The Effect of Time

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December 09, 2019

Analysis of data collected from a Cleveland & McGill style study investigating the effects of time.

References:
- https://github.com/mjskay/tidybayes
- @codementum

Libraries needed

```
library("jsonlite")
library(RCurl)
library(plyr)
library(tidyverse)
library(uuid)
```

Grab the JSON file from firebase and convert into a list in R

```
tables <- fromJSON("https://clevelandmcgill-final.firebaseio.com/.json")
options(warn = -1)
```

Create the `sessions` tibble

```
sessions <- tibble()
for (session in tables$Session) {
  new_row <- as_tibble(session)
  sessions <- sessions %>% bind_rows(new_row)
}
```

Create the `trials` tibble

```
#tables$Trial
trials = tibble()
for (img_name in tables$Trial) {
  #img_name
  for (observation in img_name) {
      new_row <- as_tibble(observation)
      trials <- trials %>% bind_rows(new_row)
    # trials <- rbind(trials_df, data.frame(observation))
  }
}
#Filter incomplete trials to not skew data.
 trials <- trials %>%
  filter(session_id != "c071ee29-5210-498b-9af4-3f361a9a68ba" & session_id != "98f79c48-4803-4300-8c92-8
```

Clean the data to make later function calls easier

Create `condition` column from `image_name` (to easily filter by condition)

```r
trials$condition <- NA
for (i in seq_along(trials$image_name)) {
  if (length(grep("B", trials$image_name[i])) > 0)
    condition <- 'Bar'
  else if (length(grep("P", trials$image_name[i])) > 0)
    condition <- 'Pie'
  else
    condition <- '???'

  trials$condition[i] <- condition
}
```

```r
trials$time <- NA
for (i in seq_along(trials$image_name)) {
  if (length(grep("1000", trials$image_name[i])) > 0)
    time <- 'One Second'
  else if (length(grep("0500", trials$image_name[i])) > 0)
    time <- 'Half Second'
  else if (length(grep("3000", trials$image_name[i])) > 0)
    time <- 'Three Seconds'
  else
    time <- "???"

  trials$time[i] <- time
}
```

```r
trials$time_chart <- NA
for (i in seq_along(trials$image_name)) {
  if(length(grep("B", trials$image_name[i]) > 0)){
    if (length(grep("1000", trials$image_name[i])) > 0)
      time_chart <- 'One Second Bar'
    else if (length(grep("0500", trials$image_name[i])) > 0)
      time_chart <- 'Half Second Bar'
    else if (length(grep("3000", trials$image_name[i])) > 0)
      time_chart <- 'Three Seconds Bar'
    else
      time_chart <- "Unknown Bar"
  }else{
    if (length(grep("1000", trials$image_name[i])) > 0)
      time_chart <- 'One Second Pie'
    else if (length(grep("0500", trials$image_name[i])) > 0)
      time_chart <- 'Half Second Pie'
    else if (length(grep("3000", trials$image_name[i])) > 0)
      time_chart <- 'Three Seconds Pie'
    else
      time_chart <- "Unknown Pie"
  }
  trials$time_chart[i] <- time_chart
}
```

Create column for the log__2 error rate (as described in the paper by Cleveland and McGill)

```
trials$log2_error <- log(abs(strtoi(trials$actual_answer) - strtoi(trials$expected_answer)) + 0.125, ba
```

Create participant column from session_id (to make the facet plot tidier)

