

Stats 101B Final project

2025-09-18

```
coffee <- read.csv("~/Downloads/Stats 101b data collection - Sheet1.csv")
coffee
```

##	Gender	Substance	STB	STA	Age	Name
## 1	Male	Coffee	713	699	25	Tatsuya Sato
## 2	Male	Coffee	771	764	28	Jorn Solberg
## 3	Male	Coffee	829	836	52	Mohal Achari
## 4	Male	Coffee	829	852	59	Masaru Endo
## 5	Male	Coffee	787	781	39	Matthias Lund
## 6	Male	Coffee	768	767	30	Raine Morris
## 7	Male	Coffee	825	822	49	Massimo White
## 8	Male	Coffee	847	824	53	Barnard Wilson
## 9	Male	Coffee	731	740	29	Nathan Rao
## 10	Male	Coffee	710	714	23	Theodore Sato
## 11	Male	Coffee	900	878	63	Marshall Lund
## 12	Male	Coffee	720	724	29	Soren Solberg
## 13	Male	Coffee	750	756	30	Antoine Devar
## 14	Male	Coffee	779	774	37	Jack Suzuki
## 15	Male	Coffee	696	707	21	Helge Marx
## 16	Male	Coffee	795	805	37	Seymour Bertrand
## 17	Male	Coffee	749	745	31	Raphael Bager
## 18	Male	Coffee	819	813	49	Mathis Collins
## 19	Male	Coffee	718	738	25	Samuel Carlsen
## 20	Male	Coffee	776	790	37	Aadiv Ganaka
## 21	Male	Coffee	759	770	35	Taylor Collins
## 22	Male	Coffee	869	860	58	Gyan Shah
## 23	Male	Coffee	745	752	37	Pierrick Jensen
## 24	Male	Coffee	758	759	30	Blaise Krishna
## 25	Male	Coffee	732	715	23	Gunnar Blomgren
## 26	Male	Coffee	723	761	31	Jules Puri
## 27	Male	Coffee	800	807	40	Marshall Gauthier
## 28	Male	Coffee	808	793	49	Felix Kumar
## 29	Male	Coffee	927	939	70	Halden Eklund
## 30	Male	Coffee	792	780	38	Noel Larsen
## 31	Male	Coffee	840	812	52	Anand Laha
## 32	Male	Coffee	850	821	55	Ketan Bhatt
## 33	Female	Coffee	712	730	24	Kate Connolly
## 34	Female	Coffee	809	816	40	Rosalind Solberg
## 35	Female	Coffee	748	748	31	Sarah Solberg
## 36	Female	Coffee	708	703	19	Laura Jensen
## 37	Female	Coffee	753	759	32	Helga Jensen
## 38	Female	Coffee	768	779	36	Justine Kimura
## 39	Female	Coffee	909	921	101	Mirai Sharma
## 40	Female	Coffee	816	812	44	Karina Sorensen

