# Package 'AATtools'

January 20, 2025

**Type** Package

**Title** Reliability and Scoring Routines for the Approach-Avoidance Task

**Version** 0.0.3

**Description** Compute approach bias scores using different scoring algorithms,
compute bootstrapped and exact split-half reliability estimates,
and compute confidence intervals for individual participant scores.

**Depends** R (>= 3.6.0)

**Imports** magrittr, dplyr, doParallel, foreach

**License** GPL-3

**Encoding** UTF-8

**BugReports** https://github.com/Spiritspeak/AATtools/issues

**LazyData** true

**ByteCompile** true

**RoxygenNote** 7.3.2

**NeedsCompilation** no

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**Repository** CRAN

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# Contents

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aat_bootstrap                 *Compute bootstrapped approach-bias scores*

---

### Description

Compute bootstrapped approach-bias scores with confidence intervals.

### Usage

```
aat_bootstrap(
  ds,
  subjvar,
  pullvar,
  targetvar = NULL,
  rtvar,
  iters,
  algorithm = c("aat_doublemeandiff", "aat_doublemediandiff", "aat_dscore",
    "aat_dscore_multiblock", "aat_regression", "aat_standardregression",
    "aat_singlemeandiff", "aat_singlemediandiff"),
  trialdropfunc = c("prune_nothing", "trial_prune_3SD", "trial_prune_3MAD",
   "trial_prune_SD_dropcases", "trial_recode_SD", "trial_prune_percent_subject",
    "trial_prune_percent_sample", "trial_prune_grubbs"),
  errortrialfunc = c("prune_nothing", "error_replace_blockmeanplus",
    "error_prune_dropcases"),
  plot = TRUE,
  include.raw = FALSE,
  parallel = TRUE,
  ...
)

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

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

## Arguments

| | |
|---|---|
| ds | a longformat data.frame |
| subjvar | Quoted name of the participant identifier column |
| pullvar | Quoted name of the column indicating pull trials. Pull trials should either be represented by 1, or by the second level of a factor. |
| targetvar | Name of the column indicating trials featuring the target stimulus. Target stimuli should either be represented by 1, or by the second level of a factor. |
| rtvar | Name of the reaction time column. |
| iters | Total number of desired iterations. At least 200 are required to get confidence intervals that make sense. |
| algorithm | Function (without brackets or quotes) to be used to compute AAT scores. See [Algorithms](#) for a list of usable algorithms. |
| trialdropfunc | Function (without brackets or quotes) to be used to exclude outlying trials in each half. The way you handle outliers for the reliability computation should mimic the way you do it in your regular analyses. It is recommended to exclude outlying trials when computing AAT scores using the mean double-dfference scores and regression scoring approaches, but not when using d-scores or median double-difference scores. |

  - `prune_nothing` excludes no trials (default)
  - `trial_prune_grubbs` applies a Grubbs' test to the data, removing one outlier at a time until the test is no longer significant.
  - `trial_prune_3SD` excludes trials deviating more than 3SD from the mean per participant.
  - `trial_prune_SD_dropcases` removes trials deviating more than a specific number of standard deviations from the participant's mean, and removes participants with an excessive percentage of outliers. Required arguments:
    - `trialsd` - trials deviating more than `trialsd` standard deviations from the participant's mean are excluded (optional; default is 3)
    - `maxoutliers` - participants with a higher percentage of outliers are removed from the data. (optional; default is .15)
  - `trial_recode_SD` recodes outlying reaction times to the nearest non-outlying value, with outliers defined as reaction times deviating more than a certain number of standard deviations from the participant's mean. Required argument:
    - `trialsd` - trials deviating more than this many standard deviations from the mean are classified as outliers.
  - `trial_prune_percent_subject` and `trial_prune_percent_sample` remove trials below and/or above certain percentiles, on a subject-by-subject basis or sample-wide, respectively. The following arguments are available:
    - `lowerpercent` and `uppperpercent` (optional; defaults are .01 and .99).

| | |
|---|---|
| errortrialfunc | Function (without brackets or quotes) to apply to an error trial. |

  - `prune_nothing` removes no errors (default).

- • error_replace_blockmeanplus replaces error trial reaction times with
  the block mean, plus an arbitrary extra quantity. If used, the following
  additional arguments are required:
  - – blockvar - Quoted name of the block variable (mandatory)
  - – errorvar - Quoted name of the error variable, where errors are 1 or
    TRUE and correct trials are 0 or FALSE (mandatory)
  - – errorbonus - Amount to add to the reaction time of error trials. De-
    fault is 0.6 (recommended by Greenwald, Nosek, & Banaji, 2003)
- • error_prune_dropcases removes errors and drops participants if they have
  more errors than a given percentage. The following arguments are avail-
  able:
  - – errorvar - Quoted name of the error variable, where errors are 1 or
    TRUE and correct trials are 0 or FALSE (mandatory)
  - – maxerrors - participants with a higher percentage of errors are ex-
    cluded from the dataset. Default is .15.

| | |
|---|---|
| plot | Plot the bias scores and their confidence intervals after computation is complete. This gives a good overview of the data. |
| include.raw | logical indicating whether raw split-half data should be included in the output object. |
| parallel | If TRUE (default), will use parallel computing to compute results faster. If a doParallel backend has not been registered beforehand, this function will register a cluster and stop it after finishing, which takes some extra time. |
| ... | Other arguments, to be passed on to the algorithm or outlier rejection functions (see arguments above) |
| x | An aat_bootstrap object. |

## Value

A list, containing bootstrapped bias scores, their variance, bootstrapped 95 percent confidence in-
tervals, the number of iterations, and a matrix of bias scores for each iteration.

## Author(s)

Sercan Kahveci

## Examples

```
# Compute 10 bootstrapped AAT scores.
boot<-aat_bootstrap(ds=erotica[erotica$is_irrelevant==0,], subjvar="subject",
                    pullvar="is_pull", targetvar="is_target",rtvar="RT",
                    iters=10,algorithm="aat_doublemediandiff",
                    trialdropfunc="trial_prune_3SD",
                    plot=FALSE, parallel=FALSE)
plot(boot)
print(boot)
```

---

| aat_compute | *Compute simple AAT scores* |
|---|---|

---

### Description

Compute simple AAT scores, with optional outlier exclusion and error trial recoding.

### Usage