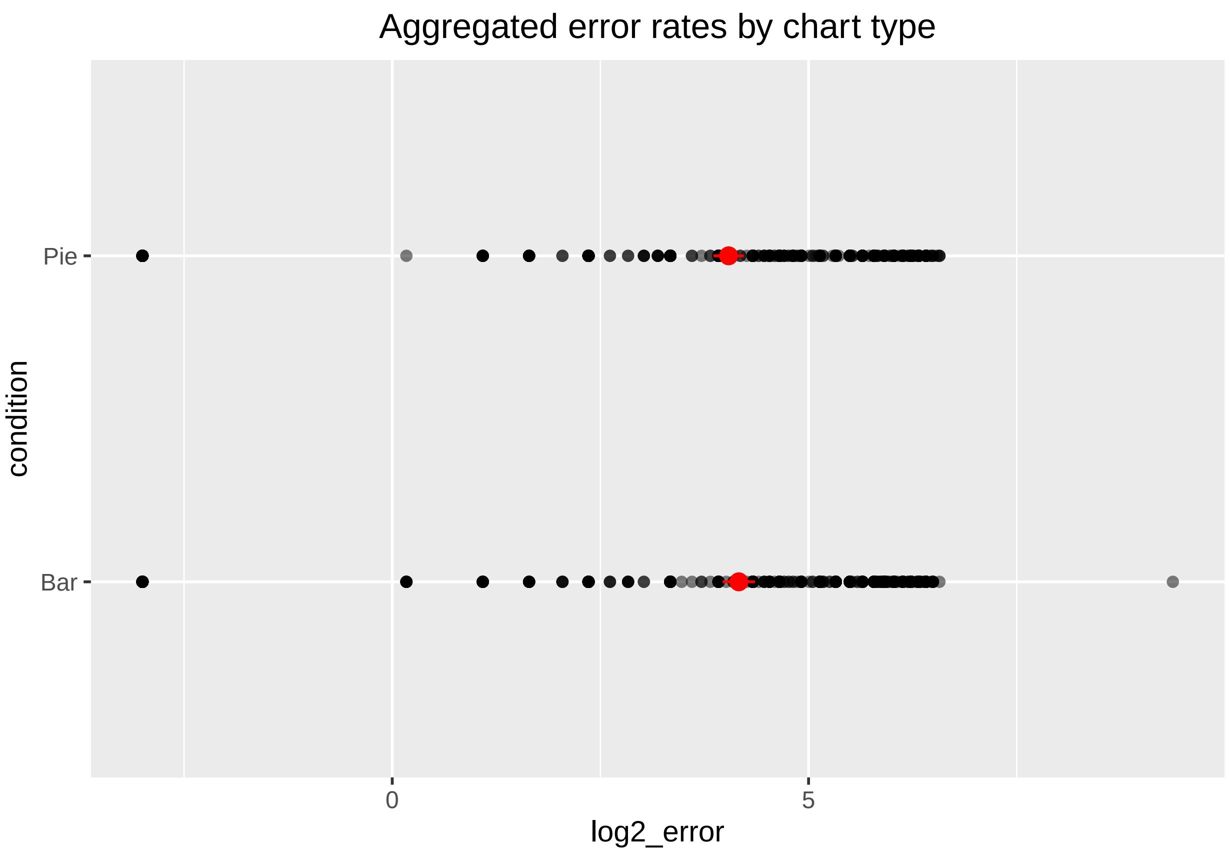
```
trials$participant <- factor(
  trials$session_id, levels=unique(trials$session_id), labels = seq_along(unique(trials$session_id))
)

trials %>% filter(participant == 45)
```

