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.

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

   It would take 21 observations to detect moderate-to-large effect d=0.65

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`).

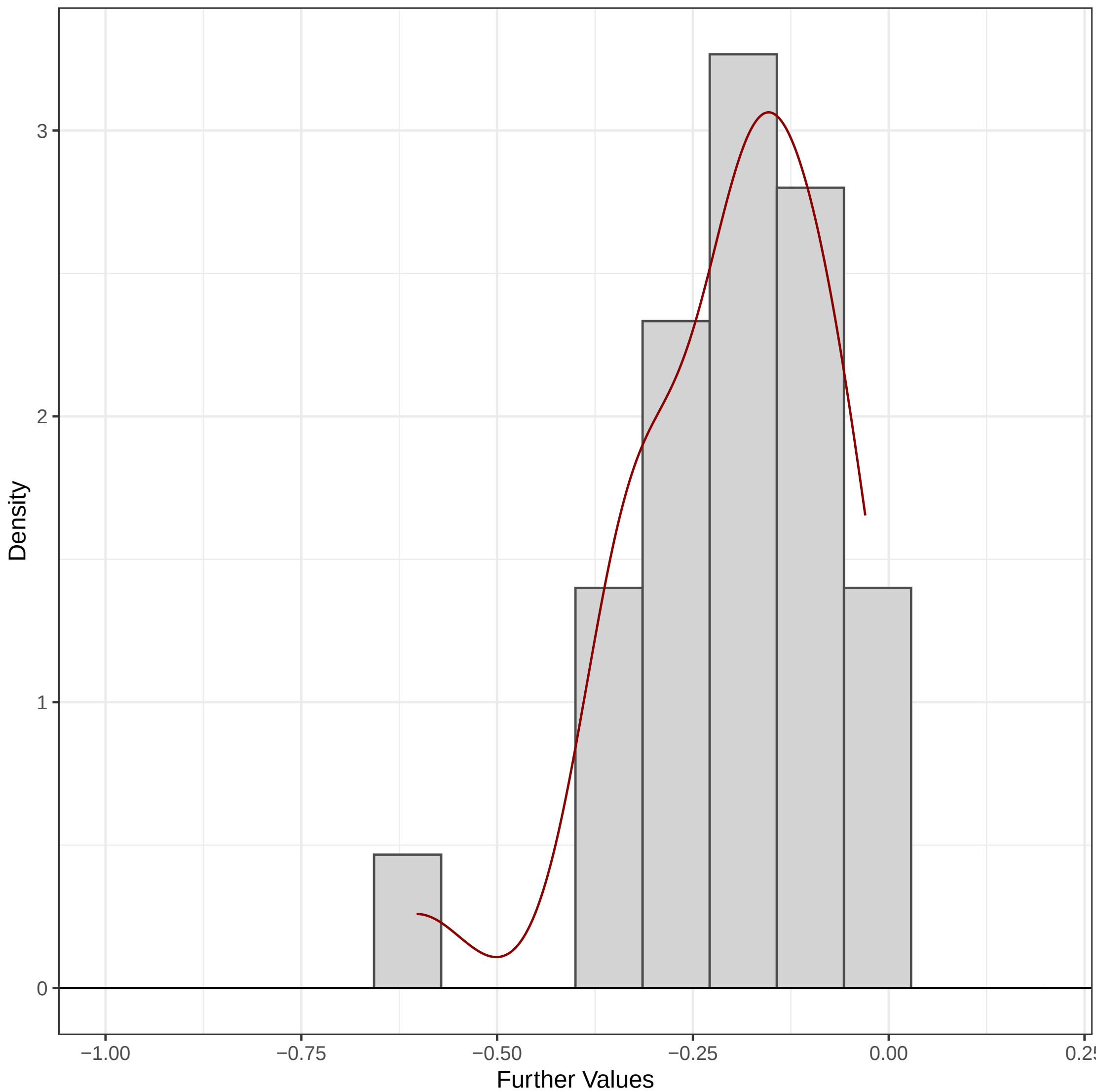
```
library(tidyverse)
library(readxl)
finch.dat <- read_excel("Lab11data.xlsx")

finch.tib = tibble(finch.dat) |>
  mutate(diff_vals=closer_vals - further_vals)
```

