

# Package ‘jfa’

July 16, 2023

**Title** Statistical Methods for Auditing

**Version** 0.6.7

**Date** 2023-07-14

**Description** Provides statistical methods for auditing as implemented in JASP for Audit (Derks et al., 2021 <[doi:10.21105/joss.02733](https://doi.org/10.21105/joss.02733)>). First, the package makes it easy for an auditor to plan a statistical sample, select the sample from the population, and evaluate the misstatement in the sample compliant with international auditing standards. Next to classical audit sampling methodology, the package implements Bayesian equivalents of these methods whose statistical underpinnings are described in Derks et al. (2021) <[doi:10.1111/jjau.12240](https://doi.org/10.1111/jjau.12240)>, Derks et al. (2021) <[doi:10.31234/osf.io/kzqp5](https://doi.org/10.31234/osf.io/kzqp5)>, and Derks et al. (2022) <[doi:10.31234/osf.io/8nf3e](https://doi.org/10.31234/osf.io/8nf3e)>. Second, the package provides statistical methods for auditing data, including (Bayesian) tests of digit distributions and tests for repeated values.

**Depends** R (>= 3.5.0)

**Imports** bde (>= 1.0.1.1), extraDistr (>= 1.9.1), ggplot2 (>= 3.4.2), methods, Rcpp (>= 0.12.0), RcppParallel (>= 5.0.1), rstan (>= 2.18.1), rstantools (>= 2.2.0), stats, truncdist (>= 1.0-2)

**Suggests** benford.analysis (>= 0.1.5), BenfordTests (>= 1.2.0), BeyondBenford (>= 1.4), kableExtra (>= 1.3.4), knitr, MUS (>= 0.1.6), rmarkdown, samplingbook (>= 1.2.4), testthat

**LinkingTo** BH (>= 1.66.0), Rcpp (>= 0.12.0), RcppEigen (>= 0.3.3.3.0), RcppParallel (>= 5.0.1), rstan (>= 2.18.1), StanHeaders (>= 2.18.0)

**VignetteBuilder** knitr

**URL** <https://koenderks.github.io/jfa/>, <https://github.com/koenderks/jfa>

**BugReports** <https://github.com/koenderks/jfa/issues>

**License** GPL (>= 3)

**Encoding** UTF-8

**LazyData** true

**NeedsCompilation** yes

**SystemRequirements** C++17, GNU make

**Language** en-US

**RoxygenNote** 7.2.3

**Biarch** true

**Author** Koen Derks [aut, cre] (<<https://orcid.org/0000-0002-5533-9349>>)

**Maintainer** Koen Derks <k.derks@nyenrode.nl>

**Repository** CRAN

**Date/Publication** 2023-07-16 14:40:07 UTC

## R topics documented:

jfa-package	2
allowances	4
auditPrior	4
benchmark	9
BuildIt	10
carrier	10
digit_test	11
evaluation	13
jfa-methods	18
planning	20
repeated_test	24
report	26
retailer	27
sanitizer	27
selection	28
sinoForest	31
<b>Index</b>	<b>32</b>

---

jfa-package

*jfa — Statistical Methods for Auditing*

---

## Description

jfa is an R package that provides statistical methods for auditing. The package includes functions for planning, performing, evaluating, and reporting an audit sample compliant with international auditing standards, as well as functions for auditing data, such as testing the distribution of leading digits in the data against Benford's law. In addition to offering classical frequentist methods, jfa also provides a straightforward implementation of their Bayesian counterparts.

The functionality of the jfa package and its intended workflow are implemented with a graphical user interface in the Audit module of **JASP**, a free and open-source software program for statistical analyses.

For documentation on jfa itself, including the manual and user guide for the package, worked examples, and other tutorial information visit the [package website](#).

**Author(s)**

Koen Derks (maintainer, author) <k.derks@nyenrode.nl>

Please use the citation provided by R when citing this package. A BibTeX entry is available from `citation('jfa')`.

**See Also**

Useful links:

- The [vignettes](#) for worked examples.
- The [issue page](#) to submit a bug report or feature request.

**Examples**

```
# Load the jfa package
library(jfa)

#####
### Example 1: Audit sampling ###
#####

# Load the BuildIt population
data('BuildIt')

# Stage 1: Planning
stage1 <- planning(materiality = 0.03, expected = 0.01)
summary(stage1)

# Stage 2: Selection
stage2 <- selection(data = BuildIt, size = stage1,
                    units = 'values', values = 'bookValue',
                    method = 'interval', start = 1)
summary(stage2)

# Stage 3: Execution
sample <- stage2[['sample']]

# Stage 4: Evaluation
stage4 <- evaluation(data = sample, method = 'stringer',
                    values = 'bookValue', values.audit = 'auditValue')
summary(stage4)

#####
### Example 2: Data auditing ###
#####

# Load the sinoForest data set
```

```
data('sinoForest')

# Test first digits in the data against Benford's law
digit_test(sinoForest[["value"]], check = "first", reference = "benford")
```

---

allowances

*Legitimacy Audit*


---

### Description

Fictional population from a legitimacy audit, containing 4189 records with identification numbers, stratum identifiers, book values, and audit values. The audit values are added for illustrative purposes, as these would need to be assessed by the auditor in the execution stage of the audit.

### Usage

```
data(allowances)
```

### Format

A data frame with 4189 rows and 5 variables.

**item** a unique record identification number.

**branch** the stratum identifier / branch number.

**bookValue** the item book value in US dollars.

**auditValue** the item audit (true) value in US dollars.

**times** a sample selection indicator ( $\emptyset$  = not in sample).

### Examples

```
data(allowances)
```

---

auditPrior

*Audit Sampling: Prior Distributions*


---

### Description

`auditPrior()` is used to create a prior distribution for Bayesian audit sampling. The interface allows a complete customization of the prior distribution as well as a formal translation of pre-existing audit information into a prior distribution. The function returns an object of class `jfaPrior` that can be used in the `planning()` and `evaluation()` functions via their `prior` argument. Objects with class `jfaPrior` can be further inspected via associated `summary()` and `plot()` methods. They can also be used to compute a convoluted prior using the `+` (for addition) and `*` (for weighing) operators.