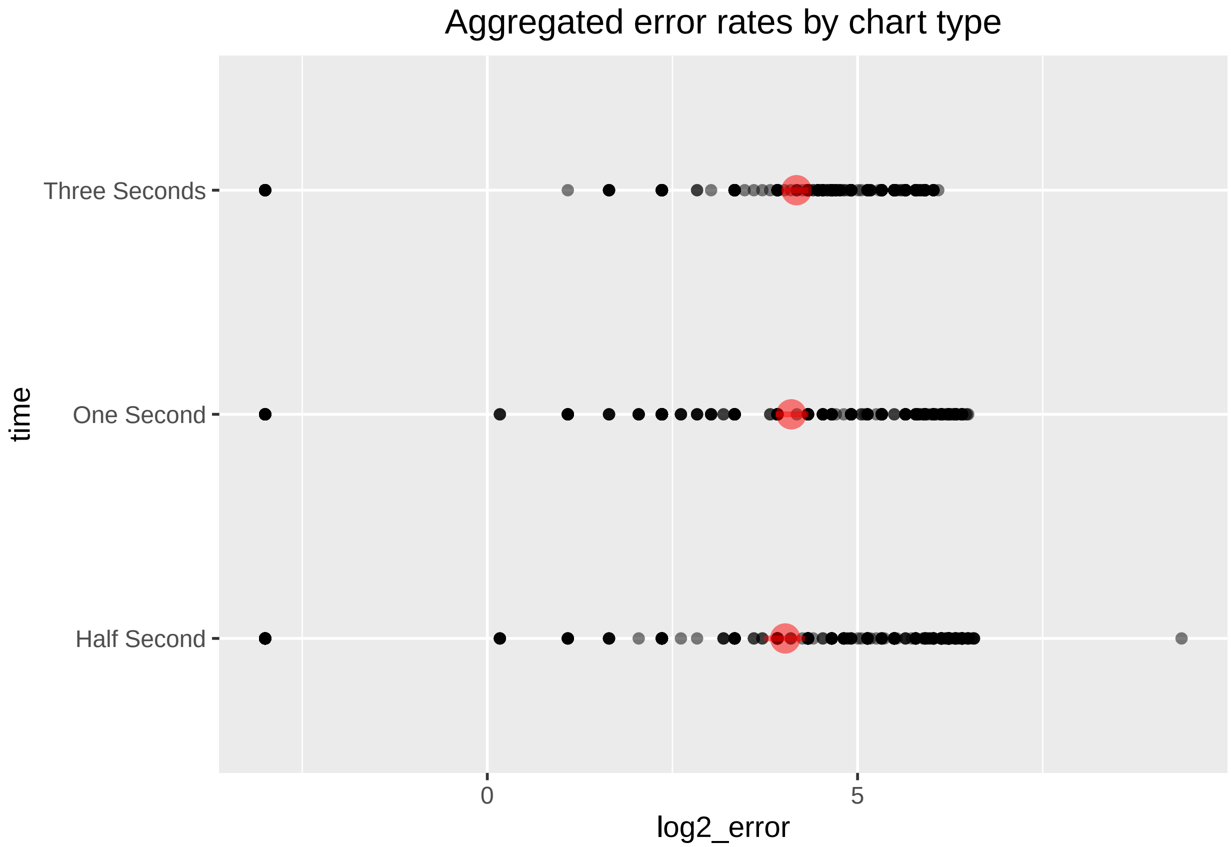
```
## # A tibble: 0 x 9
## # ... with 9 variables: actual_answer <chr>, expected_answer <chr>,
## #   image_name <chr>, session_id <chr>, condition <chr>, time <chr>,
## #   time_chart <chr>, log2_error <dbl>, participant <fct>
```

