Kasdin et al. (2025) show that dopamine in the brains of young zebra finches acts as a learning signal, increasing when they sing closer to their adult song and decreasing when they sing further away, effectively guiding their vocal development through trial-and-error. This suggests that complex natural behaviors, like learning to sing, are shaped by dopamine-driven reinforcement learning, similar to how artificial intelligence learns. You can find the paper at this link: https://www.nature.com/articles/s41586-025-08729-1..

Note they measure dopamine using fibre photometry, changes in the fluorescence indicate dopamine changes in realtime. Their specific measurement considers changes in flourescence in 100-ms windows between 200 and 300 ms from the start of singing, averaged across development.

1. Using the `pwr` package for `R` (Champely, 2020), conduct a power analysis. How many observations would the researchers need to detect a moderate-to-large effect ($d = 0.65$) when using $\alpha = 0.05$ and default power (0.80) for a two-sided one sample t test.

```
library(pwr)
(n.value = pwr.t.test(d = 0.65, # large effect
           power = 0.80,
           sig.level = 0.05,
           alternative = "two.sided",
           type = "one.sample")$n)

## [1] 20.58039
```

2. Click the link to go to the paper. Find the source data for Figure 2. Download the Excel file. Describe what you needed to do to collect the data for Figure 2(g). Note that you only need the `closer_vals` and `further_vals`. Ensure to `mutate()` the data to get a difference (e.g., `closer_vals - further_vals`). **We first collected the data from the given website and downloaded the right source data. Once we had the file, we first accessed the `closer_vals` and `further_vals` sheets and copy and pasted them together into one sheet. After, we added column names and then downloaded the file as a CSV to be accessed in R. From there, we were able to mutate and add a column showing the difference.**

```
  data = read_csv("data.csv") |>
  mutate(difference = `Closer Values` - `Farther Values`)

## Rows:  25 Columns:  2
## -- Column specification --------------------------------------------------------
## Delimiter:  ","
## dbl (2):  Farther Values, Closer Values
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

3. Summarize the data.

   (a) Summarize the further data. Do the data suggest that dopamine in the brains of young zebra finches decreases when they sing further away?

	Type	Mean	SD
1	Closer Values	0.16	0.09
2	Farther Values	-0.20	0.13
3	Difference	0.36	0.21

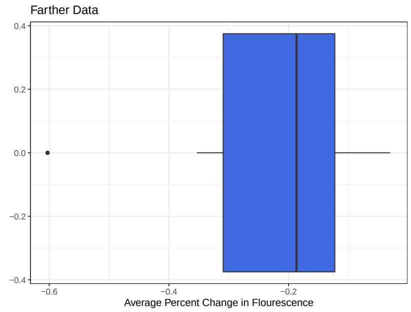

Figure 1:

The data suggests that the average percent change in flourescence within the brains of the animal decreases because all values within the range of the box plot are negative with no large outliers. This means that for every distant syllable rendition, the finches dopamine levels decrease.

(b) Summarize the closer data. Do the data suggest that dopamine in the brains of young zebra finches increases when they sing closer to their adult song?

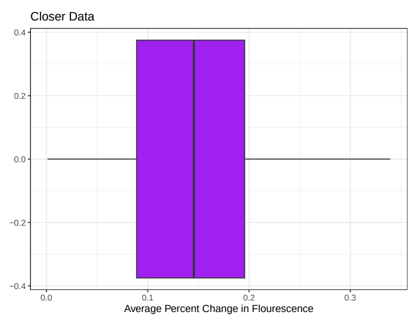

Figure 2:

The data suggests that the average percent change in flourescence within the brains of the animal increases in this case because all values within the range of the box plot are positive with no low outliers. This means that for every distant syllable rendition, the finches dopamine levels increases.

(c) Summarize the paired differences. Do the data suggest that there is a difference between dopamine in the brains of young zebra finches when they sing further away compared to closer to their adult song?

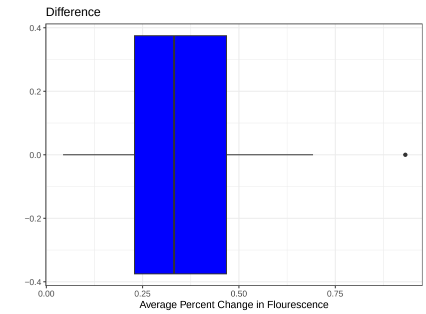

Figure 3:

All of the values for difference (closer values farther values) in average percent change in flourescence are non-zero and positive as shown by the box plot. This means that there is a difference between the change in flourescence among close and far renditions, which ultimately means that there impact on dopamine levels is different.

(d) **Optional Challenge:** Can you reproduce Figure 2(g)? Note that the you can use `geom_errorbar()` to plot the range created by adding the mean ± one standard deviation.

4. Conduct the inferences they do in the paper. Make sure to report the results a little more comprehensively – that is your parenthetical should look something like: ($t = 23.99$, $p < 0.0001$; $g = 1.34$; 95% CI: 4.43, 4.60).
Note: Your numbers may vary slightly as they performed some unclear correction of their p-values. I'm waiting to hear back from them via email!

   (a) "The close responses differed significantly from 0 ($p = 1.63 \times 10^{-8}$)." ($t = 8.3024$, $p < .0001$; $g = 1.61$.; 95% CI: .117, .195)

   (b) "The far responses differed significantly from 0 ($p = 5.17 \times 10^{-8}$)." ($t = -7.778$, $p < .0001$; $g = -1.51$.; 95% CI: -.257, -0.149)

   (c) "The difference between populations was significant ($p = 1.04 \times 10^{-8}$)." ($t = 8.5109$, $p < .0001$; $g = 1.65$.; 95% CI: .272, .446)

5. Reverse engineer the hypothesis test plot from Lecture 20 to create accurate hypothesis testing plots for each part of the previous question.

   (a) Question 4, part(a).

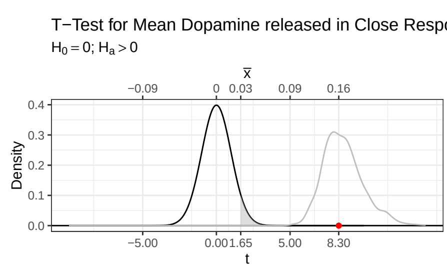

Figure 4:

   (b) Question 4, part(b).

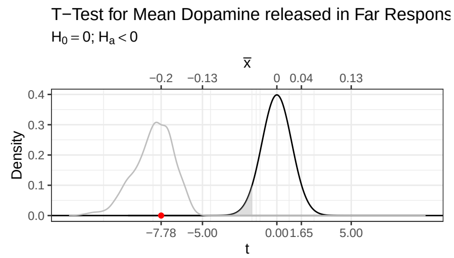

Figure 5:

(c) Question 4, part(c).

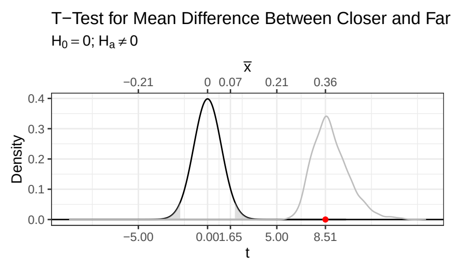

Figure 6:

References

Champely, S. (2020). *pwr: Basic Functions for Power Analysis*. R package version 1.3-0.

Kasdin, J., Duffy, A., Nadler, N., Raha, A., Fairhall, A. L., Stachenfeld, K. L., and Gadagkar, V. (2025). Natural behaviour is learned through dopamine-mediated reinforcement. *Nature*, pages 1–8.