10 - Review

HCI/PSYCH 522
Iowa State University

February 22, 2022

Review

- Statistical inference
  - Scientific question
  - Response variable
  - Explanatory variable (or grouping)
  - Random sample? (If yes, inference to the population.)
  - Randomized treatment? (If yes, causal inference.)
- Statistical analysis
  - Response variable
    - Count data with known maximum $\rightarrow$ binomial
    - Continuous data $\rightarrow$ normal
  - Explanatory variable
    - None $\rightarrow$ one group models
    - Groups $\rightarrow$ multiple group models
    - Continuous $\rightarrow$ regression

Audio guide messages

An experiment was conducted to understand the impact of audio guide messages in emergency warnings. Students at Iowa State University voluntarily enrolled in a virtual reality simulation experiment where they were randomly assigned to a scenario that either included or did not include audio guide messages during the emergency warning. For each student, researchers recorded whether or not the student successfully navigated the emergency.

- Scientific question
- Response variable
- Explanatory variable (or grouping)
- Random sample? (If yes, inference to the population.)
- Randomized treatment? (If yes, causal inference.)

Audio guide messages: inference

- Scientific question: How do audio guide messages affect successful navigation during an emergency?
- Response variable: Number of students who successfully navigated the emergency.
- Explanatory variable (or grouping): With and without audio guide messages (two groups)
- Random sample? (If yes, inference to the population.): No, volunteers
- Randomized treatment? (If yes, causal inference.): Yes, presence of audio guide messages was randomized.

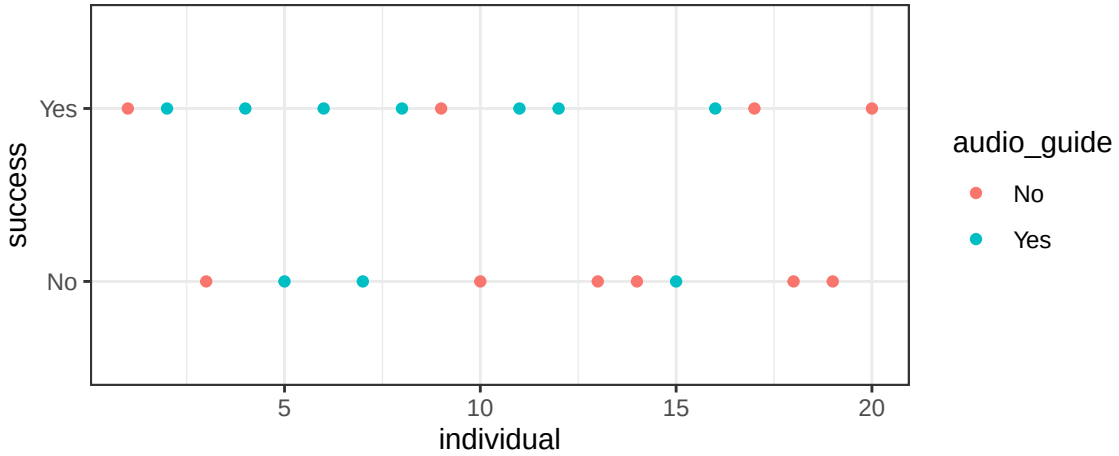
Audio guide messages: data

```
emergency <- read_csv("emergency.csv")

emergency
```

```
## # A tibble: 20 x 5
##    individual audio_guide success cortisol_baseline cortisol_stress
##         <dbl> <chr>       <chr>               <dbl>           <dbl>
##  1          1 No          Yes                 107.             130.
##  2          2 Yes         Yes                  96.5            120.
##  3          3 No          No                  100.             130.
##  4          4 Yes         Yes                 105.             119.
##  5          5 Yes         No                  103.             119.
##  6          6 Yes         Yes                  95.7            119.
##  7          7 Yes         No                   99.3            120.
##  8          8 Yes         Yes                  98.1            118.
##  9          9 No          Yes                  97.9            131.
## 10         10 No          No                  105.             129.
## 11         11 Yes         Yes                 105.             118.
## 12         12 Yes         Yes                  89.2            120.
## 13         13 No          No                   99.5            131.
```

```
ggplot(emergency, aes(x = individual, y = success, color = audio_guide)) +
  geom_point()
```



