Package 'MixedPsy'

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Title Statistical Tools for the Analysis of Psychophysical Data

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Description Tools for the analysis of psychophysical data in R. This package allows to estimate the Point of Subjective Equivalence (PSE)
and the Just Noticeable Difference (JND), either from a psychometric function or from a Generalized Linear Mixed Model (GLMM).
Additionally, the package allows plotting the fitted models and the response data, simulating psychometric functions of different shapes, and simulating data sets.
For a description of the use of GLMMs applied to psychophysical data, refer to Moscatelli et al. (2012).

Depends R (>= 3.5.0)

Imports beepr, boot, brglm, lme4, Matrix, mnormt, ggplot2

LazyData true

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BugReports https://github.com/moskante/MixedPsy/issues

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`MixDelta` *PSE/JND from GLMM Estimates using Delta Method*

Description

Estimate Points of Subjective Equivalence (PSE), Just Noticeable Differences (JND) and the related Standard Errors from a GLMM by means of delta method. The method applies to models with a *probit* link function, one continuous predictor, and one (optional) factorial predictor.

Usage

```
MixDelta(xplode.obj, alpha = 0.05, p = 0.75)
```

Arguments

`xplode.obj`	an object of class `xplode.obj`. The fitted model (object of class `merMod`, specifically of subclass `glmerMod`) includes one continuous predictor and one (optional) factorial predictor.
`alpha`	significance level of the confidence intervals. Default is 0.05 (value for 95% confidence interval).
`p`	probability value relative to the JND upper limit. Default is 0.75 (value for 50% JND).

Details

When the model includes a factorial predictor, the function is based on a recursive use of `glmer` and re-order of levels of the factorial predictor. The JND estimate assumes a *probit* link function.

Value

A matrix including estimate, standard error, inferior and superior bounds of the confidence interval of PSE and JND. If a factorial predictor is included in the model, the function returns a list, each item containing a matrix for the estimates relative to a level of the predictor.

Note

The delta method is based on the assumption of asymptotic normal distribution of the parameters estimates. This may result in an incorrect variance estimation. For a more reliable (but more time-consuming) estimation based on bootstrap method, use `pseMer`.

References

Moscatelli, A., Mezzetti, M., & Lacquaniti, F. (2012). Modeling psychophysical data at the population-level: The generalized linear mixed model. Journal of Vision, 12(11):26, 1-17. doi:10.1167/12.11.26

Casella, G., & Berger, R. L. (2002). Statistical inference (2nd ed.). Pacific Grove, CA: Duxbury Press

See Also

`glmer` for fitting Generalized Linear Mixed Models. `xplode` for interfacing values from a fitted GLMM to `MixedPsy` functions. `pseMer` for bootstrap-based confidence intervals of psychometric parameters.

Examples

```
library(lme4)

#univariable GLMM (one continuous predictor)
mod.uni = glmer(formula = cbind(Longer, Total - Longer) ~ X + (1 | Subject),
family = binomial(link = "probit"), data = simul_data)
xplode.uni = xplode(model = mod.uni, name.cont = "X")
MixDelta(xplode.uni)

#multivariable GLMM (one continuous and one factorial predictor)
mod.multi <- glmer(cbind(faster, slower) ~ speed * vibration + (1 + speed| subject),
family = binomial(link = "probit"), data = vibro_exp3)
xplode.multi <- xplode(model = mod.multi, name.cont = "speed", name.factor = "vibration")
MixDelta(xplode.multi)
```

MixPlot *Plot Individual Responses from GLMM*

Description

Plot response curve for each individual in a population sample, given a GLMM with one continuous predictor and one (optional) factorial predictor. If the factorial predictor is specified, the response is plotted separately for each individual and each predictor level.

Usage

```
MixPlot(xplode.obj, facet_by = NULL, showData = TRUE)
```

Arguments

xplode.obj	an object of class xplode.
facet_by	optional. A string specifying the name of the faceting variable (either the participant identification or the factorial predictor).
showData	logical, defines if proportion of binomial responses for each stimulus level are presented. Default is TRUE.

Details

If the model includes only a continuous predictor, the figure consist of a single panel, and each individual's response is assigned a different color. If a factorial predictor is included in the model, the faceting variable can be either the participant identification or the factorial predictor. By default, each panel shows an individual's response, different levels of the factorial predictor are coded by color.

Value

MixPlot returns a ggplot object.