**Usage**

```

auditPrior(
  method = c(
    "default", "param", "strict", "impartial", "hyp",
    "arm", "bram", "sample", "factor", "nonparam"
  ),
  likelihood = c(
    "poisson", "binomial", "hypergeometric",
    "normal", "uniform", "cauchy", "t", "chisq",
    "exponential"
  ),
  N.units = NULL,
  alpha = NULL,
  beta = NULL,
  materiality = NULL,
  expected = 0,
  ir = NULL,
  cr = NULL,
  ub = NULL,
  p.hmin = NULL,
  x = NULL, n = NULL,
  factor = NULL,
  samples = NULL,
  conf.level = 0.95
)

```

**Arguments**

method	a character specifying the method by which the prior distribution is constructed. Possible options are default, strict, impartial, param, arm, bram, hyp, sample, and factor. See the details section for more information.
likelihood	a character specifying the likelihood for updating the prior distribution. Possible options are poisson (default) for a conjugate gamma prior distribution, binomial for a conjugate beta prior distribution, or hypergeometric for a conjugate beta-binomial prior distribution. See the details section for more information.
N.units	a numeric value larger than 0 specifying the total number of units in the population. Required for the hypergeometric likelihood.
alpha	a numeric value specifying the $\alpha$ parameter of the prior distribution. Required for method param.
beta	a numeric value specifying the $\beta$ parameter of the prior distribution. Required for method param.
materiality	a numeric value between 0 and 1 specifying the performance materiality (i.e., the maximum tolerable misstatement in the population) as a fraction. Required for methods impartial, arm, and hyp.

expected	a numeric value between 0 and 1 specifying the expected (tolerable) misstatements in the sample relative to the total sample size. Required for methods impartial, arm, bram, and hyp.
ir	a numeric value between 0 and 1 specifying the inherent risk (i.e., the probability of material misstatement occurring due to inherent factors) in the audit risk model. Required for method arm.
cr	a numeric value between 0 and 1 specifying the internal control risk (i.e., the probability of material misstatement occurring due to internal control systems) in the audit risk model. Required for method arm.
ub	a numeric value between 0 and 1 specifying the conf.level-% upper bound for the prior distribution as a fraction. Required for method bram.
p.hmin	a numeric value between 0 and 1 specifying the prior probability of the hypothesis of tolerable misstatement ( $H1: \theta < \text{materiality}$ ). Required for method hyp.
x	a numeric value larger than, or equal to, 0 specifying the sum of proportional misstatements (taints) in a prior sample. Required for methods sample and factor.
n	a numeric value larger than 0 specifying the number of units in a prior sample. Required for methods sample and factor.
factor	a numeric value between 0 and 1 specifying the weight of a prior sample specified via x and n. Required for method factor.
samples	a numeric vector containing samples of the prior distribution. Required for method nonparam.
conf.level	a numeric value between 0 and 1 specifying the confidence level (1 - audit risk).

## Details

To perform Bayesian audit sampling you must assign a prior distribution to the parameter in the model, i.e., the population misstatement  $\theta$ . The prior distribution can incorporate pre-existing audit information about  $\theta$  into the analysis, which consequently allows for a more efficient or more accurate estimates. The default priors used by `jfa` are indifferent towards the possible values of  $\theta$ , while still being proper. Note that the default prior distributions are a conservative choice of prior since they, in most cases, assume all possible misstatement to be equally likely before seeing a data sample. It is recommended to construct an informed prior distribution based on pre-existing audit information when possible.

This section elaborates on the available input options for the method argument.

- `default`: This method produces a *gamma(1, 1)*, *beta(1, 1)*, *beta-binomial(N, 1, 1)*, *normal(0.5, 1000)*, *cauchy(0, 1000)*, *student-t(1)*, or *chi-squared(1)* prior distribution. These prior distributions are mostly indifferent about the possible values of the misstatement.
- `param`: This method produces a custom *gamma(alpha, beta)*, *beta(alpha, beta)*, *beta-binomial(N, alpha, beta)* prior distribution, *normal(alpha, beta)*, *cauchy(alpha, beta)*, *student-t(alpha)*, or *chi-squared(alpha)*. The alpha and beta parameters must be set using `alpha` and `beta`.
- `strict`: This method produces an improper *gamma(1, 0)*, *beta(1, 0)*, or *beta-binomial(N, 1, 0)* prior distribution. These prior distributions match sample sizes and upper limits from classical methods and can be used to emulate classical results.

- **impartial**: This method produces an impartial prior distribution. These prior distributions assume that tolerable misstatement ( $\theta < \text{materiality}$ ) and intolerable misstatement ( $\theta > \text{materiality}$ ) are equally likely.
- **hyp**: This method translates an assessment of the prior probability for tolerable misstatement ( $\theta < \text{materiality}$ ) to a prior distribution.
- **arm**: This method translates an assessment of inherent risk and internal control risk to a prior distribution.
- **bram**: This method translates an assessment of the expected most likely error and  $x$ -% upper bound to a prior distribution.
- **sample**: This method translates the outcome of an earlier sample to a prior distribution.
- **factor**: This method translates and weighs the outcome of an earlier sample to a prior distribution.
- **nonparam**: This method takes a vector of samples from the prior distribution (via samples) and constructs a bounded density (between 0 and 1) on the basis of these samples to act as the prior.

This section elaborates on the available input options for the likelihood argument and the corresponding conjugate prior distributions used by jfa.

- **poisson**: The Poisson distribution is an approximation of the binomial distribution. The Poisson distribution is defined as:

$$f(\theta, n) = \frac{\lambda^\theta e^{-\lambda}}{\theta!}$$

. The conjugate  $gamma(\alpha, \beta)$  prior has probability density function:

$$p(\theta; \alpha, \beta) = \frac{\beta^\alpha \theta^{\alpha-1} e^{-\beta\theta}}{\Gamma(\alpha)}$$

- **binomial**: The binomial distribution is an approximation of the hypergeometric distribution. The binomial distribution is defined as:

$$f(\theta, n, x) = \binom{n}{x} \theta^x (1 - \theta)^{n-x}$$

. The conjugate  $beta(\alpha, \beta)$  prior has probability density function:

$$p(\theta; \alpha, \beta) = \frac{1}{B(\alpha, \beta)} \theta^{\alpha-1} (1 - \theta)^{\beta-1}$$

- **hypergeometric**: The hypergeometric distribution is defined as:

$$f(x, n, K, N) = \frac{\binom{K}{x} \binom{N-K}{n-x}}{\binom{N}{n}}$$

. The conjugate  $beta\text{-binomial}(\alpha, \beta)$  prior (Dyer and Pierce, 1993) has probability mass function:

$$f(x, n, \alpha, \beta) = \binom{n}{x} \frac{B(x + \alpha, n - x + \beta)}{B(\alpha, \beta)}$$

**Value**

An object of class `jfaPrior` containing:

<code>prior</code>	a string describing the functional form of the prior distribution.
<code>description</code>	a list containing a description of the prior distribution, including the parameters of the prior distribution and the implicit sample on which the prior distribution is based.
<code>statistics</code>	a list containing statistics of the prior distribution, including the mean, mode, median, and upper bound of the prior distribution.
<code>specifics</code>	a list containing specifics of the prior distribution that vary depending on the method.
<code>hypotheses</code>	if <code>materiality</code> is specified, a list containing information about the hypotheses, including prior probabilities and odds for the hypothesis of tolerable misstatement (H1) and the hypothesis of intolerable misstatement (H0).
<code>method</code>	a character indicating the method by which the prior distribution is constructed.
<code>likelihood</code>	a character indicating the likelihood of the data.
<code>materiality</code>	if <code>materiality</code> is specified, a numeric value between 0 and 1 giving the materiality used to construct the prior distribution.
<code>expected</code>	a numeric value larger than, or equal to, 0 giving the input for the number of expected misstatements.
<code>conf.level</code>	a numeric value between 0 and 1 giving the confidence level.
<code>N.units</code>	if <code>N.units</code> is specified, the number of units in the population.

