Legal Drafting Experiment Analysis

The socio-pragmatic function of linguistic complexity in the domain of law

Setup

Load packages

```
library(tidyverse)
library(jsonlite)
library(lme4)
library(lmerTest)
library(emmeans)
library(ggthemes)
```

Load and preprocess data

```
# Load all participant CSVs
data_dir <- "../data/full_sample/full_sample"
files <- list.files(data_dir, pattern = "\\.csv$", full.names = TRUE)

df_raw <- purrr::map_dfr(files, ~ readr::read_csv(.x, show_col_types = FALSE) %>%
                           mutate(source_file = basename(.x)))

# Create participant IDs
file_map <- tibble(source_file = sort(unique(df_raw$source_file))) %>%
  mutate(participant_file = sprintf("no.%03d", row_number()))

df <- df_raw %>%
  left_join(file_map, by = "source_file")
```

```r
# Fill condition info across trial phases
df <- df %>%
  arrange(participant_file, trial_index, time_elapsed) %>%
  group_by(participant_file, sent_id) %>%
  fill(condition, syn_level, sem_level, modal_pres, .direction = "downup") %>%
  ungroup()

cat("Participants:", n_distinct(df$participant_file), "\n")
```

```
Participants: 203
```

```r
cat("Total rows:", nrow(df), "\n")
```

```
Total rows: 13398
```

Extract response variables

Comprehension accuracy

```r
# Parse comprehension response from JSON
parse_comp_response <- function(x) {
  if (is.na(x)) return(NA_character_)
  tryCatch({
    parsed <- jsonlite::fromJSON(x)
    if (!is.null(parsed$comp)) return(parsed$comp)
    return(NA_character_)
  }, error = function(e) NA_character_)
}

# Compute accuracy (comp_correct has extra quotes that need stripping)
df <- df %>%
  mutate(
    comp_response_parsed = purrr::map_chr(response, parse_comp_response),
    comp_correct_clean = gsub('^"|"$', '', comp_correct),
    is_correct = ifelse(
      phase == "comprehension",
      trimws(comp_response_parsed) == trimws(comp_correct_clean),
      NA
    )
  )
```

Authority ratings

```r
# Parse Likert rating from JSON
extract_likert_q0 <- function(x) {
  if (is.null(x) || length(x) == 0 || is.na(x)) return(NA_real_)
  if (!is.character(x)) return(suppressWarnings(as.numeric(x)))
  out <- tryCatch(jsonlite::fromJSON(x), error = function(e) NULL)
  if (is.null(out)) return(suppressWarnings(as.numeric(x)))
  if (is.atomic(out)) return(suppressWarnings(as.numeric(out)))
  if (is.list(out) && !is.null(out[["Q0"]])) return(suppressWarnings(as.numeric(out[["Q0"]]))
  NA_real_
}

# Extract and convert to 1-5 scale
df <- df %>%
  mutate(
    authority_rating = ifelse(
      phase == "authority_rating",
      purrr::map_dbl(response, extract_likert_q0) + 1,
      NA_real_
    )
  )
```

Create analysis dataframes

```r
# Authority ratings dataframe
authority_df <- df %>%
  filter(phase == "authority_rating") %>%
  select(participant_file, sent_id, authority_rating, syn_level, sem_level, modal_pres)

# Comprehension dataframe
comp_df <- df %>%
  filter(phase == "comprehension") %>%
  select(participant_file, sent_id, is_correct, syn_level, sem_level, modal_pres)

# Combined dataframe (for comprehension-authority analysis)
combined_df <- authority_df %>%
  inner_join(
    comp_df %>% select(participant_file, sent_id, is_correct),
    by = c("participant_file", "sent_id")
  )

cat("Authority observations:", nrow(authority_df), "\n")
```

```
Authority observations: 3248
```

```r
cat("Comprehension observations:", nrow(comp_df), "\n")
```

```
Comprehension observations: 3248
```

Descriptive Statistics

Authority ratings

```r
authority_df %>%
  summarise(
    Mean = mean(authority_rating, na.rm = TRUE),
    SD = sd(authority_rating, na.rm = TRUE),
    Median = median(authority_rating, na.rm = TRUE),
    Min = min(authority_rating, na.rm = TRUE),
    Max = max(authority_rating, na.rm = TRUE),
    N = n()
  ) %>%
  knitr::kable(digits = 2, caption = "Authority rating summary")
```

