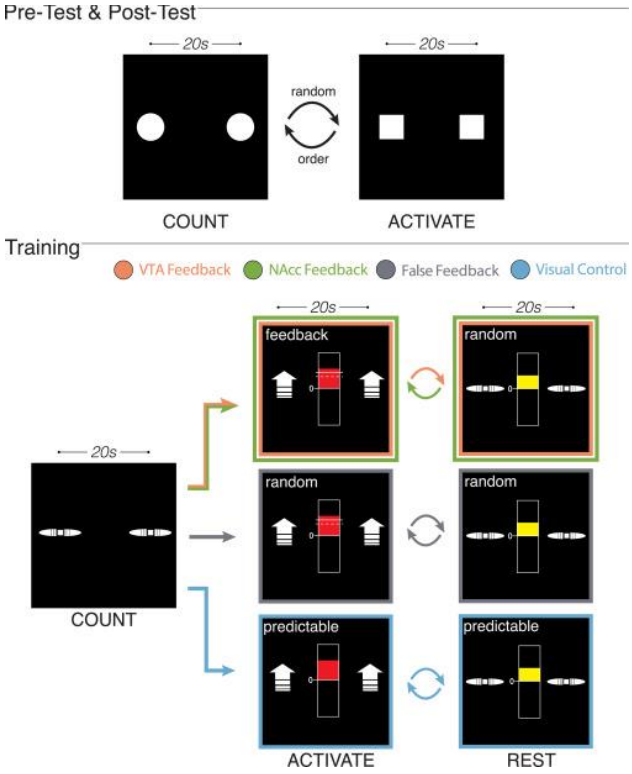
Study 1 (Neurofeedback)[1].

Researchers in the Adcock lab wanted to know whether giving you feedback about how active brain regions associated with learning and motivation are could help you self-control activation in that brain region. In other words, can you self-activate a brain region (with internal imagery) after feedback training ("cognitive neurostimulation")? As a comparison, the researchers measured activation at baseline (no feedback/FB), during training (feedback/FB), and after training (no FB). They also measured activation for different trials: 'activate' (feedback on-screen or, as in post-test and pre-test, they are generating internal imagery), counting backwards, and rest (doing nothing; only training). During training, for the valid FB groups, they gave participants FB of their activation in the region they were interested in (midbrain) and an alternate region (nucleus accumbens). The alternate FB groups included one in which the training FB was random (noise; false feedback) and on in which it was predictable (a simple repeating pattern; visual control – i.e., seeing the feedback bar).



The researchers determined that participants were able to self-motivate their activation of the midbrain / ventral tegmentum area (VTA) but not the nucleus accumbens (NAcc). For the VTA, activation was non-significantly different for the pre-test (baseline) between feedback groups, but significantly different for the post-test (no feedback; post-training).

Level 1 Questions

1. What are the independent variables (IV)?
2. What is the dependent variable (DV)?
3. Is it an experimental or a correlational study?
4. Is the study between-subjects or within-subjects?
5. What is the null hypothesis (H_0)? Did researchers *reject* the null, or *fail to reject* the null?
6. What is a possible *p*-value that the researchers might have found when analyzing the VTA post-test? VTA Pre-test?
7. What cognitive methodology is being used here?

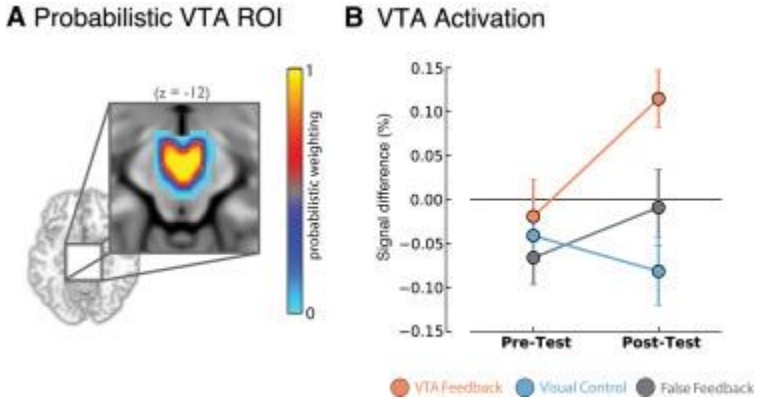
Level 2 Questions

8. What could a within-/between-subject version of the experiment look like? (i.e. What would the study be like changed to the other design?)
9. What is a limitation of this study?
10. Re-visit your answer to Q3 and Q7. What are some pros and cons of this scientific and methodological approach?

