Package 'hlmLab'

May 8, 2026

Type Package

Title Hierarchical Linear Modeling with Visualization and Decomposition

Version 0.1.0

Description Provides functions for visualization and decomposition in hierarchical linear models (HLM) for applications in education, psychology, and the social sciences. Includes variance decomposition for two-level and three-level data structures following Snijders and Bosker (2012, ISBN:9781849202015), intraclass correlation (ICC) estimation and design effect computation as described in Shrout and Fleiss (1979) <doi:10.1037/0033-2909.86.2.420>, and contextual effect decomposition via the Mundlak (1978) <doi:10.2307/1913646> specification distinguishing within- and between-cluster components. Supports visualization of random slopes and cross-level interactions following Hofmann and Gavin (1998) <doi:10.1177/014920639802400504> and Hamaker and Muthen (2020) <doi:10.1037/met0000239>. Multilevel models are estimated using 'lme4' (Bates et al., 2015 <doi:10.18637/jss.v067.i01>). An optional 'Shiny' application enables interactive exploration of model components and parameter variation. The implementation follows the multilevel modeling framework of Raudenbush and Bryk (2002, ISBN:9780761919049).

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Encoding UTF-8

Language en-US

Depends R (>= 4.1.0)

Imports dplyr, ggplot2 (>= 3.4.0), lme4, scales, stats

Suggests shiny, spelling, testthat (>= 3.0.0)

Config/testthat/edition 3

RoxygenNote 7.3.3

URL https://github.com/causalfragility-lab/hlmLab

BugReports https://github.com/causalfragility-lab/hlmLab/issues

NeedsCompilation no

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Repository CRAN

Date/Publication 2026-04-16 10:50:02 UTC

Contents

`hlm_context` *Contextual effect for a Level-1 predictor (Mundlak decomposition)*

Description

Given a multilevel model with a within-cluster centered predictor and its cluster-mean counterpart (Mundlak specification), this function extracts the within- and between-cluster effects and computes the contextual effect (between - within).

Usage

```
hlm_context(model, x_within, x_between)
```

Arguments

`model`	A fitted `lmerMod` model.
`x_within`	Name of the within-cluster centered predictor (string).
`x_between`	Name of the cluster-mean predictor (string).

Value

An object of class `hlm_context`, which is a tibble with:

`effect_type`	Within, between, or contextual.
`estimate`	Estimate of the effect.
`se`	Standard error (approximate for contextual).

Examples

```
# Build a small toy dataset (no external data needed)
set.seed(1)
n_schools <- 8
n_students <- 12
school_id <- rep(seq_len(n_schools), each = n_students)
SES_raw   <- rnorm(n_schools * n_students)
SES_mean  <- rep(tapply(SES_raw, school_id, mean), each = n_students)
SES_c     <- SES_raw - SES_mean
math_score <- 50 + 2 * SES_c + 3 * SES_mean + rep(rnorm(n_schools, sd = 2), each = n_students) +
              rnorm(n_schools * n_students)
toy <- data.frame(math_score = math_score, SES_c = SES_c,
                  SES_mean = SES_mean, school_id = school_id)


m   <- lme4::lmer(math_score ~ SES_c + SES_mean + (1 | school_id), data = toy)
ctx <- hlm_context(m, x_within = "SES_c", x_between = "SES_mean")
ctx
hlm_context_plot(ctx)
```

`hlm_context_plot` *Convenience wrapper to plot contextual effects*

Description

Convenience wrapper to plot contextual effects

Usage

```
hlm_context_plot(object)
```

Arguments

`object`	An object of class `hlm_context`.

Value

A ggplot object.

`hlm_decompose` *Multilevel variance decomposition (within/between/longitudinal)*

Description

Decomposes a continuous variable into between-cluster, and within-cluster components (2-level), or into between-cluster (B), between-person (P), and within-person (W) components for longitudinal 3-level data.

Usage

```
hlm_decompose(data, var, cluster, id = NULL, time = NULL)
```

Arguments

`data`	A data frame.
`var`	Name of the focal variable (string).
`cluster`	Name of the cluster ID variable (e.g., school/classroom).
`id`	Optional person ID variable for longitudinal data.
`time`	Optional time variable (not required for the algebra, but noted in the output for clarity).

Details

This is primarily a teaching tool: it shows how total variance is partitioned across levels.

Value

An object of class `hlm_decompose` with components:

`data`	Original data with added decomposition columns.
`summary`	A tibble summarizing variance components and shares.

Examples

```
# 2-level example (students in schools)
set.seed(2)
toy <- data.frame(
  math_score = rnorm(80, mean = 50, sd = 10),
  school_id  = rep(letters[1:8], each = 10)
)
hlm_decompose(toy, var = "math_score", cluster = "school_id")

# 3-level longitudinal example (waves within students within schools)

toy3 <- data.frame(
  math_score = rnorm(120, 50, 10),
```

```
  school_id  = rep(letters[1:4], each = 30),
  student_id = rep(seq_len(24), each = 5)
)
hlm_decompose(toy3, var = "math_score", cluster = "school_id",
              id = "student_id", time = NULL)
```

`hlm_decompose_long` *Longitudinal three-level variance decomposition (B-P-W)*

Description

Convenience wrapper around `hlm_decompose()` for 3-level data: clusters (e.g., schools), persons within clusters, and repeated measures within persons over time.