**Author(s)**

Koen Derks, <k.derks@nyenrode.nl>

**References**

- Derks, K., de Swart, J., van Batenburg, P., Wagenmakers, E.-J., & Wetzels, R. (2021). Priors in a Bayesian audit: How integration of existing information into the prior distribution can improve audit transparency and efficiency. *International Journal of Auditing*, 25(3), 621-636. doi:10.1111/ijau.12240
- Derks, K., de Swart, J., Wagenmakers, E.-J., Wille, J., & Wetzels, R. (2021). JASP for audit: Bayesian tools for the auditing practice. *Journal of Open Source Software*, 6(68), 2733. doi:10.21105/joss.02733
- Derks, K., de Swart, J., Wagenmakers, E.-J., & Wetzels, R. (2022). An impartial Bayesian hypothesis test for audit sampling. *PsyArXiv*. doi:10.31234/osf.io/8nf3e

**See Also**

[planning selection evaluation report](#)



## Examples

```
# Default beta prior
auditPrior(likelihood = "binomial")

# Impartial prior
auditPrior(method = "impartial", materiality = 0.05)

# Non-conjugate prior
auditPrior(method = "param", likelihood = "normal", alpha = 0, beta = 0.1)
```

---

benchmark

*Benchmark Analysis of Sales Versus Cost of Sales*

---

## Description

Fictional data from a benchmark analysis comparing industry sales versus the industry cost of sales.

## Usage

```
data(benchmark)
```

## Format

A data frame with 100 rows and 2 variables.

**sales** book value in US dollars (\$100,187,432–\$398,280,933).

**costofsales** true value in US dollars (\$71,193,639–\$309,475,784).

## References

Derks, K., de Swart, J., van Batenburg, P., Wagenmakers, E.-J., & Wetzels, R. (2021). Priors in a Bayesian audit: How integration of existing information into the prior distribution can improve audit transparency and efficiency. *International Journal of Auditing*, 25(3), 621-636. doi:[10.1111/ijau.12240](https://doi.org/10.1111/ijau.12240)

## Examples

```
data(benchmark)
```

---

**BuildIt***BuildIt Construction Financial Statements*

---

**Description**

Fictional data from a construction company in the United States, containing 3500 observations identification numbers, book values, and audit values. The audit values are added for illustrative purposes, as these would need to be assessed by the auditor in the execution stage of the audit.

**Usage**

```
data(BuildIt)
```

**Format**

A data frame with 3500 rows and 3 variables.

**ID** unique record identification number.

**bookValue** book value in US dollars (\$14.47–\$2,224.40).

**auditValue** true value in US dollars (\$14.47–\$2,224.40).

**References**

Derks, K., de Swart, J., Wagenmakers, E.-J., Wille, J., & Wetzels, R. (2021). JASP for audit: Bayesian tools for the auditing practice. *Journal of Open Source Software*, 6(68), 2733.

**Examples**

```
data(BuildIt)
```

---

**carrier***Carrier Company Financial Statements*

---

**Description**

Fictional data from a carrier company in Europe, containing 202 ledger items across 10 company entities.

**Usage**

```
data(carrier)
```

**Format**

A data frame with 202 rows and 12 variables.

**description** description of the ledger item.

**entity1** recorded values for entity 1, in US dollars.

**entity2** recorded values for entity 2, in US dollars.

**entity3** recorded values for entity 3, in US dollars.

**entity4** recorded values for entity 4, in US dollars.

**entity5** recorded values for entity 5, in US dollars.

**entity6** recorded values for entity 6, in US dollars.

**entity7** recorded values for entity 7, in US dollars.

**entity8** recorded values for entity 8, in US dollars.

**entity9** recorded values for entity 9, in US dollars.

**entity10** recorded values for entity 10, in US dollars.

**total** total value, in US dollars.

**Source**

<https://towardsdatascience.com/data-driven-audit-1-automated-sampling-using-python-52e83347add5>

**Examples**

```
data(carrier)
```

---

digit\_test

*Data Auditing: Digit Distribution Test*

---

**Description**

This function extracts and performs a test of the distribution of (leading) digits in a vector against a reference distribution. By default, the distribution of leading digits is checked against Benford's law.

**Usage**

```
digit_test(  
  x,  
  check = c("first", "last", "firsttwo"),  
  reference = "benford",  
  conf.level = 0.95,  
  prior = FALSE  
)
```

**Arguments**

x	a numeric vector.
check	location of the digits to analyze. Can be first, firsttwo, or last.
reference	which character string given the reference distribution for the digits, or a vector of probabilities for each digit. Can be benford for Benford's law, uniform for the uniform distribution. An error is given if any entry of reference is negative. Probabilities that do not sum to one are normalized.
conf.level	a numeric value between 0 and 1 specifying the confidence level (i.e., 1 - audit risk / detection risk).
prior	a logical specifying whether to use a prior distribution, or a numeric vector containing the prior parameters for the Dirichlet distribution on the digit categories.

**Details**

Benford's law is defined as  $p(d) = \log_{10}(1/d)$ . The uniform distribution is defined as  $p(d) = 1/d$ .

**Value**

An object of class `jfaDistr` containing:

observed	the observed counts.
expected	the expected counts under the null hypothesis.
n	the number of observations in x.
statistic	the value the chi-squared test statistic.
parameter	the degrees of freedom of the approximate chi-squared distribution of the test statistic.
p.value	the p-value for the test.
check	checked digits.
digits	vector of digits.
reference	reference distribution
match	a list containing the row numbers corresponding to the observations matching each digit.
data.name	a character string giving the name(s) of the data.

**Author(s)**

Koen Derks, <k.derks@nyenrode.nl>

**References**

Benford, F. (1938). The law of anomalous numbers. *In Proceedings of the American Philosophical Society*, 551-572.

**See Also**

[repeated\\_test](#)

**Examples**

```

set.seed(1)
x <- rnorm(100)

# First digit analysis against Benford's law
digit_test(x, check = "first", reference = "benford")

# Bayesian first digit analysis against Benford's law
digit_test(x, check = "first", reference = "benford", prior = TRUE)

# Last digit analysis against the uniform distribution
digit_test(x, check = "last", reference = "uniform")

# Bayesian last digit analysis against the uniform distribution
digit_test(x, check = "last", reference = "uniform", prior = TRUE)

# First digit analysis against a custom distribution
digit_test(x, check = "last", reference = 1:9)

# Bayesian first digit analysis against a custom distribution
digit_test(x, check = "last", reference = 1:9, prior = TRUE)

```

---

evaluation

*Audit Sampling: Evaluation*


---

**Description**

evaluation() is used to perform statistical inference about the misstatement in a population after auditing a statistical sample. It allows specification of statistical requirements for the sample with respect to the performance materiality or the precision. The function returns an object of class `jfaEvaluation` that can be used with associated `summary()` and `plot()` methods.