[1] Adapted from MacInnes, J. J., Dickerson, K. C., Chen, N. K., & Adcock, R. A. (2016). Cognitive neurostimulation: learning to volitionally sustain ventral tegmental area activation. *Neuron*, *89*(6), 1331-1342. (research done at Duke in the Adcock lab!)

Study 1 Key

1. IV: what feedback group participants were in (VTA Feedback, n = 19; Visual Control [VC], n = 20; NAcc Feedback, n = 20; and Noise FF, n = 14), comparison timepoints (baseline, training, post-training), and trial type (activate (all timepoints), rest trials (i.e., doing nothing during training), and counting backwards trials (all timepoints))
2. DV: BOLD activation (arbitrary units or expressed as 'signal change %')
3. Experimental
4. Mixed Between-subjects & within-subjects. Each participant had count, activate, and rest trials (within subjects), for instance, but participants were placed into different feedback groups (between subjects).
5. Any answer that captures this idea: receiving feedback has no impact on how much BOLD activation is observed (in this case, they want to make sure activation increases significantly relative to the visual control (i.e., seeing the feedback bar) and the random, false feedback). Because differences were found, the researchers *rejected* the null hypothesis.

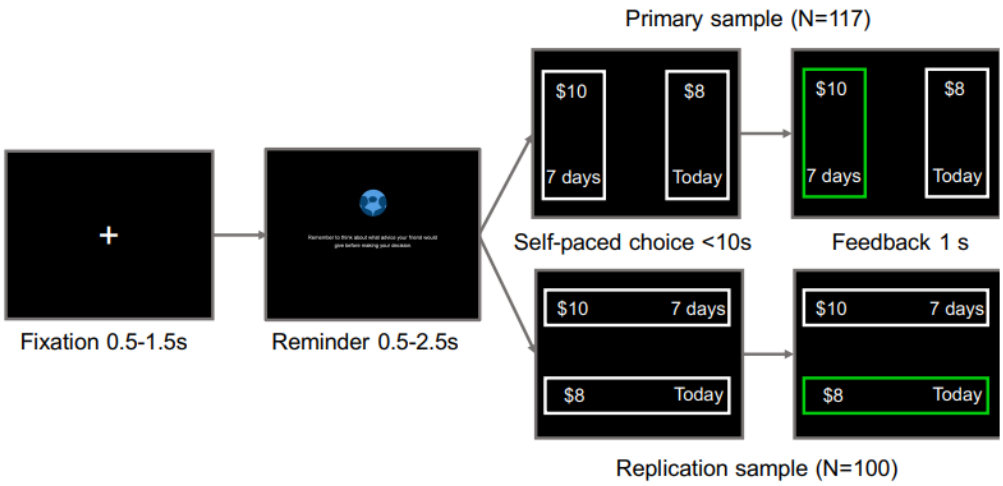


6. Post-test: $p < .05$, for example, .01, .025, .049. Pre-test: $p > 0.05$ Note that the ".05" is an arbitrary cut-off.
7. fMRI. (Most other methods would not work for this study – why not?)
8. A within-subject version of this experiment would involve *each participant* receiving all types of feedback. For example, maybe on day 1, a person would be in the regular feedback day for either brain region, then receive false feedback on day 2, etc. The researcher would need to implement a number of other controls, however, if this experiment was within-subjects instead of between subjects (what do you think they would have to do?).
9. They only looked at these two brain regions, which are both known to be involved in learning and motivation. It might have been good to also look at another region as a control group. The NAcc did not show significant differences, but the results were in the right direction; perhaps more participants, and they would've seen a difference. (This isn't the only limitation; it's one possible example.)
10. The fMRI signal is delayed enough that they can actually give participants trial by trial feedback on their neural signal. It also has enough spatial resolution so that they can target specific regions and give activation feedback for those regions. Nonetheless, it is a bit interesting to consider what exactly participants are doing by self-motivating greater activation (i.e., blood flow); the authors interpret this largely in relation to dopamine signals, but we have no direct evidence of that.