```
aat_compute(
  ds,
  subjvar,
  pullvar,
  targetvar = NULL,
  rtvar,
  algorithm = c("aat_doublemeandiff", "aat_doublemediandiff", "aat_dscore",
    "aat_dscore_multiblock", "aat_regression", "aat_standardregression",
    "aat_doublemeanquotient", "aat_doublemedianquotient", "aat_singlemeandiff",
    "aat_singlemediandiff"),
  trialdropfunc = c("prune_nothing", "trial_prune_3SD", "trial_prune_3MAD",
   "trial_prune_SD_dropcases", "trial_recode_SD", "trial_prune_percent_subject",
    "trial_prune_percent_sample", "trial_prune_grubbs"),
  errortrialfunc = c("prune_nothing", "error_replace_blockmeanplus",
    "error_prune_dropcases"),
  ...
)
```

### Arguments

| | |
|---|---|
| ds | a long-format data.frame |
| subjvar | column name of subject variable |
| pullvar | column name of pull/push indicator variable, must be numeric or logical (where pull is 1 or TRUE) |
| targetvar | column name of target stimulus indicator, must be numeric or logical (where target is 1 or TRUE) |
| rtvar | column name of reaction time variable |
| algorithm | Function (without brackets or quotes) to be used to compute AAT scores. See [Algorithms](#) for a list of usable algorithms. |
| trialdropfunc | Function (without brackets or quotes) to be used to exclude outlying trials in each half. The way you handle outliers for the reliability computation should mimic the way you do it in your regular analyses. It is recommended to exclude outlying trials when computing AAT scores using the mean double-dfference scores and regression scoring approaches, but not when using d-scores or median double-difference scores.

    • prune_nothing excludes no trials (default) |

- `trial_prune_3SD` excludes trials deviating more than 3SD from the mean per participant.
- `trial_prune_grubbs` applies a Grubbs' test to the data, removing one outlier at a time until the test is no longer significant.
- `trial_prune_SD_dropcases` removes trials deviating more than a specific number of standard deviations from the participant's mean, and removes participants with an excessive percentage of outliers. Required arguments:
  - `trialsd` - trials deviating more than `trialsd` standard deviations from the participant's mean are excluded (optional; default is 3)
  - `maxoutliers` - participants with a higher percentage of outliers are removed from the data. (optional; default is .15)
- `trial_recode_SD` recodes outlying reaction times to the nearest non-outlying value, with outliers defined as reaction times deviating more than a certain number of standard deviations from the participant's mean. Required argument:
  - `trialsd` - trials deviating more than this many standard deviations from the mean are classified as outliers.
- `trial_prune_percent_subject` and `trial_prune_percent_sample` remove trials below and/or above certain percentiles, on a subject-by-subject basis or sample-wide, respectively. The following arguments are available:
  - `lowerpercent` and `uppperpercent` (optional; defaults are .01 and .99).

errortrialfunc    Function (without brackets or quotes) to apply to an error trial.

- `prune_nothing` removes no errors (default).
- `error_replace_blockmeanplus` replaces error trial reaction times with the block mean, plus an arbitrary extra quantity. If used, the following additional arguments are required:
  - `blockvar` - Quoted name of the block variable (mandatory)
  - `errorvar` - Quoted name of the error variable, where errors are 1 or TRUE and correct trials are 0 or FALSE (mandatory)
  - `errorbonus` - Amount to add to the reaction time of error trials. Default is 0.6 (recommended by `Greenwald, Nosek, & Banaji, 2003`)
- `error_prune_dropcases` removes errors and drops participants if they have more errors than a given percentage. The following arguments are available:
  - `errorvar` - Quoted name of the error variable, where errors are 1 or TRUE and correct trials are 0 or FALSE (mandatory)
  - `maxerrors` - participants with a higher percentage of errors are excluded from the dataset. Default is .15.

...               Other arguments, to be passed on to the algorithm or outlier rejection functions (see arguments above)

### Examples

```
#Compute the correlation between relevant-feature and irrelevant-feature AAT scores
ds<-erotica[erotica$correct==1,]
relevant <- aat_compute(ds=ds[ds$is_irrelevant==0,],
```

```
                              pullvar="is_pull",targetvar="is_target",
                              rtvar="RT",subjvar="subject",
                              trialdropfunc="trial_prune_3SD",
                              algorithm="aat_doublemediandiff")

  irrelevant <- aat_compute(ds=ds[ds$is_irrelevant==1,],
                              pullvar="is_pull",targetvar="is_target",
                              rtvar="RT",subjvar="subject",
                              trialdropfunc="trial_prune_3SD",
                              algorithm="aat_doublemediandiff")

  comparison.df <- merge(relevant, irrelevant, by = "subject")
  cor(comparison.df$ab.x, comparison.df$ab.y)
  # 0.1145726
```

---

aat_covreliability     *Compute a dataset's reliability from its covariance matrix*

---

### Description

This function computes mean single-difference scores (push minus pull) for individual stimuli, and computes the reliability from that information. Missing values are dealt with using multiple imputation.

This function computes the reliability when stimuli and participants are removed, allowing for the diagnosis of potential sources of unreliability within the data.

### Usage

```
aat_covreliability(
  ds,
  subjvar,
  stimvar,
  pullvar,
  targetvar = NULL,
  rtvar,
  aggfunc = c("mean", "median"),
  algorithm = c("calpha", "lambda2", "lambda4"),
  iters = 5
)

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

aat_covreliability_jackknife(
  ds,
  subjvar,
  stimvar,
  pullvar,
```

```
    targetvar = NULL,
    rtvar,
    algorithm = c("calpha", "lambda2", "lambda4"),
    iters = 5,
    holdout = c("both", "participant", "stimulus", "cross")
)

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

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

## Arguments

| | |
|---|---|
| ds | the data.frame to use |
| subjvar | Name of the subject-identifying variable |
| stimvar | Name of the stimulus-identifying variable |
| pullvar | Name of the movement-direction identifying variable |
| targetvar | Optional. Name of the stimulus-category identifying variable |
| rtvar | Name of the reaction-time identifying variable |
| aggfunc | The function with which to aggregate the RTs before computing difference scores. Defaults to mean but can be changed to median. |
| algorithm | The reliability formula to use. Defaults to Cronbach's alpha, but Guttman's Lambda-2 is recommended instead. |
| iters | If there are missing values (which is almost inevitable) then multiple imputation will be used to complete the covariance matrix - this option sets the number of multiple imputations to be used. |
| x | Object to be printed |
| ... | Ignored |
| holdout | What should be removed from the data for computation of jackknife statistics? "both" computes reliability when stimuli and participants are separately removed, while "cross" computes reliability when stimuli and participants are simultaneously removed. |

## Details

When only one stimulus category is indicated, one of the commonly known reliability algorithms provided with the algorithm argument is used. When two stimulus categories are indicated, this function uses Lord's (1963) algorithm to compute the reliability of a double mean difference score, using the algorithms in algorithm to estimate the reliability of indiviau lstimulus categories.