Comparing aggregate error rates for bar and pie charts

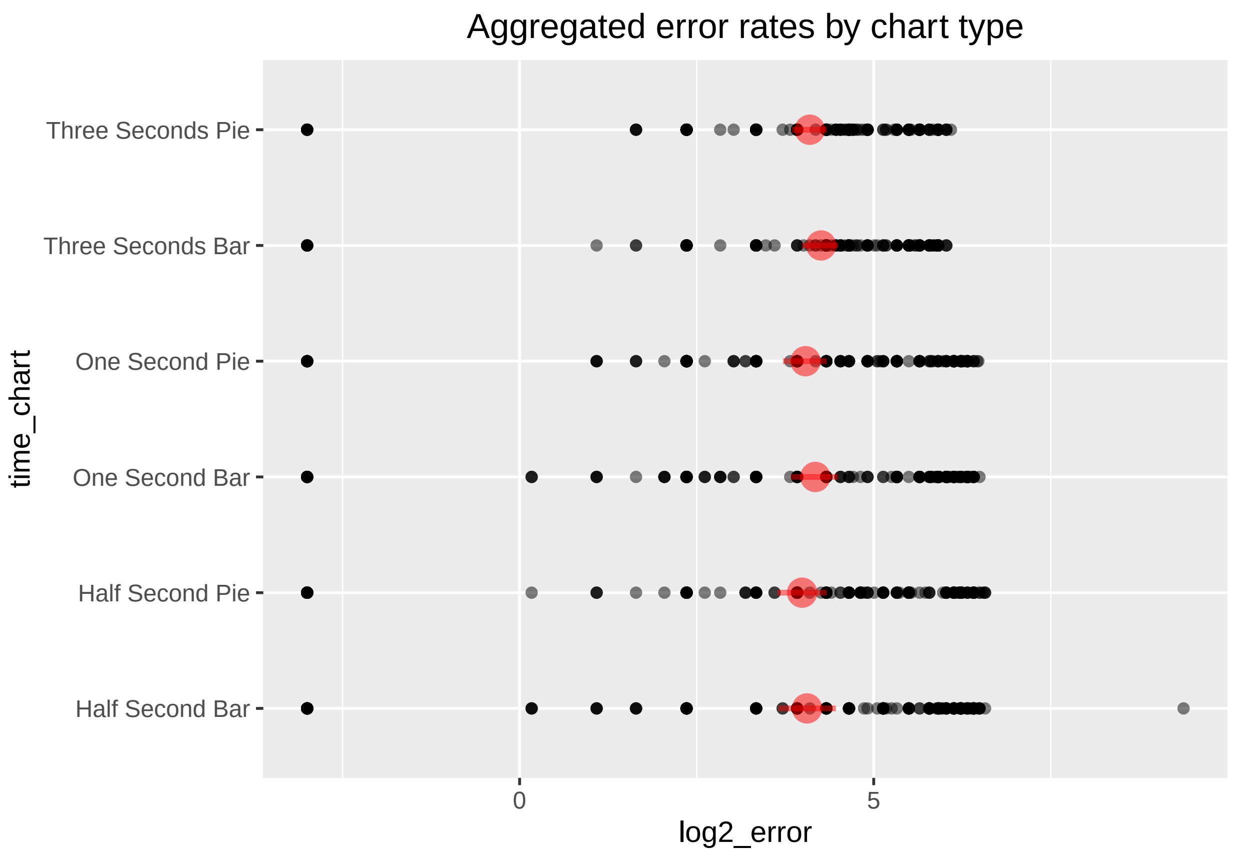
```
trials %>%
  ggplot(aes(x = condition, y = log2_error)) +
  geom_point(alpha = 0.5) +
  stat_summary(fun.data = "mean_cl_boot", colour = "red", size = .50, alpha=1) +
  coord_flip() +
  theme(plot.title = element_text(hjust = 0.5)) +
  ggtitle("Aggregated error rates by chart type")
```



```
trials %>%
  ggplot(aes(x = time, y = log2_error)) +
  geom_point(alpha = 0.5) +
  stat_summary(fun.data = "mean_cl_boot", colour = "red", size = 1.0, alpha=0.5) +
  coord_flip() +
  theme(plot.title = element_text(hjust = 0.5)) +
  ggtitle("Aggregated error rates by chart type")
```