**Usage**

```

evaluation(
  materiality = NULL,
  method = c(
    "poisson", "binomial", "hypergeometric", "stringer",
    "stringer.meikle", "stringer.lta", "stringer.pvz", "rohrbach",
    "moment", "coxsnell", "direct", "difference", "quotient",
    "regression", "mpu"
  ),
  alternative = c("less", "two.sided", "greater"),
  conf.level = 0.95,
  data = NULL,
  values = NULL,
  values.audit = NULL,
  strata = NULL,

```

```

times = NULL,
x = NULL,
n = NULL,
N.units = NULL,
N.items = NULL,
pooling = c("none", "complete", "partial"),
prior = FALSE
)

```

### Arguments

<code>materiality</code>	a numeric value between 0 and 1 specifying the performance materiality (i.e., the maximum tolerable misstatement in the population) as a fraction of the total number of units in the population. Can be NULL. Not used for methods <code>direct</code> , <code>difference</code> , <code>quotient</code> , and <code>regression</code> .
<code>method</code>	a character specifying the statistical method. Possible options are <code>poisson</code> (default), <code>binomial</code> , <code>hypergeometric</code> , <code>mpu</code> , <code>stringer</code> , <code>stringer.meikle</code> , <code>stringer.lta</code> , <code>stringer.pvz</code> , <code>rohrbach</code> , <code>moment</code> , <code>direct</code> , <code>difference</code> , <code>quotient</code> , or <code>regression</code> . See the details section for more information.
<code>alternative</code>	a character indicating the alternative hypothesis and the type of confidence / credible interval returned by the function. Possible options are <code>less</code> (default), <code>two.sided</code> , or <code>greater</code> .
<code>conf.level</code>	a numeric value between 0 and 1 specifying the confidence level (i.e., 1 - audit risk / detection risk).
<code>data</code>	a data frame containing a data sample.
<code>values</code>	a character specifying name of a numeric column in data containing the book values of the items.
<code>values.audit</code>	a character specifying name of a numeric column in data containing the audit (true) values of the items.
<code>strata</code>	a character specifying name of a factor column in data indicating to which stratum the item belongs.
<code>times</code>	a character specifying name of an integer column in data containing the number of times an item should be counted due to (not) being selected (multiple times) for the sample. Items for which this value is 0 will not be included in the evaluation.
<code>x</code>	a numeric value or vector of values equal to or larger than 0 specifying the sum of (proportional) misstatements in the sample or, if this is a vector, the sum of taints in each stratum. If this argument is specified, the input for the <code>data</code> , <code>values</code> and <code>values.audit</code> arguments is discarded and it is assumed that the data come from summary statistics specified by <code>x</code> and <code>n</code> .
<code>n</code>	an integer or vector of integers larger than 0 specifying the sum of (proportional) misstatements in the sample or, if this is a vector, the sum of taints in each stratum. If this argument is specified, the input for the <code>data</code> , <code>values</code> and <code>values.audit</code> arguments is discarded and it is assumed that the data come from summary statistics specified by <code>x</code> and <code>n</code> .

<code>N.units</code>	a numeric value or vector of values than 0 specifying the total number of units in the population or, if this is a vector, the total number of units in each stratum of the population. This argument is strictly required for the hypergeometric, direct, difference, quotient, and regression methods, but is also used in stratification to weigh the estimates of each individual stratum to arrive at the population estimate. If NULL, each stratum is assumed to be equally represented in the population.
<code>N.items</code>	an integer larger than 0 specifying the number of items in the population. Only used for methods <code>direct</code> , <code>difference</code> , <code>quotient</code> , and <code>regression</code> .
<code>pooling</code>	a character specifying the type of model to use when analyzing stratified samples. Possible options are <code>none</code> (default) for no pooling (i.e., no information is shared between strata), <code>complete</code> for complete pooling (i.e., all information is shared between strata) or <code>partial</code> for partial pooling (i.e., some information is shared between strata). The latter two options fit a Bayesian model to the data using a MCMC sampling procedure whose options can be set globally using <code>options("mc.iterations")</code> (otherwise: 2000), <code>options("mc.warmup")</code> (otherwise: 1000), <code>options("mc.chains")</code> (otherwise: 4) and <code>options("mc.cores")</code> (otherwise: 1).
<code>prior</code>	a logical specifying whether to use a prior distribution, or an object of class <code>jfaPrior</code> or <code>jfaPosterior</code> . If this argument is specified as <code>FALSE</code> (default), the function performs classical evaluation. If this argument is specified as <code>TRUE</code> or as a prior from <code>auditPrior</code> , this function performs Bayesian evaluation using the specified prior.

## Details

This section lists the available options for the `method` argument.

- `poisson`: Evaluates the sample with the Poisson distribution. If combined with `prior = TRUE`, performs Bayesian evaluation using a *gamma* prior.
- `binomial`: Evaluates the sample with the binomial distribution. If combined with `prior = TRUE`, performs Bayesian evaluation using a *beta* prior.
- `hypergeometric`: Evaluates the sample with the hypergeometric distribution. If combined with `prior = TRUE`, performs Bayesian evaluation using a *beta-binomial* prior.
- `mpu`: Evaluates the sample using the mean-per-unit estimator.
- `stringer`: Evaluates the sample using the Stringer bound (Stringer, 1963).
- `stringer.meikle`: Evaluates the sample using the Stringer bound with Meikle's correction for understatements (Meikle, 1972).
- `stringer.lta`: Evaluates the sample using the Stringer bound with LTA correction for understatements (Leslie, Teitlebaum, and Anderson, 1979).
- `stringer.pvz`: Evaluates the sample using the Stringer bound with Pap and van Zuijlen's correction for understatements (Pap and van Zuijlen, 1996).
- `rohrbach`: Evaluates the sample using Rohrbach's augmented variance bound (Rohrbach, 1993).
- `moment`: Evaluates the sample using the modified moment bound (Dworin and Grimlund, 1984).

- `coxsnell`: Evaluates the sample using the Cox and Snell bound (Cox and Snell, 1979).
- `direct`: Evaluates the sample using the direct estimator (Touw and Hoogduin, 2011).
- `difference`: Evaluates the sample using the difference estimator (Touw and Hoogduin, 2011).
- `quotient`: Evaluates the sample using the quotient estimator (Touw and Hoogduin, 2011).
- `regression`: Evaluates the sample using the regression estimator (Touw and Hoogduin, 2011).

## Value

An object of class `jfaEvaluation` containing:

<code>conf.level</code>	a numeric value between 0 and 1 giving the confidence level.
<code>mle</code>	a numeric value between 0 and 1 giving the most likely misstatement in the population as a fraction.
<code>ub</code>	a numeric value between 0 and 1 giving the upper bound for the misstatement in the population.
<code>lb</code>	a numeric value between 0 and 1 giving the lower bound for the misstatement in the population.
<code>precision</code>	a numeric value between 0 and 1 giving the difference between the most likely misstatement and the bound relative to alternative.
<code>p.value</code>	for classical tests, a numeric value giving the p-value.
<code>x</code>	an integer larger than, or equal to, 0 giving the number of misstatements in the sample.
<code>t</code>	a value larger than, or equal to, 0, giving the sum of proportional misstatements in the sample.
<code>n</code>	an integer larger than 0 giving the sample size.
<code>materiality</code>	if <code>materiality</code> is specified, a numeric value between 0 and 1 giving the performance materiality as a fraction.
<code>alternative</code>	a character indicating the alternative hypothesis.
<code>method</code>	a character the method used.
<code>N.units</code>	if <code>N.units</code> is specified, in integer larger than 0 indicating the number of units in the population
<code>N.items</code>	if <code>N.items</code> is specified, in integer larger than 0 indicating the number of items in the population.
<code>K</code>	if <code>method = 'hypergeometric'</code> , an integer indicating the assumed total errors in the population.
<code>prior</code>	an object of class <code>jfaPrior</code> that contains the prior distribution.
<code>posterior</code>	an object of class <code>jfaPosterior</code> that contains the posterior distribution.
<code>data</code>	a data frame containing the relevant columns from the data.
<code>strata</code>	a data frame containing the relevant statistical results for the strata.
<code>data.name</code>	a character giving the name of the data.



