Where were we?

- Decision making is hard because of the credit assignment problem.
- To solve this it helps to learn to predict the future.
- In Pavlovian conditioning we set up a predictable scenario. Animals (including humans!) learn predictions. We know this because we can measure their conditional responses.
- In Pavlovian conditioning (also called classical conditioning), animals don’t get to choose the CS or US; we don’t get to choose their responses.
CS-US-CR compatibility

- Different USs are more easily conditioned to certain CSs (e.g. Garcia and Koelling’s 1996 “noisy water” experiment, with shock US versus LiCl US)
  - also depends on the animal species: pigeons associate color with illness, rats associate flavor with illness
- The CR is mostly similar to the UR
  - but does not have to be:
    freezing versus jumping as a response to shock, salivating versus biting as a response to food

examples of Pavlovian conditioning from daily life

- In groups of 4: share some of your examples of Pavlovian conditioning from daily life. Write for each, on a piece of paper, CS, US, CR, UR. Come up with a name for your group and write it on top. (10 min)
- Now: check the other group’s examples. Are they all Pavlovian? (remember the criteria for Pavlovian conditioning) (10 min)
- Share some examples you especially liked (or that were controversial)
what are the conditions for learning?

“pairing a tone (CS) and food (US) is sufficient to induce classical conditioning (prediction learning)”
But... 1) Rescorla’s control condition

will Group 2 show a CR to the tone?
A. Yes
B. No
C. It depends

Rescorla (1968)
And... 2) Kamin’s blocking

Phase I

Phase II

contingency is also not enough.. need surprise

P(food | noise+light) ≠ P(food | noise alone)

Finally... 3) Reynold’s overshadowing

stimuli compete for learning
Summary so far...

- Naïvely it seemed that pairing a CS and a US is enough for conditioning (prediction learning)...
- But now we see that we also need contingency and surprise
- And that different stimuli compete for learning such that even with contingency and surprise learning is not guaranteed
- What is going on here?

5 min break
PART I - Some challenging results

PART II - A theory (model)

desiderata/goals of a learning theory

- Explain why the CS comes to elicit a response
- When (under what conditions) does this happen?
- Basic phenomena: gradual learning and extinction curves
- More elaborate behavioral phenomena (blocking, overshadowing)
- (explain neural data)
Rescorla & Wagner (1972)

The idea: error-driven learning*
Change in value is proportional to the difference between actual and predicted outcome

\[ \Delta V(CS_j) = \eta \cdot (R_{US} - \sum_{i \in \text{trial}} V(CS_i)) \]

Two assumptions/hypotheses:
(1) learning is driven by error (formalize notion of surprise)
(2) summation of predictors

* strictly speaking it was Bush & Mosteller’s (1951) idea

Summary so far...

- Prediction learning can be explained by an error-correcting learning rule: predictions are learned from experiencing the world and comparing predictions to reality
- That is: learning from prediction errors
- R-W: A simple model - but very powerful!
“The picture that emerges from this discussion of the circumstances that produce conditioning is quite different from that given by the classical descriptions. Pavlovian conditioning is not a stupid process by which the organism willy-nilly forms associations between any two stimuli that happen to co-occur. Rather, the organism is better seen as an information seeker using logical and perceptual relations among events, along with its own preconceptions, to form a sophisticated representation of its world. Indeed, […] I favor an analogy between animals showing Pavlovian conditioning and scientists identifying the cause of a phenomenon” (Rescorla, 1988)

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How is this related to my life?

- We make predictions all the time (our brain is a prediction device)
- All. The. Time.
- We are fundamentally biased (by our predictions)
- Further reading: “Deep down, you are a scientist”

Deep down, you are a scientist

Yael Niv, Princeton University

You may not know it, but deep down you are a scientist. To be precise, your brain is a scientist, and a good one too! The kind of scientist that makes clear hypotheses, gathers data from several sources, and then reaches a well-founded conclusion.

Although we are not aware of the scientific experimentation occurring in our brains on a momentary basis, the scientific process is fundamental to how our brains work. This process involves three key components: first, hypotheses; second, predictions; and third, the time-lagged movement that we make while predicting — where will my arm and spine engage this muscle, how heavy is the cup of coffee that I am planning to grasp and whether my muscles, etc. A good example is the familiar experience of going up the stairs in the dark (or while reading email on your phone) and almost falling because you expected, predictably, there would be a step. If you have ever taken a trip through the dark or blindfolded, you can then consider whether there is a step or not based on sensory feedback (am I feeling a hard surface or not), but anyone who has traveled a flight of stairs in pitch dark knows that this is extremely slow and attention-demanding. Our normal stair-climbing is quick and effortless thanks to accurate predictions.

This is also how we learn from experience: we don’t just wait for things to happen in order to learn, but rather we make predictions about what will happen, and learn only if our predictions are wrong. If you cross the street, you predict whether the approaching car will make it to the crosswalk before proceeding to the other side of the street. This is a simple prediction: it relies on inferring from visual input what the distance and speed of the car is, as well as having a good idea of how fast you walk and how wide the street is. Nevertheless, young kids can master this complex inference and prediction. If you have taught young kids to cross the street, and then see them cross it by themselves, they will do this through trial and error by observing discrepancies between their predictions and reality every time they cross the street. Although they will have created successfully, as their brain had produced, their brain will automatically register small discrepancies between predictions and reality. That car is still very far from me, even though I am closer to the other sidewalk. They will learn to adjust their predictions accordingly, and ever time, will cross the street more like an adult.

Our brains, from over a century of research about learning from experience with the world, that animals, from snails and bees (to monkeys and humans (17), all have, by making predictions and then comparing these predictions to reality so it unfolds, this is called “error-driven learning” — you don’t just learn from what happens, you specifically learn from your mistakes in predicting what will happen.