Simulating the Effects of Direct and Indirect Pathway Balance in a Spiking Basal Ganglia Network

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MOTIVATION

The cortico-basal ganglia-thalamo-cortical loop plays a central role in perceptual decision making [2].

Pathways in basal ganglia play key roles in modulating the decision-making process.

- Direct (STR-GPe) and indirect (STR-GPi) pathways compete for action disinhibition or inhibition [1].

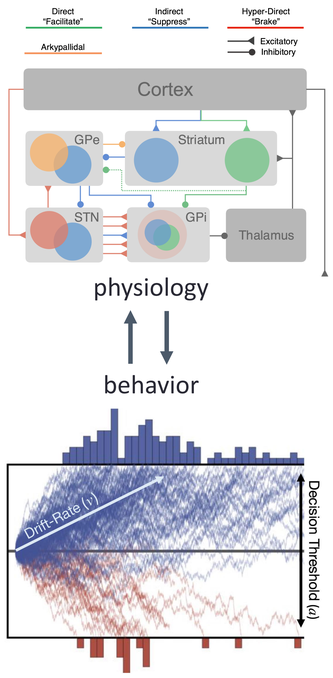
Drift-diffusion is a behavioral model describing evidence accumulation and speed-accuracy tradeoff [3].

- Drift rate: signal-to-noise ratio
- Threshold: confidence in decision

Postulated that striatal pathways influence threshold level and performance tradeoffs [2].

How are drift-diffusion parameters embodied in the physical network?

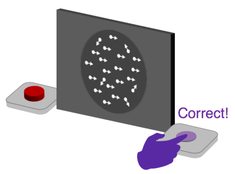
How does variation in direct/indirect pathway relative strength affect decision-making?



METHODS

Simulation of random dot motion visual discrimination task

- Choice between two alternatives based on sensory data



Fully spiking basal ganglia network model

- Two action channels, one per alternative, each containing cortical, basal ganglia, and thalamic populations
- Includes direct, indirect, and arkypallidal (GPe-STR) pathways
- Two striatal populations (D1 and D2) per channel

Sensory input represented by excitatory input to cortical populations

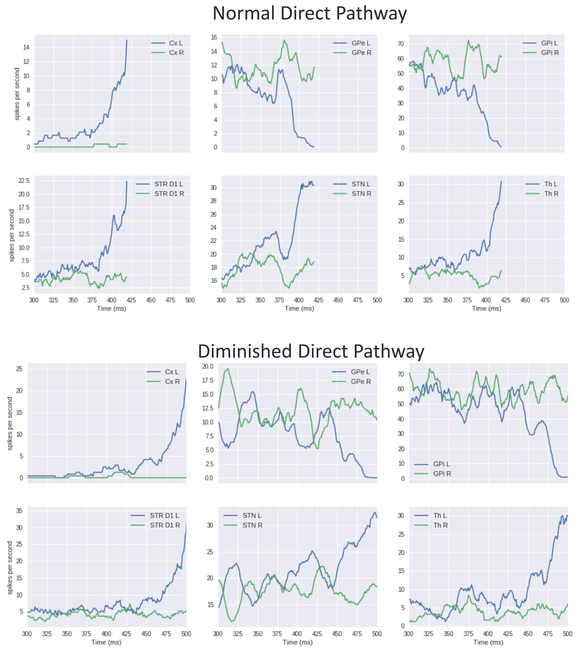
The ramping of thalamic activity to a cut-off (30 spikes / sec) interpreted as a decision made by the network. Maximum trial length was 1 second, and trials in which the cut-off was not reach were deemed incomplete decisions.

