process involves midbrain dopamine (DA) neurons, which encode reward prediction errors (RPEs). The RPE signal is used for updating the action values stored by striatal neurons and thus provide a neural substrate for reinforcement learning processes that underlie action selection. Activity and plasticity in the DA system depends on glutamatergic (Glu) inputs. Impairments in Glu-dependent signaling may lead to aberrant reinforcement learning and maladaptive decision-making.

Here, by using genetically modified mouse lines with selective inactivation of NMDA or mGluR5 receptors in dopaminergic and D1 receptor-expressing neurons we investigate the specific role of Glu-DA interaction in reward-based learning.



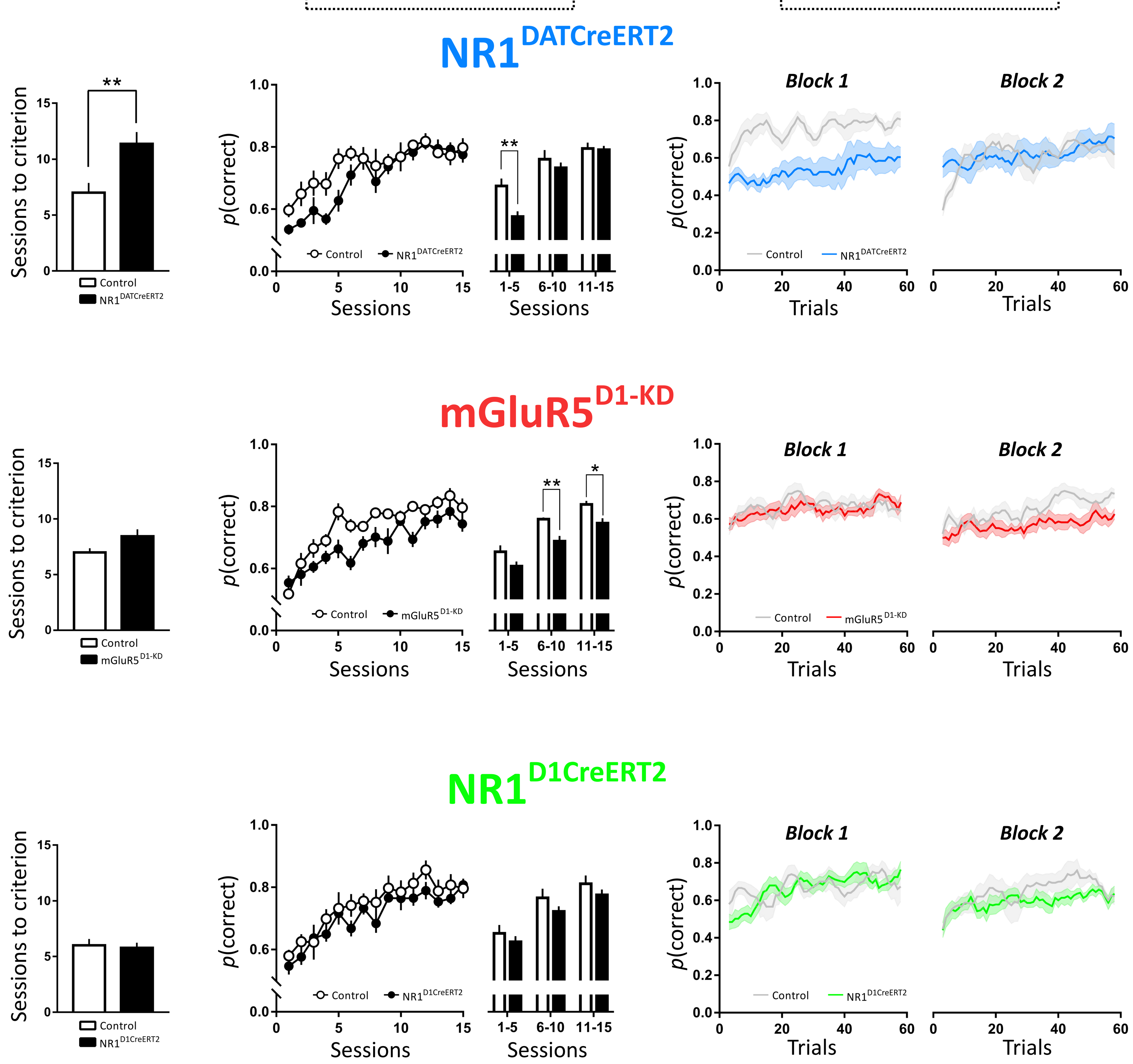
Performance in the Two-Armed Bandit task



Autoshaping (FR1)

Two-Armed Bandit task (session by session)

Two-Armed Bandit task (trial by trial)