When one wants to compute the reliability of a double median difference score or D-score, aat_splithalf() is recommended instead.

## Value

Returns an `aat_covreliability` object containing the reliability value as well as the dataset and covariance matrix with replaced missing values. When the argument `targetvar` is provided, the output also contains the reliability of the individual stimulus categories and their intercorrelation.

`aat_covreliability_jackknife()` returns an `aat_covreliability_jackknife` object, containing jackknife reliability statistics. If argument `holdout` was set to "cross", then these statistics are provided in a matrix where rows represent participants and columns represent stimuli. Otherwise, they are provided in `data.frames` where the stimulus or participant is represented in a column alongside the associated reliability value.

## Methods (by generic)

- `print(aat_covreliability)`: Print an `aat_covreliability` object

## Functions

- `print(aat_covreliability_jackknife)`: Print an `aat_covreliability_jackknife` object
- `plot(aat_covreliability_jackknife)`: Plot an `aat_covreliability_jackknife` object

## References

Lord, F.Y. (1963), "Elementary Models for Measuring Change", in Problems in Measuring Change, C.W. Harris, ed.. Madison. Wisconsin: University of Wisconsin.

## Examples

```
#We generate a dataset with 16 stimuli in each category
ds<-aat_simulate(biasfx_jitter=40,nstims=16)
ds$stim<-paste0(ds$stim,"-",ds$is_target)

# If Lord's formula and
# bootstrapped splithalf measure something similar,
# then the outcomes should be close to each other.
aat_covreliability(ds=ds,subjvar="subj",stimvar="stim",pullvar="is_pull",
                            targetvar="is_target",rtvar="rt")
aat_splithalf(ds=ds,subjvar="subj",pullvar="is_pull",targetvar="is_target",rtvar="rt",
              algorithm="aat_doublemeandiff",iters=100,plot=FALSE)

#Testing reliability for single-difference scores
ds<-ds[ds$is_target==1,]
aat_covreliability(ds=ds,subjvar="subj",stimvar="stim",pullvar="is_pull",rtvar="rt")
hh<-aat_simulate()
test<-aat_covreliability_jackknife(ds=hh,subjvar="subj",stimvar="stim",pullvar="is_pull",
                                   targetvar="is_target",rtvar="rt",holdout="cross")
print(test)
plot(test)
```

---

aat_simulate          *Simulate AAT datasets and predict parameters*

---

### Description

aat_simulate() generates approach-avoidance task datasets.

aat_getstudydata() retrieves the properties of datasets from a number of pre-existing studies

### Usage

```
aat_simulate(
  npps = 36,
  nstims = 16,
  stimreps = 4,
  meanrt = 632,
  meanrt_jitter = 90.1,
  sdrt = 158,
  sdrt_jitter = 49.9,
  pullfx = -39.2,
  pullfx_jitter = 40.5,
  stimfx = -30.9,
  stimfx_jitter = 32.5,
  biasfx = 39,
  biasfx_jitter = 60.1,
  empirical = FALSE,
  ...
)

aat_simulate2(..., defaults = "none", slowols = 0, fastols = 0, olsd = 3)

aat_getstudydata()
```

### Arguments

| | |
|---|---|
| npps | Number of participants |
| nstims | Number of stimuli |
| stimreps | Number of repetitions of each stimulus within each group (i.e. within approach target, avoid target, approach control, avoid control) |
| meanrt | Mean sample reaction time |
| meanrt_jitter | Extent by which participants' mean RTs deviate from mean sample RT. |
| sdrt | Standard deviation of samplewide RTs, ignoring effects of movement, stimulus, and approach bias. In essence, this represents the amount of pure noise present in the data. |
| sdrt_jitter | Extent by which standard deviations of individual participants' RTs are larger or smaller than the samplewide SD. |

| pullfx | size of the effect of approach-versus-avoidance, in milliseconds |
|---|---|
| pullfx_jitter | Individual variation in the effect of approach-versus-avoidance |
| stimfx | size of the effect of stimulus category, in milliseconds |
| stimfx_jitter | Individual variation in the effect of stimulus category |
| biasfx | Size of the approach bias effect, in milliseconds |
| biasfx_jitter | Individual variation in the approach bias effect |
| empirical | If TRUE, then effect sizes and standard deviations will be exact |
| ... | Any parameters of aat_simulate provided here will override the defaults from the defaults parameter. |
| defaults | Which set of default values should be used? |
| slowols | Number of slow outliers to insert per participant |
| fastols | Number of fats outliers to insert per participant |
| olsd | Number of standard deviations by which (slow) outliers deviate |

## Details

Defaults of aat_simulate() are based on Kahveci, Van Alebeek, Berking, & Blechert (2021).

"Lender2018" parameters are taken from the relevant-feature AAT of Lender, Meule, Rinck, Brockmeyer, & Blechert (2018). "Kahveci2021" parameters are taken from Kahveci, Van Alebeek, Berking, & Blechert (in review).

Lender, A., Meule, A., Rinck, M., Brockmeyer, T., & Blechert, J. (2018). Measurement of food-related approach–avoidance biases: Larger biases when food stimuli are task relevant. Appetite, 125, 42-47.

Kahveci, S., Van Alebeek, H., Berking, M., & Blechert, J. (in review). Touchscreen based assessment of food approach biases: investigation of reliability and stimulus-specific effects.