## 41	Female	Coffee	743	746	27	Dionne Shah
## 42	Female	Coffee	709	695	24	Karena Jensen
## 43	Female	Coffee	741	727	30	Reina Kimura
## 44	Female	Coffee	821	809	55	Dionne Basu
## 45	Female	Coffee	730	733	22	Eva Kimura
## 46	Female	Coffee	690	689	19	Abbey Faure
## 47	Female	Coffee	790	806	46	Rina Babu
## 48	Female	Coffee	804	791	47	Viktoria Carlsen
## 49	Female	Coffee	740	745	28	Anna Larsen
## 50	Female	Coffee	896	884	69	Sophie Kimura
## 51	Female	Coffee	806	813	45	Francine Ruiz
## 52	Female	Coffee	783	793	39	Leira Solberg
## 53	Female	Coffee	838	856	57	Naina Chandra
## 54	Female	Coffee	729	704	18	Mallory Carlsen
## 55	Female	Coffee	820	823	51	Phoebe Collins
## 56	Female	Coffee	810	821	46	Melissa Ferguson
## 57	Female	Coffee	722	725	26	Johanna Solberg
## 58	Female	Coffee	716	747	21	Katie Solberg
## 59	Female	Coffee	746	754	21	Molly Yamada
## 60	Female	Coffee	761	811	38	Freya Solberg
## 61	Female	Coffee	710	710	21	Delaney Hall
## 62	Female	Coffee	836	805	50	Beata Bergmann
## 63	Female	Coffee	857	872	66	Kanoko Matsumoto
## 64	Male	Decaf	878	853	55	Remy Tiwari
## 65	Male	Decaf	735	742	33	Ole Sorensen
## 66	Male	Decaf	778	759	38	Hallmar Sorensen
## 67	Male	Decaf	865	879	69	Ragnar Carlsen
## 68	Male	Decaf	743	751	32	Anton Connolly
## 69	Male	Decaf	903	908	82	Takuya Suzuki
## 70	Male	Decaf	928	934	75	Jackson Morris
## 71	Male	Decaf	822	831	51	Lukas Sorensen
## 72	Male	Decaf	726	723	26	Pavak Banerjee
## 73	Male	Decaf	852	877	65	Yuta Kimura
## 74	Male	Decaf	838	847	47	Sven Ibsen
## 75	Male	Decaf	890	922	69	Gunnar Erickson
## 76	Male	Decaf	907	905	98	Dylan Jackson
## 77	Male	Decaf	760	792	38	Marcel Ibsen
## 78	Male	Decaf	924	918	70	Ansel Page
## 79	Male	Decaf	734	732	24	Scott Moore
## 80	Male	Decaf	876	869	65	Reinhardt Koch
## 81	Male	Decaf	853	863	66	Halden Eklund
## 82	Male	Decaf	908	911	104	Nayan Patel
## 83	Male	Decaf	731	745	28	Alex Brown
## 84	Male	Decaf	748	739	27	Axel Jones
## 85	Male	Decaf	730	753	27	Fabrice Dupont
## 86	Male	Decaf	774	814	40	Pierrick Blomgren
## 87	Male	Decaf	727	739	27	Jules Sorensen
## 88	Male	Decaf	927	923	74	Kyle Sato
## 89	Male	Decaf	728	724	25	Mohal Karmarkar
## 90	Male	Decaf	891	887	73	Samuel Clausen
## 91	Male	Decaf	758	757	34	Henrik Sorensen
## 92	Male	Decaf	851	855	61	Lomash Gupta
## 93	Male	Decaf	767	764	33	Tristan Connolly
## 94	Male	Decaf	836	839	51	Leon Thorn

```
## 95 Male Decaf 728 706 22 Tomas Jensen
## 96 Female Decaf 783 803 42 Franziska Bergmann
## 97 Female Decaf 755 752 31 Lena Ibsen
## 98 Female Decaf 745 746 32 Malena Erickson
## 99 Female Decaf 800 823 45 Svetlana Bergmann
## 100 Female Decaf 829 790 48 Rosalind Solberg
## 101 Female Decaf 726 710 21 Erika Carlsen
## 102 Female Decaf 744 763 32 Sonja Blomgren
## 103 Female Decaf 856 841 59 Rida Page
## 104 Female Decaf 734 717 24 Kate Connolly
## 105 Female Decaf 702 709 22 Julia Solberg
## 106 Female Decaf 758 739 29 Olina Ibsen
## 107 Female Decaf 737 735 30 Dionne Shah
## 108 Female Decaf 792 800 45 Ava Wilson
## 109 Female Decaf 691 697 23 Katie Brown
## 110 Female Decaf 886 911 75 Esme Mangal
## 111 Female Decaf 870 890 68 Florence McCarthy
## 112 Female Decaf 743 718 29 Ava McCarthy
## 113 Female Decaf 811 815 49 Suhanisa Mishra
## 114 Female Decaf 713 738 23 Coralie Burke
## 115 Female Decaf 748 743 25 Halle Carlsen
## 116 Female Decaf 781 787 41 Emma Lund
## 117 Female Decaf 723 722 25 Sophie Sorensen
## 118 Female Decaf 712 707 24 Hailey Hall
## 119 Female Decaf 206 692 24 Sonja Sorensen
## 120 Female Decaf 744 758 27 Megane Eklund
## 121 Female Decaf 697 716 21 Sandrine Picard
## 122 Female Decaf 782 784 44 Mimori Miyasaki
## 123 Female Decaf 913 890 68 Rachelle Mori
## 124 Female Decaf 795 786 43 Karishma Achari
## 125 Female Decaf 879 875 69 Ami Sato
## 126 Female Decaf 754 738 27 Jade Kimura
## 127 Female Decaf 782 808 38 Chantel Kimura
```

```
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ----- tidyverse 2.0.0 --
## v dplyr      1.1.4      v readr      2.1.5
## v forcats    1.0.0      v stringr    1.5.1
## v ggplot2    3.5.2      v tibble     3.2.1
## v lubridate  1.9.4      v tidyr      1.3.1
## v purrr      1.1.0
## -- Conflicts ----- tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()     masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```
library(afex)
```

```
## Loading required package: lme4
## Loading required package: Matrix
##
## Attaching package: 'Matrix'
```

```
##
## The following objects are masked from 'package:tidyr':
##
##     expand, pack, unpack
##
## *****
## Welcome to afex. For support visit: http://afex.singmann.science/
## - Functions for ANOVAs: aov_car(), aov_ez(), and aov_4()
## - Methods for calculating p-values with mixed(): 'S', 'KR', 'LRT', and 'PB'
## - 'afex_aov' and 'mixed' objects can be passed to emmeans() for follow-up tests
## - Get and set global package options with: afex_options()
## - Set sum-to-zero contrasts globally: set_sum_contrasts()
## - For example analyses see: browseVignettes("afex")
## *****
##
## Attaching package: 'afex'
##
## The following object is masked from 'package:lme4':
##
##     lmer
```

```
library(emmeans)
```

```
## Welcome to emmeans.
## Caution: You lose important information if you filter this package's results.
## See '? untidy'
```

```
coffee_analysis <- coffee %>% mutate(id = row_number(),
  Substance = factor(Substance, levels = c("Decaf", "Coffee"))) %>%
  pivot_longer(c(STB, STA), names_to = "Time", values_to = "RT") %>%
  mutate(Time = factor(Time, levels = c("STB", "STA"),
    labels = c("Before", "After")))
fit_aov <- aov_car(RT ~ Substance*Time + Error(id/Time), data = coffee_analysis, factorize = FALSE)
```

```
## Contrasts set to contr.sum for the following variables: Substance
```

```
summary(fit_aov)
```

```
##
## Univariate Type III Repeated-Measures ANOVA Assuming Sphericity
##
##               Sum Sq num Df Error SS den Df    F value Pr(>F)
## (Intercept)  156875031     1  1228609    125 15960.6369 <2e-16 ***
## Substance       7050     1  1228609    125   0.7172 0.3987
## Time            2165     1   130178    125   2.0788 0.1519
## Substance:Time   1244     1   130178    125   1.1946 0.2765
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
emmeans(fit_aov, ~ Substance*Time) %>% pairs(by = "Time")
```

```
## Time = Before:
## contrast      estimate    SE  df t.ratio p.value
## Decaf - Coffee      6.11 14.6 125   0.419  0.6758
##
## Time = After:
## contrast      estimate    SE  df t.ratio p.value
## Decaf - Coffee     14.96 11.4 125   1.313  0.1916
```

```
emmeans(fit_aov, ~ Time | Substance) %>% pairs()
```

```
## Substance = Decaf:
## contrast      estimate    SE  df t.ratio p.value
## Before - After  -10.27  5.70 125  -1.799  0.0744
##
## Substance = Coffee:
## contrast      estimate    SE  df t.ratio p.value
## Before - After   -1.41  5.75 125  -0.246  0.8063
```

```
library(ggplot2)
library(ggdist)
library(patchwork)
```

```
afex_options(type = 3)
fit_aov <- aov_car(RT ~ Substance*Time + Error(id/Time), data = coffee_analysis, factorize = FALSE)
```

```
## Contrasts set to contr.sum for the following variables: Substance
```

```
emm <- emmeans(fit_aov, ~ Substance * Time)
```