Table 1: Authority rating summary

Mean	SD	Median	Min	Max	N
3.98	1.09	4	1	5	3248

```r
authority_df %>%
  count(authority_rating) %>%
  mutate(Percent = sprintf("%.1f%%", n / sum(n) * 100)) %>%
  knitr::kable(caption = "Distribution of authority ratings")
```

Table 2: Distribution of authority ratings

authority_rating	n	Percent
1	117	3.6%
2	236	7.3%
3	544	16.7%
4	1037	31.9%
5	1314	40.5%

Comprehension accuracy

```r
comp_df %>%
  summarise(
    Accuracy = mean(is_correct, na.rm = TRUE),
    N_correct = sum(is_correct, na.rm = TRUE),
    N_total = n()
  ) %>%
  mutate(Accuracy = sprintf("%.1f%%", Accuracy * 100)) %>%
  knitr::kable(caption = "Overall comprehension accuracy")
```

Table 3: Overall comprehension accuracy

Accuracy	N_correct	N_total
89.6%	2911	3248

By condition

```r
authority_df %>%
  group_by(syn_level, sem_level, modal_pres) %>%
  summarise(
    Mean = mean(authority_rating, na.rm = TRUE),
    SD = sd(authority_rating, na.rm = TRUE),
    N = n(),
    .groups = "drop"
  ) %>%
  arrange(syn_level, sem_level, modal_pres) %>%
  knitr::kable(digits = 2, caption = "Authority ratings by condition")
```

Table 4: Authority ratings by condition

syn_level	sem_level	modal_pres	Mean	SD	N
high	high	S	4.10	1.04	406
high	high	partial_may	3.93	1.06	406
high	low	S	3.89	1.19	406
high	low	partial_may	4.03	1.07	406
low	high	S	4.05	1.05	406
low	high	partial_may	4.19	1.04	406
low	low	S	3.93	1.10	406
low	low	partial_may	3.74	1.10	406

Main Analysis: Three-Way Interaction Model

Model specification

We fit a linear mixed-effects model with:

- **Fixed effects**: Syntactic complexity × Jargon density × Modal presence (all interactions)
- **Random effects**: Random intercepts for participant and item

Random slopes were not included due to sparse within-cell observations (2 items per condition per participant), which caused singular fit.

```r
model_3way <- lmer(
  authority_rating ~ syn_level * sem_level * modal_pres +
    (1 | participant_file) + (1 | sent_id),
  data = authority_df
)

summary(model_3way)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: authority_rating ~ syn_level * sem_level * modal_pres + (1 |
    participant_file) + (1 | sent_id)
   Data: authority_df

REML criterion at convergence: 8863.1
```

```
Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.9805 -0.5116  0.1233  0.6220  2.9512

Random effects:
 Groups           Name        Variance Std.Dev.
 participant_file (Intercept) 0.39506  0.6285
 sent_id          (Intercept) 0.01352  0.1163
 Residual                     0.77165  0.8784
Number of obs: 3248, groups:  participant_file, 203; sent_id, 16

Fixed effects:
                                     Estimate Std. Error       df t value
(Intercept)                           3.93350    0.10298 11.96954  38.196
syn_levellow                          0.26108    0.13160  7.99991   1.984
sem_levellow                          0.09606    0.13160  7.99991   0.730
modal_presS                           0.16256    0.13160  7.99991   1.235
syn_levellow:sem_levellow            -0.54680    0.18611  7.99991  -2.938
syn_levellow:modal_presS             -0.30296    0.18611  7.99991  -1.628
sem_levellow:modal_presS             -0.30049    0.18611  7.99991  -1.615
syn_levellow:sem_levellow:modal_presS  0.62315    0.26320  7.99991   2.368
                                     Pr(>|t|)
(Intercept)                          7.08e-14 ***
syn_levellow                           0.0825 .
sem_levellow                           0.4863
modal_presS                            0.2518
syn_levellow:sem_levellow              0.0188 *
syn_levellow:modal_presS               0.1422
sem_levellow:modal_presS               0.1451
syn_levellow:sem_levellow:modal_presS   0.0454 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) syn_lv sm_lvl mdl_pS syn_:_ sy_:_S sm_:_S
syn_levellw -0.639
sem_levellw -0.639  0.500
modal_presS -0.639  0.500  0.500
syn_lvllw:_  0.452 -0.707 -0.707 -0.354
syn_lvll:_S  0.452 -0.707 -0.354 -0.707  0.500
sm_lvllw:_S  0.452 -0.354 -0.707 -0.707  0.500  0.500
syn_lv:_:_S -0.319  0.500  0.500  0.500 -0.707 -0.707 -0.707
```

