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

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

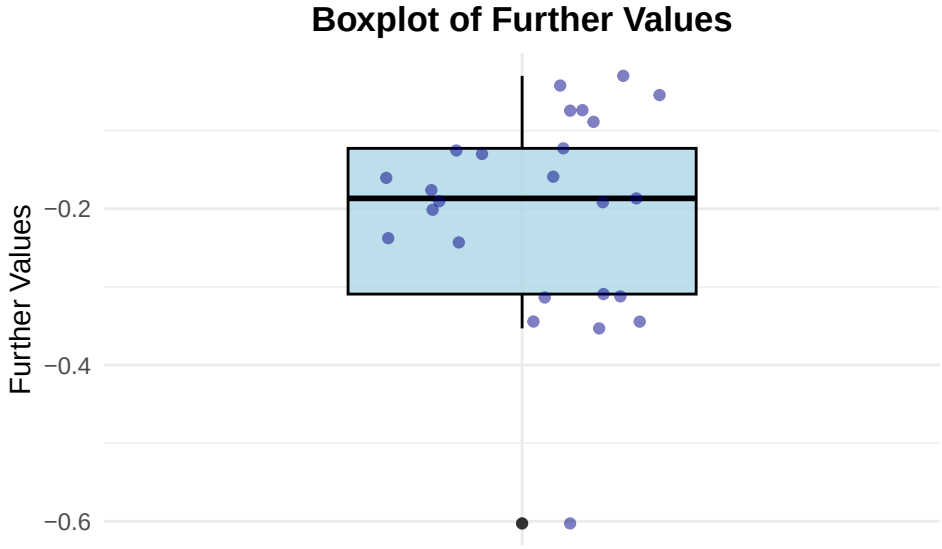
When we perform two-sample one-sided t-test with with power = 0.80, and $\alpha = 0.05$, we get an output of n = 20.58039. So, to detect a moderate-to-large effect (d= 0.65), the researchers must use atleast 21 observations.

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`).

   To collect the data for Figure2(g), we had to download the Excel file from the link and then isolate the two specific Excel sheets we wanted; which were the closer values sheet and the farther values sheet. Then, we combined the two Excel sheets and saved them to a csv which we then read with `read_csv`. Finally, we used mutate to create a difference column which was calculated by subtracting the closer value column from the farther value column.

3. Summarize the data.

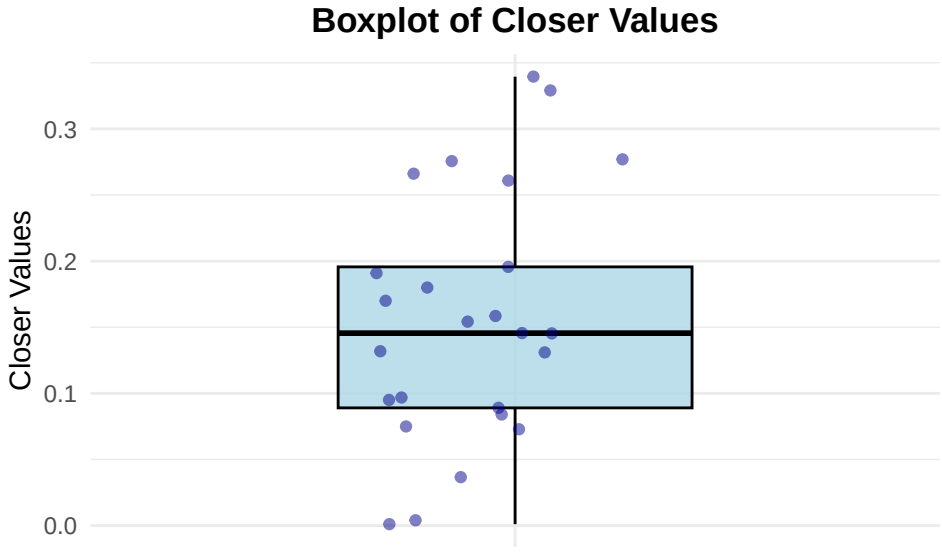
(a) Summarize the further data. Do the data suggest that dopamine in the brains of young zebra finches decreases when they sing further away?



mean_further	sd_further	median_further	IQR_further	skewness_further	exkurtosis_further
-0.203	0.130	-0.187	0.187	-1.036	1.192

The data suggest that dopamine in the brains of young zebra finches decreases when they sing further away since the mean and median are both negative. Looking at the boxplot, it is abundantly clear that nearly all of the points are negative, further showing that the dopamine in the brans of young zebra fiches decreases when they sing further away.