## Value

aat_simulate() returns a data.frame with the following columns: subj (participant ID), stim (stimulus number), rep (stimulus repetition number), is_pull (0 = avoid, 1 = approach), is_target (0 = control stimulus, 1 = target stimulus), meanrt (participant's mean RT), sdrt (participant's residual standard deviation), pullfx (participant approach-avoidance effect size in ms), stimfx (participant stimulus category effect size in ms), biasfx (participant approach bias effect size in ms), and rt (trial reaction time). Additionally, the data.frame has the attribute population_reliability which represents the expected reliability of the data given the provided parameters.

## Examples

```
ts<- aat_simulate(pullfx = 50, stimfx = 10, biasfx = 100)
mod<-lm(rt~is_pull*is_target,data=ts)
coef(mod) #these should be somewhat close to the provided coefficients

# Here's how one might derive the parameters used in this function from a real dataset
## Not run:
mod<-lmer(decisiontime ~ is_pull * is_food + (is_pull * is_food | subjectid),data=dsa)
```

```
fixef(mod) # from here, all the fx and mean RTs are derived
ranef(mod)$subjectid %>% apply(2,sd) #from here, all the fx jitters are derived
dsa %>% group_by(subjectid) %>% summarise(sd=sd(resid)) %>%
summarise(m=mean(sd),s=sd(sd)) # from here, sdrt_jitter is derived

## End(Not run)
hist(aat_simulate2(defaults="Lender2018_relevant_raw",slowols=10,fastols=10)$rt)
```

---

aat_splithalf                 *Compute the bootstrapped split-half reliability for approach-*
                              *avoidance task data*

---

### Description

Compute bootstrapped split-half reliability for approach-avoidance task data.

### Usage

```
aat_splithalf(
  ds,
  subjvar,
  pullvar,
  targetvar = NULL,
  rtvar,
  stratvars = NULL,
  iters = 6000,
  algorithm = c("aat_doublemeandiff", "aat_doublemediandiff", "aat_dscore",
    "aat_dscore_multiblock", "aat_regression", "aat_standardregression",
    "aat_singlemeandiff", "aat_singlemediandiff"),
  trialdropfunc = c("prune_nothing", "trial_prune_3SD", "trial_prune_3MAD",
   "trial_prune_SD_dropcases", "trial_recode_SD", "trial_prune_percent_subject",
    "trial_prune_percent_sample", "trial_prune_grubbs"),
  errortrialfunc = c("prune_nothing", "error_replace_blockmeanplus",
    "error_prune_dropcases"),
  casedropfunc = c("prune_nothing", "case_prune_3SD"),
  plot = TRUE,
  include.raw = FALSE,
  parallel = TRUE,
  ...
)

## S3 method for class 'aat_splithalf'
print(x, coef = c("SpearmanBrown", "Raju", "FlanaganRulon"), ...)

## S3 method for class 'aat_splithalf'
plot(x, type = c("median", "minimum", "maximum", "random"), ...)
```

## Arguments

| | |
|---|---|
| ds | a longformat data.frame |
| subjvar | Quoted name of the participant identifier column |
| pullvar | Quoted name of the column indicating pull trials. Pull trials should either be represented by 1, or by the second level of a factor. |
| targetvar | Name of the column indicating trials featuring the target stimulus. Target stimuli should either be represented by 1, or by the second level of a factor. |
| rtvar | Name of the reaction time column. |
| stratvars | Names of additional variables to stratify splits by. |
| iters | Total number of desired iterations. At least 6000 are recommended for reasonable estimates. |
| algorithm | Function (without brackets or quotes) to be used to compute AAT scores. See [Algorithms](#) for a list of usable algorithms. |
| trialdropfunc | Function (without brackets or quotes) to be used to exclude outlying trials in each half. The way you handle outliers for the reliability computation should mimic the way you do it in your regular analyses. It is recommended to exclude outlying trials when computing AAT scores using the mean double-dfference scores and regression scoring approaches, but not when using d-scores or median double-difference scores. |

- prune_nothing excludes no trials (default)
- trial_prune_grubbs applies a Grubbs' test to the data, removing one outlier at a time until the test is no longer significant.
- trial_prune_3SD excludes trials deviating more than 3SD from the mean per participant.
- trial_prune_SD_dropcases removes trials deviating more than a specific number of standard deviations from the participant's mean, and removes participants with an excessive percentage of outliers. Required arguments:
    - trialsd - trials deviating more than trialsd standard deviations from the participant's mean are excluded (optional; default is 3)
    - maxoutliers - participants with a higher percentage of outliers are removed from the data. (optional; default is .15)
- trial_recode_SD recodes outlying reaction times to the nearest non-outlying value, with outliers defined as reaction times deviating more than a certain number of standard deviations from the participant's mean. Required argument:
    - trialsd - trials deviating more than this many standard deviations from the mean are classified as outliers.
- trial_prune_percent_subject and trial_prune_percent_sample remove trials below and/or above certain percentiles, on a subject-by-subject basis or sample-wide, respectively. The following arguments are available:
    - lowerpercent and uppperpercent (optional; defaults are .01 and .99).

| | |
|---|---|
| errortrialfunc | Function (without brackets or quotes) to apply to an error trial. |

- prune_nothing removes no errors (default).

- `error_replace_blockmeanplus` replaces error trial reaction times with the block mean, plus an arbitrary extra quantity. If used, the following additional arguments are required:
    - `blockvar` - Quoted name of the block variable (mandatory)
    - `errorvar` - Quoted name of the error variable, where errors are 1 or TRUE and correct trials are 0 or FALSE (mandatory)
    - `errorbonus` - Amount to add to the reaction time of error trials. Default is 0.6 (recommended by Greenwald, Nosek, & Banaji, 2003)
- `error_prune_dropcases` removes errors and drops participants if they have more errors than a given percentage. The following arguments are available:
    - `errorvar` - Quoted name of the error variable, where errors are 1 or TRUE and correct trials are 0 or FALSE (mandatory)
    - `maxerrors` - participants with a higher percentage of errors are excluded from the dataset. Default is .15.

| | |
|---|---|
| `casedropfunc` | Function (without brackets or quotes) to be used to exclude outlying participant scores in each half. The way you handle outliers here should mimic the way you do it in your regular analyses. |