**Author(s)**

Koen Derks, <k.derks@nyenrode.nl>

**References**

- Cox, D. and Snell, E. (1979). On sampling and the estimation of rare errors. *Biometrika*, 66(1), 125-132. doi:[10.1093/biomet/66.1.125](https://doi.org/10.1093/biomet/66.1.125).
- Derks, K., de Swart, J., van Batenburg, P., Wagenmakers, E.-J., & Wetzels, R. (2021). Priors in a Bayesian audit: How integration of existing information into the prior distribution can improve audit transparency and efficiency. *International Journal of Auditing*, 25(3), 621-636. doi:[10.1111/ijau.12240](https://doi.org/10.1111/ijau.12240)
- Derks, K., de Swart, J., Wagenmakers, E.-J., Wille, J., & Wetzels, R. (2021). JASP for audit: Bayesian tools for the auditing practice. *Journal of Open Source Software*, 6(68), 2733. doi:[10.21105/joss.02733](https://doi.org/10.21105/joss.02733)
- Derks, K., de Swart, J., Wagenmakers, E.-J., & Wetzels, R. (2021). The Bayesian approach to audit evidence: Quantifying statistical evidence using the Bayes factor. *PsyArXiv*. doi:[10.31234/osf.io/kzqp5](https://doi.org/10.31234/osf.io/kzqp5)
- Derks, K., de Swart, J., Wagenmakers, E.-J., & Wetzels, R. (2022). An impartial Bayesian hypothesis test for audit sampling. *PsyArXiv*. doi:[10.31234/osf.io/8nf3e](https://doi.org/10.31234/osf.io/8nf3e)
- Derks, K., de Swart, J., Wagenmakers, E.-J., & Wetzels, R. (2022). Bayesian generalized linear modeling for audit sampling: How to incorporate audit information into the statistical model. *PsyArXiv*. doi:[10.31234/osf.io/byj2a](https://doi.org/10.31234/osf.io/byj2a)
- Dworin, L. D. and Grimlund, R. A. (1984). Dollar-unit sampling for accounts receivable and inventory. *The Accounting Review*, 59(2), 218-241. <https://www.jstor.org/stable/247296>
- Leslie, D. A., Teitlebaum, A. D., & Anderson, R. J. (1979). *Dollar-unit Sampling: A Practical Guide for Auditors*. Copp Clark Pitman; Belmont, CA. ISBN: 9780773042780.
- Meikle, G. R. (1972). *Statistical Sampling in an Audit Context*. Canadian Institute of Chartered Accountants.
- Pap, G., and van Zuijlen, M. C. (1996). On the asymptotic behavior of the Stringer bound. *Statistica Neerlandica*, 50(3), 367-389. doi:[10.1111/j.14679574.1996.tb01503.x](https://doi.org/10.1111/j.14679574.1996.tb01503.x).
- Rohrbach, K. J. (1993). Variance augmentation to achieve nominal coverage probability in sampling from audit populations. *Auditing*, 12(2), 79.
- Stringer, K. W. (1963). Practical aspects of statistical sampling in auditing. In *Proceedings of the Business and Economic Statistics Section* (pp. 405-411). American Statistical Association.
- Touw, P., and Hoogduin, L. (2011). *Statistiek voor Audit en Controlling*. Boom uitgevers Amsterdam.

**See Also**

[auditPrior planning selection report](#)

**Examples**

```

# Using summary statistics
evaluation(materiality = 0.05, x = 0, n = 100)
evaluation(materiality = 0.05, x = c(2, 1, 0), n = c(50, 70, 40))

# Using data
data("BuildIt")
BuildIt$inSample <- c(rep(1, 100), rep(0, 3400))
levs <- c("low", "medium", "high")
BuildIt$stratum <- factor(c(levs[3], levs[2], rep(levs, times = 1166)))
sample <- subset(BuildIt, BuildIt$inSample == 1)

evaluation(
  materiality = 0.05, data = sample,
  values = "bookValue", values.audit = "auditValue"
)
evaluation(
  materiality = 0.05, data = sample, values = "bookValue",
  values.audit = "auditValue", strata = "stratum"
)

```

---

jfa-methods

*Methods for jfa objects*


---

**Description**

Methods defined for objects returned from the [auditPrior](#), [planning](#), [selection](#), and [evaluation](#) functions.

**Usage**

```

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

## S3 method for class 'summary.jfaPrior'
print(x, digits = getOption("digits"), ...)

## S3 method for class 'jfaPrior'
summary(object, digits = getOption("digits"), ...)

## S3 method for class 'jfaPrior'
predict(object, n, cumulative = FALSE, ...)

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

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

```

```
## S3 method for class 'jfaPredict'  
plot(x, ...)  
  
## S3 method for class 'jfaPosterior'  
print(x, ...)  
  
## S3 method for class 'summary.jfaPosterior'  
print(x, digits = getOption("digits"), ...)  
  
## S3 method for class 'jfaPosterior'  
summary(object, digits = getOption("digits"), ...)  
  
## S3 method for class 'jfaPosterior'  
predict(object, n, cumulative = FALSE, ...)  
  
## S3 method for class 'jfaPosterior'  
plot(x, ...)  
  
## S3 method for class 'jfaPlanning'  
print(x, ...)  
  
## S3 method for class 'summary.jfaPlanning'  
print(x, digits = getOption("digits"), ...)  
  
## S3 method for class 'jfaPlanning'  
summary(object, digits = getOption("digits"), ...)  
  
## S3 method for class 'jfaPlanning'  
plot(x, ...)  
  
## S3 method for class 'jfaSelection'  
print(x, ...)  
  
## S3 method for class 'summary.jfaSelection'  
print(x, digits = getOption("digits"), ...)  
  
## S3 method for class 'jfaSelection'  
summary(object, digits = getOption("digits"), ...)  
  
## S3 method for class 'jfaEvaluation'  
print(x, digits = getOption("digits"), ...)  
  
## S3 method for class 'summary.jfaEvaluation'  
print(x, digits = getOption("digits"), ...)  
  
## S3 method for class 'jfaEvaluation'  
summary(object, digits = getOption("digits"), ...)
```

```

## S3 method for class 'jfaEvaluation'
plot(x, type = c("posterior", "estimates"), ...)

## S3 method for class 'jfaDistr'
print(x, digits = getOption("digits"), ...)

## S3 method for class 'summary.jfaDistr'
print(x, digits = getOption("digits"), ...)

## S3 method for class 'jfaDistr'
summary(object, digits = getOption("digits"), ...)

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

## S3 method for class 'jfaRv'
print(x, digits = getOption("digits"), ...)

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

```

### Arguments

...	further arguments, currently ignored.
digits	an integer specifying the number of digits to which output should be rounded. Used in summary.
object, x	an object of class <code>jfaPrior</code> , <code>jfaPosterior</code> , <code>jfaPlanning</code> , <code>jfaSelection</code> , <code>jfaEvaluation</code> , <code>jfaDistr</code> , or <code>jfaRv</code> .
n	used in <code>predict</code> . Specifies the sample size for which predictions should be made.
cumulative	used in <code>predict</code> . Specifies whether cumulative probabilities should be shown.
type	used in <code>plot</code> . Specifies the type of plot to produce.

