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.

```
## Warning: package 'pwr' was built under R version 4.4.3
```

```
pwr.t.test(
  d = 0.65,
  sig.level = 0.05,
  power = 0.80,
  type = "one.sample",
  alternative = "two.sided"
)


##
##      One-sample t test power calculation
##
##               n = 20.58039
##               d = 0.65
##       sig.level = 0.05
##           power = 0.8
##     alternative = two.sided
```

   Using the `pwr.t.test()` function indicates that we need 21 obervations.

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`).

   In order to collect `closer_vals` and `further_vals` from the excel file I had to manual go through the file and copy and paste both of those columns of values onto a new excel page. Once I had the data on a new excel file I then renamed the columns using the `rename()` function and use mutate to create the difference.

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?

mean	sd	median	min	max
-0.20	0.13	-0.19	-0.60	-0.03

   The mean dopamine response when zebra finches sang farther from their adult songs was -0.20 with a standard deviation of 0.13 which may indicate a decrease in dopamine. The responses ranged from -.60 to -.03 which tell us that all of our observed values indicated that singing farther away from their adult songs had a negative impact on their dopamine levels. We can also look to Figure 1 which visual shows us that all of our obersvations are recorded below zero and our median is well below zero indicating a negative effect.

   (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?

mean	sd	median	min	max
0.16	0.09	0.15	0.00	0.34

The mean dopamine response when zebra finches sang closer to their adult songs was 0.16 with a standard deviation of 0.09 which may indicate a increase in dopamine. The responses ranged from 0 to .34 which tell us that all of our observed values indicated that singing closer to their adult songs had a positive impact on their dopamine levels. We can also look to Figure 1 which visual shows us that all of our obersvations are recorded at or above zero and are median is well above zero again, indicating a postive effect.

(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?

mean	sd	median	min	max
0.36	0.21	0.33	0.04	0.93

Taking the difference for each bird allows us to control for variability in baseline dopamine levels and assess the direct effect that singing closer or farther from their adult song might have on their dopamine levels. Given this we see that the mean difference between closer and farther dopamine levels is .36. Our data indicate that the zebra finches showed higher dopamine levels when singing closer to their adult song compared to when they sing further away. We can again visual see this in Figure 1 which reinforces our numerical summary of our data and our original conclusion.

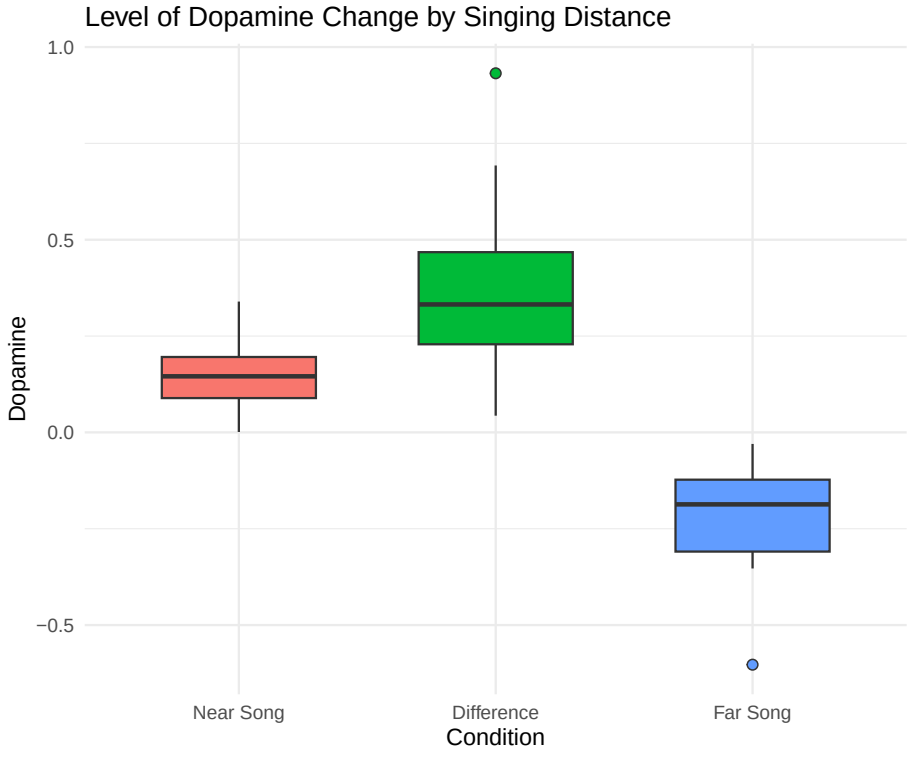

Figure 1: Box Plot of Dopmaine in Zebra Finches

(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.