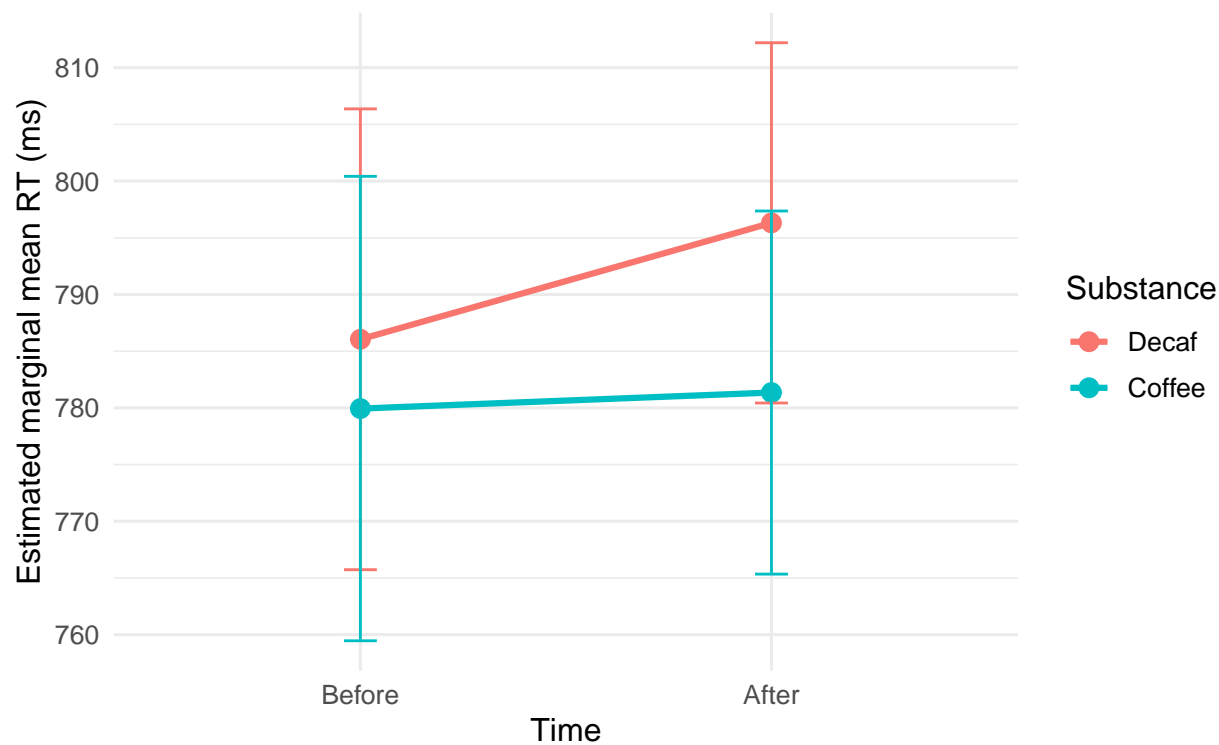
```
library(emmeans)
emm <- emmeans(fit_aov, ~ Substance * Time)
emm_df <- as.data.frame(emm)

p_emm <- ggplot(emm_df,
               aes(x = Time, y = emmean,
                   color = Substance, group = Substance)) +
  geom_line(linewidth = 1.1) +
  geom_point(size = 3) +
  geom_errorbar(aes(ymin = lower.CL, ymax = upper.CL), width = 0.08) +
  labs(y = "Estimated marginal mean RT (ms)",
       title = "Interaction plot from mixed ANOVA",
       subtitle = "95% CIs from emmeans") +
  theme_minimal(base_size = 12)

print(p_emm)
```