- `prune_nothing` excludes no participants (default)
- `case_prune_3SD` excludes participants deviating more than 3SD from the sample mean.

| | |
|---|---|
| `plot` | Create a scatterplot of the AAT scores computed from each half of the data from the last iteration. This is highly recommended, as it helps to identify outliers that can inflate or diminish the reliability. |
| `include.raw` | logical indicating whether raw split-half data should be included in the output object. |
| `parallel` | If TRUE (default), will use parallel computing to compute results faster. If a doParallel backend has not been registered beforehand, this function will register a cluster and stop it after finishing, which takes some extra time. |
| `...` | Other arguments, to be passed on to the algorithm or outlier rejection functions (see arguments above) |
| `x` | an `aat_splithalf` object |
| `coef` | Optional character argument, indicating which reliability coefficient should be printed. Defaults to Raju's beta. |
| `type` | Character argument indicating which iteration should be chosen. Must be an abbreviation of `"median"` (default), `"minimum"`, `"maximum"`, or `"random"`. |

## Details

The calculated split-half coefficients are described in Warrens (2016).

## Value

A list, containing the mean bootstrapped split-half reliability, bootstrapped 95 a list of data.frames used over each iteration, and a vector containing the split-half reliability of each iteration.

**Note**

The Spearman-Brown, Raju, and Flanagan-Rulon correlation coefficients are modified to prevent negative correlations from reaching extreme and impossible values (e.g. below -1).

**Author(s)**

Sercan Kahveci

**References**

Warrens, M. J. (2016). A comparison of reliability coefficients for psychometric tests that consist of two parts. Advances in Data Analysis and Classification, 10(1), 71-84.

**See Also**

q_reliability

**Examples**

```
split <- aat_splithalf(ds=erotica[erotica$is_irrelevant==0,],
                       subjvar="subject", pullvar="is_pull", targetvar="is_target",
                       rtvar="RT", stratvars="stimuluscode", iters=10,
                       trialdropfunc="trial_prune_3SD",
                       casedropfunc="case_prune_3SD", algorithm="aat_dscore",
                       plot=FALSE, parallel=FALSE)

print(split)

plot(split)


#Regression Splithalf
aat_splithalf(ds=erotica[erotica$is_irrelevant==0,],
              subjvar="subject", pullvar="is_pull", targetvar="is_target",
              rtvar="RT", iters=10, trialdropfunc="trial_prune_3SD",
              casedropfunc="case_prune_3SD", algorithm="aat_regression",
              formula = RT ~ is_pull * is_target, aatterm = "is_pull:is_target",
              plot=FALSE, parallel=FALSE)
```

---

| aat_stimulusscores | *Compute stimulus-specific bias scores Computes mean single-difference scores (push - pull) for each stimulus.* |
|---|---|

---

**Description**

Compute stimulus-specific bias scores Computes mean single-difference scores (push - pull) for each stimulus.

## Usage

```
aat_stimulusscores(
  ds,
  subjvar,
  stimvar,
  pullvar,
  targetvar = NULL,
  rtvar,
  aggfunc = c("mean", "median"),
  iters = 5
)
```

## Arguments

| | |
|---|---|
| ds | the data.frame to use |
| subjvar | Name of the subject-identifying variable |
| stimvar | Name of the stimulus-identifying variable |
| pullvar | Name of the movement-direction identifying variable |
| targetvar | Optional. Name of the stimulus-category identifying variable |
| rtvar | Name of the reaction-time identifying variable |
| aggfunc | The function with which to aggregate the RTs before computing difference scores. Defaults to mean but can be changed to median. |
| iters | If there are missing values (which is almost inevitable) then multiple imputation will be used to complete the covariance matrix - this argument sets the number of multiple imputations to be used. |

## Value

Exports a list containing a data.frame with stimulus-specific bias scores, indicated in the column names, a covariance matrix of that same data, and a data.frame indicating to which stimulus category each stimulus belongs.

## Examples

```
ds<-aat_simulate(biasfx_jitter=40,nstims=16)
ds$stim<-paste0(ds$stim,"-",ds$is_target)
aat_stimulusscores(ds,"subj","stim","is_pull","is_target","rt")
```

| aat_stimulus_rest | *Compute stimulus-rest correlations of double-difference scores This function provides a statistic that can give an indication of how deviant the responses to specific stimuli are, in comparison to the rest of the stimulus set. The algorithm computes stimulus-rest correlations of stimulus-specific double-difference scores. It takes single-difference approach-avoidance scores for each stimulus, and computes every possible subtraction between individual stimuli from both stimulus categories. It then computes correlations between every such subtraction of stimuli on one hand, and the mean double difference score of all other stimuli. Stimulus-rest correlations are then computed by averaging every such subtraction-rest correlation involving a specific stimulus.* |
|---|---|

## Description

Compute stimulus-rest correlations of double-difference scores This function provides a statistic that can give an indication of how deviant the responses to specific stimuli are, in comparison to the rest of the stimulus set. The algorithm computes stimulus-rest correlations of stimulus-specific double-difference scores. It takes single-difference approach-avoidance scores for each stimulus, and computes every possible subtraction between individual stimuli from both stimulus categories. It then computes correlations between every such subtraction of stimuli on one hand, and the mean double difference score of all other stimuli. Stimulus-rest correlations are then computed by averaging every such subtraction-rest correlation involving a specific stimulus.

## Usage

```
aat_stimulus_rest(
  ds,
  subjvar,
  stimvar,
  pullvar,
  targetvar,
  rtvar,
  method = c("pearson", "spearman", "kendall")
)

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

## Arguments

| | |
|---|---|
| ds | a data.frame |
| subjvar | the label of the participant identifier variable |
| stimvar | the label of the stimulus identifier variable |
| pullvar | the label of the movement direction identifier variable |

| | |
|---|---|
| targetvar | the label of the stimulus category identifier variable |
| rtvar | the label of the reaction time variable |
| method | Optional, the correlation method to be used (pearson, spearman, kendall) |
| x | an `aat_stimulus_rest` object |
| ... | Ignored. |

## Value

Returns a `aat_stimulus_rest` object containing statistics for each stimulus. Stats include the average stimulus-rest correlation (mcor); the standard deviation of dyad-rest correlations for this stimulus (sdcor); the number of valid correlations involved in these statistic (n); the average percentile of dyad-rest correlations involving the stimulus within the distribution of all other dyad-rest correlations (restpercentile); as well as z-scores (zpercentile) and p-values for this percentile (pval).

## Examples