   In order to collect the data for figure 2(g) I first needed to got to the research paper (Kasdin et al., 2025) and download the data for figure 2. After, I needed to create a separate excel sheet taking only two of the tabs I wanted for figure 2(g) of further_vals and closer_vals. I then had to upload the excel file into R and then mutate the tibble I made to add a new column called diff_vals which was the difference of the other rows of data.

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?

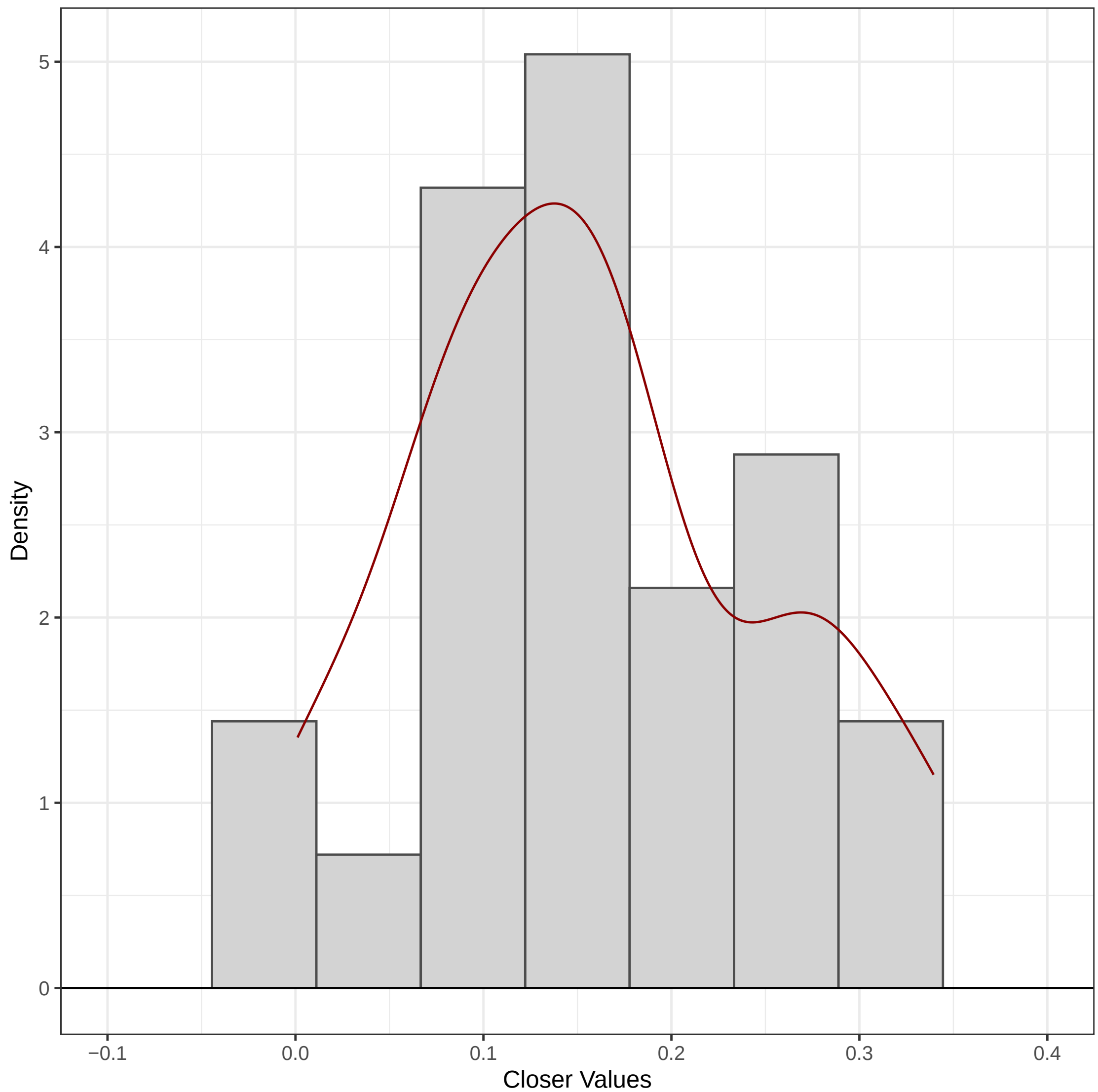
```
## # A tibble: 1 x 6
##     mean    sd median   IQR skewness exkurtosis
##    <dbl> <dbl>  <dbl> <dbl>    <dbl>      <dbl>
## 1 -0.203 0.130 -0.187 0.187    -1.04       1.19
```