Three-way interaction

```
# Test the three-way interaction
anova(model_3way)
```

```
Type III Analysis of Variance Table with Satterthwaite's method
                              Sum Sq Mean Sq NumDF  DenDF F value  Pr(>F)
syn_level                     0.0114  0.0114     1 7.9999  0.0148 0.90617
sem_level                     5.2601  5.2601     1 7.9999  6.8167 0.03109 *
modal_pres                    0.0493  0.0493     1 7.9999  0.0638 0.80690
syn_level:sem_level           2.4652  2.4652     1 7.9999  3.1947 0.11169
syn_level:modal_pres          0.0033  0.0033     1 7.9999  0.0043 0.94938
sem_level:modal_pres          0.0055  0.0055     1 7.9999  0.0071 0.93495
syn_level:sem_level:modal_pres 4.3254  4.3254     1 7.9999  5.6054 0.04542 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The three-way interaction is significant (p = .045), indicating that the effect of jargon depends on both syntactic complexity and modal presence.

Simple effects analysis

To interpret the three-way interaction, we examine the effect of jargon at each combination of syntax and modal presence.

```
# Get estimated marginal means
emm_3way <- emmeans(model_3way, ~ syn_level * sem_level * modal_pres)

# Simple effects of jargon within each syntax × modal combination
jargon_contrasts <- contrast(emm_3way, method = "pairwise", by = c("syn_level", "modal_pres"
summary(jargon_contrasts)
```

```
syn_level = high, modal_pres = partial_may:
 contrast   estimate    SE  df z.ratio p.value
 high - low  -0.0961 0.132 Inf  -0.730  0.4654

syn_level = low, modal_pres = partial_may:
 contrast   estimate    SE  df z.ratio p.value
 high - low   0.4507 0.132 Inf   3.425  0.0006
```

```
syn_level = high, modal_pres = S:
 contrast   estimate    SE  df z.ratio p.value
 high - low   0.2044 0.132 Inf   1.553  0.1203

syn_level = low, modal_pres = S:
 contrast   estimate    SE  df z.ratio p.value
 high - low   0.1281 0.132 Inf   0.973  0.3304

Degrees-of-freedom method: asymptotic
```

```
# Create a cleaner summary table
simple_effects <- as.data.frame(summary(jargon_contrasts)) %>%
  filter(grepl("high - low", contrast)) %>%
  mutate(
    Syntax = ifelse(syn_level == "high", "High", "Low"),
    Modal = ifelse(modal_pres == "S", "With shall", "Without shall"),
    `Jargon effect (Δ)` = sprintf("%.2f", -estimate),  # flip sign for high-low
    `z` = sprintf("%.2f", -z.ratio),
    `p` = ifelse(p.value < .001, "< .001", sprintf("%.3f", p.value)),
    Sig = ifelse(p.value < .05, "*", "")
  ) %>%
  select(Syntax, Modal, `Jargon effect (Δ)`, z, p, Sig)

knitr::kable(simple_effects, caption = "Simple effects of jargon (high - low) at each syntax
```

Table 5: Simple effects of jargon (high - low) at each syntax × modal combination

Syntax	Modal	Jargon effect (Δ)	z	p	Sig
High	Without shall	0.10	0.73	0.465	
Low	Without shall	-0.45	-3.43	< .001	*
High	With shall	-0.20	-1.55	0.120	
Low	With shall	-0.13	-0.97	0.330	

Key finding: Jargon significantly increases authority ratings only when syntax is low AND shall is absent ($\Delta = 0.45$, $z = 3.43$, $p < .001$).

Comprehension Analysis

Effect of comprehension on authority ratings

```r
comp_authority_model <- lmer(
  authority_rating ~ is_correct + (1 | participant_file) + (1 | sent_id),
  data = combined_df
)

summary(comp_authority_model)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: authority_rating ~ is_correct + (1 | participant_file) + (1 |
    sent_id)
   Data: combined_df