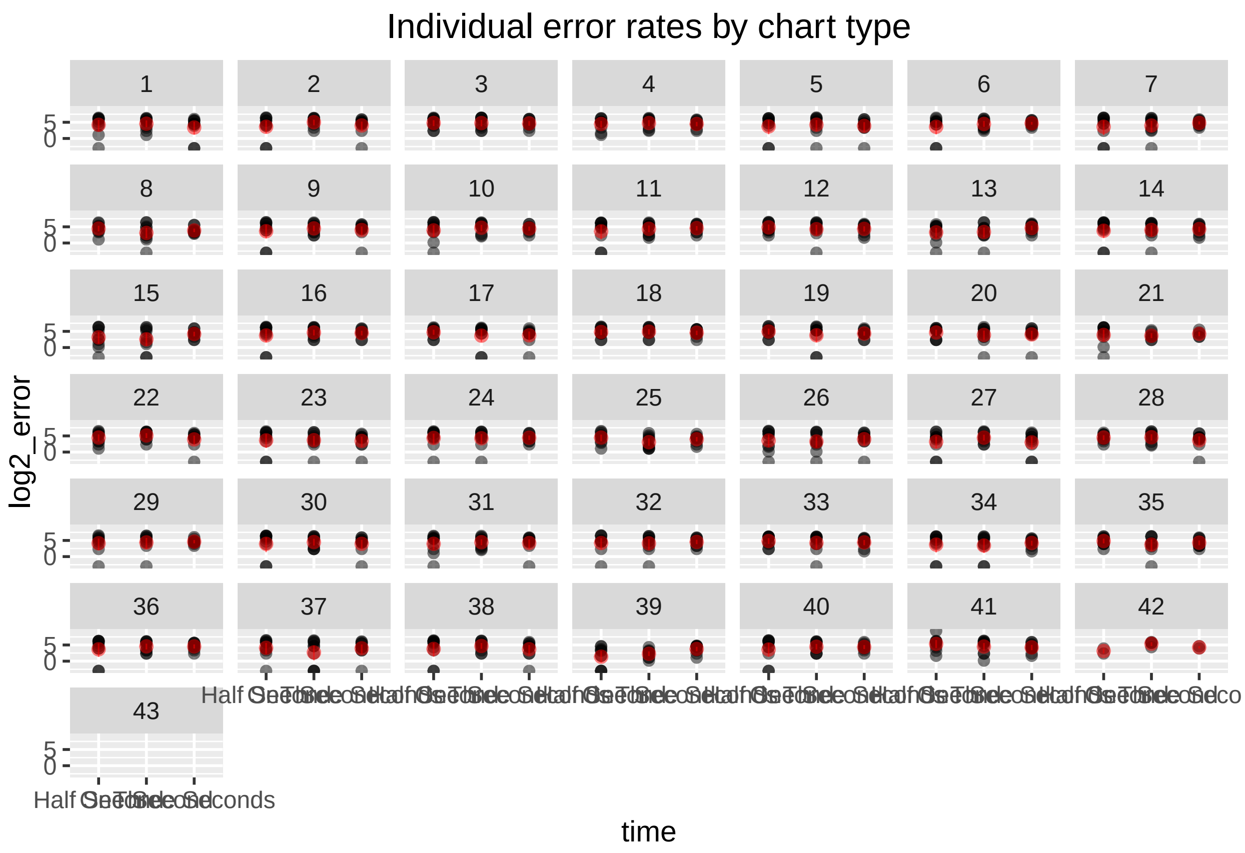
```
trials %>%
  ggplot(aes(x = time_chart, y = log2_error)) +
  geom_point(alpha = 0.5) +
  stat_summary(fun.data = "mean_cl_boot", colour = "red", size = 1.0, alpha=0.5) +
  coord_flip() +
  theme(plot.title = element_text(hjust = 0.5)) +
  ggtitle("Aggregated error rates by chart type")
```



As expected, error rates on pie charts are higher than the error rates on bar charts

Comparing individual participant error rates by chart type

```
trials %>%
  ggplot(aes(x = time, y = log2_error)) +
  geom_point(alpha = 0.5) +
  stat_summary(fun.data = "mean_cl_boot", colour = "red", size = .3, alpha=0.5) +
  facet_wrap(~ participant) +
  theme(plot.title = element_text(hjust = 0.5)) +
  ggtitle("Individual error rates by chart type")
```



```
  theme(panel.spacing = unit(2, "lines"))
```

```
## List of 1
##  $ panel.spacing: 'unit' num 2lines
##   ..- attr(*, "valid.unit")= int 3
##   ..- attr(*, "unit")= chr "lines"
##  - attr(*, "class")= chr [1:2] "theme" "gg"
##  - attr(*, "complete")= logi FALSE
##  - attr(*, "validate")= logi TRUE
```

```
ggsave('barvpie_byparticipant.pdf', units="in", width=8, height=11)
```