Summary statistics

```
s_emergency <- emergency %>%
  group_by(audio_guide) %>%
  summarize(n = n(),
            y = sum(success == "Yes"))
s_emergency
```

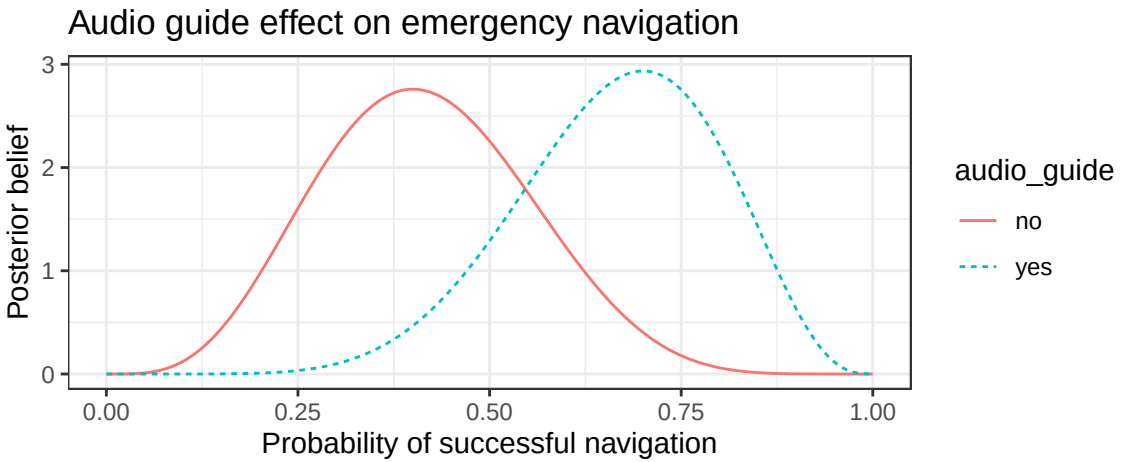
```
## # A tibble: 2 x 3
##   audio_guide     n     y
##   <chr>       <int> <int>
## 1 No             10     4
## 2 Yes            10     7
```

Posterior belief about probability of success

```
d <- data.frame(theta = seq(from=0, to=1, length=1001)) %>%
  mutate(yes = dbeta(theta, shape1 = 1+7, shape2 = 1+10-7),
         no  = dbeta(theta, shape1 = 1+4, shape2 = 1+10-4)) %>%
  pivot_longer(cols = -theta, names_to = "audio_guide", values_to = "density")

ggplot(d, aes(x = theta, y = density, color = audio_guide, linetype = audio_guide)) +
  geom_line() +
  labs(x = "Probability of successful navigation",
       y = "Posterior belief",
       title = "Audio guide effect on emergency navigation")
```

Posterior belief about probability of success



Probability difference

```
n_reps <- 100000
prob_yes <- rbeta(n_reps, shape1 = 1+7, shape2 = 1+10-7)
prob_no  <- rbeta(n_reps, shape1 = 1+4, shape2 = 1+10-4)
mean(prob_yes > prob_no)

## [1] 0.90215

# Credible interval for the difference
a <- 1-0.95
quantile(prob_yes - prob_no, probs = c(a/2, 1-a/2))

##       2.5%      97.5%
## -0.1327103  0.6000329
```

Audio guide messages

An experiment was conducted to understand the impact of audio guide messages in emergency warnings. Students at Iowa State University voluntarily enrolled in a virtual reality simulation experiment where they were randomly assigned to a scenario that either included or did not include audio guide messages during the emergency warning. For each student, researchers recorded a baseline level of cortisol before the experiment began and a stress level of cortisol immediately after the experiment concluded.

- Scientific question
- Response variable
- Explanatory variable (or grouping)
- Random sample? (If yes, inference to the population.)
- Randomized treatment? (If yes, causal inference.)

Audio guide messages: inference

- Scientific question: How do audio guide messages affect cortisol levels during an emergency?
- Response variable: Ratio of stress to baseline cortisol levels.
- Explanatory variable (or grouping): With and without audio guide messages (two groups)
- Random sample? (If yes, inference to the population.): No, volunteers
- Randomized treatment? (If yes, causal inference.): Yes, presence of audio guide messages was randomized.