```
ds<-aat_simulate()
stimrest<-aat_stimulus_rest(ds,subjvar="subj",stimvar="stim",pullvar="is_pull",
                    targetvar="is_target",rtvar="rt")
plot(stimrest)
print(stimrest)
```

---

Algorithms                          *AAT score computation algorithms*

---

## Description

AAT score computation algorithms

## Usage

```
aat_doublemeandiff(ds, subjvar, pullvar, targetvar, rtvar, ...)

aat_doublemediandiff(ds, subjvar, pullvar, targetvar, rtvar, ...)

aat_dscore(ds, subjvar, pullvar, targetvar, rtvar, ...)

aat_mediandscore(ds, subjvar, pullvar, targetvar, rtvar, ...)

aat_dscore_multiblock(ds, subjvar, pullvar, targetvar, rtvar, blockvar, ...)

aat_regression(ds, subjvar, formula, aatterm, ...)

aat_standardregression(ds, subjvar, formula, aatterm, ...)

aat_singlemeandiff(ds, subjvar, pullvar, rtvar, ...)

aat_singlemediandiff(ds, subjvar, pullvar, rtvar, ...)
```

**Arguments**

| | |
|---|---|
| ds | A long-format data.frame |
| subjvar | Column name of the participant identifier variable |
| pullvar | Column name of the movement variable (0: avoid; 1: approach) |
| targetvar | Column name of the stimulus category variable (0: control stimulus; 1: target stimulus) |
| rtvar | Column name of the reaction time variable |
| ... | Other arguments passed on by functions (ignored) |
| blockvar | name of the variable indicating block number |
| formula | A regression formula to fit to the data to compute an AAT score |
| aatterm | A character naming the formula term representing the approach bias. Usually this is the interaction of the movement-direction and stimulus-category terms. |

**Value**

A data.frame containing participant number and computed AAT score.

**Functions**

- `aat_doublemeandiff()`: computes a mean-based double-difference score: (mean(push_target) – mean(pull_target)) – (mean(push_control) – mean(pull_control))

- `aat_doublemediandiff()`: computes a median-based double-difference score: (median(push_target) – median(pull_target)) – (median(push_control) – median(pull_control))

- `aat_dscore()`: computes D-scores for a 2-block design (see Greenwald, Nosek, and Banaji, 2003): ((mean(push_target) – mean(pull_target)) – (mean(push_control) – mean(pull_control))) / sd(participant_reaction_times)

- `aat_mediandscore()`: computes a double-difference score usign medians, and divides it by the median absolute deviation of the participant's overall reaction times: ((median(push_target) – median(pull_target)) – (median(push_control) – median(pull_control))) / mad(participant_reaction

- `aat_dscore_multiblock()`: computes D-scores for pairs of sequential blocks and averages the resulting score (see Greenwald, Nosek, and Banaji, 2003). Requires extra `blockvar` argument, indicating the name of the block variable.

- `aat_regression()`: aat_regression and aat_standardregression fit regression models to participants' reaction times and extract a term that serves as AAT score. aat_regression extracts the raw coefficient, equivalent to a mean difference score. aat_standardregression extracts the t-score of the coefficient, standardized on the basis of the variability of the participant's reaction times. These algorithms can be used to regress nuisance variables out of the data before computing AAT scores. When using these functions, additional arguments must be provided:

  - `formula` - a formula to fit to the data
  - `aatterm` - the term within the formula that indicates the approach bias; this is usually the interaction of the pull and target terms.

- `aat_standardregression()`: See above

- `aat_singlemeandiff()`: subtracts the mean approach reaction time from the mean avoidance reaction time. Using this algorithm is only sensible if the supplied data contain a single stimulus category.
- `aat_singlemediandiff()`: subtracts the median approach reaction time from the median avoidance reaction time. Using this algorithm is only sensible if the supplied data contain a single stimulus category.

---

cormean                                      *Compute a minimally biased average of correlation values*

---

### Description

This function computes a minimally biased average of correlation values. This is needed because simple averaging of correlations is negatively biased, and the often used z-transformation method of averaging correlations is positively biased. The algorithm was developed by Olkin & Pratt (1958).

### Usage

```
cormean(
  r,
  n,
  wts = c("none", "n", "df"),
  type = c("OP5", "OP2", "OPK"),
  na.rm = F
)
```

### Arguments

| | |
|---|---|
| r | a vector containing correlation values |
| n | a single value or vector containing sample sizes |
| wts | Character. How should the correlations be weighted? none leads to no weighting, n weights by sample size, df weights by sample size minus one. |
| type | Character. Determines which averaging algorithm to use, with "OP5" being the most accurate. |
| na.rm | Logical. Should missing values be removed? |

### Value

An average correlation.

### References

Olkin, I., & Pratt, J. (1958). Unbiased estimation of certain correlation coefficients. The Annals of Mathematical Statistics, 29. https://doi.org/10.1214/aoms/1177706717

Shieh, G. (2010). Estimation of the simple correlation coefficient. Behavior Research Methods, 42(4), 906-917. https://doi.org/10.3758/BRM.42.4.906

## Examples

```
cormean(c(0,.3,.5),c(30,30,60))
```

---

correlation-tools          *Correlation tools*

---

## Description

Helper functions to compute important statistics from correlation coefficients.

## Usage

```
r2z(r)

z2r(z)

r2t(r, n)

t2r(t, n)

r2p(r, n)

rconfint(r, n, alpha = 0.05)

compcorr(r1, r2, n1, n2)

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

## Arguments

| | |
|---|---|
| r, r1, r2 | a correlation value |
| z | a Z-score |
| n, n1, n2 | sample sizes |
| t | a t-score |
| alpha | the significance level to use |
| x | a compcorr object to print |
| ... | ignored |

## Functions

- r2z(): converts correlation coefficients to z-scores
- z2r(): converts z-scores to correlation coefficients
- r2t(): Converts correlation coefficients to t-scores

