

# Package ‘GLMMRR’

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**Type** Package

**Title** Generalized Linear Mixed Model (GLMM) for Binary Randomized Response Data

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**Imports** lattice, stats, utils, grDevices, RColorBrewer

**Description** Generalized Linear Mixed Model (GLMM) for Binary Randomized Response Data. Includes Cauchit, Compl. Log-Log, Logistic, and Probit link functions for Bernoulli Distributed RR data. RR Designs: Warner, Forced Response, Unrelated Question, Kuk, Crosswise, and Triangular. Reference: Fox, J-P, Veen, D. and Klotzke, K. (2018). Generalized Linear Mixed Models for Randomized Responses. Methodology. <[doi:10.1027/1614-2241/a000153](https://doi.org/10.1027/1614-2241/a000153)>.

**License** GPL-3

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 ETHBE

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*Online Survey on "Exams and Written Papers"*


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## Description

The goal of the survey was to estimate the prevalence of various forms of student misconduct such as plagiarizing or cheating in exams. Because students might be reluctant to reveal information on such behaviors, special techniques for sensitive questions were employed in addition to direct questioning. Respondents were randomly assigned to direct questioning or one of five different sensitive question techniques. The dataset contains the (randomized or direct) responses from 4281 students of the University of Bern and ETH Zurich. Each row holds the response to one question for one respondent. The variables are as follows:

## Usage

```
data(ETHBE)
```

## Format

A data frame in long format with 21405 rows and 29 variables

**Details**

- id. Identification code of the respondent
- RR\_response. Binary randomized or direct response
- Question. Which question was asked
- expcond. Experimental condition
- protect. Level of respondent protection
- subgroup. Subgroups for balanced assignment to experimental conditions
- sample. Sample group
- survey duration. Total time to complete survey (in seconds)
- mobile. Respondent used mobile device (at start of interview)
- java. Javascript version (at start of interview)
- age\_cat. Year of birth category
- gender. Gender
- misconduct. Sum score of five binary items on student misconduct
- misconduct2. String of responses to five binary items on student misconduct
- field. Major field of study
- education. Type of study program
- semester. Current semester
- working. Working next to studying
- germanlang. German language skills
- riskattitude. Risk attitude (GSOEP 11-point scale)
- gpa. Current grade point average
- pressure. Studying is a lot of pressure
- stressed. Feeling very stressed in exams
- exams. Number of exams taken
- numberpapers. Number of papers handed in
- RRmodel. Randomized Response Model
- p1. Randomized Response parameter p1
- p2. Randomized Response parameter p2

**Author(s)**

Marc Hoeglinger, Ben Jann and Andreas Diekmann

**References**

<https://ideas.repec.org/p/bss/wpaper/8.html>

---

getCellMeans	<i>Get cell means for unique groups of covariates</i>
--------------	---

---

**Description**

Get cell means for unique groups of covariates

**Usage**

```
getCellMeans(x, y, factor.groups)
```

**Arguments**

x a matrix-like object containing the covariates.  
y a vector of values to compute the means from.  
factor.groups a factor of unique groups of covariates.

**Value**

the cell means.

---

getCellSizes	<i>Get number of units in each cell</i>
--------------	---

---

**Description**

Get number of units in each cell

**Usage**

```
getCellSizes(x, n, factor.groups)
```

**Arguments**

x a matrix-like object containing the covariates.  
n the total number of units.  
factor.groups a factor of unique groups of covariates.

**Value**

the number of units in each cell.

---

getMLPrevalence      *Compute Estimated Population Prevalence*

---

**Description**

Compute Estimated Population Prevalence

**Usage**

```
getMLPrevalence(mu, n, c, d)
```

**Arguments**

mu	observed mean response.
n	number of units.
c	randomized response parameter c.
d	randomized response parameter d.

**Value**

maximum likelihood estimate of the population prevalence and its variance.

---

getRRparameters      *Compute Randomized Response parameters*

---

**Description**

Compute Randomized Response parameters

**Usage**

```
getRRparameters(vec.RRmodel, vec.p1, vec.p2)
```

**Arguments**

vec.RRmodel	a character vector of Randomized Response models.
vec.p1	a numeric vector of p1 values.
vec.p2	a numeric vector of p2 values.