Reaction time distributions fit to drift-diffusion model using Bayesian estimation

REACTION TIME AND ACCURACY

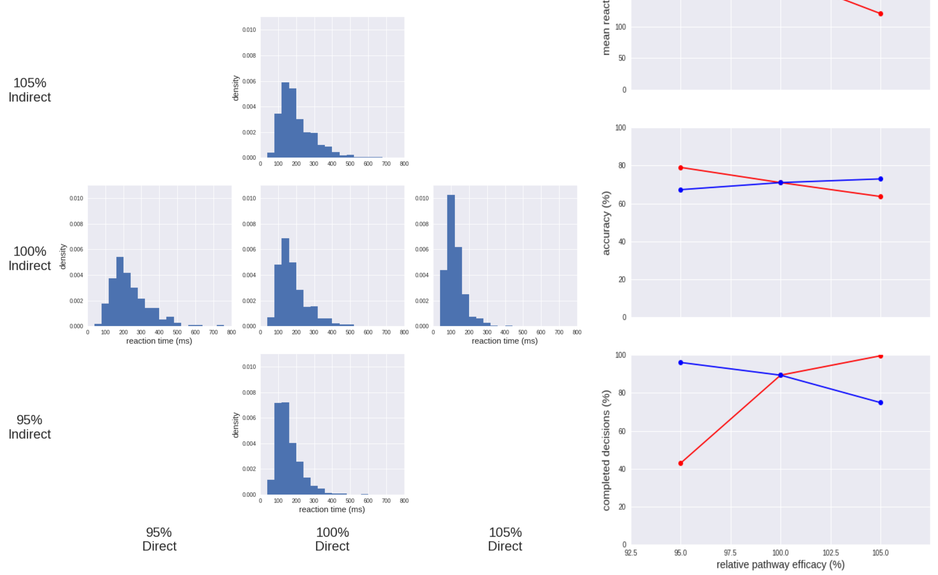
Relative pathway strengths affect rate of activity ramping in the Cx-BG-TH loop.

- Decreased direct pathway strength leads to slower ramping and slower reaction times, but improved accuracy.

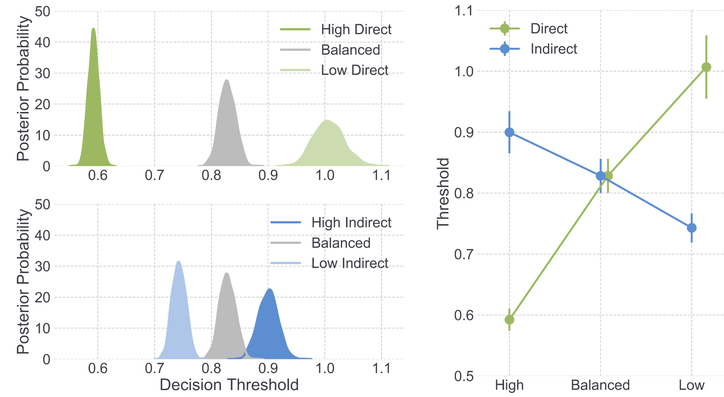


Direct and indirect pathways have opposing effects on reaction time, decision accuracy, and decision completion.

- Strengthened direct pathways and weakened indirect pathways lead to shorter reaction time, narrower RT distributions, decreased accuracy, and increased response rate.
- Variation of direct pathway had larger influence.

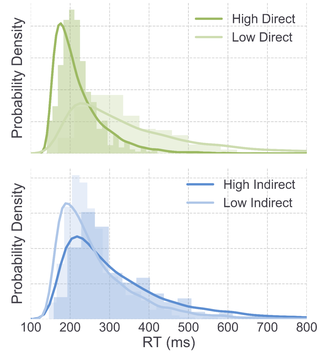


BEHAVIORAL MODEL FITTING



Pathway strength affects the behavioral decision threshold – the level of confidence necessary to evoke a response.

- High direct lowers threshold while high indirect raises threshold.
- Variation in RT distributions is better explained by changes in decision threshold than in drift rate.
- RT distributions reasonably fit those predicted by drift-diffusion model.



SUMMARY & DISCUSSION

Direct and indirect pathway strengths have counterbalancing effects on speed-accuracy tradeoff.

- High direct and low indirect associated with faster speed and lower accuracy.

Tradeoff can be explained as modulation of behavioral decision threshold.

- Drift rate might be primarily determined by other simulation parameters.

Change in direct pathway had stronger effect on decision threshold and performance tradeoff.

REFERENCES & ACKNOWLEDGEMENTS

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