

Surprise Is the Teacher

One dopamine computation drives learning from external rewards, internal benchmarks and social feedback

Dopamine is usually called the brain’s pleasure chemical. It isn’t. It reports the gap between what was expected and what happened — and that one computation turns up almost everywhere.

Aurea Maria Marchini Charloux

auramarchini@gmail.com
Mentor: Jesse H. Goldberg, M.D., Ph.D.
Cornell University

THE PROBLEM

Introduction

Almost all the evidence came from one kind of experiment: a lab animal receiving a food reward.

Does the same signal work when there is no reward at all?

Research question. Is reward prediction error one general learning mechanism, and how far does it adapt across behaviours?

APPROACH

Methods

A structured review of published experiments.

- Searched PubMed, NCBI, Google Scholar, ScienceDirect.
- Kept peer-reviewed studies measuring dopamine activity directly.
- Removed studies treating dopamine only as pleasure.

22 of 40 sources retained, compared figure by figure.

RESULTS · THE MECHANISM

1 · Juice arrives with no warning

dopamine fires at the juice



2 · A light now predicts the juice

the response moves to the light



3 · The light appears, but no juice

activity drops below normal

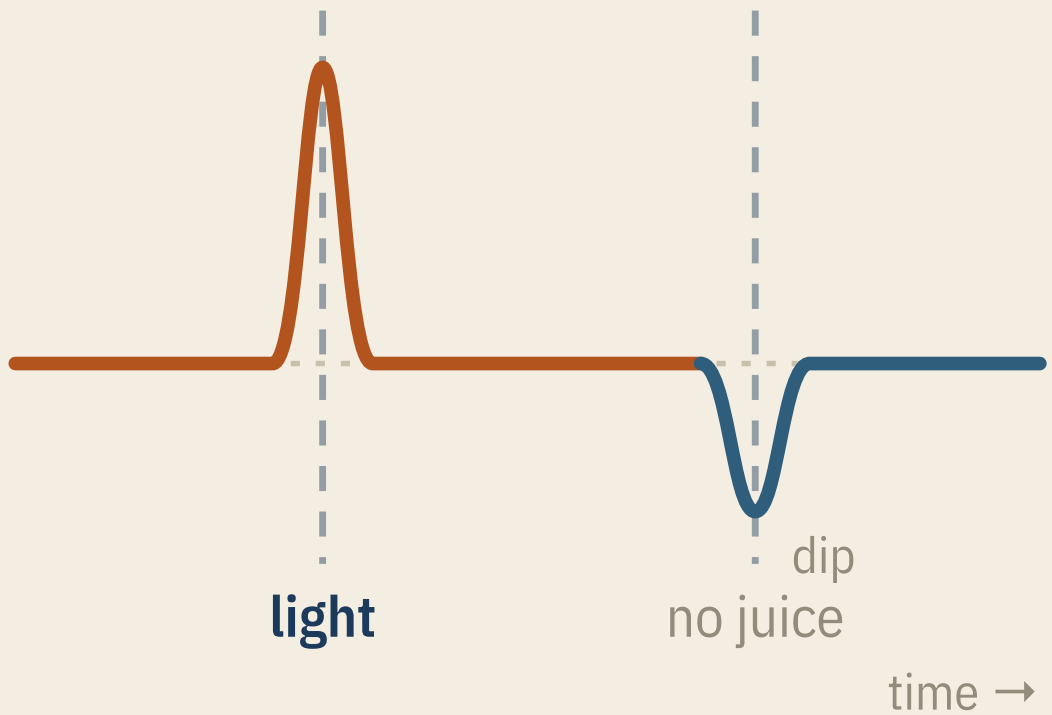


Figure 1. A monkey receives juice, and a light comes to predict it. Each line shows how fast dopamine neurons fire. Dopamine tracks the difference from expectation, not the reward itself. Original diagram, after Schultz et al. [1].

RESULTS · FOUR WORLDS

01

EXTERNAL REWARD

Primates & juice

Unexpected juice triggers a burst. Once a cue predicts it, the burst moves to the cue; withhold the reward and firing dips.

Schultz, Dayan & Montague 1997 [1]

02

INTERNAL BENCHMARK

Songbirds & their own notes

No reward is involved. A young bird compares its song to a memory of how it should sound. Distort one syllable and dopamine drops 58 ms later.

Gadagkar 2016 [2]

03

SOCIAL FEEDBACK

Courtship & parenting

In courtship, error signals retune from the bird’s own song toward the female’s reply. In mice, dopamine bursts at pup contact, then shifts onto the cue predicting it.

Roeser 2023 [3]; Xie 2023 [4]

04

WHEN IT BREAKS

Addiction & Parkinson’s

Drugs create an error that never settles, so value rises without limit. In Parkinson’s the signal is lost — yet switching the circuit back on with light restores movement.

Redish 2004 [5]; Kravitz 2010 [6]