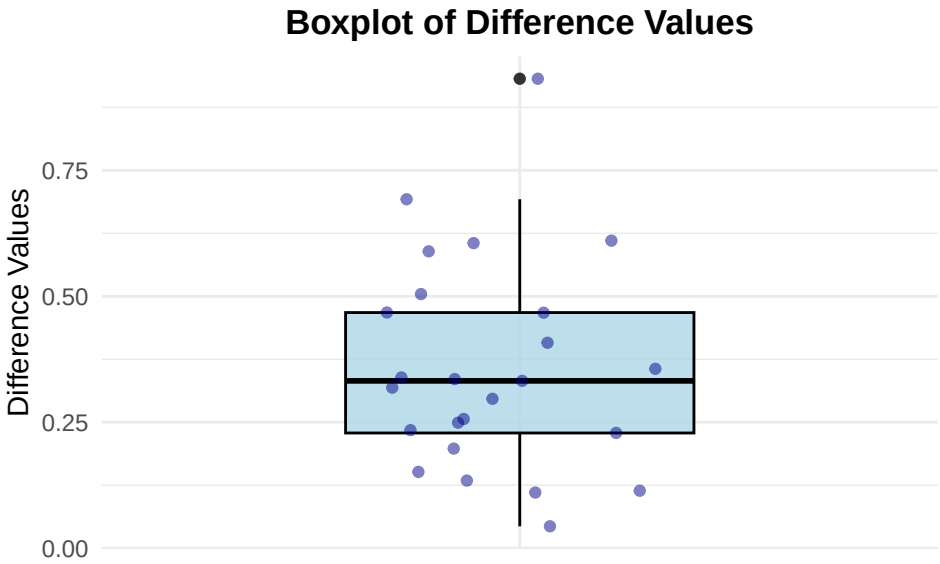
(b) Summarize the closer data. Do the data suggest that dopamine in the brains of young zebra finches increases when they sing closer to their adult song?



mean_closer	sd_closer	median_closer	IQR_closer	skewness_closer	exkurtosis_closer
0.156	0.094	0.146	0.107	0.295	-0.859

The data suggest that dopamine in the brains of young zebra finches increases when they sing further away since the mean and median are both positive Looking at the boxplot, it is abundantly clear that nearly all of the points are positive, further showing that the dopamine in the brans of young zebra fiches increases when they sing further away.

(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_difference	sd_difference	median_difference	IQR_difference	skewness_difference	exkurtosis_difference
0.359	0.211	0.332	0.239	0.773	0.128

The data suggest that there is a difference between dopamine in the brains of young zebra finches when they sing further away from their adultsong compared to closer to their adultsong. If there were no difference, we would expect all of the data points to be around zero and for the mean and median to both be around zero. However, all of these values are positive, indicating that dopamine levels are generally higher when the birds sing closer to their adultsong. Therefore, we have reason to believe that there may be a difference between dopamine in the brains of young zebra finches when they sing further away compared to closer to their adultsong.

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!

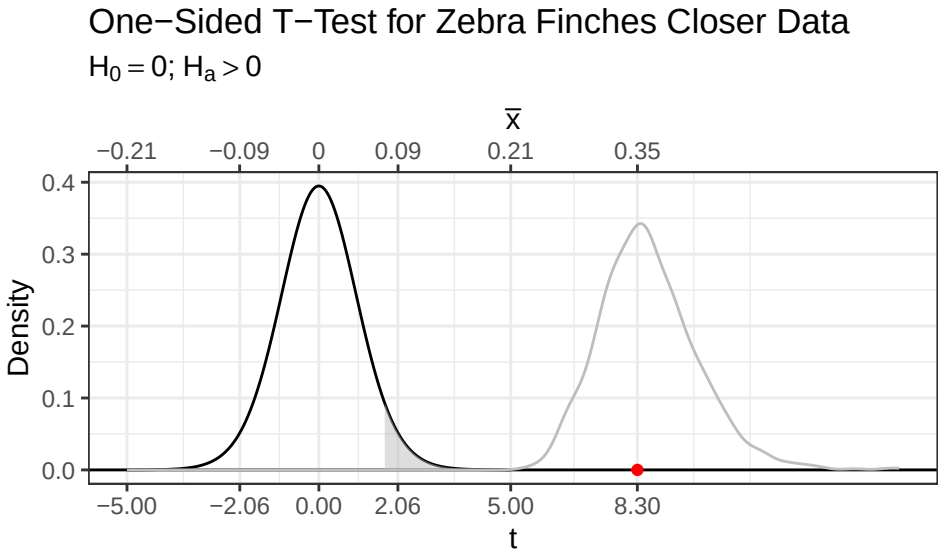
   (a) "The close responses differed significantly from 0 ($p = 1.63 \times 10^{-8}$)."
   ($t = 8.3024$, $p = 8.132e-09$; $g = 1.61$; 95% CI: 1.10, Inf).