**Value**

a list with c and d values.

getUniqueGroups      *Get unique groups of covariates*

---

**Description**

Get unique groups of covariates

**Usage**

```
getUniqueGroups(x)
```

**Arguments**

x                      a matrix-like object containing the covariates.

**Value**

a factor of unique groups.

---

MTURK

*MTurk Survey on "Mood and Personality"*

---

**Description**

Data from an online validation experiment in which respondents' self-reports of norm breaking behavior were validated against observed actual behavior. After playing a dice game, respondents were asked whether they played honestly, using one of several randomly assigned sensitive question techniques. Furthermore, three other sensitive questions on shoplifting, tax evasion, and voting were asked. The dataset contains the randomized responses from 6152 Amazon Mechanical Turk (MTURK) workers. Each row holds the response to one question for one respondent. The variables are as follows:

**Usage**

```
data(MTURK)
```

**Format**

A data frame in long format with 24594 rows and 26 variables

**Details**

- id. Identification code of the respondent
- Question. Which question was asked
- RR\_response. Binary randomized response
- RRp1. Randomized Response parameter p1
- RRp2. Randomized Response parameter p2
- RRmodel. Randomized Response Model
- dicegame. Dice game assignment (1: prediction, 2: roll-a-six)
- cheater. The respondent is classified as honest or cheater if dice game assignment was 'roll-a-six'
- agecategory. Age category
- education. Level of education
- employment. Employment status
- locationinterview. Interview location
- extraversion. Extraversion score on a scale of 2-10
- agreeableness. Agreeableness score on a scale of 2-10
- conscientiousness. Conscientiousness score on a scale of 2-10
- neuroticism. Neuroticism score on a scale of 2-10
- openness. Openness score on a scale of 2-10
- gender. Gender (0: female, 1: male)
- age. Age in years
- privacyquestion1. How well are respondents' anonymity and privacy protected? (1: very poorly, 2: rather poorly, 3: moderately, 4: rather well, 5: very well)
- privacyquestion2. How likely could respondents' sensitive behavior be disclosed by this survey? (1: impossible, 2: not likely, 3: somewhat likely, 4: quite likely, 5: very likely)
- privacyquestion3. Does the special technique absolutely protect your answers? (1: not at all, 2: a little, 3: moderately, 4: quite a bit, 5: definitely)
- privacyquestion4. Do you think you properly followed the instructions for the special technique? (1: not at all, 2: a little, 3: moderately, 4: quite a bit, 5: definitely)
- privacyquestion5. Did you understand how the technique protects respondents? (1: not at all, 2: a little, 3: moderately, 4: quite a bit, 5: definitely)
- region. Region code
- country. Country

**Author(s)**

Marc Hoeglinger and Ben Jann

**References**

<https://ideas.repec.org/p/bss/wpaper/17.html>

---

Plagiarism	<i>An Experimental Survey Measuring Plagiarism Using the Crosswise Model</i>
------------	--

---

### Description

A dataset containing the responses to sensitive questions about plagiarism and other attributes of 812 students. The crosswise model (CM) and direct questioning (DQ) were utilized to gather the data. Each row holds the response to one question for one student. The variables are as follows:

### Usage

```
data(Plagiarism)
```

### Format

A data frame in long format with 812 rows and 24 variables

### Details

- id. Identification code of the student
- question. Which question was asked (1 and 3: Partial Plagiarism, 2 and 4: Severe Plagiarism)
- response. Binary randomized response
- gender. Gender of the student (0: male, 1: female)
- age. Age in years
- nationality. Nationality of the student (0: German or Swiss, 1: other)
- no\_papers. Number of papers
- uni. Location of data collection (1: ETH Zurich, 2: LMU Munich, 3: University Leipzig)
- course. Course in which the data was collected
- Aspired\_Degree. Aspired degree of the student
- Semester. semesters enrolled
- ur\_none. Used resources: none
- ur\_books. Used resources: books
- ur\_art. Used resources: articles
- ur\_int. Used resources: internet
- ur\_fsp. Used resources: fellow students' papers
- ur\_other. Used resources: other
- preading. Proofreading
- gradesf. Satisfaction with grades
- pp. Plagiarism indicator (0: Severe Plagiarism, 1: Partial Plagiarism)
- RR. Randomized Response indicator (0: DQ, 1: Crosswise)
- RRp1. Randomized Response parameter p1
- RRp2. Randomized Response parameter p2
- RRmodel. Randomized Response Model