As seen in the graph and the mean of the data, it is clearly less than 0 suggesting that the the dopamine of the young zebra finches decreases when they song further from their adult song.

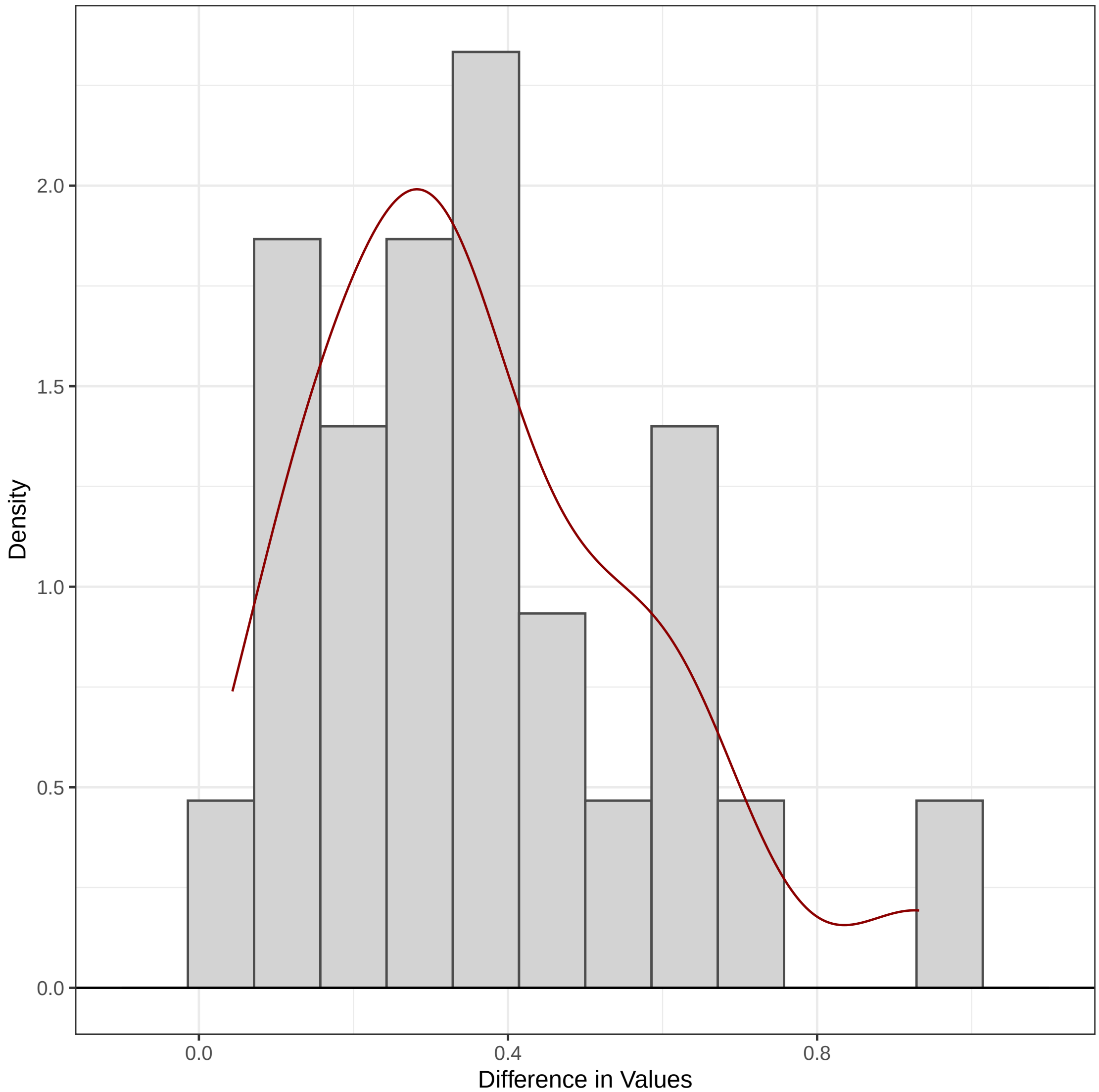
(b) Summarize the closer data. Do the data suggest that dopamine in the brains of young zebra finches increases when they sing closer to their adult song?

```
## # A tibble: 1 x 6
##    mean     sd median   IQR skewness exkurtosis
##   <dbl>  <dbl>  <dbl> <dbl>    <dbl>      <dbl>
## 1 0.156 0.0941  0.146 0.107    0.295     -0.859
```