See Also

xplode for objects of class xplode. ggplot2 for creating data visualizations. PsychPlot for plotting a a psychometric function from a GLM.

Examples

```
library(lme4)
mod.multi <- glmer(cbind(faster, slower) ~ speed * vibration + (1 + speed| subject),
family = binomial(link = "probit"), data = vibro_exp3)
xplode.multi <- xplode(model = mod.multi, name.cont = "speed", name.factor = "vibration")

MixPlot(xplode.multi)
#alternative visualization
MixPlot(xplode.multi, facet_by = "vibration", showData = FALSE)
```

---

pseMer *PSE/JND from GLMM Estimates Using Bootstrap Method*

Description

Estimates the Point of Subjective Equivalence (PSE), the Just Noticeable Difference (JND) and the related Standard Errors by means of Bootstrap Method, given an object of class merMod.

Usage

```
pseMer(
  mer.obj,
  B = 200,
  FUN = NULL,
  alpha = 0.05,
  ci.type = c("norm", "basic", "perc"),
  beep = F
)
```

Arguments

mer.obj	an object of class merMod.
B	integer. Number of bootstrap samples.
FUN	an optional, custom made function to specify the required parameters to be estimated. If NULL, pseMer estimates PSE and 50%JND of a univariable GLMM with a single intercept and slope.
alpha	significance level of the confidence intervals. Default is 0.05 (95% confidence interval).
ci.type	vector of character strings representing the type of intervals required. The value should be any subset of the values accepted by boot.ci: c("norm","basic", "stud", "perc", "bca"). Specify "all" for all five types of intervals. "perc" should be always included for the summary table.
beep	logical. If TRUE, a "ping" sound alerts that the simulation is complete. Default is FALSE.

Details

pseMer estimates PSE and JND (and additional user defined parameters) from a fitted GLMM model (class merMod).

Value

pseMer returns a list of length 3 including a summary table (estimate, inferior and superior bounds of the confidence interval), the output of bootMer, and that of boot.ci, for further analyses. Confidence intervals in the summary table are based on the percentile method.

Note

A first custom function was written in 2012 for the non-CRAN package MERpsychophisics, based on the algorithm in Moscatelli et al. (2012). The current function is a wrapper of function bootMer and boot.ci.

Increasing the number of bootstrap samples (B) makes the estimate more reliable. However, this will also increase the duration of the computation.

References

Moscatelli, A., Mezzetti, M., & Lacquaniti, F. (2012). Modeling psychophysical data at the population-level: The generalized linear mixed model. Journal of Vision, 12(11):26, 1-17. doi:10.1167/12.11.26

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67(1), 51. https://doi.org/10.18637/jss.v067.i01

See Also

bootMer and boot.ci for estimation of confidence intervals with the bootstrap method. MixDelta for confidence intervals with delta method.

Examples

```
library(lme4)
#example 1: univariable GLMM
mod.uni = glmer(formula = cbind(Longer, Total - Longer) ~ X + (1 | Subject),
family = binomial(link = "probit"), data = simul_data)

BootEstim.uni <- pseMer(mod.uni, B = 100, ci.type = c("perc"))

#example 2: specify custom parameters for multivariable model
mod.multi <- glmer(cbind(faster, slower) ~ speed * vibration + (1 + speed| subject),
family = binomial(link = "probit"), data = vibro_exp3)

fun2mod = function(mer.obj){
#allocate space: 4 parameters (jnd_A, jnd_B, pse_A, pse_B)
jndpse = vector(mode = "numeric", length = 4)
names(jndpse) = c("pse_0", "pse_32","jnd_0", "jnd_32")
jndpse[1] = -fixef(mer.obj)[1]/fixef(mer.obj)[2] #pse_0
jndpse[2] = -(fixef(mer.obj)[1]+fixef(mer.obj)[3])/(fixef(mer.obj)[2]+ fixef(mer.obj)[4]) #pse_0
jndpse[3] = qnorm(0.75)/fixef(mer.obj)[2] #jnd_0
jndpse[4] = qnorm(0.75)/(fixef(mer.obj)[2]+ fixef(mer.obj)[4]) #jnd_32
return(jndpse)
}

BootEstim.multi = pseMer(mod.multi, B = 100, FUN = fun2mod)
```

PsychDelta *PSE/JND from GLM Using Delta Method*

Description

Estimate Point of Subjective Equivalence (PSE), Just Noticeable Difference (JND), and related Standard Errors of an individual participant by means of Delta Method. The method only applies to a GLM (object of class glm) with one continuous predictor and a *probit* link function.