Interaction plot from mixed ANOVA

95% CIs from emmeans



coffee_analysis

```
## # A tibble: 254 x 7
##   Gender Substance   Age Name      id Time      RT
##   <chr>   <fct>     <int> <chr>    <int> <fct> <int>
## 1 Male   Coffee       25 Tatsuya Sato    1 Before   713
## 2 Male   Coffee       25 Tatsuya Sato    1 After    699
## 3 Male   Coffee       28 Jorn Solberg    2 Before   771
## 4 Male   Coffee       28 Jorn Solberg    2 After    764
## 5 Male   Coffee       52 Mohal Achari    3 Before   829
## 6 Male   Coffee       52 Mohal Achari    3 After    836
## 7 Male   Coffee       59 Masaru Endo     4 Before   829
## 8 Male   Coffee       59 Masaru Endo     4 After    852
## 9 Male   Coffee       39 Matthias Lund   5 Before   787
## 10 Male  Coffee       39 Matthias Lund   5 After    781
## # i 244 more rows
```

```
library(tidyverse)
library(afex)

coffee_long <- coffee %>%
  mutate(
    id = row_number(),
    Substance = factor(Substance, levels = c("Decaf", "Coffee"))
  ) %>%
```

```

pivot_longer(c(STB, STA), names_to = "Time", values_to = "RT") %>%
mutate(Time = factor(Time, levels = c("STB", "STA"),
      labels = c("Before", "After")))

stopifnot(all(c("id", "RT", "Time", "Substance") %in% names(coffee_long)))

afex_options(type = 3)
fit_ez <- aov_ez(
  id      = "id",
  dv      = "RT",
  data    = coffee_long,
  between = "Substance",
  within  = "Time"
)