As seen in the graph and the mean of the data, it is clearly greater than 0 suggesting that the dopamine of the young zebra finches increases when they sing closer to their adult song.

(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?



As seen in the graph and mean of the data, the difference is not 0 suggesting that their is a difference between the dopamine in the brains of young finches when they sing further away compared to closer to their adult song.

(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 ($p = 1.63 \times 10^{-8}$)."

```
library(effectsize)
hedges_g(x = finch.tib$closer_vals, mu = 0, alternative = "greater")

## Hedges' g |      95% CI
## ------------------------
## 1.61      | [1.10, Inf]
```

```
##
## - One-sided CIs: upper bound fixed at [Inf].
```

```
t.test(x=finch.tib$closer_vals, mu = 0, alternative = "greater")
```

```
##
##  One Sample t-test
##
## data:  finch.tib$closer_vals
## t = 8.3024, df = 24, p-value = 8.132e-09
## alternative hypothesis: true mean is greater than 0
## 95 percent confidence interval:
##  0.1240301       Inf
## sample estimates:
## mean of x
## 0.1562231
```

The data I got was $t = 8.3024, p = 8.132 \times 10^{-8}, g = 1.61$, 95% CI: $1.10, \infty$.

(b) "The far responses differed significantly from 0 ($p = 5.17 \times 10^{-8}$)."

```
library(effectsize)
hedges_g(x = finch.tib$further_vals, mu = 0, alternative = "less")
```

```
## Hedges' g |         95% CI
## -------------------------
## -1.51     | [-Inf, -1.02]
##
## - One-sided CIs: lower bound fixed at [-Inf].
```

```
t.test(x=finch.tib$further_vals, mu = 0, alternative = "less")
```

```
##
##  One Sample t-test
##
## data:  finch.tib$further_vals
## t = -7.778, df = 24, p-value = 2.587e-08
## alternative hypothesis: true mean is less than 0
## 95 percent confidence interval:
##        -Inf -0.1581322
## sample estimates:
##  mean of x
## -0.2027244
```

The data I got was $t = -7.778, p = 2.587 \times 10^{-8}, g = -1.51$, 95% CI: $-\infty, -1.02$.