Usage

```
PsychDelta(model.obj, alpha = 0.05, p = 0.75)
```

Arguments

model.obj	the fitted psychometric function. An object of class glm.
alpha	significance level of the confidence interval.Default is 0.05 (95% confidence interval).
p	probability value relative to the JND upper limit. Default is 0.75 (value for 50% JND).

Details

PsychDelta estimates PSE and JND of a psychometric function (object of class glm).

Value

PsychDelta returns a matrix including estimate, standard error, inferior and superior bounds of the confidence interval of PSE and JND. Confidence Intervals are computed as: $Estimate +/- z(1 - (\alpha/2)) * Std.Error$.

Note

The function assumes that the first model coefficient is the intercept and the second is the slope. The estimate of the JND assumes a *probit* link function.

References

Faraggi, D., Izikson, P., & Reiser, B. (2003). Confidence intervals for the 50 per cent response dose. Statistics in medicine, 22(12), 1977-1988. https://doi.org/10.1002/sim.1368

Knoblauch, K., & Maloney, L. T. (2012). Modeling psychophysical data in R (Vol. 32). Springer Science & Business Media.

Moscatelli, A., Mezzetti, M., & Lacquaniti, F. (2012). Modeling psychophysical data at the population-level: The generalized linear mixed model. Journal of Vision, 12(11):26, 1-17. doi:10.1167/12.11.26

See Also

glm for fitting a Generalized Linear Model to a single-subject response. glmer for Generalized Linear Mixed Models (including fixed and random effects). MixDelta for estimating PSE and JND at a population level with delta method.

Examples

```
data.S1 <- subset(simul_data, Subject == "S1")
model.glm = glm(formula = cbind(Longer, Total - Longer) ~ X,
family = binomial(link = "probit"), data = data.S1)
PsychDelta(model.glm)
```

PsychFunction *Psychometric Function and PSE/JND Parameters from Single-Subject Response*

Description

Fit psychometric functions using `glm` or `brglm`. Estimate PSE, JND, and related confidence intervals with Delta Method.

Usage

```
PsychFunction(ps.formula, ps.link, ps.data, br = F)
```

Arguments

`ps.formula`	an object of class `formula`, such as `cbind(yes, no) ~ X`
`ps.link`	link function for the binomial family of error distribution. Default is `probit`.
`ps.data`	a data frame including the variables used in the model.
`br`	logical. If TRUE, `brglm` for bias reduction is used if values are equal to 0 or 1. Default is FALSE.

Details

Estimates are computed only for GLM of the type `F(Y) ~ X`, where X is a continuous predictor. Std. Errors and 95% confidence intervals of PSE and JND are estimated via Delta Methods. Currently only working with *probit* link function.

Value

`PsychFunction` returns a list including the fitted model, the estimate of PSE and JND and a flag to indicate if `brglm` was called.

Note

`PsychFunction` returns the same parameter estimate as `PsychDelta`, without an explicit call to `glm`. Moreover, it allows to fit the model using `brglm` in case of complete or quasi separation.

References

Faraggi, D., Izikson, P., & Reiser, B. (2003). Confidence intervals for the 50 per cent response dose. Statistics in medicine, 22(12), 1977-1988. https://doi.org/10.1002/sim.1368

Moscatelli, A., Mezzetti, M., & Lacquaniti, F. (2012). Modeling psychophysical data at the population-level: The generalized linear mixed model. Journal of Vision, 12(11):26, 1-17. doi:10.1167/12.11.26

See Also

glm for Generalized Linear Models. brglm for fitting a GLM using bias reduction. PsychPlot for plotting a psychometric function given a glm (or brglm) object. PsychPlot for plotting a a psychometric function from a GLM. PsychShape for plotting a psychometric function given PSE and JND.

Examples

```
data.S1 <- subset(simul_data, Subject == "S1")
psych.S1 <- PsychFunction(ps.formula = cbind(Longer, Total - Longer) ~ X,
ps.link = "probit", ps.data = data.S1)
```

PsychPlot *Plot Psychometric Function from GLM*

Description

Plot a psychometric function given an object of class glm or brglm. The plot can be drawn on a new or existing ggplot object.