	CORRELATIONAL	EXPERIMENTAL
STRENGTHS	Widely applicable, naturalistic	Can infer causation
WEAKNESSES	Cannot infer causation	Can be artificial, Can be unethical, Not always possible

Study 2 (Intertemporal Choice)[2], via Wikipedia: "Intertemporal choice is the process by which people make decisions about what and how much to do at various points in time, when choices at one time influence the possibilities available at other points in time. These choices are influenced by the relative value people assign to two or more payoffs at different points in time. Most choices require decision-makers to trade off costs and benefits at different points in time."

Researchers in the Huettel lab were interested in knowing whether participants chose between smaller, sooner and larger, later monetary rewards based on the amount of the reward and the time at which it was delivered.



Researchers tracked the eye movements of the participants as they considered both options before registering their choice and receiving feedback on what they chose. For example, they could look at whether participants looked at one option longer or whether they looked at one option first or last, and whether these patterns related to choice behavior. They also modeled the behavior of the participants to determine whether their choices depended on "subjective value" (the idea that participants will choose the option that maximizes their reward, i.e., the most $ and thus highest subjective value).

The researchers found that the eye-tracking predicted both participants' individual choices (e.g., halfway through the experiment, where participants looked last predicted their choices ~75% of the time) and overall patience and that modeling the behavior was likewise predictive of choice.

Level 1 Questions

1. What are the independent variables (IV)?
2. What is the dependent variable (DV)?
3. Is it an experimental or a correlational study?
4. Is the study between-subjects or within-subjects?
5. What is the null hypothesis (H_0)? Did researchers *reject* the null, or *fail to reject* the null?
6. What does the *p*-value tell you?

Level 2 Questions

7. Why do you think that researchers used computational modeling and eye-tracking here? What benefits did those methodologies offer in an experiment like this?
8. This study was done in a laboratory setting, what might the pros or cons be of this environment for generalizing findings to the "real" world?
9. This study was replicated by the authors. What might be reasons for why this study replicated?

(Note that I have highly simplified the modeling here so that you are not bogged down in the details).

[2] Adapted from Amasino, D. R., Sullivan, N. J., Kranton, R. E., & Huettel, S. A. (2019). Amount and time exert independent influences on intertemporal choice. *Nature Human Behaviour*, 1 (research done in Huettel lab at Duke!)

Study 2 Answer Key

1. IV: amount & time, a smaller, sooner reward vs. larger, later reward
2. DV: proportion of choices for each option
3. Experimental (with some correlations, relating 'patience' (choosing larger, later reward) and modeling estimates)
4. Within subjects: it's looking at choices that each individual makes
5. Null hypothesis is that there is no difference between the choices made based on the amount of the reward and the time at which the reward was delivered. They rejected the null hypothesis.
6. The probability that we would get this difference between the groups (given p-value: the probability that we would get this difference between these groups (given this variability and sample size) by chance alone, if H0 is true.
7. Eye-tracking allowed the researchers to see how much attention participants paid to each option (did they fixate on one option more often than the others? Did they choose the option they looked at first? The one they looked at the longest? Etc.). Modeling allowed them to look at individual differences as well as group differences (i.e., whether an individual chooses smaller sooner rewards but the group at large chooses larger later rewards), because it specifies what the researchers think is happening at a mechanistic level.
8. Pros: allowed them to control the specific 'value' and comparison between options for their computational modeling (i.e., the difference is $2 and 7 days in the figure); Cons: highly contrived, maybe not really showing how people make choices when they're out in the real world with more options.
9. Generally, within-subjects designs are often considered more reliable, because you're controlling for individual variability within a person. Methodology wise, it is also considered favorable for researchers to use computational modeling to specify the exact cognitive mechanisms. While modeling can limit generalizability, it does also mean that it's made concrete predictions, and if the model is a useful model (per our first class), those predictions should not only be reliable, but valid too. The study had N = 100 and N = 117 participants in both experiments, which is a much larger sample than most other studies. It had fewer conditions that it was comparing (fewer comparisons means more trials within each condition, which means behavioral estimates will be more reliable).

(Also not listed in the description: the authors explicitly write out all the tests they ran, and they shared their code and data online – good open science practices, per our discussion/reading!)