Models of choice behavior

Matching Law

$$\log_2\left(\frac{C_L}{C_R}\right) = a \cdot \log_2\left(\frac{R_L}{R_R}\right) + \log_2 b$$

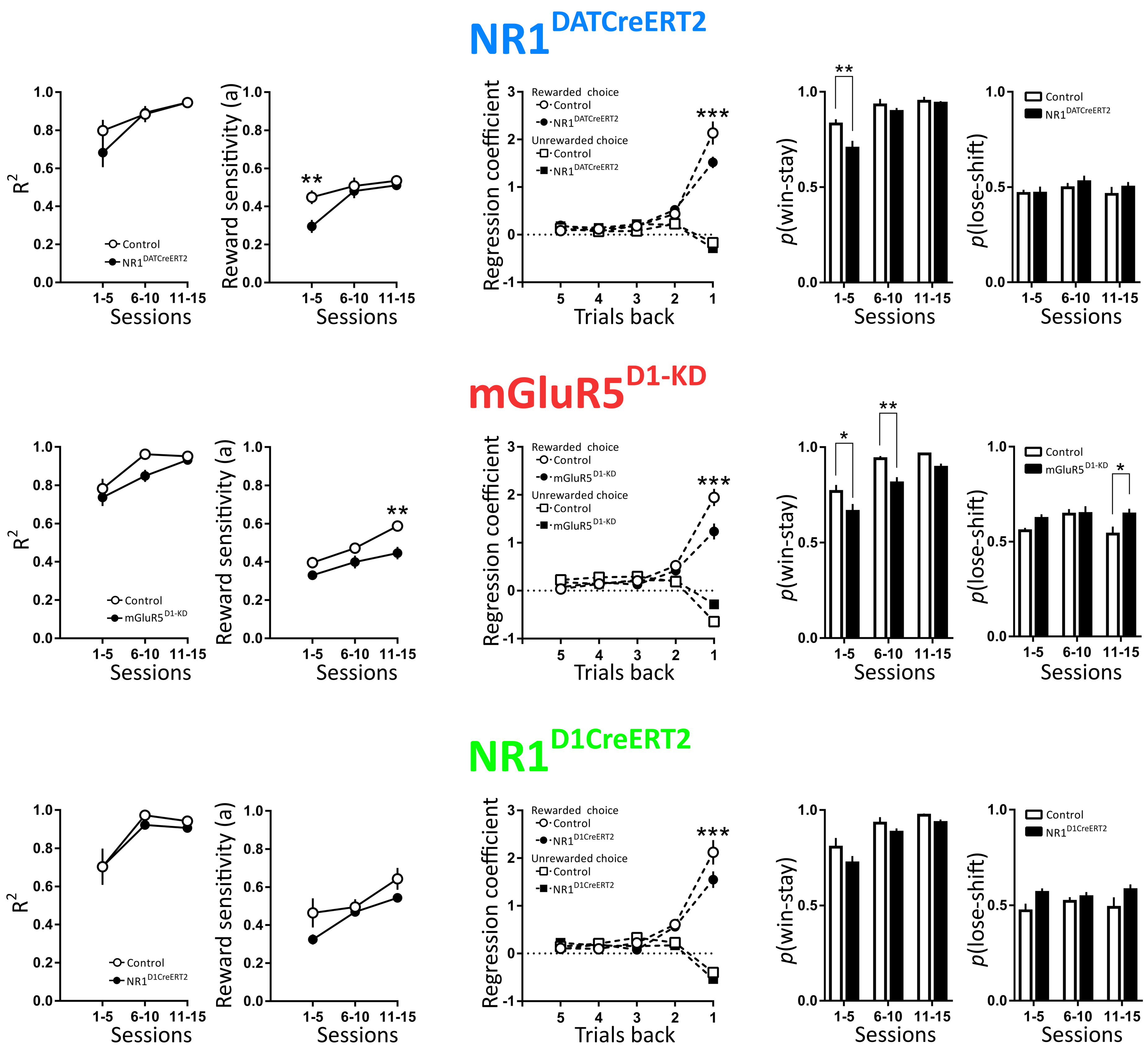
Logistic Regression

$$\log\left(\frac{C(i)}{1-C(i)}\right) = \beta_0 + \sum_{j=1}^{n} \beta_j^R R(i-j) + \sum_{j=1}^{n} \beta_j^N N(i-j) + error$$