### Value

The summary methods return a `data.frame` which contains the input and output.

The print methods simply print and return nothing.

**Description**

`planning()` is used to calculate a minimum sample size for audit samples. It allows specification of statistical requirements for the sample with respect to the performance materiality or the precision. The function returns an object of class `jfaPlanning` that can be used with associated `summary()` and `plot()` methods.

**Usage**

```
planning(
  materiality = NULL,
  min.precision = NULL,
  expected = 0,
  likelihood = c("poisson", "binomial", "hypergeometric"),
  conf.level = 0.95,
  N.units = NULL,
  by = 1,
  max = 5000,
  prior = FALSE
)
```

**Arguments**

<code>materiality</code>	a numeric value between 0 and 1 specifying the performance materiality (i.e., the maximum tolerable misstatement in the population) as a fraction. Can be NULL, but <code>min.precision</code> should be specified in that case.
<code>min.precision</code>	a numeric value between 0 and 1 specifying the minimum precision (i.e., the estimated upper bound minus the estimated most likely error) as a fraction. Can be NULL, but <code>materiality</code> should be specified in that case.
<code>expected</code>	a numeric value between 0 and 1 specifying the expected (tolerable) misstatements in the sample relative to the total sample size, or a number ( $\geq 1$ ) specifying the expected (tolerable) number of misstatements in the sample. It is advised to set this value conservatively to minimize the probability of the observed misstatements in the sample exceeding the expected misstatements, which would imply that insufficient work has been done in the end and that additional samples are required.
<code>likelihood</code>	a character specifying the likelihood of the data. Possible options are <code>poisson</code> (default) for the Poisson likelihood, <code>binomial</code> for the binomial likelihood, or <code>hypergeometric</code> for the hypergeometric likelihood. See the details section for more information about the possible likelihoods.
<code>conf.level</code>	a numeric value between 0 and 1 specifying the confidence level (i.e., 1 - audit risk / detection risk).
<code>N.units</code>	a numeric value larger than 0 specifying the total number of units in the population. Required for the <code>hypergeometric</code> likelihood.
<code>by</code>	an integer larger than 0 specifying the increment between acceptable sample sizes (e.g., <code>increment = 5</code> considers only sample sizes of 5, 10, 15, ...).
<code>max</code>	an integer larger than 0 specifying the sample size at which the algorithm terminates (e.g., <code>max = 100</code> will terminate the algorithm at $n = 100$ ).

`prior` a logical specifying whether to use a prior distribution, or an object of class `jfaPrior` or `jfaPosterior`. If this argument is specified as `FALSE` (default), the function performs classical planning. If this argument is specified as `TRUE` or as a prior from `auditPrior`, this function performs Bayesian planning using a prior that is conjugate to the specified likelihood.

## Details

This section elaborates on the available input options for the likelihood argument and the corresponding conjugate prior distributions used by `jfa`.

- `poisson`: The Poisson distribution is an approximation of the binomial distribution. The Poisson distribution is defined as:

$$f(\theta, n) = \frac{\lambda^\theta e^{-\lambda}}{\theta!}$$

. The conjugate  $gamma(\alpha, \beta)$  prior has probability density function:

$$p(\theta; \alpha, \beta) = \frac{\beta^\alpha \theta^{\alpha-1} e^{-\beta\theta}}{\Gamma(\alpha)}$$

- `binomial`: The binomial distribution is an approximation of the hypergeometric distribution. The binomial distribution is defined as:

$$f(\theta, n, x) = \binom{n}{x} \theta^x (1 - \theta)^{n-x}$$

. The conjugate  $beta(\alpha, \beta)$  prior has probability density function:

$$p(\theta; \alpha, \beta) = \frac{1}{B(\alpha, \beta)} \theta^{\alpha-1} (1 - \theta)^{\beta-1}$$

- `hypergeometric`: The hypergeometric distribution is defined as:

$$f(x, n, K, N) = \frac{\binom{K}{x} \binom{N-K}{n-x}}{\binom{N}{n}}$$

. The conjugate  $beta-binomial(\alpha, \beta)$  prior (Dyer and Pierce, 1993) has probability mass function:

$$f(x, n, \alpha, \beta) = \binom{n}{x} \frac{B(x + \alpha, n - x + \beta)}{B(\alpha, \beta)}$$

## Value

An object of class `jfaPlanning` containing:

`conf.level` a numeric value between 0 and 1 giving the confidence level.  
`x` a numeric value larger than, or equal to, 0 giving (the proportional sum of) the tolerable errors in the sample.

n	an integer larger than 0 giving the minimal sample size.
ub	a numeric value between 0 and 1 giving the expected upper bound.
precision	a numeric value between 0 and 1 giving the expected precision.
p.value	a numeric value giving the expected one-sided p-value.
K	if likelihood = 'hypergeometric', an integer larger than 0 giving the assumed population errors.
N.units	an integer larger than 0 giving the number of units in the population (only returned if N.units is specified).
materiality	a numeric value between 0 and 1 giving the performance materiality if specified.
min.precision	a numeric value between 0 and 1 giving the minimum precision if specified.
expected	a numeric value larger than, or equal to, 0 giving the expected misstatement input.
likelihood	a character indicating the likelihood.
errorType	a character indicating the expected misstatements input.
iterations	an integer giving the number of iterations of the algorithm.
prior	if a prior distribution is specified, an object of class <code>jfaPrior</code> that contains information about the prior distribution.
posterior	if a prior distribution is specified, an object of class <code>jfaPosterior</code> that contains information about the expected posterior distribution.