**Author(s)**

Ben Jann and Laurence Brandenberger

**References**

[doi:10.7892/boris.51190](https://doi.org/10.7892/boris.51190)

---

plot.RRglm

*Plot diagnostics for a RRglm object*

---

**Description**

Six plots (selectable by which) are currently available: (1) a plot of estimated population prevalence per RR model, (2) a plot of estimated population prevalence per protection level, (3) a plot of ungrouped residuals against fitted response probability, (4) a plot of grouped (on covariates) residuals against fitted response probability, (5) a plot of grouped Hosmer-Lemeshow residuals against fitted response probability, and (6) a Normal Q-Q plot of grouped (on covariates) residuals. By default, plots 1, 3, 4 and 6 are provided.

**Usage**

```
## S3 method for class 'RRglm'
plot(
  x,
  which = c(1, 3, 4, 6),
  type = c("deviance", "pearson"),
  ngroups = 10,
  ...
)
```

**Arguments**

x	an object of class RRglm.
which	if a subset of the plots is required, specify a subset of the numbers 1:6 (default: 1, 3, 4, 6).
type	the type of residuals which should be used to be used for plots 3, 4 and 6. The alternatives are: "deviance" (default) and "pearson".
ngroups	the number of groups to compute the Hosmer-Lemeshow residuals for (default: 10).
...	further arguments passed to or from other methods.

**Examples**

```
out <- RRglm(response ~ Gender + RR + pp + age, link="RRlink.logit", RRmodel=RRmodel,
             p1=RRp1, p2=RRp2, data=Plagiarism, etastart=rep(0.01, nrow(Plagiarism)))
plot(out, which = 1:6, type = "deviance", ngroups = 50)
```

---

plot.RRglmerMod      *Plot diagnostics for a RRglmerMod object*

---

### Description

Five plots (selectable by which) are currently available: (1) a plot of estimated population prevalence per RR model, (2) a plot of estimated population prevalence per protection level, (3) a plot of random effects and their conditional variance (95 (4) a plot of conditional pearson residuals against fitted randomized response probability, and (5) a plot of unconditional pearson residuals against fitted randomized response probability. By default, plots 1, 3, 4 and 5 are provided.

### Usage

```
## S3 method for class 'RRglmerMod'
plot(x, which = c(1, 3, 4, 5), ...)
```

### Arguments

x	an object of class RRglmerMod.
which	if a subset of the plots is required, specify a subset of the numbers 1:5 (default: 1, 3, 4, 5).
...	further arguments passed to or from other methods.

### Examples

```
out <- RRglmer(response ~ Gender + RR + pp + (1+pp|age), link="RRlink.logit", RRmodel=RRmodel,
  p1=RRp1, p2=RRp2, data=Plagiarism, na.action = "na.omit",
  etastart = rep(0.01, nrow(Plagiarism)),
  control = glmerControl(optimizer = "Nelder_Mead", tolPwrss = 1e-03), nAGQ = 1)
plot(out, which = 1:5)
```

---

print.RRglmGOF      *Print RRglmGOF values*

---

### Description

Print RRglmGOF values

### Usage

```
## S3 method for class 'RRglmGOF'
print(x, digits = 3, ...)
```

### Arguments

x                    an object of class RRglmGOF.  
digits                minimal number of *significant digits* (default: 3).  
...                    further arguments passed to or from other methods.

---

`print.summary.RRglm`    *Print RRglm summary*

---

### Description

Print RRglm summary

### Usage

```
## S3 method for class 'summary.RRglm'  
print(  
  x,  
  printPrevalence = TRUE,  
  printPrevalencePerLevel = FALSE,  
  printResiduals = FALSE,  
  digits = 5,  
  ...  
)
```

### Arguments

x                    an object of class `summary.RRglm`.  
`printPrevalence`    print estimated population prevalence per item and RR model (default: true).  
`printPrevalencePerLevel`    print estimated population prevalence per item, RRmodel and protection level (default: false).  
`printResiduals`    print deviance residuals (default: false).  
digits                minimal number of *significant digits* (default: 5).  
...                    further arguments passed to or from other methods.