Usage

```
PsychPlot(
  model.obj,
  addTo = NULL,
  showData = TRUE,
  ps.type = "solid",
  ps.size = 1,
  ps.lab = ""
)
```

Arguments

model.obj	the fitted psychometric function. An object of class glm or brglm.
addTo	specifies an existing ggplot object where the new line should be plotted. If no object is given, the function is drawn on a new plot.
showData	logical, defines if proportion of binomial responses for each stimulus level are presented. Default is TRUE.
ps.type, ps.size	type and size of the plotted line (see "ggplot2-spec").
ps.lab	label assigned to the psychometric curve. The label is coded by the color aesthetic.

Value

PsychPlot returns a ggplot object.

References

Moscatelli, A., Mezzetti, M., & Lacquaniti, F. (2012). Modeling psychophysical data at the population-level: The generalized linear mixed model. Journal of Vision, 12(11):26, 1-17. doi:10.1167/12.11.26

Knoblauch, K., & Maloney, L. T. (2012). Modeling psychophysical data in R (Vol. 32). Springer Science & Business Media.

See Also

`glm` for for Generalized Linear Models. `PsychFunction` for estimation of PSE and JND. `MixPlot` for plotting individual responses from a GLMM.

Examples

```
data.S1 <- subset(simul_data, Subject == "S1")
psych.S1 <- PsychFunction(ps.formula = cbind(Longer, Total - Longer) ~ X,
ps.link = "probit", ps.data = data.S1)
plotP1 <- PsychPlot(psych.S1$model, showData = TRUE, ps.lab = "S1")

data.S2 <- subset(simul_data, Subject == "S2")
glm.S2 <- glm(formula = cbind(Longer, Total - Longer) ~ X,
           family = binomial(link = "probit"), data = data.S2)
plotP2 <- PsychPlot(glm.S2, addTo = plotP1, ps.lab = "S2")
```

`PsychShape` *Plot Psychometric Functions given PSE and JND*

Description

Plot a psychometric function with known PSE and JND on a new or existing `ggplot` object.

Usage

```
PsychShape(
  pse = 0,
  jnd = 1,
  p = 0.75,
  x.range = c(NA, NA),
  ps.link = c("probit"),
  ps.type = "solid",
  ps.size = 1,
  ps.color = "black",
  addTo = NULL
)
```

Arguments

pse, jnd	point of subjective equivalende (PSE) and just noticeable difference (JND) of the desired psychometric function.
p	probability value relative to the JND upper limit. Default is 0.75 (value for 50% JND).
x.range	vector of length two specifying the range of the psychometric function.
ps.link	a link function for the binomial family of error distribution.
ps.type, ps.size, ps.color	type, size, and color of the plotted line (see "ggplot2-spec").
addTo	specifies an existing ggplot object where the new line should be plotted. If no object is given, the function is drawn on a new plot.

Details

PsychShape() can be used to visualize the predicted results of a psychophysical experiment or to plot a fitted psychometric function whose values of pse and jnd are known. Currently only working with probit and logit link function.

Value

PsychShape returns a ggplot object.

References

Moscatelli, A., Mezzetti, M., & Lacquaniti, F. (2012). Modeling psychophysical data at the population-level: The generalized linear mixed model. Journal of Vision, 12(11):26, 1-17. doi:10.1167/12.11.26

Knoblauch, K., & Maloney, L. T. (2012). Modeling psychophysical data in R (Vol. 32). Springer Science & Business Media.

See Also

glm for for Generalized Linear Models. PsychFunction and PsychDelta for estimation of PSE and JND from response data. PsychPlot for plotting a a psychometric function from a GLM.

Examples

```
p <- PsychShape(pse = 0, jnd = 6, x.range = c(-40, 40), ps.color = "gray", ps.size = 3)
p1 <- PsychShape(pse = 6, jnd = 6, x.range = c(-40, 40), ps.col = "black", addTo = p)
p2 <- PsychShape(pse = 6, jnd = 6, x.range = c(-40, 40), ps.col = "red", ps.link = "logit",
ps.type = "dashed", addTo = NULL)
```

PsySimulate *Simulate psychophysical data*

Description

The function simulates data of a typical psychophysics experiment. For each simulated participant, the function returns the following information: individual slope and intercept coefficients, given the fixed and random effects parameters provided as input; summary of the simulated binomial response to a range of intensity levels between a specified range.