### Author(s)

Koen Derks, <k.derks@nyenrode.nl>

### References

- Derks, K., de Swart, J., van Batenburg, P., Wagenmakers, E.-J., & Wetzels, R. (2021). Priors in a Bayesian audit: How integration of existing information into the prior distribution can improve audit transparency and efficiency. *International Journal of Auditing*, 25(3), 621-636. doi:10.1111/ijau.12240
- Derks, K., de Swart, J., Wagenmakers, E.-J., Wille, J., & Wetzels, R. (2021). JASP for audit: Bayesian tools for the auditing practice. *Journal of Open Source Software*, 6(68), 2733. doi:10.21105/joss.02733
- Dyer, D. and Pierce, R.L. (1993). On the choice of the prior distribution in hypergeometric sampling. *Communications in Statistics - Theory and Methods*, 22(8), 2125 - 2146. doi:10.1080/03610929308831139

### See Also

[auditPrior selection evaluation report](#)

**Examples**

```
# Classical planning
planning(materiality = 0.03)

# Bayesian planning using a default prior
planning(materiality = 0.03, prior = TRUE)

# Bayesian planning using a custom prior
prior <- auditPrior(method = "impartial", materiality = 0.05)
planning(materiality = 0.05, prior = prior)
```

repeated\_test

*Data Auditing: Repeated Values Test***Description**

This function analyzes the frequency with which values get repeated within a set of numbers. Unlike Benford's law, and its generalizations, this approach examines the entire number at once, not only the first or last digit(s).

**Usage**

```
repeated_test(
  x,
  check = c("last", "lasttwo", "all"),
  method = c("af", "entropy"),
  samples = 2000
)
```

**Arguments**

x	a numeric vector of values from which the digits should be analyzed.
check	which digits to shuffle during the procedure. Can be last or lasttwo.
method	which statistics is used. Defaults to af for average frequency, but can also be entropy for entropy.
samples	how many samples to use in the bootstrapping procedure.

**Details**

To determine whether the data show an excessive amount of bunching, the null hypothesis that  $x$  does not contain an unexpected amount of repeated values is tested against the alternative hypothesis that  $x$  has more repeated values than expected. The statistic can either be the average frequency ( $AF = \text{sum}(f_i^2) / \text{sum}(f_i)$ ) of the data or the entropy ( $E = -\text{sum}(p_i * \log(p_i))$ ), with  $p_i = f_i/n$ ) of the data. Average frequency and entropy are highly correlated, but the average frequency is often more interpretable. For example, an average frequency of 2.5 means that, on average, your observations contain a value that appears 2.5 times in the data set. To quantify what is expected, this test requires the assumption that the integer portions of the numbers are not associated with their decimal portions.



**Value**

An object of class `jfaRv` containing:

<code>x</code>	input data.
<code>frequencies</code>	frequencies of observations in <code>x</code> .
<code>samples</code>	vector of simulated samples.
<code>integers</code>	counts for extracted integers.
<code>decimals</code>	counts for extracted decimals.
<code>n</code>	the number of observations in <code>x</code> .
<code>statistic</code>	the value the average frequency or entropy statistic.
<code>p.value</code>	the p-value for the test.
<code>cor.test</code>	correlation test for the integer portions of the number versus the decimals portions of the number.
<code>method</code>	method used.
<code>check</code>	checked digits.
<code>data.name</code>	a character string giving the name(s) of the data.

**Author(s)**

Koen Derks, <k.derks@nyenrode.nl>

**References**

Simohnsohn, U. (2019, May 25). Number-Bunching: A New Tool for Forensic Data Analysis. Retrieved from <https://datacolada.org/77>.

**See Also**

[digit\\_test](#)

**Examples**

```
set.seed(1)
x <- rnorm(50)

# Repeated values analysis shuffling last digit
repeated_test(x, check = "last", method = "af", samples = 2000)
```

---

report

*Audit Sampling: Reporting*

---

### Description

report() takes an object of class `jfaEvaluation` as returned by the `evaluation()` function automatically generates a html or pdf report containing the most relevant statistical results and their interpretation.

### Usage

```
report(  
  object,  
  file = "report.html"  
)
```

### Arguments

`object` an object of class `jfaEvaluation` as returned by the `evaluation()` function.  
`file` a character specifying the name and format of the report (e.g. `report.html`).

### Value

A html or pdf file containing the report.

### Author(s)

Koen Derks, <k.derks@nyenrode.nl>

### See Also

[auditPrior](#) [planning](#) [selection](#) [evaluation](#)

### Examples

```
result <- evaluation(x = 0, n = 100)  
## Not run:  
report(result)  
  
## End(Not run)
```

---

retailer	<i>Retailer Group Audit</i>
----------	-----------------------------

---

**Description**

Sample outcomes summarized per branch from an audit of a retail company consisting of 20 branches.

**Usage**

```
data(retailer)
```

**Format**

A data frame with 20 rows and 5 variables.

**stratum** branch/stratum number.

**items** total number of items in each branch.

**samples** number of items in sample per branch.

**errors** number of errors in sample per branch.

**Source**

Derks, K., de Swart, J., & Wetzels, R. (2022). Een Bayesiaanse blik op gestratificeerde steekproeven heeft voordelen voor de auditor. *Maandblad voor Accountancy en Bedrijfseconomie*, 96(1/2), 37-46. [doi:10.5117/mab.96.78836](https://doi.org/10.5117/mab.96.78836)

**Examples**

```
data(retailer)
```

---

sanitizer	<i>Factory Workers' use of Hand Sanitizer</i>
-----------	---

---

**Description**

Data from a study on factory workers' use of hand sanitizer. Sanitizer use was measured to a 100th of a gram.

**Usage**

```
data(sanitizer)
```

**Format**

A data frame with 1600 rows and 1 variable.

**Source**

<http://datacolada.org/appendix/74/>

**References**

[Retracted] Li, M., Sun, Y., & Chen, H. (2019). The decoy effect as a nudge: Boosting hand hygiene with a worse option. *Psychological Science*, 30, 139–149.

**Examples**

```
data(sanitizer)
```

---

selection

*Audit Sampling: Selection*

---

**Description**

`selection()` is used to perform statistical selection of audit samples. It offers flexible implementations of the most common audit sampling algorithms for attributes sampling and monetary unit sampling. The function returns an object of class `jfaSelection` that can be used with the associated `summary()` method.

**Usage**

```
selection(  
  data,  
  size,  
  units = c("items", "values"),  
  method = c("interval", "cell", "random", "sieve"),  
  values = NULL,  
  order = NULL,  
  decreasing = FALSE,  
  randomize = FALSE,  
  replace = FALSE,  
  start = 1  
)
```

**Arguments**

<code>data</code>	a data frame containing the population data.
<code>size</code>	an integer larger than 0 specifying the number of units to select. Can also be an object of class <code>jfaPlanning</code> .
<code>units</code>	a character specifying the type of sampling units. Possible options are <code>items</code> (default) for selection on the level of items (rows) or <code>values</code> for selection on the level of monetary units.

method	a character specifying the sampling algorithm. Possible options are <code>interval</code> (default) for fixed interval sampling, <code>cell</code> for cell sampling, <code>random</code> for random sampling, or <code>sieve</code> for modified sieve sampling.
values	a character specifying the name of a column in data containing the book values of the items.
order	a character specifying the name of a column in data containing the ranks of the items. The items in the data are ordered according to these values in the order indicated by decreasing.
decreasing	a logical specifying whether to order the items from smallest to largest. Only used if <code>order</code> is specified.
randomize	a logical specifying if items should be randomly shuffled prior to selection. Note that <code>randomize = TRUE</code> overrules <code>order</code> .
replace	a logical specifying if sampling units should be selected with replacement. Only used for method <code>random</code> .
start	an integer larger than 0 specifying index of the unit that should be selected. Only used for method <code>interval</code> .