REML criterion at convergence: 8858.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.9582 -0.5146  0.1457  0.6153  2.9586

Random effects:
 Groups           Name        Variance Std.Dev.
 participant_file (Intercept) 0.39012  0.6246
 sent_id          (Intercept) 0.02407  0.1551
 Residual                     0.77129  0.8782
Number of obs: 3248, groups:  participant_file, 203; sent_id, 16

Fixed effects:
                Estimate Std. Error        df t value Pr(>|t|)
(Intercept)    3.877e+00  7.900e-02 1.669e+02  49.069   <2e-16 ***
is_correctTRUE 1.194e-01  5.665e-02 3.164e+03   2.107   0.0352 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr)
is_crrcTRUE -0.643
```

Correctly answering the comprehension question is associated with higher authority ratings (= 0.12, p = .038).

Summary by comprehension

```
combined_df %>%
  group_by(is_correct) %>%
  summarise(
    Mean = mean(authority_rating, na.rm = TRUE),
    SD = sd(authority_rating, na.rm = TRUE),
    N = n(),
    SE = SD / sqrt(N),
    .groups = "drop"
  ) %>%
  mutate(Comprehension = ifelse(is_correct, "Correct", "Incorrect")) %>%
  select(Comprehension, Mean, SD, N, SE) %>%
  knitr::kable(digits = 2, caption = "Authority ratings by comprehension accuracy")
```

Table 6: Authority ratings by comprehension accuracy

Comprehension	Mean	SD	N	SE
Incorrect	3.72	1.04	337	0.06
Correct	4.01	1.09	2911	0.02

Figures

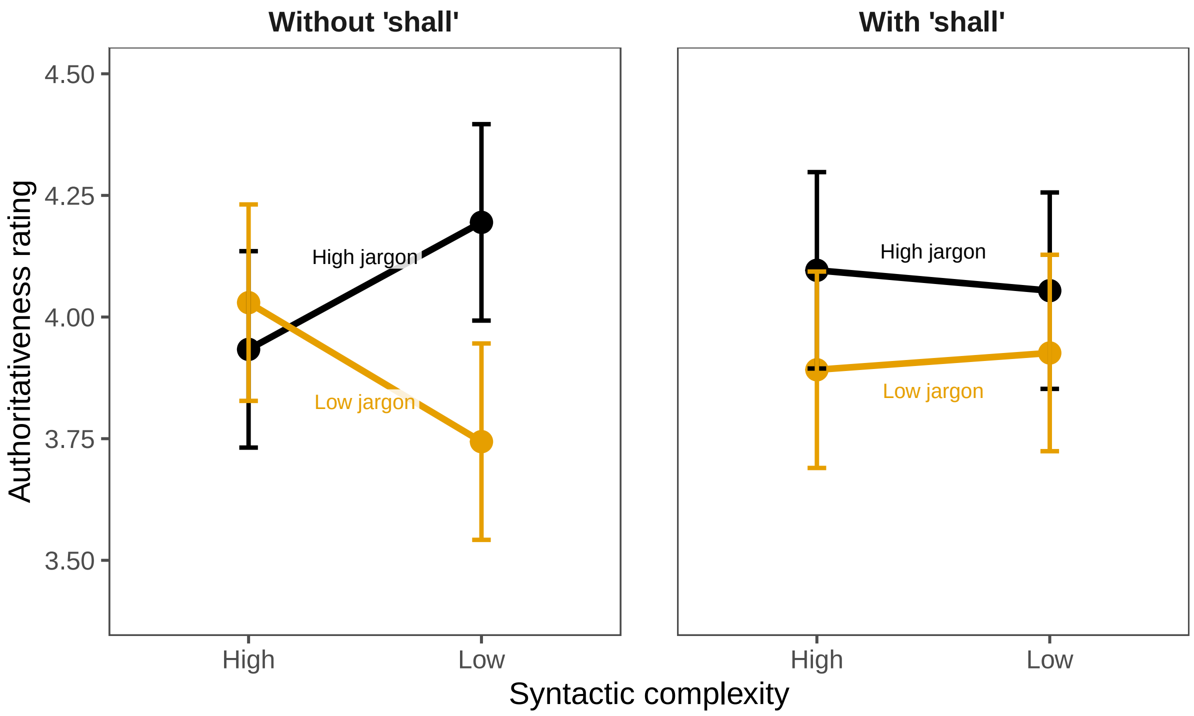
Figure 1: Three-way interaction (main results)

```
# Get emmeans for plotting
emm_df <- as.data.frame(emm_3way) %>%
  mutate(
    Syntax = factor(ifelse(syn_level == "high", "High", "Low"), levels = c("High", "Low")),
    Jargon = factor(ifelse(sem_level == "high", "High jargon", "Low jargon"),
                    levels = c("High jargon", "Low jargon")),
    Modal = factor(ifelse(modal_pres == "S", "With 'shall'", "Without 'shall'"),
                   levels = c("Without 'shall'", "With 'shall'"))
  )
```

```
# Create labels at midpoint of each line
label_df <- emm_df %>%
  group_by(Modal, Jargon) %>%
  summarise(
    y_mid = mean(emmean),
    .groups = "drop"
  ) %>%
  mutate(
    x_mid = 1.5,
    label = as.character(Jargon),
    y_offset = ifelse(Jargon == "High jargon", 0.06, -0.06)
  )

# Plot
p_3way <- ggplot(emm_df, aes(x = Syntax, y = emmean, color = Jargon, group = Jargon)) +
  geom_line(linewidth = 1.2) +
  geom_point(size = 3.5) +
  geom_errorbar(aes(ymin = asymp.LCL, ymax = asymp.UCL), width = 0.08, linewidth = 0.8) +
  geom_label(data = label_df,
             aes(x = x_mid, y = y_mid + y_offset, label = label, color = Jargon),
             size = 2.8, label.padding = unit(0.15, "lines"),
             linewidth = 0, fill = "white", alpha = 0.85,
             show.legend = FALSE) +
  facet_wrap(~ Modal) +
  scale_color_colorblind() +
  scale_y_continuous(limits = c(3.4, 4.5), breaks = seq(3.5, 4.5, 0.25)) +
  labs(
    x = "Syntactic complexity",
    y = "Authoritativeness rating"
  ) +
  theme_few(base_size = 12) +
  theme(
    legend.position = "none",
    strip.text = element_text(size = 11, face = "bold"),
    panel.spacing = unit(1.5, "lines")
  )

p_3way
```



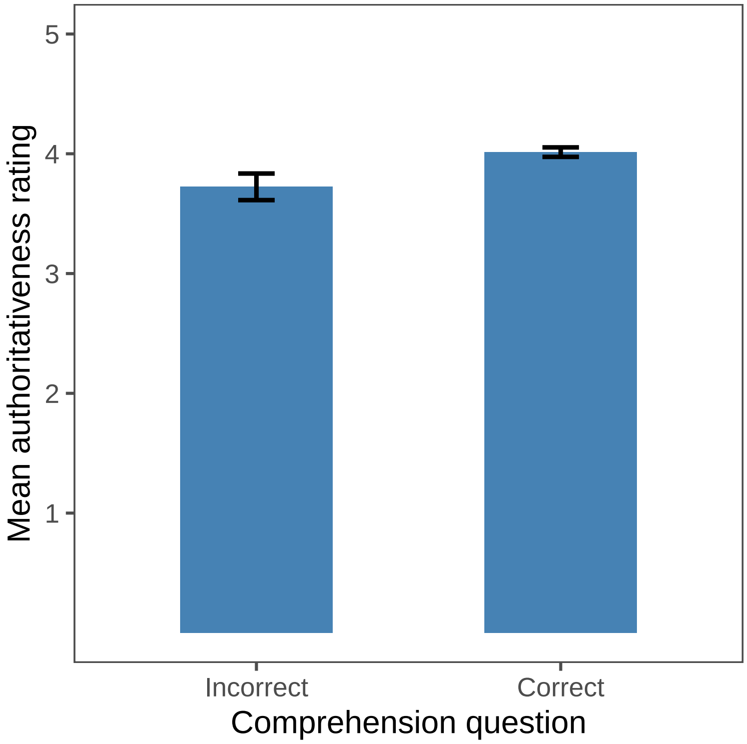
```
ggsave("../paper/figure_results.pdf", p_3way, width = 6.5, height = 4)
ggsave("../paper/figure_results.png", p_3way, width = 6.5, height = 4, dpi = 300)
```

Figure 2: Comprehension and authority

```
# Summary for plot
comp_summary <- combined_df %>%
  group_by(is_correct) %>%
  summarise(
    mean_rating = mean(authority_rating, na.rm = TRUE),
    sd = sd(authority_rating, na.rm = TRUE),
    n = n(),
    se = sd / sqrt(n),
    .groups = "drop"
  ) %>%
  mutate(
    Comprehension = factor(ifelse(is_correct, "Correct", "Incorrect"),
                           levels = c("Incorrect", "Correct"))
  )
```

```r
p_comp <- ggplot(comp_summary, aes(x = Comprehension, y = mean_rating)) +
  geom_col(fill = "steelblue", width = 0.5) +
  geom_errorbar(aes(ymin = mean_rating - 1.96*se, ymax = mean_rating + 1.96*se),
                width = 0.12, linewidth = 0.8) +
  scale_y_continuous(limits = c(0, 5), breaks = 1:5) +
  labs(
    x = "Comprehension question",
    y = "Mean authoritativeness rating"
  ) +
  theme_few(base_size = 12)

p_comp
```



```r
ggsave("../paper/figure_comprehension_authority.pdf", p_comp, width = 4, height = 4)
ggsave("../paper/figure_comprehension_authority.png", p_comp, width = 4, height = 4, dpi = 30
```

Session Info

```r
sessionInfo()
```

```
R version 4.5.2 (2025-10-31)
Platform: aarch64-apple-darwin25.0.0
Running under: macOS Tahoe 26.2

Matrix products: default
BLAS:   /opt/homebrew/Cellar/openblas/0.3.30/lib/libopenblasp-r0.3.30.dylib
LAPACK: /opt/homebrew/Cellar/r/4.5.2_1/lib/R/lib/libRlapack.dylib;  LAPACK version 3.12.1

locale:
[1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8

time zone: America/Los_Angeles
tzcode source: internal

attached base packages:
[1] stats     graphics  grDevices utils     datasets  methods   base

other attached packages:
 [1] ggthemes_5.2.0  emmeans_2.0.1   lmerTest_3.1-3  lme4_1.1-38
 [5] Matrix_1.7-4    jsonlite_2.0.0  lubridate_1.9.4 forcats_1.0.1
 [9] stringr_1.6.0   dplyr_1.1.4     purrr_1.2.0     readr_2.1.6
[13] tidyr_1.3.2     tibble_3.3.0    ggplot2_4.0.1   tidyverse_2.0.0

loaded via a namespace (and not attached):
 [1] gtable_0.3.6        xfun_0.55           lattice_0.22-7
 [4] tzdb_0.5.0          numDeriv_2016.8-1.1 vctrs_0.6.5
 [7] tools_4.5.2         Rdpack_2.6.4        generics_0.1.4
[10] parallel_4.5.2      pkgconfig_2.0.3     RColorBrewer_1.1-3
[13] S7_0.2.1            lifecycle_1.0.4     compiler_4.5.2
[16] farver_2.1.2        textshaping_1.0.4   tinytex_0.58
[19] htmltools_0.5.9     yaml_2.3.12         pillar_1.11.1
[22] nloptr_2.2.1        crayon_1.5.3        MASS_7.3-65
[25] reformulas_0.4.3    boot_1.3-32         nlme_3.1-168
[28] tidyselect_1.2.1    digest_0.6.39       mvtnorm_1.3-3
[31] stringi_1.8.7       splines_4.5.2       fastmap_1.2.0
[34] grid_4.5.2          cli_3.6.5           magrittr_2.0.4
[37] withr_3.0.2         scales_1.4.0        bit64_4.6.0-1
```

```
[40] timechange_0.3.0    estimability_1.5.1  rmarkdown_2.30
[43] bit_4.6.0           ragg_1.5.0          hms_1.1.4
[46] coda_0.19-4.1       evaluate_1.0.5      knitr_1.51
[49] rbibutils_2.4       rlang_1.1.6         Rcpp_1.1.0
[52] glue_1.8.0          vroom_1.6.7         minqa_1.2.8
[55] R6_2.6.1            systemfonts_1.3.1
```