Usage

```
hlm_decompose_long(data, var, cluster, id, time = NULL)
```

Arguments

`data`	A data frame.
`var`	Name of the focal variable (string).
`cluster`	Cluster ID (e.g., school/classroom) (string).
`id`	Person ID within cluster (string).
`time`	Optional time variable (string); stored in the output for reference but not required for the algebra.

Value

An object of class `hlm_decompose` with between-cluster (B), between-person (P), and within-person (W) variance components and shares.

Examples

```
set.seed(4)
toy_long <- data.frame(
  math_score = rnorm(120, 50, 10),
  school_id  = rep(letters[1:4], each = 30),
  student_id = rep(seq_len(24), each = 5),
  wave       = rep(seq_len(5), times = 24)
)
hlm_decompose_long(data = toy_long,
                   var     = "math_score",
                   cluster = "school_id",
                   id      = "student_id",
                   time    = "wave")
```

`hlm_icc` *Intraclass correlation and design effect from a random-intercept model*

Description

Computes the intraclass correlation (ICC) and, optionally, a design effect from a random-intercept multilevel model fitted with `lme4::lmer()`.

Usage

```
hlm_icc(model, cluster_size = NULL)
```

Arguments

`model`	A fitted `lmerMod` object with at least one random intercept.
`cluster_size`	Optional scalar giving the average cluster size, used to compute the design effect. If `NULL`, the design effect is not computed.

Value

An object of class `hlm_icc` with components:

`icc`	Estimated intraclass correlation.
`deff`	Design effect (if cluster_size supplied).
`re_var`	Random intercept variance.
`resid_var`	Residual variance.

Examples

```
set.seed(3)
toy <- data.frame(
  math_score = rnorm(80, 50, 10),
  SES        = rnorm(80),
  school_id  = rep(seq_len(8), each = 10)
)

library(lme4)
m <- lmer(math_score ~ SES + (1 | school_id), data = toy)
hlm_icc(m, cluster_size = 10)
```

hlm_icc_plot *Teaching plot for intraclass correlation (ICC)*

Description

Visualizes the intraclass correlation by plotting the between- and within-cluster variance components as a stacked bar. This is intended as a teaching diagram to help students see how the ICC reflects the share of variance that lies between clusters.

Usage

```
hlm_icc_plot(model, cluster_size = NULL)
```

Arguments

model	A fitted lmerMod model with a random intercept.
cluster_size	Optional scalar giving the average cluster size, passed to hlm_icc() to compute the design effect.

Value

A ggplot object.

hlm_xint_geom *Geometry of a cross-level interaction (random slopes fan plot)*

Description

Produces a "fan plot" of predicted lines for each cluster to illustrate a cross-level interaction (random slope) in a multilevel model.

Usage

```
hlm_xint_geom(model, x_within, cluster, n_points = 20, n_clusters = 20)
```

Arguments

model	A fitted lmerMod model with a random slope term of the form (x_within | cluster).
x_within	Name of the Level-1 predictor with a random slope (string).
cluster	Name of the clustering factor (string).
n_points	Number of points to plot along the x-axis. Defaults to 20.
n_clusters	Maximum number of clusters to display (sampled) for clarity.

Value

A ggplot object showing predicted lines by cluster.

Examples

```
# Small toy example using inline data (runs automatically)
set.seed(42)  # seed set by the *user* in the example, not inside the function
n_schools <- 10
n_students <- 15
school_id <- rep(seq_len(n_schools), each = n_students)
SES_c <- rnorm(n_schools * n_students)
u0 <- rep(rnorm(n_schools, sd = 0.5), each = n_students)
u1 <- rep(rnorm(n_schools, sd = 0.3), each = n_students)
math_score <- 50 + 2 * SES_c + u0 + u1 * SES_c + rnorm(n_schools * n_students, sd = 1)
toy <- data.frame(math_score = math_score, SES_c = SES_c, school_id = school_id)


m <- lme4::lmer(math_score ~ SES_c + (SES_c | school_id), data = toy)
hlm_xint_geom(m, x_within = "SES_c", cluster = "school_id")
```

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plot.hlm_context *Plot method for hlm_context objects*

Description

Produces an error-bar plot of within, between, and contextual effects with 95% confidence intervals. Intended as a teaching diagram.

Usage

```
## S3 method for class 'hlm_context'
plot(x, ...)
```

Arguments

x	An object of class hlm_context.
...	Not used.

Value

A ggplot object.

`plot.hlm_decompose` *Plot method for hlm_decompose objects*

Description

Produces a simple bar chart of variance shares across components, suitable for teaching how variance is partitioned across levels.

Usage

```
## S3 method for class 'hlm_decompose'
plot(x, ...)
```

Arguments

`x`	An object of class `hlm_decompose`.
`...`	Not used.

Value

A ggplot object.

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