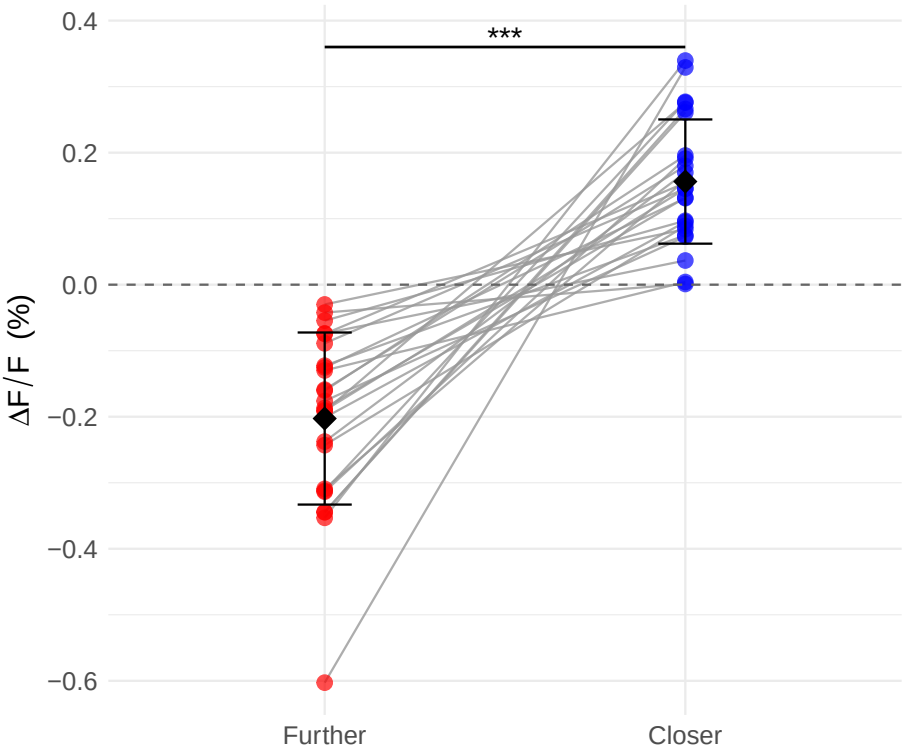

Figure 2: optional graph

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 ($t = 8.3$, p≤0.0001; g=1.61; 95% CI: 0.12, 0.2)."

   (b) "The far responses differed significantly from 0 ($t = -7.78$, p≤0.0001; g=-1.51; 95% CI: -0.26, -0.15)."

   (c) "The difference between populations was significant ($t = 8.51$, p≤0.0001; g=1.65; 95% CI: 0.27, 0.45)."

   Each of the above parentheticals are from the two tailed test.

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).

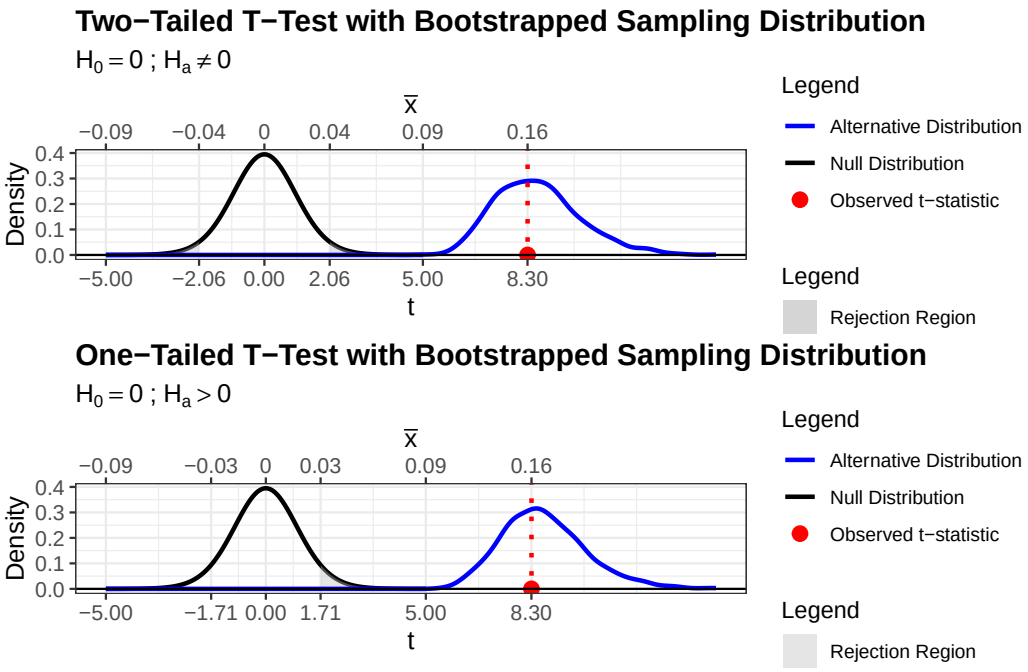

Figure 3: Two-tailed and one-tailed hypothesis tests for dopamine levels when singing closer to the adult song

(b) Question 4, part(b).