Usage

```
PsySimulate(
  fixeff = c(-7, 0.0875),
  raneff = c(2.4, -0.002, 2e-06),
  nsubjects = 8,
  ntrials = 40,
  nintervals = 9,
  xint = c(40, 120),
  constant = T
)
```

Arguments

fixeff	array of fixed effects. First item is the intercept, second item is the slope.
raneff	array of random effects. First item is the intercept, second item is the covariance, third item is the slope.
nsubjects	number of subjects to simulate. Default is 8.
ntrials	number of trials for each stimulus level. Default is 40.
nintervals	number of stimulus levels. Default is 9.
xint	range of the stimulus interval. Default is c(40,120)
constant	logical. If set to FALSE, stimulus levels are randomly generated, uniformly distributed values within the selected interval. otherwise, the X interval is divided in intervals of constant length. Default is TRUE.

Value

PsySimulate returns a simulated dataset. If no input arguments are specified, the function returns a dataset with the same characteristics as simul_data.

See Also

PsychShape for plotting a psychometric function given PSE and JND.

Examples

```
datafr.S1 <- PsySimulate(fixeff = c(0, 1), xint = c(-5,5),
nsubject = 1, ntrials = 60, nintervals = 10, constant = FALSE)
library(ggplot2)
g <- ggplot(datafr.S1, aes(X,Longer/Total)) + geom_point()

PsychShape(pse = 0, jnd = qnorm(0.75)/1, ps.link = "probit",
x.range = c(-5,5), addTo = g, ps.color = "red")
```

`simul_data` *A simulated psychophysical dataset*

Description

A dataset containing simulated responses to a forced-choice task for eight clusters. Created using `PsySimulate()`. The variables are as follows:

Usage

```
data(simul_data)
```

Format

A data frame with 72 rows (9 observations x 8 simulated participants) and 6 variables:

X samples in the continuous interval (range `c(40,120)`)

Intercept,Slope simulated participant's coefficients (combination of random and fixed effect)

Longer number of trials in which response is judged "longer" than standard

Total total number of trials for sample in X

Subject simulated participant's identification code (S1 to S8)

See Also

`PsySimulate` for simulating dataframes with custom parameters.

vibro_exp3 *Data from tactile discrimination task - (Dallmann et al., 2015).*

Description

A dataset containing the response recorded from a tactile discrimination task (nine participants). In a forced-choice experiment, participants were required to discriminate the motion speed of a moving surface by touching it. Simultaneously with the motion stimulus, a 32Hz masking vibration occurred in half of the trials.

Usage

```
data(vibro_exp3)
```

Format

A data frame with 126 rows (14 observations x 9 participants) and 5 variables:

speed numeric, speed of the moving surface (in cm/s, range `c(1,16)`)

vibration factor representing the vibration frequency of the masking stimulus. Two levels: 32 (vibration in the experimental condition, in Hz) or 0 (no vibration - control condition)

faster proportion of trials in which the comparison stimulus was judged as faster than the reference

slower proportion of trials in which the comparison stimulus was judged as slower than the reference

subject participant's identification code

Source

Original data were published in Dallmann et al. (2015).

References

Dallmann, C. J., Ernst, M. O., & Moscatelli, A. (2015). The role of vibration in tactile speed perception. Journal of Neurophysiology, 114(6), 3131–3139. <doi:10.1152/jn.00621.2015>

xplode *Extract values from a fitted GLMM object*

Description

Extract values from an object of class `merMod` (more specifically, from an object of subclass `glmerMod`).

Usage

```
xplode(model.obj, name.cont = NA, name.factor = NA, names.response = NA)
```

Arguments

model.obj	The GLMM fitted with glmer. An object of class "merMod".
name.cont	A string providing the name of the continuous predictor, as in the formula object of the fitted model
name.factor	A string providing the name of name of the categorical predictor, as in the formula object of the fitted model
names.response	Optional. A string providing the name of name of the response variable, as in the formula object of the fitted model

Details

For simplicity and maintenance reasons, several MixedPsy functions take as input an object of class xplode instead of an object of class merMod.

See Also

merMod-class and glmer. MixDelta, MixPlot for use of objects of class xplode.

Examples

```
library(lme4)
multi.mod <- glmer(cbind(faster, slower) ~ speed * vibration  + (1 + speed| subject),
family = binomial(link = "probit"), data = vibro_exp3)
xplode.mod <- xplode(multi.mod, name.cont = "speed", name.factor = "vibration")
MixPlot(xplode.mod)
MixDelta(xplode.mod)
```

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