Audio guide messages: data

```
emergency <- emergency %>%
  mutate(ratio = cortisol_stress / cortisol_baseline)

emergency
```

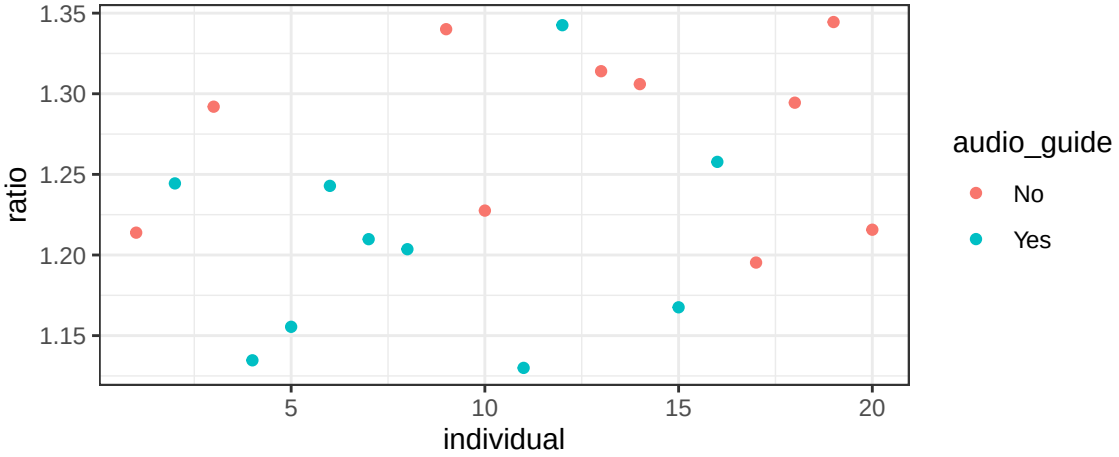
```
## # A tibble: 20 x 6
##    individual audio_guide success cortisol_baseline cortisol_stress ratio
##         <dbl> <chr>       <chr>               <dbl>           <dbl> <dbl>
##  1          1 No          Yes                 107.             130.  1.21
##  2          2 Yes         Yes                  96.5            120.  1.24
##  3          3 No          No                  100.             130.  1.29
##  4          4 Yes         Yes                 105.             119.  1.13
##  5          5 Yes         No                  103.             119.  1.16
##  6          6 Yes         Yes                  95.7            119.  1.24
##  7          7 Yes         No                   99.3            120.  1.21
##  8          8 Yes         Yes                  98.1            118.  1.20
##  9          9 No          Yes                  97.9            131.  1.34
## 10         10 No          No                  105.             129.  1.23
## 11         11 Yes         Yes                 105.             118.  1.13
## 12         12 Yes         Yes                  89.2            120.  1.34
```