(c) "The difference between populations was significant ($p = 1.04 \times 10^{-8}$)."

```
library(effectsize)
hedges_g(x = finch.tib$diff_vals, mu = 0, alternative = "two.sided")
```

```
## Hedges' g |       95% CI
## ------------------------
## 1.65      | [1.04, 2.24]
```

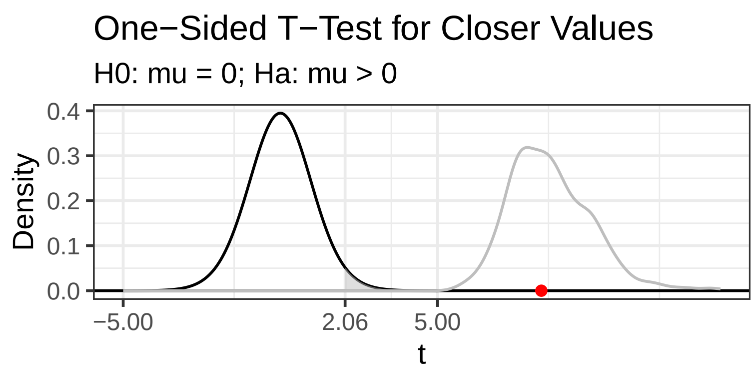
```
t.test(x=finch.tib$diff_vals, mu = 0, alternative = "two.sided")
```

```
##
##  One Sample t-test
```

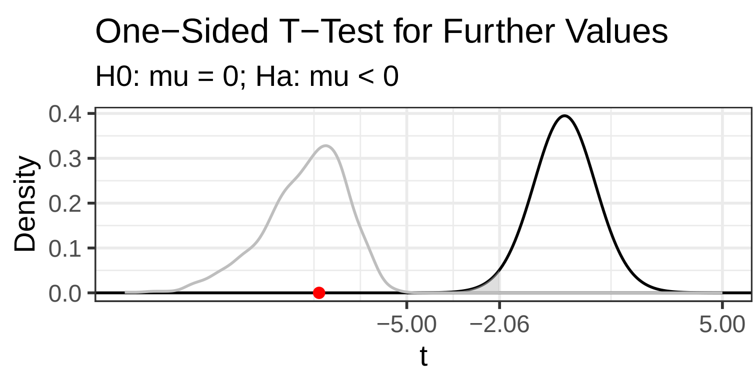
```
##
## data:  finch.tib$diff_vals
## t = 8.5109, df = 24, p-value = 1.037e-08
## alternative hypothesis: true mean is not equal to 0
## 95 percent confidence interval:
##  0.2719028 0.4459921
## sample estimates:
## mean of x
## 0.3589475
```

The data I got was $t = 8.5109, p = 1.037 \times 10^{-8}, g = 1.65$, 95% CI: $1.04, 2.24$.

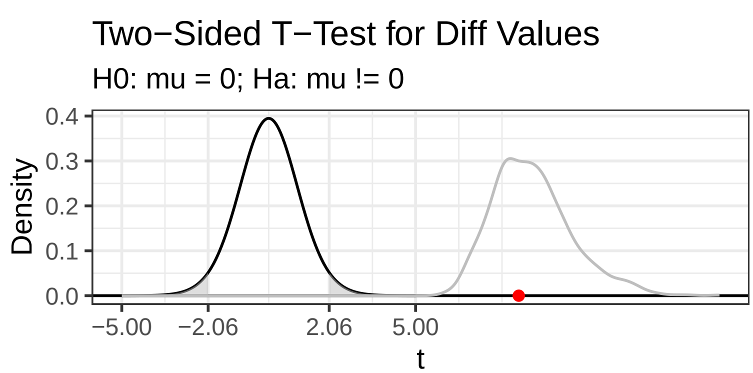
5. Reverse engineer the hypothesis test plot from Lecture 20 to create accurate hypothesis testing plots for each part of the previous question.



(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.