### Details

This section elaborates on the possible options for the `units` argument:

- `items`: In attributes sampling each item in the population is a sampling unit. An item with a book value of \$5000 is therefore equally likely to be selected as an item with a book value of \$500.
- `values`: In monetary unit sampling each monetary unit in the population is a sampling unit. An item with a book value of \$5000 is therefore ten times more likely to be selected as an item with a book value of \$500.

This section elaborates on the possible options for the `method` argument:

- `interval`: In fixed interval sampling the sampling units are divided into a number of equally large intervals. In each interval, a single sampling unit is selected according to a fixed starting point (specified by `start`).
- `cell`: In cell sampling the sampling units in the population are divided into a number (equal to the sample size) of equally large intervals. In each interval, a single sampling unit is selected randomly.
- `random`: In random sampling all sampling units are drawn with equal probability.
- `sieve`: In modified sieve sampling items are selected with the largest sieve ratio (Hoogduin, Hall, & Tsay, 2010).

### Value

An object of class `jfaSelection` containing:

<code>data</code>	a data frame containing the population data.
<code>sample</code>	a data frame containing the selected data sample.

n.req	an integer giving the requested sample size.
n.units	an integer giving the number of obtained sampling units.
n.items	an integer giving the number of obtained sample items.
N.units	an integer giving the number of sampling units in the population data.
N.items	an integer giving the number of items in the population data.
interval	if method = "interval", a numeric value giving the size of the selection interval.
units	a character indicating the type of sampling units.
method	a character indicating the sampling algorithm.
values	if values is specified, a character indicating the book value column.
start	if method = "interval", an integer giving the index of the selected unit in each interval.
data.name	a character indicating the name of the population data.

### Author(s)

Koen Derks, <k.derks@nyenrode.nl>

### References

- Derks, K., de Swart, J., Wagenmakers, E.-J., Wille, J., & Wetzels, R. (2021). JASP for audit: Bayesian tools for the auditing practice. *Journal of Open Source Software*, 6(68), 2733. doi:10.21105/joss.02733
- Hoogduin, L. A., Hall, T. W., & Tsay, J. J. (2010). Modified sieve sampling: A method for single- and multi-stage probability-proportional-to-size sampling. *Auditing: A Journal of Practice & Theory*, 29(1), 125-148. doi:10.2308/aud.2010.29.1.125
- Leslie, D. A., Teitlebaum, A. D., & Anderson, R. J. (1979). *Dollar-unit Sampling: A Practical Guide for Auditors*. Copp Clark Pitman; Belmont, CA. ISBN: 9780773042780.

### See Also

[auditPrior planning evaluation report](#)

### Examples

```
data("BuildIt")

# Select 100 items using random sampling
set.seed(1)
selection(data = BuildIt, size = 100, method = "random")

# Select 150 monetary units using fixed interval sampling
selection(
  data = BuildIt, size = 150, units = "values",
  method = "interval", values = "bookValue"
)
```

---

sinoForest	<i>Sino Forest Corporation's Financial Statements.</i>
------------	--

---

**Description**

Financial statement numbers of Sino Forest Corporation's 2010 Report.

**Usage**

```
data(sinoForest)
```

**Format**

A data frame with 772 rows and 1 variable.

**Source**

<https://cran.r-project.org/package=benford.analysis>

**References**

Nigrini, M. J. (2012). Benford's Law: Application for Forensic Accounting, Auditing and Fraud Detection. Wiley and Sons: New Jersey.

**Examples**

```
data(sinoForest)
```

# Index

- \* **Bayesian**
    - digit\_test, 11
  - \* **Benford**
    - digit\_test, 11
  - \* **audit**
    - auditPrior, 4
    - digit\_test, 11
    - evaluation, 13
    - planning, 20
    - repeated\_test, 24
    - report, 26
    - selection, 28
  - \* **datasets**
    - allowances, 4
    - benchmark, 9
    - BuildIt, 10
    - carrier, 10
    - retailer, 27
    - sanitizer, 27
    - sinoForest, 31
  - \* **digits**
    - digit\_test, 11
  - \* **distribution**
    - digit\_test, 11
  - \* **evaluation**
    - auditPrior, 4
    - evaluation, 13
    - planning, 20
    - report, 26
  - \* **items**
    - selection, 28
  - \* **jfa**
    - jfa-package, 2
  - \* **mus**
    - selection, 28
  - \* **package**
    - jfa-package, 2
  - \* **planning**
    - auditPrior, 4
    - planning, 20
  - \* **prior**
    - auditPrior, 4
    - evaluation, 13
    - planning, 20
  - \* **repeated**
    - repeated\_test, 24
  - \* **report**
    - report, 26
  - \* **selection**
    - selection, 28
  - \* **values**
    - repeated\_test, 24
- allowances, 4
- auditPrior, 4, 17, 18, 23, 26, 30
- benchmark, 9
- BuildIt, 10
- carrier, 10
- digit\_test, 11, 25
- evaluation, 8, 13, 18, 23, 26, 30
- jfa (jfa-package), 2
- jfa-methods, 18
- jfa-package, 2
- planning, 8, 17, 18, 20, 26, 30
- plot.jfaDistr (jfa-methods), 18
- plot.jfaEvaluation (jfa-methods), 18
- plot.jfaPlanning (jfa-methods), 18
- plot.jfaPosterior (jfa-methods), 18
- plot.jfaPredict (jfa-methods), 18
- plot.jfaPrior (jfa-methods), 18
- plot.jfaRv (jfa-methods), 18
- predict.jfaPosterior (jfa-methods), 18
- predict.jfaPrior (jfa-methods), 18
- print.jfaDistr (jfa-methods), 18



print.jfaEvaluation (jfa-methods), 18  
print.jfaPlanning (jfa-methods), 18  
print.jfaPosterior (jfa-methods), 18  
print.jfaPredict (jfa-methods), 18  
print.jfaPrior (jfa-methods), 18  
print.jfaRv (jfa-methods), 18  
print.jfaSelection (jfa-methods), 18  
print.summary.jfaDistr (jfa-methods), 18  
print.summary.jfaEvaluation  
    (jfa-methods), 18  
print.summary.jfaPlanning  
    (jfa-methods), 18  
print.summary.jfaPosterior  
    (jfa-methods), 18  
print.summary.jfaPrior (jfa-methods), 18  
print.summary.jfaSelection  
    (jfa-methods), 18

repeated\_test, 12, 24  
report, 8, 17, 23, 26, 30  
retailer, 27

sanitizer, 27  
selection, 8, 17, 18, 23, 26, 28  
sinoForest, 31  
summary.jfaDistr (jfa-methods), 18  
summary.jfaEvaluation (jfa-methods), 18  
summary.jfaPlanning (jfa-methods), 18  
summary.jfaPosterior (jfa-methods), 18  
summary.jfaPrior (jfa-methods), 18  
summary.jfaSelection (jfa-methods), 18