EVIDENCE

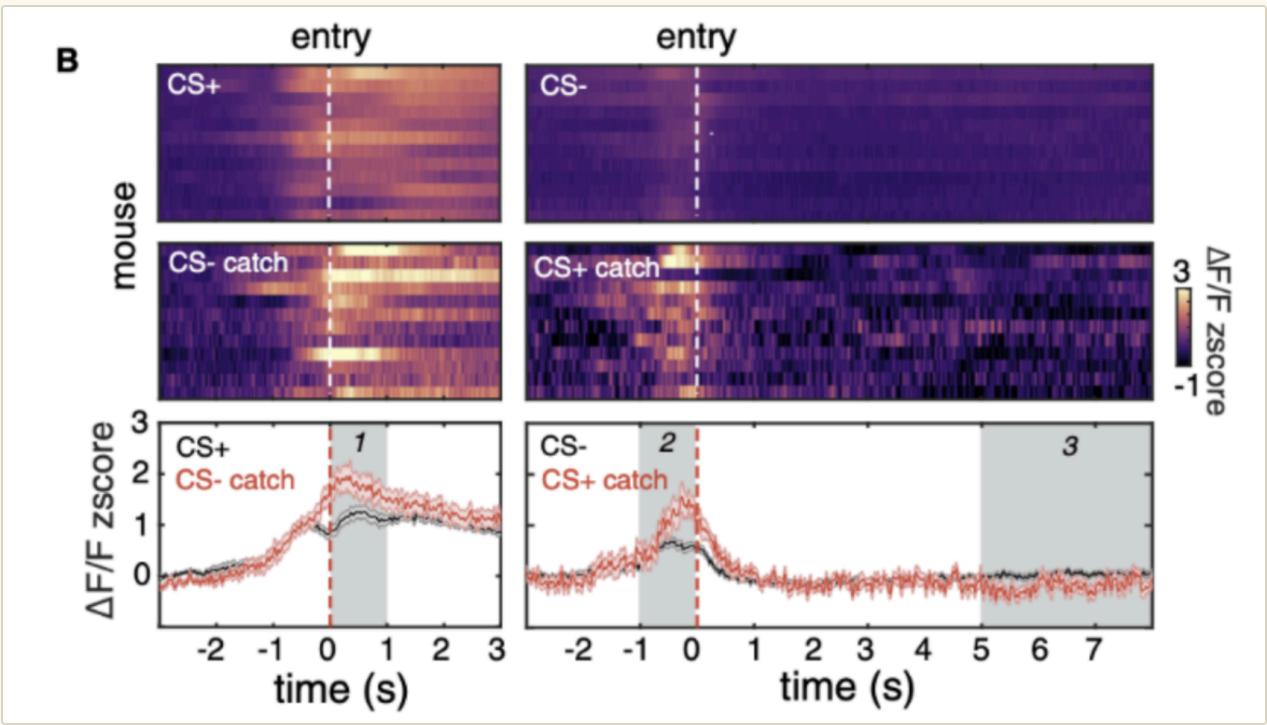


Figure 2. Each row is one mouse; brighter means more dopamine. Unexpected pup: a burst. Expected pup: little. Expected pup that never comes: a dip. Reproduced from Xie et al. [4].

EVIDENCE

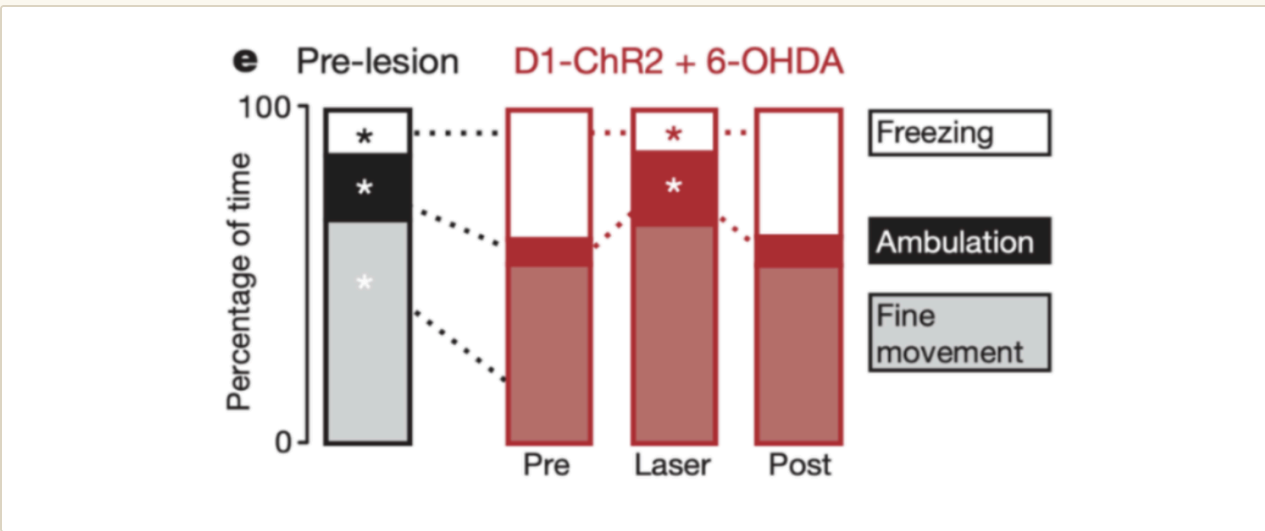


Figure 3. Each bar is how a mouse spent its time. Dopamine-depleted mice freeze; light restores movement, then loses it. The circuit is intact — only the signal is missing. Reproduced from Kravitz et al. [6].

WHAT IT MEANS

Discussion

The mechanism does not change. Its input does.

Retuning — neurons switch what they evaluate to match the animal’s current priority: song accuracy gives way to a mate’s reply.

Circuit routing — the signal goes to whichever brain region fits the task.

Downstream the rule is the same everywhere: a positive error strengthens the connections just used, a negative one weakens them.

THE ANSWER

Conclusion

Reward prediction error is conserved across every context reviewed, but it is not rigid: a single computation with a swappable input, which lets one mechanism cover behaviours this different.

This reframes Parkinson’s as a learning disorder, not only a movement one.

Limitations. Animal models; narrative, not systematic, selection.

Next. Human evidence; dopamine’s role in movement.

WHY IT MATTERS

Learning

one rule for every behaviour an animal can improve at

Machines

AI’s reinforcement learning uses the same error signal

92,000

US overdose deaths, ages 15–64, 2020–21 [7]

6.9M → 14.2M

people with Parkinson’s, 2015 → 2040 [8]

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