Audio guide messages: data

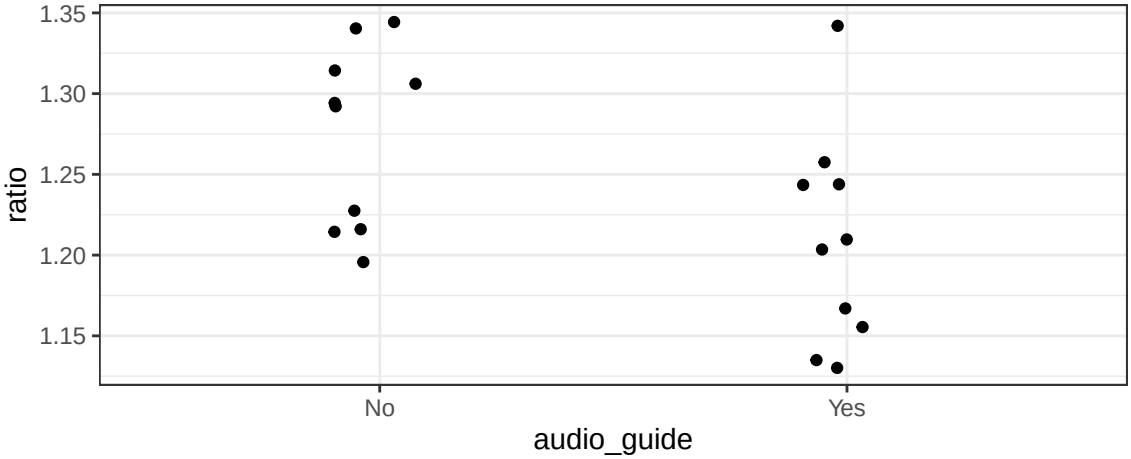
```
summary(emergency)
```

```
##    individual    audio_guide          success          cortisol_baseline cortisol_stress     ratio
##  Min.   : 1.00   Length:20          Length:20          Min.   : 89.21    Min.   :118.1   Min.   :1.130
##  1st Qu.: 5.75   Class :character   Class :character   1st Qu.: 97.85    1st Qu.:119.7   1st Qu.:1.202
##  Median :10.50   Mode  :character   Mode  :character   Median :100.19    Median :124.4   Median :1.235
##  Mean   :10.50                                         Mean   :100.73    Mean   :124.9   Mean   :1.242
##  3rd Qu.:15.25                                         3rd Qu.:104.83    3rd Qu.:130.7   3rd Qu.:1.297
##  Max.   :20.00                                         Max.   :107.94    Max.   :131.5   Max.   :1.344
```

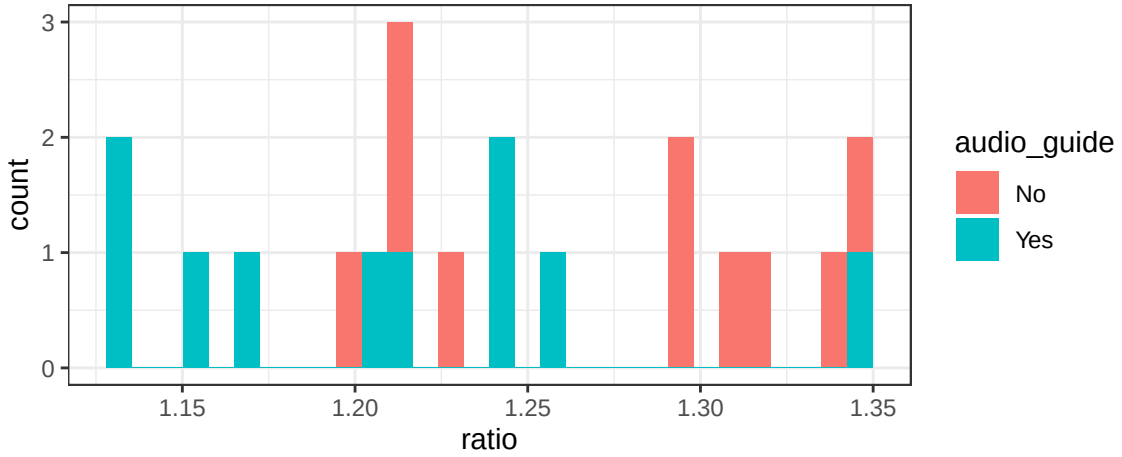
```
ggplot(emergency, aes(x = individual, y = ratio, color = audio_guide)) +
  geom_point()
```



```
ggplot(emergency, aes(x = audio_guide, y = ratio)) +
  geom_jitter(width=0.1)
```



```
ggplot(emergency, aes(x = ratio, fill = audio_guide)) +
  geom_histogram()
```



Summary statistics

```
s_emergency <- emergency %>%
  group_by(audio_guide) %>%
  summarize(n = n(),
            mean = mean(ratio),
            sd = sd(ratio)) %>%
  mutate(se = sd/sqrt(n))

s_emergency
```

```
## # A tibble: 2 x 5
##   audio_guide     n  mean     sd     se
##   <chr>       <int> <dbl>  <dbl>  <dbl>
## 1 No             10  1.27 0.0558 0.0177
## 2 Yes            10  1.21 0.0658 0.0208
```