We still see the same trend of higher error rates on pie charts (with a couple of outliers)

Statistical Analysis

Normality test of the bar and pie responses

Creating conditional columns of data

```
pie <- trials %>%
  filter(condition == "Pie")
bar <- trials %>%
  filter(condition == "Bar")

bar_time_half <- trials %>%
  filter(time_chart == "Half Second Bar")
```

```r
bar_time_one <- trials %>%
  filter(time_chart == "One Second Bar")
bar_time_three <- trials %>%
  filter(time_chart == "Three Seconds Bar")

pie_time_half <- trials %>%
  filter(time_chart == 'Half Second Pie')
pie_time_one <- trials %>%
  filter(time_chart == "One Second Pie")
pie_time_three <- trials %>%
  filter(time_chart == "Three Seconds Pie")
```

##Shapiro Tests of all variables

```r
shapiro.test(bar$log2_error)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  bar$log2_error
## W = 0.78159, p-value < 2.2e-16
```

```r
shapiro.test(pie$log2_error)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  pie$log2_error
## W = 0.78531, p-value < 2.2e-16
```

```r
shapiro.test(pie_time_half$log2_error)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  pie_time_half$log2_error
## W = 0.76007, p-value < 2.2e-16
```

```r
shapiro.test(pie_time_one$log2_error)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  pie_time_one$log2_error
## W = 0.81257, p-value = 6.234e-15
```

```r
shapiro.test(pie_time_three$log2_error)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  pie_time_three$log2_error
## W = 0.74821, p-value < 2.2e-16
```

```r
shapiro.test(bar_time_half$log2_error)
```

```
##
##  Shapiro-Wilk normality test
```

```
##
## data:  bar_time_half$log2_error
## W = 0.76811, p-value < 2.2e-16
```

```
shapiro.test(bar_time_one$log2_error)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  bar_time_one$log2_error
## W = 0.80134, p-value = 2.61e-15
```

```
shapiro.test(bar_time_three$log2_error)
```