---

```
print.summary.RRglmerMod
```

*Print RRglmer summary*

---

**Description**

Print RRglmer summary

**Usage**

```
## S3 method for class 'summary.RRglmerMod'
print(
  x,
  printPrevalence = TRUE,
  printPrevalencePerLevel = FALSE,
  printResiduals = FALSE,
  digits = 5,
  ...
)
```

**Arguments**

`x` an object of class `summary.RRglmerMod`.

`printPrevalence` print estimated population prevalence per item and RR model (default: true).

`printPrevalencePerLevel` print estimated population prevalence per item, RRmodel and protection level (default: false).

`printResiduals` print conditional deviance residuals (default: false).

`digits` minimal number of *significant digits* (default: 5).

`...` further arguments passed to or from other methods.

---

```
residuals.RRglm
```

*Accessing GLMMRR Fits for fixed-effect models*

---

**Description**

Compute residuals for RRglm objects. Extends [residuals.glm](#) with residuals for grouped binary Randomized Response data.

**Usage**

```
## S3 method for class 'RRglm'
residuals(
  object,
  type = c("deviance", "pearson", "working", "response", "partial", "deviance.grouped",
           "pearson.grouped", "hosmer-lemeshow"),
  ngroups = 10,
  ...
)
```

**Arguments**

object	an object of class RRglm.
type	the type of residuals which should be returned. The alternatives are: "deviance" (default), "pearson", "working", "response", "partial", "deviance.grouped", "pearson.grouped" and "hosmer-lemeshow".
ngroups	the number of groups if Hosmer-Lemeshow residuals are computed (default: 10).
...	further arguments passed to or from other methods.

**Value**

A vector of residuals.

**See Also**

[residuals.glm](#)

---

residuals.RRglmerMod *Accessing GLMMRR Fits for mixed-effect models*

---

**Description**

Compute residuals for RRglmer objects. Extends [residuals.glmResp](#) to access conditional and unconditional residuals for grouped binary Randomized Response data.

**Usage**

```
## S3 method for class 'RRglmerMod'
residuals(
  object,
  type = c("deviance", "pearson", "working", "response", "partial",
           "unconditional.response", "unconditional.pearson"),
  ...
)
```

**Arguments**

object	an object of class RRGlmr.
type	the type of residuals which should be returned. The alternatives are: "deviance" (default), "pearson", "working", "response", "partial", "unconditional.response" and "unconditional.pearson".
...	further arguments passed to or from other methods.

**Value**

A vector of residuals.

**See Also**

[residuals.glmResp](#)

---

RRbinomial

*Binomial family adjusted for Randomized Response parameters.*

---

**Description**

The upper and lower limits for  $\mu$ 's depend on the Randomized Response parameters.

**Usage**

```
RRbinomial(link, c, d, ...)
```

**Arguments**

link	a specification for the model link function. Must be an object of class "link-glm".
c	a numeric vector containing the parameter c.
d	a numeric vector containing the parameter d.
...	other potential arguments to be passed to <a href="#">binomial</a> .

**Value**

A binomial family object.

**See Also**

[family](#)

---

RRglm	<i>Fitting Generalized Linear Models with binary Randomized Response data</i>
-------	---

---

### Description

Fit a generalized linear model (GLM) with binary Randomized Response data. Implemented as a wrapper for [glm](#). Reference: Fox, J-P, Veen, D. and Klotzke, K. (2018). Generalized Linear Mixed Models for Randomized Responses. *Methodology*. <https://doi.org/10.1027/1614-2241/a000153>