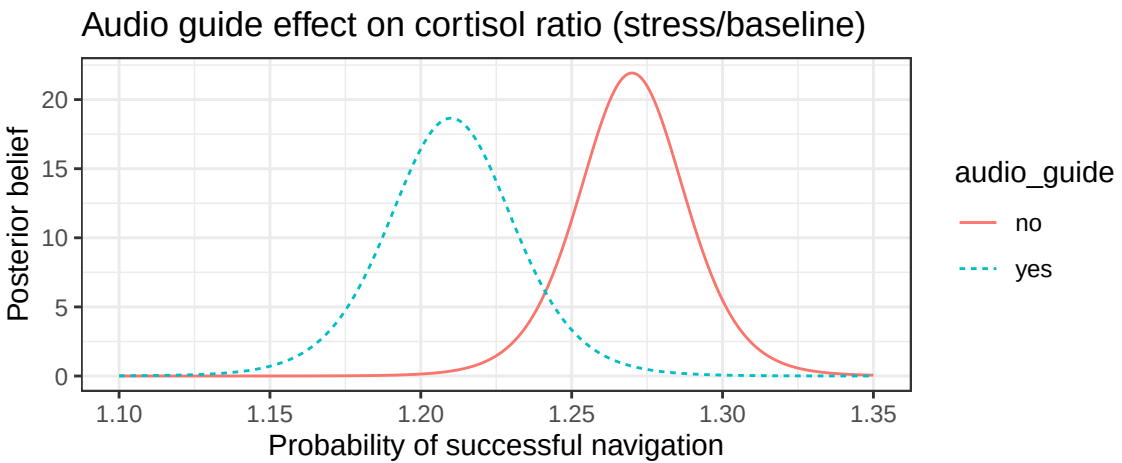
Posterior belief about means

```
dlst <- function(x, df, location, scale) {
  dt((x-location)/scale, df = df)/scale
}

d <- data.frame(mu = seq(from=1.1, to=1.35, length=1001)) %>%
  mutate(yes = dlst(mu, df = 10-1, location = 1.21, scale = 0.0208),
         no  = dlst(mu, df = 10-1, location = 1.27, scale = 0.0177)) %>%
  pivot_longer(cols = -mu, names_to = "audio_guide", values_to = "density")

ggplot(d, aes(x = mu, y = density, color = audio_guide, linetype = audio_guide)) +
  geom_line() +
  labs(x = "Probability of successful navigation",
       y = "Posterior belief",
       title = "Audio guide effect on cortisol ratio (stress/baseline)")
```

Posterior belief about mean



Cortisol ratio difference

```
n_reps <- 100000
mean_yes <- rt(n_reps, df = 10-1)*0.0208 + 1.21
mean_no  <- rt(n_reps, df = 10-1)*0.0177 + 1.27
mean(mean_no > mean_yes)

## [1] 0.97274

# Credible interval for the difference
a <- 1-0.95
quantile(mean_no - mean_yes, probs = c(a/2, 1-a/2))

##         2.5%        97.5%
## -0.001394185  0.121977226
```

Working from home

To try and understand the *working from home* trend, Nielsen conducts a nationwide survey of working adults to understand their satisfaction. Nielsen uses its database of all working adults to select a random sample of adults to survey. Of the subset of those respondents who indicated they are working from home, Nielsen records their "job satisfaction" on a scale from 0-10 (with 10 being the highest satisfaction).

- Scientific question
- Response variable
- Explanatory variable (or grouping)
- Random sample? (If yes, inference to the population.)
- Randomized treatment? (If yes, causal inference.)

Working from home: inference

- Scientific question: How satisfied are those who are working from home?
- Response variable: Likert (0-10) scale satisfaction response.
- Explanatory variable (or grouping): None
- Random sample? (If yes, inference to the population.): Apparently those sent a survey were randomly sampled, but unclear what percentage returned the survey.
- Randomized treatment? (If yes, causal inference.): Not applicable.

