Package 'rmcorr'

July 27, 2024

Title Repeated Measures Correlation

Version 0.7.0

Description Compute the repeated measures correlation, a statistical technique for determining the overall within-individual relationship among paired measures assessed on two or more occasions, first introduced by Bland and Altman (1995). Includes functions for diagnostics, p-value, effect size with confidence interval including optional bootstrapping, as well as graphing. Also includes several example datasets. For more details, see the web documentation <https://lmarusich.github.io/rmcorr/index.html> and the original paper: Bakdash and Marusich (2017) <doi:10.3389/fpsyg.2017.00456>.

Depends R (>= 4.1.0)

License GPL-2

LazyData true

Imports stats, grDevices, graphics, psych, RColorBrewer

RoxygenNote 7.3.2

Encoding UTF-8

Suggests knitr, rmarkdown, ggplot2, plotrix, lme4, merTools, pwr, AICcmodavg, pals, testthat (>= 3.0.0), vdiffr, corrplot, cocor, covr, ggExtra, gglm, dplyr, esc, patchwork

VignetteBuilder knitr

Config/testthat/edition 3

URL https://github.com/lmarusich/rmcorr

BugReports https://github.com/lmarusich/rmcorr/issues

NeedsCompilation no

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Contents

`bland1995` *Repeated measurements of intramural pH and PaCO2*

Description

A dataset containing the repeated measurements of intramural pH and PaCO2 for eight subjects, from Bland & Altman (1995).

Usage

```
bland1995
```

Format

A data frame with 47 rows and 3 variables

`[,1]`	`Subject`	Unique identifer
`[,2]`	`pH`	Potential of hydrogen, acidity to base
`[,3]`	`PaCO2`	Partial pressure of carbon dioxide

Source

Bland, J.M., & Altman, D.G. (1995). Calculating correlation coefficients with repeated observations: Part 1 – correlation within subjects. *BMJ, 310*, 446, doi:10.1136/bmj.310.6977.446

geom_rmc *geom_rmc: ggplot2 geom for simplified graphing*

Description

geom_rmc: ggplot2 geom for simplified graphing

Usage

```
geom_rmc(rmc)
```

Arguments

rmc	an object of class "rmc" generated from the rmcorr function.

See Also

rmcorr, plot.rmc for base plotting

Examples

```
my.rmc <- rmcorr(participant = Subject, measure1 = PaCO2, measure2 = pH,
                 dataset = bland1995)

ggplot2::ggplot(bland1995,
     ggplot2::aes(x = PaCO2,
                  y = pH,
                  color = factor(Subject))) +
     geom_rmc(my.rmc)


##manually:
ggplot2::ggplot(bland1995,
     ggplot2::aes(x = PaCO2,
                  y = pH,
                  color = factor(Subject))) +
    ggplot2::geom_point(ggplot2::aes(colour = factor(Subject))) +
    ggplot2::geom_line(ggplot2::aes(y = my.rmc$model$fitted.values),
                       linetype = 1)


##another example:
##new theme, remove legend, and custom color pal
ggplot2::ggplot(bland1995,
                ggplot2::aes(x = PaCO2,
                             y = pH,
                             color = factor(Subject))) +
   geom_rmc(my.rmc) +
   ggplot2::theme_minimal() +
   ggplot2::theme(legend.position="none") +
```

```
ggplot2::scale_color_brewer(palette="Dark2")
```

`gilden2010` *Repeated measurements of reaction time and accuracy*

Description

A dataset containing four repeated measurements of reaction time (RT) and accuracy from eleven subjects in a visual search experiment. Each measurement is the mean RT and accuracy from a block of 288 search trials. blocks of visual search, for eleven subjects.

Usage

```
gilden2010
```

Format

A data frame with 44 rows and 4 variables

`[,1]`	`sub`	Subject ID
`[,2]`	`block`	Block ID
`[,3]`	`rt`	Mean reaction time
`[,4]`	`acc`	Mean accuracy

Source

Gilden, D.L., Thornton, T.L., & Marusich, L.R. (2010). The serial process in visual search. *Journal of Experimental Psychology: Human Perception and Performance, 36*, 533-542, doi:10.1037/a0016464

`HCAHPS2022` *Nested and multivariate survey measures of hospital patient experience and other measures*

Description

A summary dataset from non-independent units of analysis (six regions nesting 50 U.S. states and 3 U.S. territories) with multivariate (composite) measures. This is a survey assessing patient experience for hospitalized care, the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) Survey; also referred to as the CAHPS® Hospital Survey. The data were publicly released in April 2023 by the U.S. Centers for Medicare & Medicaid Services (CMS).