### Usage

```
RRglm(formula, link, item, RRmodel, p1, p2, data, na.action = "na.omit", ...)
```

### Arguments

formula	a two-sided linear formula object describing the model to be fitted, with the response on the left of a ~ operator and the terms, separated by + operators, on the right.
link	a glm link function for binary outcomes. Must be a function name. Available options: "RRlink.logit", "RRlink.probit", "RRlink.cloglog" and "RRlink.cauchit"
item	optional item identifier for long-format data.
RRmodel	the Randomized Response model, defined per case. Available options: "DQ", "Warner", "Forced", "UQM", "Crosswise", "Triangular" and "Kuk"
p1	the Randomized Response parameter p1, defined per case. Must be $0 \leq p1 \leq 1$ .
p2	the Randomized Response parameter p2, defined per case. Must be $0 \leq p2 \leq 1$ .
data	a data frame containing the variables named in <a href="#">formula</a> as well as the Randomized Response model and parameters. If the required information cannot be found in the data frame, or if no data frame is given, then the variables are taken from the environment from which RRglm is called.
na.action	a function that indicates what should happen when the data contain NAs. The default action ( <a href="#">na.omit</a> , as given by <code>getOption("na.action")</code> ) strips any observations with any missing values in any variables.
...	other potential arguments to be passed to <a href="#">glm</a> .

### Value

An object of class RRglm. Extends the class glm with Randomize Response data.

### See Also

[glm](#)

**Examples**

```
# Fit the model with fixed effects for gender, RR, pp and age using the logit link function.
# The Randomized Response parameters p1, p2 and model
# are specified for each observation in the dataset.
out <- RRglm(response ~ Gender + RR + pp + age, link="RRlink.logit", RRmodel=RRmodel,
             p1=RRp1, p2=RRp2, data=Plagiarism, etastart=rep(0.01, nrow(Plagiarism)))
summary(out)
```

RRglmer

*Fitting Generalized Linear Mixed-Effects Models with binary Randomized Response data*

**Description**

Fit a generalized linear mixed-effects model (GLMM) with binary Randomized Response data. Both fixed effects and random effects are specified via the model formula. Randomize response parameters can be entered either as single values or as vectors. Implemented as a wrapper for [glmer](#). Reference: Fox, J-P, Veen, D. and Klotzke, K. (2018). Generalized Linear Mixed Models for Randomized Responses. *Methodology*. <https://doi.org/10.1027/1614-2241/a000153>

**Usage**

```
RRglmer(
  formula,
  item,
  link,
  RRmodel,
  p1,
  p2,
  data,
  control = glmerControl(),
  na.action = "na.omit",
  ...
)
```

**Arguments**

formula	a two-sided linear formula object describing both the fixed-effects and fixed-effects part of the model, with the response on the left of a ~ operator and the terms, separated by + operators, on the right. Random-effects terms are distinguished by vertical bars (" ") separating expressions for design matrices from grouping factors.
item	optional item identifier for long-format data.
link	a glm link function for binary outcomes. Must be a function name. Available options: "RRlink.logit", "RRlink.probit", "RRlink.cloglog" and "RRlink.cauchit"
RRmodel	the Randomized Response model, defined per case. Available options: "DQ", "Warner", "Forced", "UQM", "Crosswise", "Triangular" and "Kuk"

p1	the Randomized Response parameter p1, defined per case. Must be $0 \leq p1 \leq 1$ .
p2	the Randomized Response parameter p2, defined per case. Must be $0 \leq p2 \leq 1$ .
data	a data frame containing the variables named in <code>formula</code> as well as the Randomized Response model and parameters. If the required information cannot be found in the data frame, or if no data frame is given, then the variables are taken from the environment from which <code>RRglm</code> is called.
control	a list (of correct class, resulting from <code>lmerControl()</code> or <code>glmerControl()</code> respectively) containing control parameters, including the nonlinear optimizer to be used and parameters to be passed through to the nonlinear optimizer, see the <code>lmerControl</code> documentation for details.
na.action	a function that indicates what should happen when the data contain NAs. The default action ( <code>na.omit</code> , as given by <code>getOption("na.action")</code> ) strips any observations with any missing values in any variables.
...	other potential arguments to be passed to <code>glmer</code> .

### Value

An object of class `RRglmMod`. Extends the class `glmerMod` with Randomize Response data, for which many methods are available (e.g. `methods(class="glmerMod")`).