Nielsen satisfaction: data

```
nielsen <- read_csv("nielsen.csv")

nielsen
```

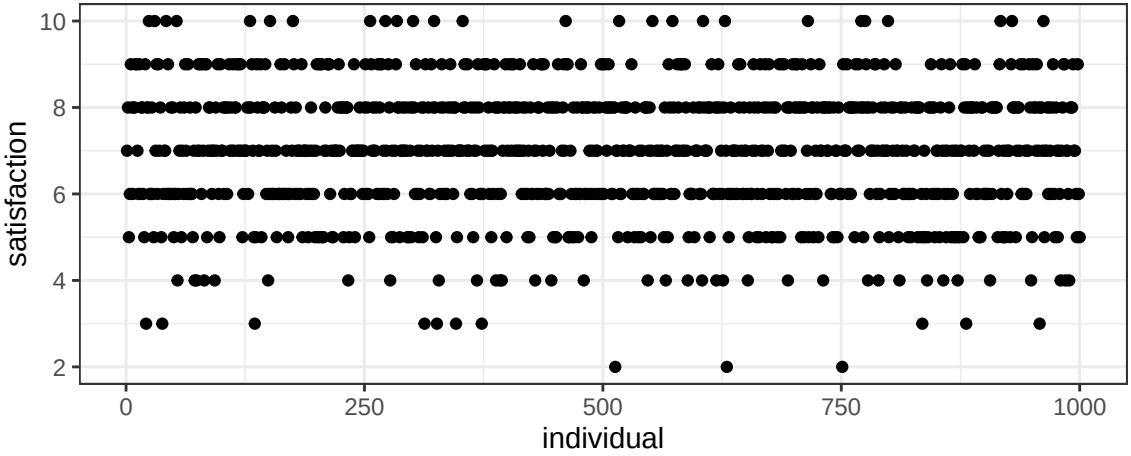
```
## # A tibble: 1,000 x 2
##    individual satisfaction
##         <dbl>        <dbl>
##  1          1            7
##  2          2            8
##  3          3            5
##  4          4            6
##  5          5            9
##  6          6            8
##  7          7            6
##  8          8            8
##  9          9            8
## 10         10            9
## # ... with 990 more rows
```

Nielsen satisfaction: data

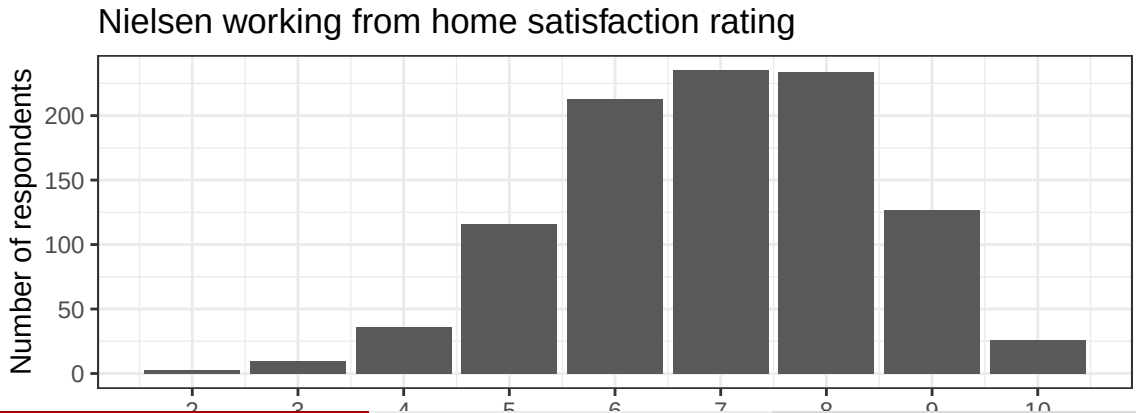
```
summary(nielsen)

##    individual      satisfaction
##  Min.   :   1.0   Min.   : 2.000
##  1st Qu.: 250.8   1st Qu.: 6.000
##  Median : 500.5   Median : 7.000
##  Mean   : 500.5   Mean   : 6.958
##  3rd Qu.: 750.2   3rd Qu.: 8.000
##  Max.   :1000.0   Max.   :10.000
```

```
ggplot(nielsen, aes(x = individual, y = satisfaction)) +
  geom_point()
```



```
ggplot(nielsen, aes(x = satisfaction)) +
  geom_bar() +
  scale_x_continuous(breaks = 0:10) +
  labs(x = "Satisfaction rating",
       y = "Number of respondents",
       title = "Nielsen working from home satisfaction rating")
```