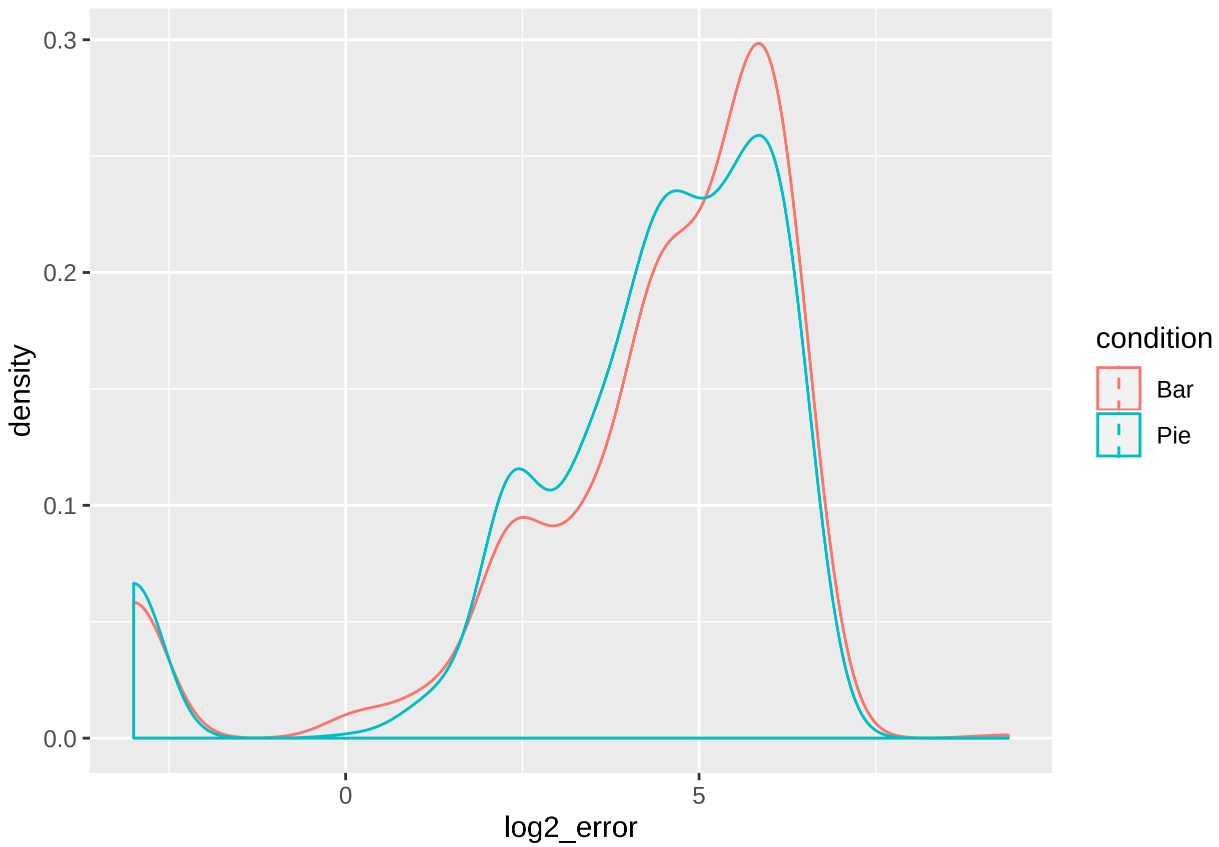
```
##
##  Shapiro-Wilk normality test
##
## data:  bar_time_three$log2_error
## W = 0.70937, p-value < 2.2e-16
```

Density plots - validating normality test

Our normality test indicates that the error rates for the bar and pie charts are not normally distributed. We validate this by creating density plots by chart type, with the mean value of each group also indicated.

