Choice reflexes in the rodent (and human) sensorimotor striatum

A new mechanism to promote exploration?

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Rapid response adaptation following poor reinforcements

Lose-switch:

Neural basis:
  - change in value?
  - high stochasticity?
  - specific mechanism?
Rapid response adaptation following poor reinforcements

Lose-switch:

Neural basis:
- change in value?
- high stochasticity?
- specific mechanism?

‘Sensorimotor habit’
S-R associations
slow to change
devaluation insensitive

‘deliberative’
A-O associations
rapid change
devaluation sensitive

Multiple brain systems

DLS
(putamen)

dMS
(caudate)
Competitive Task: 2 x 2 matrix game (‘Matching Pennies’)

- $C_n^{p_1} = C_n^{p_2}$: Player 1 wins
- $C_n^{p_1} \neq C_n^{p_2}$: Player 2 wins
Competitive Task: 2 x 2 matrix game (‘Matching Pennies’)

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- Optimal strategy against strong player is a ‘mixed strategy’ (random responding)
- Expected win probability is 0.5 against an optimal opponent
Prediction: ‘habits’ in DLS will produce patterned responses & poor performance
DLS is necessary for lose-switch responding

**Prediction:** ‘habits’ in DLS will produce patterned responses & poor performance
DLS is necessary for lose-switch responding

Prediction: ‘habits’ in DLS will produce patterned responses & poor performance

• Counter to devaluation experiments

• Led us to hypothesize that:
  1) Loss information in DLS is short lived
  2) Involves negative reward prediction error signal by dopamine
  3) General feature of DLS processing; same features in humans
Lose-Switch decays and is independent of Win-Stay

Lose-Switch and Win-Stay are:

• Prevalent
• Uncorrelated
• Change with inter-trial interval (ITI)
Lose-Switch decays and is independent of Win-Stay

Lose-Switch and Win-Stay are:
- Prevalent
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- Change with inter-trial interval (ITI)
Lose-Switch and Win-Stay are:
- Prevalent
- Uncorrelated
- Change across ITI

![Graph showing cumulative probability against ITI after lose](image)

![Graph showing probability against ITI after lose](image)
Lose-switch depends on negative RPE
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Lateral habenula

dopamine

D2 receptors

Lose-Switch

Intact

error

D2DR agonist

x
Lose-switch depends on negative RPE

<table>
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<th>Intact</th>
<th>D2DR agonist</th>
<th>d-amphetamine</th>
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Lose-switch depends on negative RPE

Lateral habenula
Dopamine
D2 receptors
Lose-Switch

Intact
D2DR agonist
d-amphetamine
Lateral habenula lesion

Error

x
Lose-switch depends on negative RPE

- Lateral habenula
- Dopamine
- D2 receptors
- Lose-Switch

**Intact**

**D2DR agonist**

**d-amphetamine**

**Lateral habenula lesion**

**Graphs**

Left:
- X-axis: DMS
- Y-axis: prob. lose-switch
- Data points for treatments: none, veh, quin, SCH

Right:
- X-axis: DLS
- Y-axis: prob. lose-switch
- Data points for treatments: none, veh, quin, SCH

* indicates significant difference.
Lose-switch depends on negative RPE

- Lateral habenula
- Dopamine
- D2 receptors
- Lose-Switch

Intact

D2DR agonist

d-amphetamine

Lateral habenula lesion

Lateral habenula

Dopamine

D2 receptors

Lose-Switch

Graph showing the effect of d-amphetamine and lateral habenula lesion on lose-switch and dopamine levels.
Lose-switch depends on negative RPE

- Lateral habenula
- Dopamine
- D2 receptors

Intact | D2DR agonist | d-amphetamine

Lateral habenula lesion: x

![cumulative probability graph]

sham | LHb lesion

Proba. Lose-Switch

*
Increased Lose-switch in humans under cognitive load

- ITI (0.5 s)
- initiate by press
- choice by press
- win $+10
  or lose $-10
- feedback (1-4.5 s)
Increased Lose-switch in humans under cognitive load
Increased Lose-switch in humans under cognitive load
Increased Lose-switch in humans under cognitive load
Summary

- LS and WS are **predominant, persistent**
- LS and WS are **uncorrelated**
- LS depends on **negative RPE** in sensorimotor striatum
- LS emerges in humans under **cognitive load**
- LS **decays** over ~7-8 seconds in rats, and >10 s in humans
  - Much shorter than devaluation
Summary

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‘**innate choice-reflex**’ as intrinsic feature of striatal physiology
Implications & Speculations:

• Confound in experiments, could improve RL model fits to behaviour

• LS may solve ethologically-relevant tasks

• LS will immediately and briefly promote exploration independent of changes in value or stochasticity

• LS may pause the current response policy so that other computationally-expensive systems can determine a new policy
Wild Speculations:

• How might this work in the brain?
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• How might this work in the brain?
• Ramifications on network dynamics:
Ongoing:

• Cellular mechanisms:

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Ongoing:

• Cellular mechanisms:

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- Afrooz Jalali
- Ali Mashhoori
- Sienna Randolph
- Justin Swada
- Rajat Thapa
- Scott Wong

• Ramifications on network dynamics: