

Setting Priors in brms

Bayesian Mixed Effects Models with brms for Linguists

Workshop Materials

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1 Setting Priors in brms (20 min)

1.1 Default vs. Weakly Informative Priors

brms uses weakly informative priors by default (not completely flat). However, for psycholinguistics, domain-specific priors are even better.

1.1.1 What is a Prior?

A prior encodes your beliefs about parameter values **before** seeing the data. In Bayesian inference:

$$\text{posterior} \propto \text{likelihood} \times \text{prior}$$

Types of priors:

- **Flat priors:** No information - any value equally likely (bad: implies ignorance)
- **Weakly informative:** Gentle regularization - allows data to dominate
- **Domain-specific:** Based on domain knowledge - prevents unreasonable values

1.1.2 The Intercept Adapts to Your Data!

This is important: The default intercept prior depends on `mean(y)`. Let's see this in action:

```
library(brms)
library(tidyverse)

# Create example datasets with different scales
set.seed(123)

# RT data: log-transformed, mean 6 ( 400ms)
rt_data_typical <- data.frame(
  subject = factor(rep(1:20, each = 10)),
  item = factor(rep(1:10, times = 20)),
  condition = factor(rep(c("A", "B"), each = 5, times = 20)),
  log_rt = rnorm(200, mean = 6, sd = 0.5)
)

# RT data: extreme scale, mean 10 ( 22,000ms - unrealistic)
rt_data_extreme <- data.frame(
  subject = factor(rep(1:20, each = 10)),
  item = factor(rep(1:10, times = 20)),
  condition = factor(rep(c("A", "B"), each = 5, times = 20)),
  log_rt = rnorm(200, mean = 10, sd = 2)
)
```

Now let's check what default priors brms suggests:

```
cat("\n==== DEFAULT PRIORS: Typical RT data (mean log-RT 6) ===\n\n")
```

```
==== DEFAULT PRIORS: Typical RT data (mean log-RT 6) ===
```

```
rt_priors_typical <- get_prior(
  log_rt ~ condition + (1 + condition | subject) + (1 | item),
  data = rt_data_typical,
  family = gaussian()
```

```

)
print(rt_priors_typical)

      prior      class      coef   group resp dpar npar lb ub tag
(flat)        b
(flat)        b conditionB
lkj(1)       cor
lkj(1)       cor           subject
student_t(3, 6, 2.5) Intercept
student_t(3, 0, 2.5)      sd
student_t(3, 0, 2.5)      sd           item
student_t(3, 0, 2.5)      sd Intercept item
student_t(3, 0, 2.5)      sd           subject
student_t(3, 0, 2.5)      sd conditionB subject
student_t(3, 0, 2.5)      sd Intercept subject
student_t(3, 0, 2.5)      sigma
source
default
(vectorized)
default
(vectorized)
default
default
(vectorized)
(vectorized)
(vectorized)
(vectorized)
(vectorized)
default

```

```
cat("\n\n==== DEFAULT PRIORS: Extreme RT data (mean log-RT 10) ===\n\n")
```

```
==== DEFAULT PRIORS: Extreme RT data (mean log-RT 10) ===
```

```
rt_priors_extreme <- get_prior(
  log_rt ~ condition + (1 + condition | subject) + (1 | item),
  data = rt_data_extreme,
  family = gaussian()
```

```

)
print(rt_priors_extreme)

      prior      class      coef   group resp dpar npar lb ub tag
(flat)        b
(flat)        b conditionB
lkj(1)       cor
lkj(1)       cor           subject
student_t(3, 10, 2.5) Intercept
student_t(3, 0, 2.5)    sd          0
student_t(3, 0, 2.5)    sd           item 0
student_t(3, 0, 2.5)    sd Intercept item 0
student_t(3, 0, 2.5)    sd           subject 0
student_t(3, 0, 2.5)    sd conditionB subject 0
student_t(3, 0, 2.5)    sd Intercept subject 0
student_t(3, 0, 2.5)    sigma         0
      source
      default
(vectorized)
      default
(vectorized)
      default
      default
(vectorized)
(vectorized)
(vectorized)
(vectorized)
(vectorized)
      default
      default

# Compare intercept priors
cat("\n==== Intercept Comparison ===\n")

```

==== Intercept Comparison ===

```

cat("Typical data prior:  ",
rt_priors_typical[rt_priors_typical$class == "Intercept", "prior"], "\n")

```

Typical data prior: student_t(3, 6, 2.5)

```
cat("Extreme data prior: ",  
    rt_priors_extreme[rt_priors_extreme$class == "Intercept", "prior"], "\n")
```

```
Extreme data prior: student_t(3, 10, 2.5)
```

```
cat("→ The intercept prior CHANGES with data scale!\n")
```

→ The intercept prior CHANGES with data scale!

Key insight: The intercept prior automatically scales with your data. This is convenient but has a problem: **if you don't specify priors, your prior assumptions implicitly depend on how you code your variables!**

1.2 Default brms Priors

When you don't specify priors, brms assigns defaults:

- **Intercept:** `student_t(3, mean(y), 2.5)` - **DATA-DEPENDENT!** Centers at your data mean
 - Adapts to your data scale automatically
 - For RT data with $\text{mean}(\log_{10}\text{RT}) = 6$: allows roughly 150ms-1100ms range
- **Slopes (b):** `(flat)` - improper uniform prior over $(-\infty, +\infty)$
 - No information: any effect size equally likely
 - Technically improper (doesn't integrate to 1)
- **Sigma** (residual SD): `student_t(3, 0, 2.5)` with lower bound 0
 - Weakly informative for residual variance
- **SD** (random effects): `student_t(3, 0, 2.5)` with lower bound 0
 - Encourages moderate between-subject/item variation
- **Cor** (correlations): `lkj(1)` - uniform over all correlation matrices

1.3 Setting Weakly Informative Priors for Reaction Times

For psycholinguistics, it's better to specify priors based on domain knowledge:

```

# Define priors explicitly
rt_priors <- c(
  prior(normal(6, 1.5), class = Intercept),      # log(RT) around 400ms
  prior(normal(0, 0.5), class = b),               # effects typically < 150ms
  prior(exponential(1), class = sigma),           # residual SD
  prior(exponential(1), class = sd),              # random effects SD
  prior(lkj(2), class = cor)                      # correlations
)

cat("Our weakly informative priors:\n")

```

Our weakly informative priors:

```
print(rt_priors)
```

	prior	class	coef	group	resp	dpar	nlnpar	lb	ub	tag	source
normal(6, 1.5)		Intercept						<NA>	<NA>		user
normal(0, 0.5)		b						<NA>	<NA>		user
exponential(1)		sigma						<NA>	<NA>		user
exponential(1)		sd						<NA>	<NA>		user
lkj(2)		cor						<NA>	<NA>		user

1.3.1 Why These Numbers?

1.3.1.1 normal(6, 1.5) for Intercept

- Mean = 6 on log scale → $\exp(6) = 403\text{ms}$ (typical RT)
- SD = 1.5 → 95% prior interval spans [3, 9] on log scale
- This translates to exp(3) to exp(9) **20ms to 8,100ms** (allows flexibility!)
- But 95% of prior mass is between $\pm 1.96 \times 1.5$ around the mean
- This puts most probability on reasonable RTs (100-1500ms), while still allowing outliers

1.3.1.2 normal(0, 0.5) for Effects

- Mean = 0 (no directional assumption)
- SD = 0.5 on log scale
- 95% prior interval: [-1, 1] on log scale
- Translates to effect sizes of roughly $\pm 65\%$ of baseline (multiplicative)
- Or approximately $\pm 100\text{-}150\text{ms}$ for typical RTs around 400-600ms
- **Why not flat?** Flat priors prefer extreme effect sizes (counterintuitive!)

1.3.1.3 `exponential(1)` for Sigma and SD

- Encourages moderate variance while allowing flexibility
- Penalizes very large residual variation or random effect variance
- Mean = 1 on the scale of log-RTs

1.3.1.4 `lkj(2)` for Correlations

- $\kappa = 2$: slight preference for correlations near 0
- Skeptical of strong correlations (like perfect intercept-slope correlation)
- If you truly expected strong correlations, you could use `lkj(1)` or lower

1.3.2 Comparison: Normal vs. Student-t

brms defaults use `student_t(3, , 2.5)` which has heavier tails than `normal()`. Why switch?

```
# Compare tail behavior
normal_99 <- quantile(rnorm(100000, 0, 0.5), c(0.001, 0.999))
studentt_99 <- quantile(rt(100000, 3) * 0.5, c(0.001, 0.999))

cat("Tails comparison (1st and 99th percentiles):\n")
```

Tails comparison (1st and 99th percentiles):

```
cat("Normal(0, 0.5):      ", round(normal_99, 2), "\n")
```

Normal(0, 0.5): -1.55 1.54

```
cat("Student-t(3) × 0.5:  ", round(studentt_99, 2), "\n")
```

Student-t(3) × 0.5: -5.19 5.13

```
cat("Student-t ratio:     ", round(studentt_99[2] / normal_99[2], 2), "x wider\n\n")
```

Student-t ratio: 3.34 x wider

```
cat("Student-t allows extreme values 2x more likely than normal!\n")
```

Student-t allows extreme values 2x more likely than normal!

When to use each: - **Student-t**: Default choice (conservative, robust to outliers) - **Normal**: When you have strong domain knowledge about plausible ranges (better for RT data in controlled experiments)

Good sign: Prior predictions should cover the plausible range of your outcome variable, but not too widely.

1.4 Summary

Key takeaways:

1. **Don't use flat priors** - they're uninformative and often lead to weak regularization
2. **Default intercept priors adapt to data** - implicit assumptions depend on your coding!
3. **Specify priors explicitly** based on domain knowledge
4. **Use prior predictive checks** - verify that priors generate plausible predictions before fitting
5. **Normal() is better than student_t()** when you have domain knowledge - more concentrated around plausible values

Next steps: - See `02_prior_predictive_checks_rt.qmd` for detailed prior validation - See `03_posterior_predictive_checks_rt.qmd` for checking if the fitted model makes sense