HCAHPS is a standardized and validated survey instrument for evaluating patient experience. Patient experience is an indicator of healthcare quality and is defined as the "... range of interactions

at patients have with the healthcare system, including their care from health plans, and from doctors, nurses, and staff in hospitals..." https://web.archive.org/web/20230206233908/https://www.ahrq.gov/cahps/about-cahps/patient-experience/index.html.

The HCAHPS composite measures consist of multiple questions and, here, are top box scores (see https://www.hcahpsonline.org/en/summary-analyses/). In addition to patient experience, there are additional measures such as whether the hospital is recommended or not, the number or participating hospitals, and the survey response rate

- Note this is *not* a representative sample
- Measures are averaged at the state/territory level
- Respondents were discharged from a hospital between July 2021 to July 2022
- Results are patient-mix adjusted, see doi:10.1111/j.14756773.2008.00914.x

Additional Information:

- For details about the data and questions comprising composite measures, see https://www.hcahpsonline.org/globalassets/hcahps/star-ratings/tech-notes/april_2023_star-ratings_tech_notes.pdf
- For the specific questions on the HCAHPS survey, see https://www.hcahpsonline.org/globalassets/hcahps/quality-assurance/2023_survey-instruments_english_mail.pdf
- CAHPS® is a registered trademark of the U.S. Agency for Healthcare Research and Quality: https://www.ahrq.gov/cahps/about-cahps/using-cahps-name/index.html

Usage

```
HCAHPS2022
```

Format

A data frame with 53 rows and 14 columns

[,1]	State	Unique identifier for each U.S. state/territory, see https://npiregist
[,2]	Region	The region nesting states and territories, according to the U.S. Census
[,3]	Communication with Nurses	Composite measure (3 questions) for nurse communication with patien
[,4]	Communication with Doctors	Composite measure (3 questions) for doctor communication with patie
[,5]	Responsiveness of Hospital Staff	Composite measure (2 questions) for responsiveness of hospital staff (
[,6]	Communication About Medicines	Composite measure (2 questions) for healthcare provider communicati
[,7]	Cleanliness of Hospital Environment	Individual item: "During this hospital stay, how often were your room
[,8]	Quietness of Hospital Environment	Individual item: "During this hospital stay, how often was the area aro
[,9]	Discharge Information	Composite measure (2 questions) for communication about care neede
[,10]	Care Transition	Composite measure (3 questions) for understanding of care needed (e.
[,11]	Hospital Rating	Ten point Likert scale rating of hospital (worse possible to best possibl
[,12]	Recommend the Hospital	Individual item: "Would you recommend this hospital...?" Percent of "
[,13]	Participating Hospitals	Number of participating hospitals in the region
[,14]	Survey Response Rate	Patient survey response rate for each state/territory (%)

Source

CAHPS Hospital Survey (2022). HCAHPS Survey Results Table (Dataset) https://www.hcahpsonline.org/globalassets/hcahps/summary-analyses/summary-results/april-2023-public-report-july-2021---june.pdf

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`marusich2016_exp2` *Repeated measurements of dyads performance and subjective situation awareness*

Description

A dataset containing three repeated measures of dyads (paired participants) working together to capture High Value Targets (lower task time is better performance) and their averaged Mission Awareness Rating Scale (MARS) score for each block, repeated three times. MARS evaluates subjective situation awareness ("knowing what is going on"), higher values indicate better situation awareness.

Usage

```
marusich2016_exp2
```

Format

A data frame with 84 rows (28 dyads/pairs) and 4 variables

`[,1]`	`Pair`	Unique identifer for each dyad
`[,2]`	`HVT_capture`	Capture time
`[,3]`	`MARS`	subjective situation awareness
`[,4]`	`Source Reliability`	1 = none, 2 = accurate, and 3 = inaccurate

Source

Marusich et al. (2016). Effects of information availability on command-and-control decision making: performance, trust, and situation awareness. *Human Factors, 58*(2), 301-321, doi:10.1177/0018720815619515

plot.rmc *Plot the repeated measures correlation coefficient.*

Description

plot.rmc produces a scatterplot of measure1 on the x-axis and measure2 on the y-axis, with a different color used for each subject. Parallel lines are fitted to each subject's data.