```

Contrasts set to contr.sum for the following variables: Substance

```

p_interact <- afex::afex_plot(
  object = fit_ez,
  x      = "Time",
  trace  = "Substance",
  error  = "within"
) +
  labs(y = "Reaction time (ms)",
       title = "Stroop RT: Before vs After by Beverage",
       subtitle = "Within-subject 95% CIs")

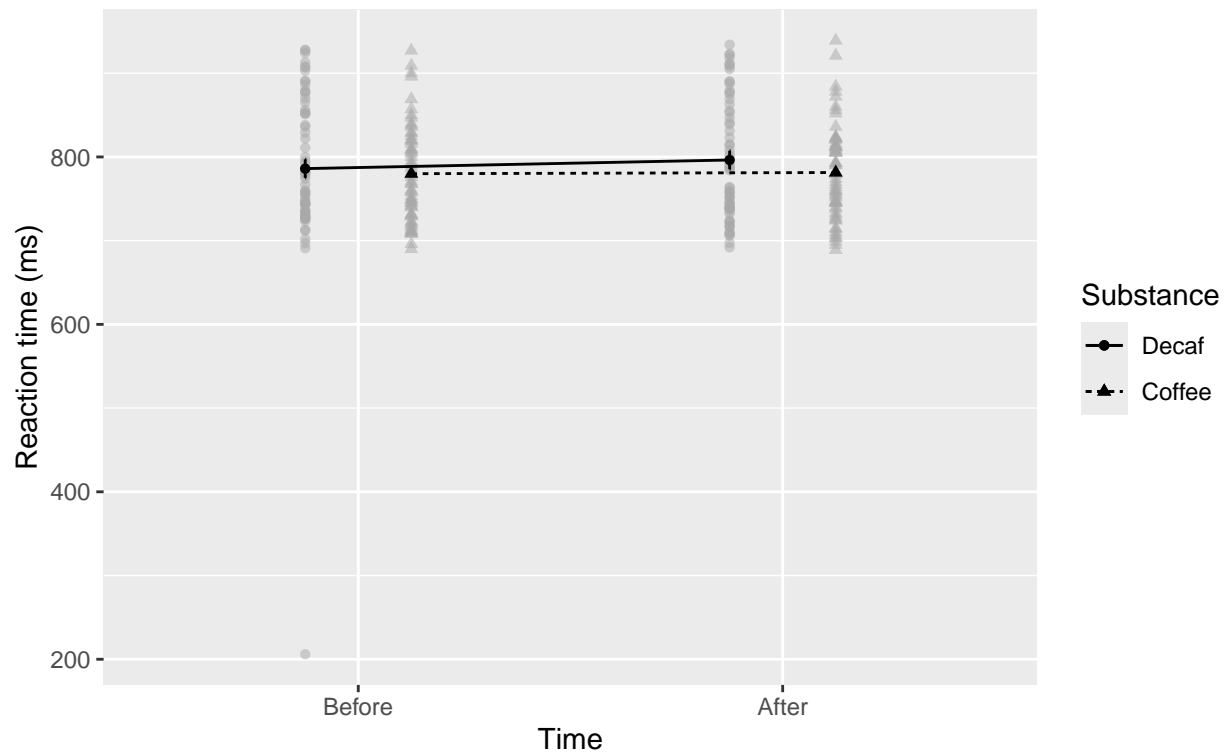
```

Warning: Panel(s) show a mixed within-between-design.
 ## Error bars do not allow comparisons across all means.
 ## Suppress error bars with: error = "none"

```
print(p_interact)
```