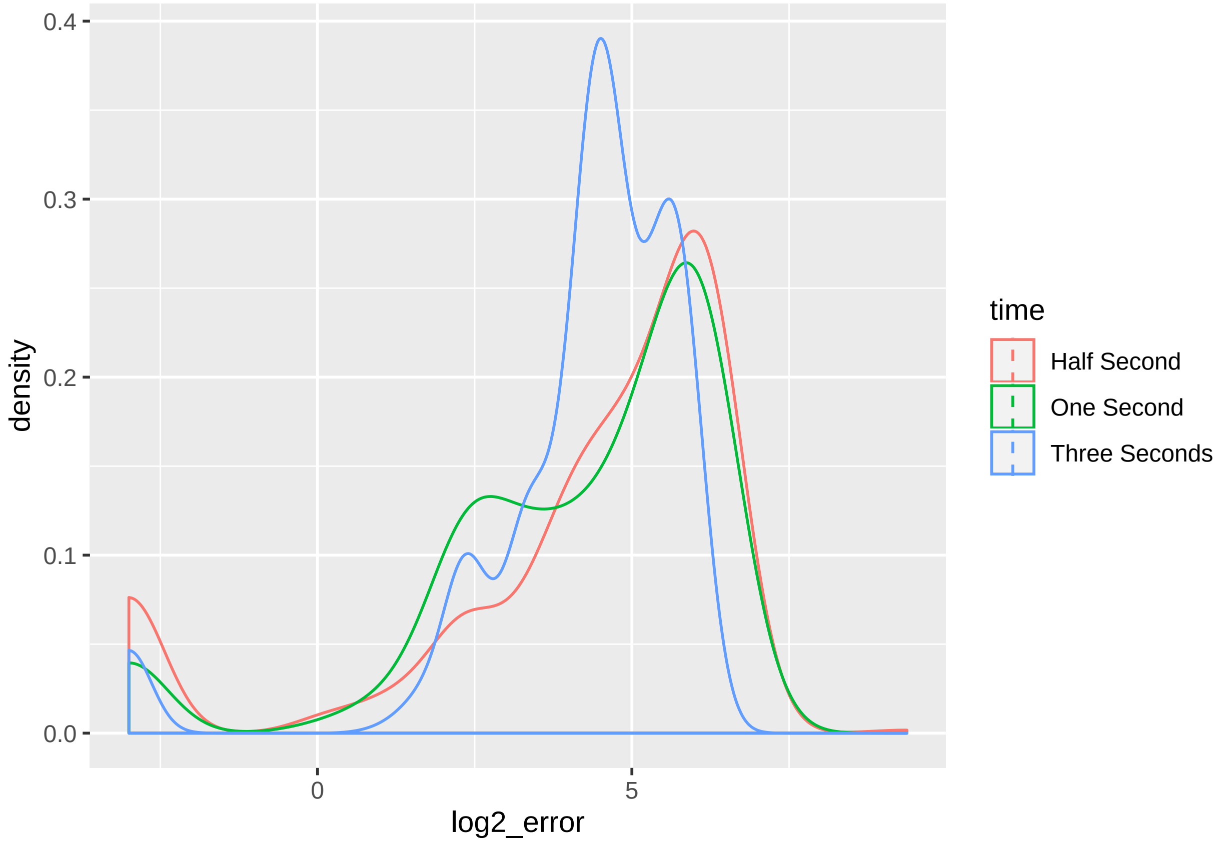
```
mu <- ddply(trials, "condition", summarise, grp.mean=mean(log2_error))

trials %>%
  ggplot(aes(x=log2_error, color=condition)) +
  geom_density() +
  geom_vline(data=mu, aes(xintercept=grp.mean, color=condition),
             linetype="dashed")
```



```
mu2 <- ddply(trials, "time", summarise, grp.mean=mean(log2_error))

trials %>%
  ggplot(aes(x=log2_error, color=time)) +
  geom_density() +
  geom_vline(data=mu2, aes(xintercept=grp.mean, color=time),
             linetype="dashed")
```



Wilcoxon rank sum test

Our test for normality came out negative therefore we perform the Wilcoxon rank sum test.

```
wilcox.test(bar_time_half$log2_error, bar_time_one$log2_error)
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  bar_time_half$log2_error and bar_time_one$log2_error
## W = 21352, p-value = 0.4707
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(bar_time_half$log2_error, bar_time_three$log2_error)
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  bar_time_half$log2_error and bar_time_three$log2_error
## W = 23819, p-value = 0.002567
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(bar_time_one$log2_error, bar_time_three$log2_error)
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  bar_time_one$log2_error and bar_time_three$log2_error
## W = 22484, p-value = 0.04951
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(pie_time_half$log2_error, pie_time_one$log2_error)
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  pie_time_half$log2_error and pie_time_one$log2_error
## W = 22298, p-value = 0.2833
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(pie_time_half$log2_error, pie_time_three$log2_error)
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  pie_time_half$log2_error and pie_time_three$log2_error
## W = 23886, p-value = 0.02119
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(pie_time_one$log2_error, pie_time_three$log2_error)
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  pie_time_one$log2_error and pie_time_three$log2_error
## W = 22373, p-value = 0.2201
## alternative hypothesis: true location shift is not equal to 0
```

```
wilcox.test(pie_time_half$log2_error, bar_time_half$log2_error)
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  pie_time_half$log2_error and bar_time_half$log2_error
## W = 19897, p-value = 0.3963
## alternative hypothesis: true location shift is not equal to 0
```