Usage

```
## S3 method for class 'rmc'
plot(x, palette = NULL, xlab = NULL, ylab = NULL, ...)
```

Arguments

x	an object of class "rmc" generated from the rmcorr function.
palette	the palette to be used. Defaults to the RColorBrewer "Paired" palette
xlab	label for the x axis, defaults to the variable name for measure1.
ylab	label for the y axis, defaults to the variable name for measure2.
...	additional arguments to plot.

See Also

rmcorr, geom_rmc for plotting with ggplot

Examples

```
## Bland Altman 1995 data
my.rmc <- rmcorr(participant = Subject, measure1 = PaCO2, measure2 = pH,
                 dataset = bland1995)
plot(my.rmc)

## Raz et al. 2005 data
my.rmc <- rmcorr(participant = Participant, measure1 = Age, measure2 =
                 Volume, dataset = raz2005)
library(RColorBrewer)
blueset <- brewer.pal(8, 'Blues')
pal <- colorRampPalette(blueset)
plot(my.rmc, overall = TRUE, palette = pal, overall.col = 'black')


## Gilden et al. 2010 data
my.rmc <- rmcorr(participant = sub, measure1 = rt, measure2 = acc,
                 dataset = gilden2010)
plot(my.rmc, overall = FALSE, lty = 2, xlab = "Reaction Time",
     ylab = "Accuracy")
```

print.rmc *Print the results of a repeated measures correlation*

Description

Print the results of a repeated measures correlation

Usage

```
## S3 method for class 'rmc'
print(x, ...)
```

Arguments

x	An object of class "rmc", a result of a call to rmcorr.
...	additional arguments to print.

See Also

rmcorr

Examples

```
## Bland Altman 1995 data
blandrmc <- rmcorr(Subject, PaCO2, pH, bland1995)
blandrmc
```

print.rmcmat *Print the repeated measures correlation matrix*

Description

Print the repeated measures correlation matrix

Usage

```
## S3 method for class 'rmcmat'
print(x, ...)
```

Arguments

x	An object of class "rmcmat", a result of a call to rmcorr_mat.
...	additional arguments to print.

See Also

rmcorr_mat,rmcorr

Examples

```
## Bland Altman 1995 data
blandrmc <- rmcorr(Subject, PaCO2, pH, bland1995)
blandrmc
```

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raz2005 *Repeated measurements of age and cerebellar volume*

Description

A dataset containing two repeated measures, on two occasions (Time), of age and adjusted volume of cerebellar hemispheres from 72 participants. Data were captured from Figure 8, Cerebellar Hemispheres (lower right) of Raz et al. (2005).

Usage

```
raz2005
```

Format

A data frame with 144 rows and 4 variables

[,1]	Participant	Participant ID
[,2]	Time	Measurement time
[,3]	Age	Participant's age (years)
[,4]	Volume	Adjusted volume of cerebellar hemispheres (cm^3)

Source

Raz, N., Lindenberger, U., Rodrigue, K.M., Kennedy, K.M., Head, D., Williamson, A., Dahle, C., Gerstorf, D., & Acker, J.D. (2005). Regional brain changes in aging healthy adults: General trends, individual differences, and modifiers. *Cerebral Cortex, 15*, 1676-1689, doi:10.1093/cercor/bhi044

rmcorr *Calculate the repeated measures correlation coefficient.*

Description

Calculate the repeated measures correlation coefficient.

Usage

```
rmcorr(
  participant,
  measure1,
  measure2,
  dataset,
  CI.level = 0.95,
  CIs = c("analytic", "bootstrap"),
  nreps = 100,
  bstrap.out = F
)
```

Arguments

participant	A variable giving the subject name/id for each observation.
measure1	A numeric variable giving the observations for one measure.
measure2	A numeric variable giving the observations for the second measure.
dataset	The data frame containing the variables.
CI.level	The confidence level of the interval
CIs	The method of calculating confidence intervals.
nreps	The number of resamples to take if bootstrapping.
bstrap.out	Determines if the output include the bootstrap resamples.