   (b) "The far responses differed significantly from 0 ($p = 5.17 \times 10^{-8}$)."
   ($t = -7.778$, $p = 2.587e-08$; $g = -1.51$; 95% CI: -Inf, -1.02).

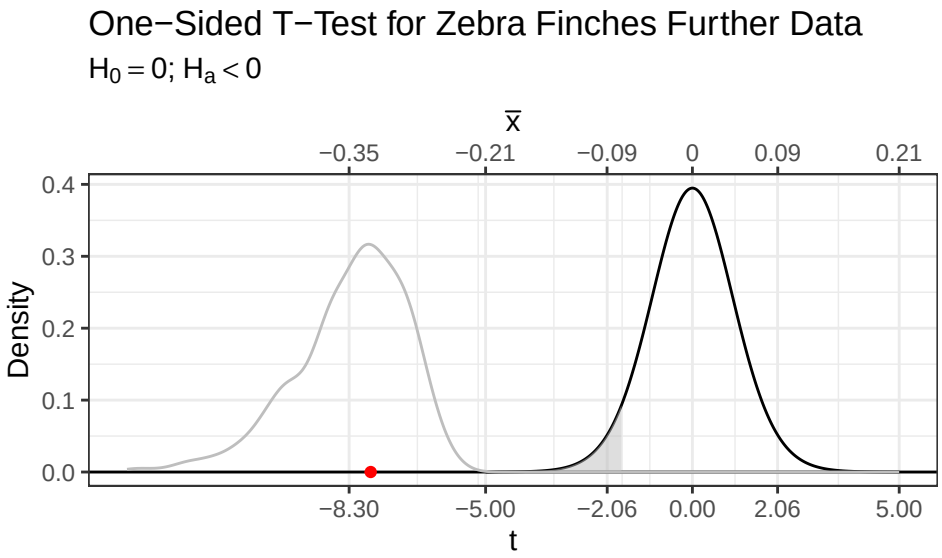
   (c) "The difference between populations was significant ($p = 1.04 \times 10^{-8}$)."
   ($t = 8.5109$, $p = 1.037e-08$; $g = 1.65$; 95% CI: 1.04, 2.24).

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

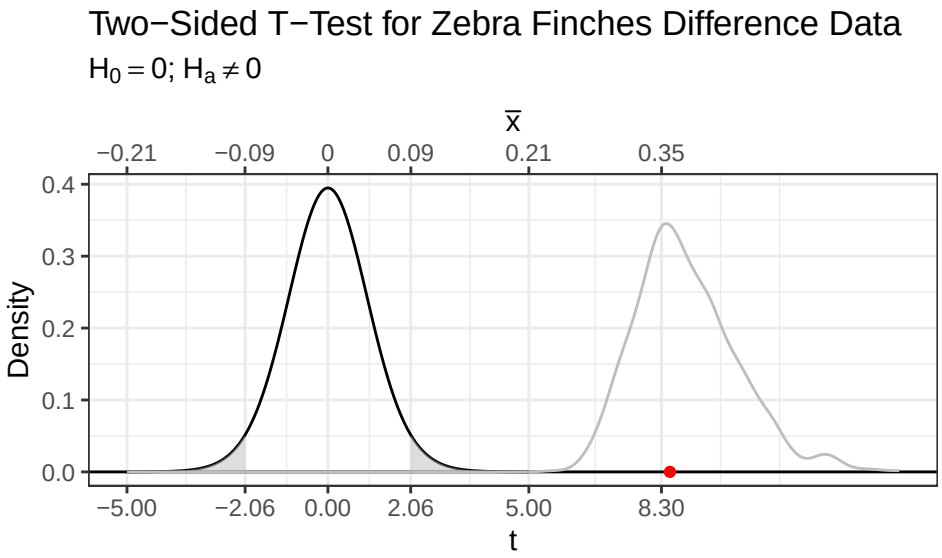
   (a) Question 4, part(a).



   (b) Question 4, part(b).



(c) Question 4, part(c).



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.