- `t2r()`: Converts t-scores to correlation coefficients
- `r2p()`: Computes the two-sided p-value for a given correlation
- `rconfint()`: Computes confidence intervals for one or multiple correlation coefficients
- `compcorr()`: computes the significance of the difference between two correlation coefficients
- `print(compcorr)`: computes the significance of the difference between two correlation coefficients

## See Also

[cormean](cormean)

## Examples

```
z <- r2z(.5)
r <- z2r(z)
t<-r2t(r,30)
r2p(r,30)
print(rconfint(r,30))
print(compcorr(.5,.7,20,20))
```

---

covEM                           *Covariance matrix computation with multiple imputation*

---

## Description

This function computes a covariance matrix from data with some values missing at random. The code was written by Eric from StackExchange. https://stats.stackexchange.com/questions/182718/ml-covariance-estimation-from-expectation-maximization-with-missing-data

## Usage

```
covEM(dat_missing, iters = 1000)
```

## Arguments

| | |
|---|---|
| `dat_missing` | a matrix with missing values |
| `iters` | the number of iterations to perform to estimate missing values |

## References

Beale, E. M. L., & Little, R. J. A.. (1975). Missing Values in Multivariate Analysis. Journal of the Royal Statistical Society. Series B (methodological), 37(1), 129–145.

## Examples

```
# make data with missing values
missing_mtcars <- mtcars
for(i in 1:20){
  missing_mtcars[sample(1:nrow(mtcars),1),sample(1:ncol(mtcars),1)]<-NA
}
covmat<-covEM(as.matrix(missing_mtcars))$sigma
calpha(covmat)
```

---

covrel                          *Covariance Matrix-Based Reliability Coefficients*

---

## Description

These functions allow for the computation of the reliability of a dataset from the covariance matrix of its variables.

## Usage

```
calpha(covmat)

lambda2(covmat)

lambda4(covmat)
```

## Arguments

covmat          a covariance matrix

## Functions

- `calpha()`: Cronbach's alpha
- `lambda2()`: Guttman's Lambda-2
- `lambda4()`: Guttman's Lambda-4. This algorithm tries to get the highest attainable reliability by

## See Also

[splitrel](splitrel)

## Examples

```
# compute reliability from covariance
h<-cov(iris[,1:4])
calpha(h)
lambda2(h)
lambda4(h)
# Lambda-2 and Lambda-4 are significantly larger because
# some of the variables in the iris dataset are negatively correlated.
```

---

erotica            *AAT examining approach bias for erotic stimuli*

---

### Description

AAT

### Usage

```
erotica
```

### Format

An object of class `"data.frame"`

### Source

[osf.io repository](#)

### References

Kahveci, S., Van Bockstaele, B.D., & Wiers, R.W. (in preparation). Pulling for Pleasure? Erotic Approach-Bias Associated With Porn Use, Not Problems. DOI:10.17605/OSF.IO/6H2RJ

---

Preprocessing            *Pre-processing rules*

---

### Description

These are pre-processing rules that can be used in [aat_splithalf](#), [aat_bootstrap](#), and [aat_compute](#).

- The following rules are to be used for the `trialdropfunc` argument. The way you handle outliers for the reliability computation and bootstrapping more broadly should mimic the way you do it in your regular analyses. It is recommended to exclude outlying trials when computing AAT scores using the mean double-dfference scores and regression scoring approaches, but not when using d-scores or median double-difference scores.

  - `prune_nothing` excludes no trials (default)
  - `trial_prune_3SD` excludes trials deviating more than 3SD from the mean per participant.
  - `trial_prune_3MAD` excludes trials deviating more than 3 median absolute deviations from the median per participant.
  - `trial_prune_grubbs` applies a Grubbs' test to the data, removing one outlier at a time until the test is no longer significant.

- – `trial_prune_SD_dropcases` removes trials deviating more than a specific number of standard deviations from the participant's mean, and removes participants with an excessive percentage of outliers. Required arguments:
  - ∗ `trialsd` - trials deviating more than `trialsd` standard deviations from the participant's mean are excluded (optional; default is 3)
  - ∗ `maxoutliers` - participants with a higher percentage of outliers are removed from the data. (optional; default is .15)
- – `trial_recode_SD` recodes outlying reaction times to the nearest non-outlying value, with outliers defined as reaction times deviating more than a certain number of standard deviations from the participant's mean. Required argument:
  - ∗ `trialsd` - trials deviating more than this many standard deviations from the mean are classified as outliers.
- – `trial_prune_percent_subject` and `trial_prune_percent_sample` remove trials below and/or above certain percentiles, on a subject-by-subject basis or sample-wide, respectively. The following arguments are available:
  - ∗ `lowerpercent` and `uppperpercent` (optional; defaults are .01 and .99).
- • The following pre-procesing rules are to be used for the `errortrialfunc` argument. They determine what is to be done with errors - remove or recode?
  - – `prune_nothing` removes no errors (default).
  - – `error_replace_blockmeanplus` replaces error trial reaction times with the block mean, plus an arbitrary extra quantity. If used, the following additional arguments are required:
    - ∗ `blockvar` - Quoted name of the block variable (mandatory)
    - ∗ `errorvar` - Quoted name of the error variable, where errors are 1 or TRUE and correct trials are 0 or FALSE (mandatory)
    - ∗ `errorbonus` - Amount to add to the reaction time of error trials. Default is 0.6 (recommended by `Greenwald, Nosek, & Banaji, 2003`)
  - – `error_prune_dropcases` removes errors and drops participants if they have more errors than a given percentage. The following arguments are available:
    - ∗ `errorvar` - Quoted name of the error variable, where errors are 1 or TRUE and correct trials are 0 or FALSE (mandatory)
    - ∗ `maxerrors` - participants with a higher percentage of errors are excluded from the dataset. Default is .15.
- • These are pre-processing rules to be used for the `casedropfunc` argument. The way you handle outliers here should mimic the way you do it in your regular analyses.
  - – `prune_nothing` excludes no participants (default)
  - – `case_prune_3SD` excludes participants deviating more than 3SD from the sample mean.