Value

A list with class "rmc" containing the following components.

r	the value of the repeated measures correlation coefficient.
df	the degrees of freedom
p	the p-value for the repeated measures correlation coefficient.
CI	the 95% confidence interval for the repeated measures correlation coefficient.
model	the multiple regression model used to calculate the correlation coefficient.
resamples	the bootstrap resampled correlation values.

References

Bakdash, J.Z., & Marusich, L.R. (2017). Repeated Measures Correlation. *Frontiers in Psychology, 8*, 456, doi:10.3389/fpsyg.2017.00456.

Bakdash, J. Z., & Marusich, L. R. (2019). Corrigendum: Repeated Measures Correlation. *Frontiers in Psychology, 10*, doi:10.3389/fpsyg.2019.01201.

Bland, J.M., & Altman, D.G. (1995a). Calculating correlation coefficients with repeated observations: Part 1 – correlation within subjects. *BMJ, 310*, 446, doi:10.1136/bmj.310.6977.446

Bland, J.M., & Altman, D.G. (1995b). Calculating correlation coefficients with repeated observations: Part 2 – correlation within subjects. *BMJ, 310*, 633, doi:10.1136/bmj.310.6980.633

See Also

`plot.rmc`, `geom_rmc`

Examples

```
## Bland Altman 1995 data
rmcorr(Subject, PaCO2, pH, bland1995)
```

`rmcorr_mat` *Create a repeated measures correlation matrix.*

Description

Create a repeated measures correlation matrix.

Usage

```
rmcorr_mat(participant, variables, dataset, CI.level = 0.95)
```

Arguments

`participant`	A variable giving the subject name/id for each observation.
`variables`	A character vector indicating the columns of variables to include in the correlation matrix.
`dataset`	The data frame containing the variables.
`CI.level`	The level of confidence intervals to use in the rmcorr models.

Value

A list with class "rmcmat" containing the following components.

`matrix`	the repeated measures correlation matrix
`summary`	a dataframe showing rmcorr stats for each pair of variables
`models`	a list of the full rmcorr model for each pair of variables

References

Bakdash, J.Z., & Marusich, L.R. (2017). Repeated Measures Correlation. *Frontiers in Psychology, 8*, 456. doi:10.3389/fpsyg.2017.00456.

Bland, J.M., & Altman, D.G. (1995). Calculating correlation coefficients with repeated observations: Part 1 – correlation within subjects. *BMJ, 310*, 446, doi:10.1136/bmj.310.6977.446.

Cohen, P., West, S. G., & Aiken, L. S. (2002). *Applied multiple regression/correlation analysis for the behavioral sciences* (3rd edition), Routledge. ISBN: 9780805822236.

See Also

`rmcorr`, `plot.rmc`

Examples

```
dist_rmc_mat <- rmcorr_mat(participant = Subject,
                           variables = c("Blindwalk Away",
                                         "Blindwalk Toward",
                                         "Triangulated BW",
                                         "Verbal",
                                         "Visual matching"),
                           dataset = twedt_dist_measures,
                           CI.level = 0.95)
plot(dist_rmc_mat$models[[2]])
```

`twedt_dist_measures` *Repeated measures and multivariate measures of perceived distance*

Description

A dataset of repeated measures of distance perception at physical distances of 7, 8, 9, 10, and 11 meters. The data are also multivariate, with five dependent measures of distance perception. This is a 5 (physical distance) x 5 (dependent measure) within-participants design with a sample size of 46. Note data is missing for 15 trials due to participant and experimenter errors.

Usage

```
twedt_dist_measures
```

Format

A data frame with 230 rows and 7 columns

`[,1]`	`Subject`	Unique identifier for each participant
`[,2]`	`Physical Distance`	Physical distance from the participant to the target cone, in meters
`[,3]`	`Blindwalk Away`	Participants put on the blindfold after viewing the target. Next, participants took one step to th
`[,4]`	`Blindwalk Toward`	Participants put on the blindfold after viewing the target. Next, participants walked forward ur
`[,5]`	`Triangulated BW`	Participants put on the blindfold after viewing the target. Next, participants turned right 90 deg

[,6]	Verbal	Participants stated the distance between the target cone and themselves, in feet and inches
[,7]	Visual Matching	An experimenter stood next to the target cone and walked away from the cone in a straight lin

Source

Twedt, E. Bakdash, J.Z., and Proffitt, D.R. (2022). Repeated and multivariate measures of perceived distance (Dataset) doi:10.5281/zenodo.6967162

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