### See Also

[glmer](#)

### Examples

```
# Fit the model with fixed effects for gender, RR and pp
# and a random effect for age using the logit link function.
# The Randomized Response parameters p1, p2 and model
# are specified for each observation in the dataset.
out <- RRglm(response ~ Gender + RR + pp + (1|age), link="RRlink.logit", RRmodel=RRmodel,
             p1=RRp1, p2=RRp2, data=Plagiarism, na.action = "na.omit",
             etastart = rep(0.01, nrow(Plagiarism)),
             control = glmerControl(optimizer = "Nelder_Mead", tolPwrss = 1e-03), nAGQ = 1)
summary(out)
```

---

RRglmGOF

*Goodness-of-fit statistics for binary Randomized Response data*

---

### Description

Compute goodness-of-fit statistics for binary Randomized Response data. Pearson, Deviance and Hosmer-Lemeshow statistics are available.

**Usage**

```
RRglmGOF(
  RRglmOutput,
  doPearson = TRUE,
  doDeviance = TRUE,
  doHlemeshow = TRUE,
  hlemeshowGroups = 10,
  rm.na = TRUE
)
```

**Arguments**

RRglmOutput	a model fitted with the <a href="#">RRglm</a> function.
doPearson	compute Pearson statistic.
doDeviance	compute Deviance statistic.
doHlemeshow	compute Hosmer-Lemeshow statistic.
hlemeshowGroups	number of groups to split the data into for the Hosmer-Lemeshow statistic (default: 10).
rm.na	remove cases with missing data.

**Value**

an option of class RRglmGOF.

**Examples**

```
out <- RRglm(response ~ Gender + RR + pp + age, link="RRlink.logit", RRmodel=RRmodel,
             p1=RRp1, p2=RRp2, data=Plagiarism, etastart=rep(0.01, nrow(Plagiarism)))
RRglmGOF(RRglmOutput = out, doPearson = TRUE, doDeviance = TRUE, doHlemeshow = TRUE)
```

---

RRlink.cauchit

*Cauchit link function with Randomized Response parameters.*


---

**Description**

Cauchit link function with Randomized Response parameters.

**Usage**

```
RRlink.cauchit(c, d)
```

**Arguments**

c	a numeric vector containing the parameter c.
d	a numeric vector containing the parameter d.

**Value**

RR link function.

---

RRlink.cloglog	<i>Log-Log link function with Randomized Response parameters.</i>
----------------	---

---

**Description**

Log-Log link function with Randomized Response parameters.

**Usage**

```
RRlink.cloglog(c, d)
```

**Arguments**

c	a numeric vector containing the parameter c.
d	a numeric vector containing the parameter d.

**Value**

RR link function.

---

RRlink.logit	<i>Logit link function with Randomized Response parameters.</i>
--------------	---

---

**Description**

Logit link function with Randomized Response parameters.

**Usage**

```
RRlink.logit(c, d)
```

**Arguments**

c	a numeric vector containing the parameter c.
d	a numeric vector containing the parameter d.

**Value**

RR link function.

---

RRlink.probit	<i>Probit link function with Randomized Response parameters.</i>
---------------	--

---

**Description**

Probit link function with Randomized Response parameters.

**Usage**

```
RRlink.probit(c, d)
```

**Arguments**

c	a numeric vector containing the parameter c.
d	a numeric vector containing the parameter d.

**Value**

RR link function.

---

summary.RRglm	<i>Summarizing GLMMRR fits for fixed-effect models</i>
---------------	--

---

**Description**

Summarizing GLMMRR fits for fixed-effect models

**Usage**

```
## S3 method for class 'RRglm'
summary(object, p1p2.digits = 2, ...)
```

**Arguments**

object	an object of class RRglm.
p1p2.digits	number of digits for aggregating data based on the level of protection (default: 2).
...	further arguments passed to or from other methods.

**Value**

An object of class summary.RRglm. Extends the class summary.glm with Randomize Response data.

---

summary.RRglmerMod      *Summarizing GLMMRR fits for fixed-effect models*

---

**Description**

Summarizing GLMMRR fits for fixed-effect models

**Usage**

```
## S3 method for class 'RRglmerMod'  
summary(object, p1p2.digits = 2, ...)
```

**Arguments**

object	an object of class RRglm.
p1p2.digits	number of digits for aggregating data based on the level of protection (default: 2).
...	further arguments passed to or from other methods.

**Value**

An object of class summary.RRglmerMod. Extends the class summary.glmMod with Randomize Response data.

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