## Usage

```
prune_nothing(ds, ...)

trial_prune_percent_subject(
  ds,
  subjvar,
  rtvar,
```

```
  lowerpercent = 0.01,
  upperpercent = 0.99,
  ...
)

trial_prune_percent_sample(
  ds,
  rtvar,
  lowerpercent = 0.01,
  upperpercent = 0.99,
  ...
)

trial_prune_3SD(ds, subjvar, rtvar, ...)

trial_prune_3MAD(ds, subjvar, rtvar, ...)

trial_prune_SD_dropcases(
  ds,
  subjvar,
  rtvar,
  trialsd = 3,
  maxoutliers = 0.15,
  ...
)

trial_recode_SD(ds, subjvar, rtvar, trialsd = 3, ...)

trial_prune_grubbs(ds, subjvar, rtvar, ...)

case_prune_3SD(ds, ...)

error_replace_blockmeanplus(
  ds,
  subjvar,
  rtvar,
  blockvar,
  errorvar,
  errorbonus,
  ...
)

error_prune_dropcases(ds, subjvar, errorvar, maxerrors = 0.15, ...)
```

### Arguments

| | |
|---|---|
| ds | A data.frame. |
| ... | Other arguments (ignored). |

| | |
|---|---|
| subjvar | The name of the subject variable. |
| rtvar | The name of the reaction time variable. |
| lowerpercent, upperpercent | |
| | for `trial_prune_percent_subject` and `trial_prune_percent_sample`, the lower and upper proportions beyond which trials are considered outliers and removed (defaults to .01 and .99). |
| trialsd | The amount of deviation from the participant mean (in SD) after which a trial is considered an outlier and excluded (defaults to 3). |
| maxoutliers | for `trial_prune_SD_dropcases`, the maximum percentage of outliers, after which a participant is excluded from the data. |
| blockvar | The name of the block variable. |
| errorvar | The name of the error variable. |
| errorbonus | for `error_replace_blockmeanplus`, the amount of seconds to add to the block mean and use as a replacement for error trial reaction times (default is 0.6). |
| maxerrors | for `error_prune_dropcases`, the maximum percentage of errors, after which a participant is excluded from the data. |

---

q_reliability            *Compute psychological experiment reliability*

---

### Description

This function can be used to compute an exact reliability score for a psychological task whose results involve a difference score. The resulting intraclass correlation coefficient is equivalent to the average all possible split-half reliability scores. It ranges from -1 to 1, with -1 implying that all variance in the data is explained by within-subjects variability, 1 implying that all variance is explained by between-subjects variability, and 0 implying that within-subjects and between-subjects variability contribute equally to the total variance in the sample.

### Usage

```
q_reliability(ds, subjvar, formula, aatterm = NA)

q_reliability2(ds, subjvar, splitvars, rtvar, dscore = F, na.rm = F)

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

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

## Arguments

| | |
|---|---|
| ds | a long-format data.frame |
| subjvar | name of the subject variable |
| formula | a formula predicting the participant's reaction time using trial-level variables such as movement direction and stimulus category |
| aatterm | a string denoting the term in the formula that contains the participant's approach bias |
| splitvars | Vector of column names over which to split the data to compute difference scores. This can be used to compute the reliability of single, double, or even triple difference scores. |
| rtvar | Column name of the variable containing reaction times |
| dscore | If true, reliability will be computed for a difference score that is divided by the subject's standard deviation (as in D-scores) |
| na.rm | If true, remove rows with missing values from the data |
| x | a qreliability object |
| ... | Other arguments passed to the generic print and plot functions. |

## Value

a qreliability object, containing the reliability coefficient, and a data.frame with participants' bias scores and score variance.

Please note that the valence of the bias scores may or may not correspond with approach and avoidance. If you plan to use these scores in your analyses, always verify that they are in the right direction by correlating them with independently calculated bias scores, for example using aat_compute().

## Author(s)

Sercan Kahveci

## Examples

```
# Double-difference score reliability
q_reliability(ds=erotica,subjvar="subject",
               formula= RT ~ is_pull * is_target, aatterm = "is_pull:is_target")

# Single-difference reliability for target stimuli
q_reliability(ds=erotica[erotica$is_target ==1,],subjvar="subject",
               formula= RT ~ is_pull, aatterm = "is_pull")

# Reliability of the mean reaction time of approaching target stimuli (no difference score)
q_reliability(ds=erotica[erotica$is_target ==1 & erotica$is_pull ==1,],subjvar="subject",
               formula= RT ~ 1, aatterm = "1")

q_reliability2(ds=erotica,subjvar="subject",
               splitvars=c("is_pull", "is_target"),rtvar="RT")
```

---

| splitrel | *Split Half-Based Reliability Coefficients* |

---

### Description

Split Half-Based Reliability Coefficients

### Usage

```
SpearmanBrown(corr, ntests = 2, fix.negative = c("none", "nullify", "mirror"))

FlanaganRulon(x1, x2, fix.negative = c("none", "nullify", "mirror"))

RajuCoefficient(x1, x2, prop, fix.negative = c("none", "nullify", "mirror"))
```

### Arguments

| | |
|---|---|
| `corr` | To-be-corrected correlation coefficient |
| `ntests` | An integer indicating how many times larger the full test is, for which the corrected correlation coefficient is being computed. When `ntests=2`, the formula will compute what the correlation coefficient would be if the test were twice as long. |
| `fix.negative` | Determines how to deal with a negative value. "nullify" sets it to zero, "mirror" applies the correction as if it were a positive number, and then sets it to negative. "none" gives the raw value. It should be noted that negative values are not supposed to occur, and there is no commonly accepted way to deal with them when they do occur. |
| `x1` | scores from half 1 |
| `x2` | scores from half 2 |
| `prop` | Proportion of the first half to the complete sample |

### Value

Spearman-Brown-corrected correlation coefficient.

### Functions

- `SpearmanBrown()`: Perform a Spearman-Brown correction on the provided correlation score.
- `FlanaganRulon()`: Compute the true reliability using the Flanagan-Rulon formula, which takes into account inequal variances between split halves.
- `RajuCoefficient()`: Compute split-half reliability using the Raju formula, which takes into account unequal split-halves and variances.

### See Also

covrel

## Examples

```
SpearmanBrown(.5)
FlanaganRulon(a<-rnorm(50),rnorm(50)+a*.5,fix.negative="mirror")
a<-rnorm(50)
b<-rnorm(50)+a*.5
RajuCoefficient(a,b,prop=.4,fix.negative="mirror")
```

# Index