Stroop RT: Before vs After by Beverage

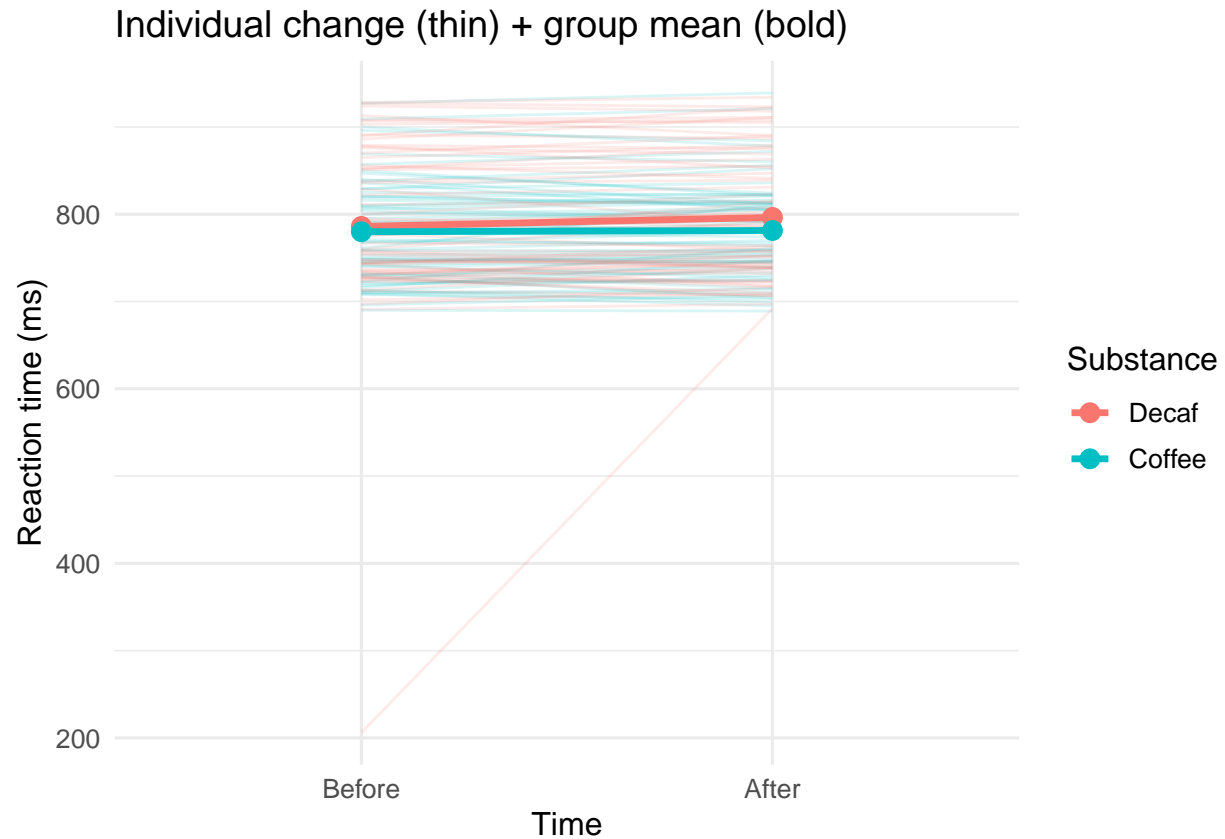
Within-subject 95% CIs



```
sumdat <- coffee_analysis %>%
  group_by(Substance, Time) %>%
  summarise(mean = mean(RT), se = sd(RT)/sqrt(n()), .groups = "drop")

p_spaghetti <- ggplot(coffee_analysis, aes(Time, RT, group = id)) +
  geom_line(aes(color = Substance), alpha = 0.15) +
  stat_summary(aes(color = Substance, group = Substance),
    fun = mean, geom = "line", linewidth = 1.2) +
  stat_summary(aes(color = Substance, group = Substance),
    fun = mean, geom = "point", size = 3) +
  labs(y = "Reaction time (ms)",
    title = "Individual change (thin) + group mean (bold)") +
  theme_minimal(base_size = 12)

ggsave("fig3_spaghetti.png", p_spaghetti, width = 7, height = 5, dpi = 300)
p_spaghetti
```

```
dat_delta <- coffee %>%
  mutate(
    id = row_number(),
    Substance = factor(Substance, levels = c("Decaf", "Coffee")),
    Delta = STA - STB
  )

p_delta <- ggplot(dat_delta, aes(Substance, Delta, fill = Substance)) +
  ggdist::stat_slab(alpha = .25) +
  geom_boxplot(width = .25, outlier.shape = NA, alpha = .4) +
  geom_jitter(width = .08, alpha = .4, size = 1) +
  geom_hline(yintercept = 0, linetype = "dashed") +
  labs(y = expression(Delta ~ "(ms) = After - Before"),
       title = "Change scores by Beverage (negative = improved)") +
  theme_minimal(base_size = 12) +
  theme(legend.position = "none")

ggsave("fig5_delta.png", p_delta, width = 6, height = 5, dpi = 300)
p_delta
```