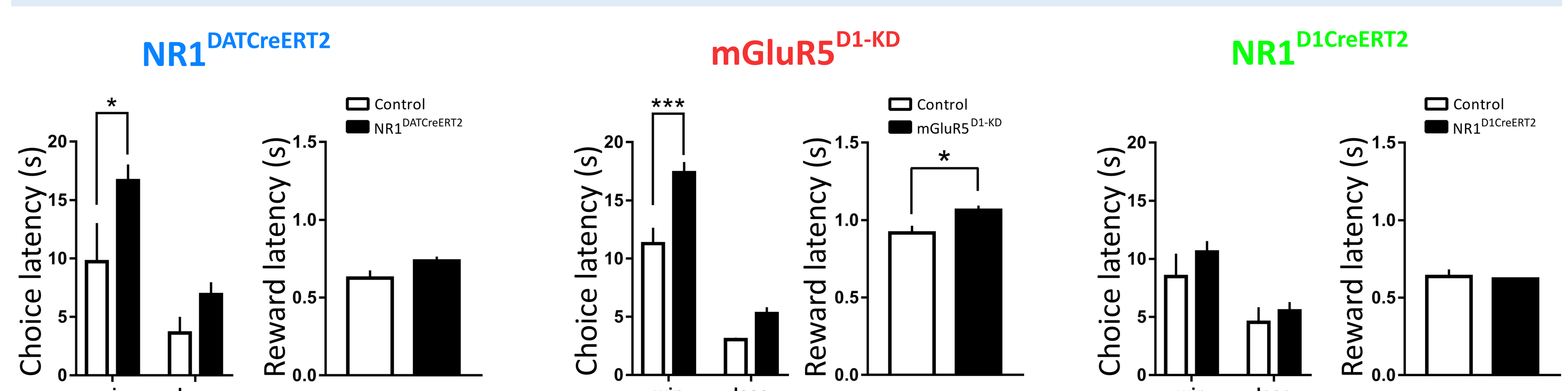
Parker et al., 2016

Win-Stay/Lose-Shift

$$Win_{Stay} = \frac{Win_{Stay}}{Win_{Stay} + WinS_{hift}} \quad Lose_{Shift} = \frac{Lose_{Shift}}{Lose_{Stay} + LoseS_{hift}}$$



Reaction times

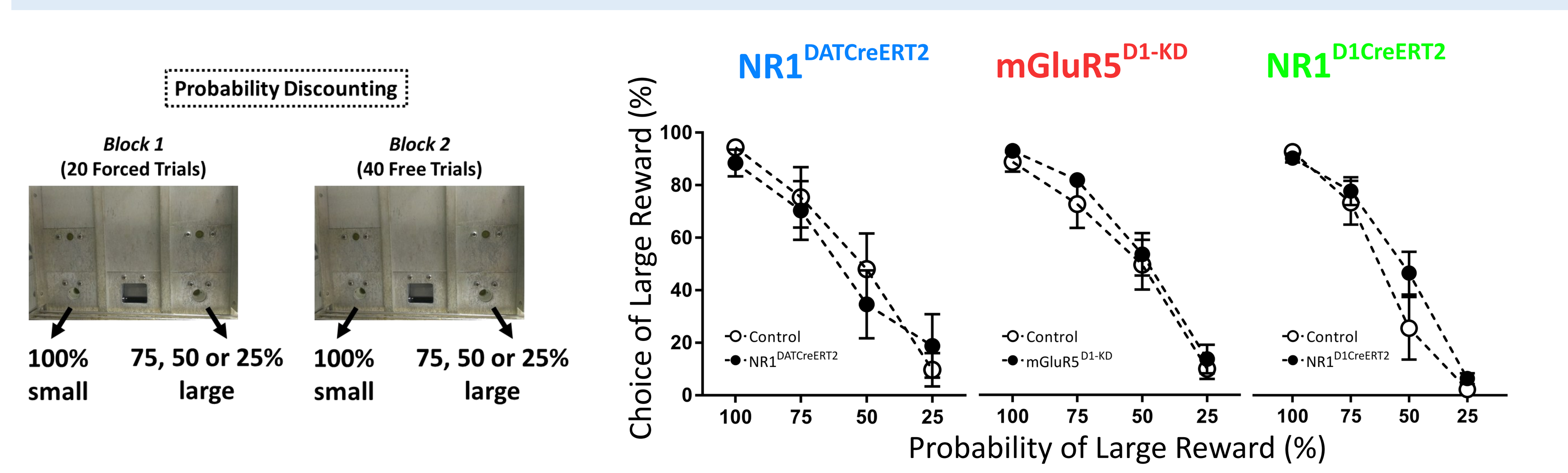


Conclusions

The findings from our study reveal that glutamate receptors in the dopamine system regulate reward-based learning and choice behavior in the two-armed bandit task.

Absence of NMDA-receptor dependent signaling in dopaminergic neurons impairs initial learning, while ablation of mGluR5 receptors in D1 receptor-expressing neurons reduces reward sensitivity. Loss of either receptor increases response latency.

Probability discounting



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