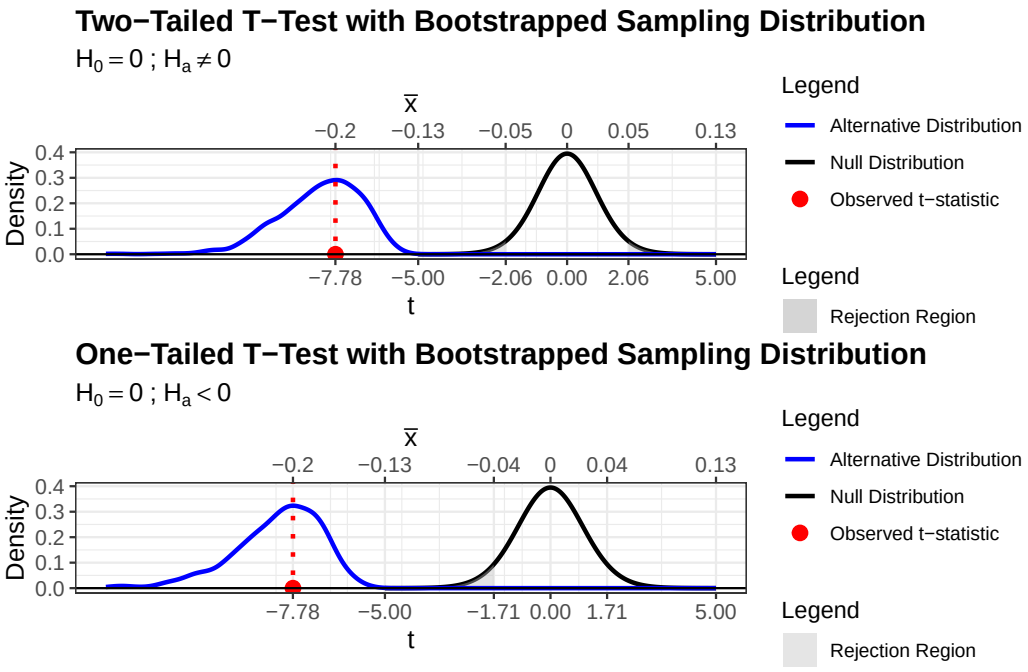

Figure 4: Two-tailed and one-tailed hypothesis tests for dopamine levels when singing farther from the adult song

(c) Question 4, part(c).

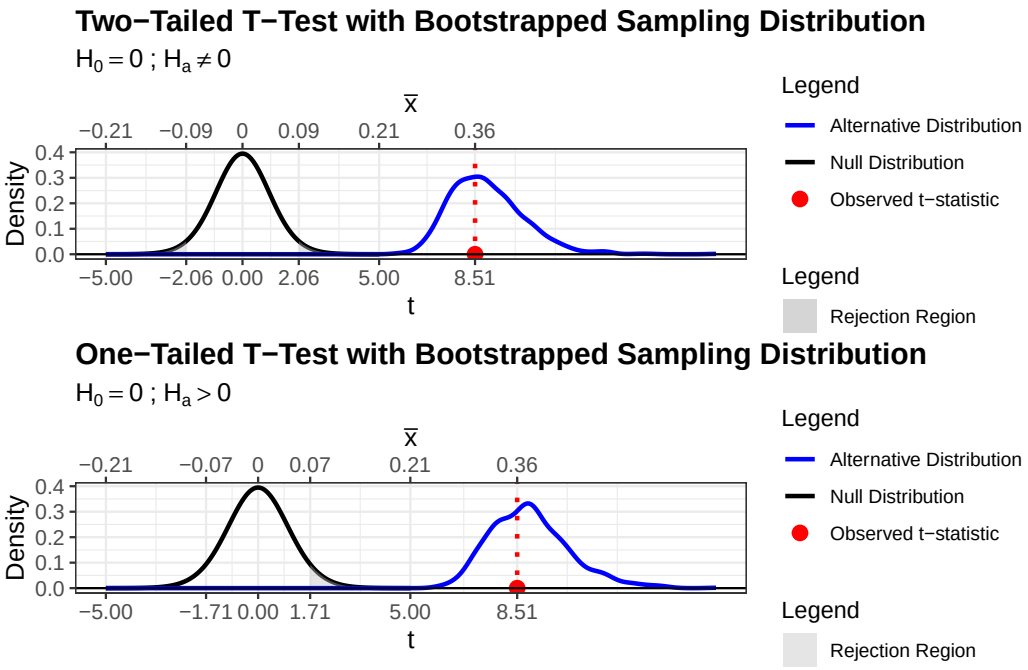

Figure 5: Two-tailed and one-tailed hypothesis tests for the difference in dopamine levels between close and far singing conditions

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.