Summary statistics

```
nielsen %>%
  summarize(n = n(),
            mean = mean(satisfaction),
            sd = sd(satisfaction)) %>%
  mutate(se = sd/sqrt(n))
```

```
## # A tibble: 1 x 4
##       n  mean    sd     se
##   <int> <dbl> <dbl>  <dbl>
## 1  1000  6.96  1.49 0.0470
```

Posterior belief about mean

```
d <- data.frame(mu = seq(from=6.75, to=7.25, length=1001)) %>%
  mutate(satisfaction = dlst(mu, df = 1000-1, location = 6.95, scale = 0.0468))

ggplot(d, aes(x = mu, y = satisfaction)) +
  geom_line() +
  labs(x = "Mean satisfaction",
       y = "Posterior belief",
       title = "Nielsen working from home mean satisfaction")
```

Posterior belief about mean

Mean satisfaction

```
# Credible interval for the difference
a <- 1-0.95
qt(c(a/2, 1-a/2), df = 1000-1)*0.0468 + 6.95

## [1] 6.858162 7.041838

# Probability less than 7.0
pt( (7-6.95)/0.0468, df = 1000-1 )

## [1] 0.8571955
```

Working from home

To try and understand the *working from home* trend, Nielsen conducts a nationwide survey of working adults to understand their satisfaction. Nielsen uses its database of all working adults to select a random sample of adults to survey. Of the subset of those respondents who indicated they are working from home, Nielsen records the number whose job satisfaction score is 7 or more (indicating satisfied and above).

- Scientific question
- Response variable
- Explanatory variable (or grouping)
- Random sample? (If yes, inference to the population.)
- Randomized treatment? (If yes, causal inference.)

Working from home: inference

- Scientific question: How satisfied are those who are working from home?
- Response variable: Count of those greater than 7.
- Explanatory variable (or grouping): None
- Random sample? (If yes, inference to the population.): Apparently those sent a survey were randomly sampled, but unclear what percentage returned the survey.
- Randomized treatment? (If yes, causal inference.): Not applicable.

Summary statistics

```
nielsen %>%
  summarize(n = n(),
            y = sum(satisfaction >= 7),
            p = y/n)

## # A tibble: 1 x 3
##       n     y     p
##   <int> <int> <dbl>
## 1  1000   622 0.622
```

Posterior belief about probability

```
d <- data.frame(theta = seq(from=0.55, to=.7, length=1001)) %>%
  mutate(satisfaction = dbeta(theta, shape1 = 1+621, shape2 = 1+1000-621))

ggplot(d, aes(x = theta, y = satisfaction)) +
  geom_line() +
  labs(x = "Probability 'satisfied or higher'",
       y = "Posterior belief",
       title = "Nielsen working from home satisfaction")
```

Posterior belief about probability

Mean satisfaction

```
# Credible interval for the difference
a <- 1-0.95
qt(c(a/2, 1-a/2), df = 1000-1)*0.0468 + 6.95

## [1] 6.858162 7.041838

# Probability less than 7.0
pt( (7-6.95)/0.0468, df = 1000-1 )

## [1] 0.8571955
```

Satisfaction probability

```
# Credible interval for the difference
a <- 1-0.95
qbeta(c(a/2, 1-a/2), shape1 = 1+621, shape2 = 1+1000-621)

## [1] 0.5905098 0.6505506

# Probability greater than 0.6
1-pbeta(0.6, shape1 = 1+621, shape2 = 1+1000-621)

## [1] 0.9115386
```

Summary

- Statistical inference
  - Scientific question
  - Response variable
  - Explanatory variable (or grouping)
  - Random sample? (If yes, inference to the population.)
  - Randomized treatment? (If yes, causal inference.)
- Statistical analysis
  - Response variable
    - Count data with known maximum $\rightarrow$ binomial
    - Continuous data $\rightarrow$ normal
  - Explanatory variable
    - None $\rightarrow$ one group models
    - Groups $\rightarrow$ multiple group models
    - Continuous $\rightarrow$ regression