Package 'ieTest'

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Type Package

Title Indirect Effects Testing Methods in Mediation Analysis

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Description Used in testing if the indirect effect from linear regression mediation analysis is equal to 0. Includes established methods such as the Sobel Test, Joint Significant test (maxP), and tests based off the distribution of the Product or Normal Random Variables. Additionally, this package adds more powerful tests based on Intersection-Union theory. These tests are the S-Test, the ps-test, and the ascending squares test. These new methods are uniformly more powerful than maxP, which is more powerful than Sobel and less anti-conservative than the Product of Normal Random Variables. These methods are explored by Kidd and Lin, (2024) <doi:10.1007/s12561-023-09386-6> and Kidd et al., (2025) <doi:10.1007/s10260-024-00777-7>.

License GPL (>= 2)

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Contents

`ieTest-package` *Indirect Effects Testing methods in Mediation Analysis*

Description

A package to provide a multitude of methods used in testing if the indirect effect from linear regression mediation analysis is equal to 0. Includes established methods such as the Sobel test, joint-significanct test (maxP), and test based off the distribution of the product or normal random variables. A modification of the Sobel test by Aroian is also provided. Additionally, this packed addes more powerful tests based on intersection-union theory. These tests are the S-test, the modified S-test, and the ascending squares test. These new methods are uniformly more powerful than maxP, which is more powerful than Sobel and less anti-conservative than the product of normal random variables.

Details

Functions should be used to test a hypothesis that the indirect effect is equal to zero. Alternate hypothesis values for individual effects can be specified. Functions are provided for one and two mediator scenarios.

Test methods for one mediator and two ordered (sequential) mediators are provided for all above mentioned methods except the S-test. The S-test has logically falacies defined in (cited paper), and thus extensions to two mediators have not been conducted. In unordered (simultaneous) mediator scenarios, two mediation affects (one through each mediator) can be determined. Single mediator approaches should be used in these circumstances. For the methods defined by Sobel and Aroian, an overall test for a mediation affect exists using a sumation.

Single mediator function names are in the format of "test_one". For ordered/sequential approaches, functions are named "test_two_seq". The two unordered approaches are called by "sobelTest_two_sim" and "aroian_two_sim".

Author(s)

John Kidd

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References

Kidd, J., Howard, A.G., Highland, H.M. et al. *Hypothesis tests of indirect effects for multiple mediators*. Stat Methods Appl, 2025.

Kidd, J., Lin, DY. *Improving the Power to Detect Indirect Effects in Mediation Analysis*. Stat Biosci, 2025.

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asq_one *ASQ-Test for the indirect effect - Single mediator path*

Description

This function takes a vector of significance levels, as well as estimates and covariances, or 2 U values, for the asq-test for either one mediator of one path of an unordered mediation scenario. If estimates are passed to the function, the user must specify what distribution is to be used to find the cumulative probabilities. The smallest significance level for which the test is significant is returned, or 1 if no provided levels are significant. Additionally, the cutoff, either specified by number of squares or the percentage towards the center of the transformation region, can be specified.

Usage

```
asq_one(
  alpha,
  u1 = NULL,
  u2 = NULL,
  V1Dist = NULL,
  V1 = NULL,
  V1_VAR = NULL,
  V1_DF = NULL,
  V2Dist = NULL,
  V2 = NULL,
  V2_VAR = NULL,
  V2_DF = NULL,
  V2b = 0,
  V2b_VAR = 0,
  V2bmult = 1L,
  V1_V2_cov = 0,
  V1_V2b_cov = 0,
  V2_V2b_cov = 0,
  V1_0 = 0,
  V2_0 = 0,
  V2b_0 = 0,
```

```
  numSquares = 4L,
  upLim = 0.5
)
```

Arguments

alpha	Significance levels to be tested.
u1, u2	The U values to be used in the test. Given priority over estimates, but both must be supplied.
V1Dist	String value specifying the distribution of the estimate of the independent variable on the mediator. Ignored if u1 and u2 are supplied.
V1	Value of the estimate of the independent variable on the mediator. Ignored if u1 and u2 are supplied.
V1_VAR	Value of the variance of the estimate of the independent variable on the mediator. Ignored if u1 and u2 are supplied.
V1_DF	Degrees of freedom for V1. Only needed if t-distribution is used.
V2Dist	String value specifying the distribution of the estimate of the mediator (and interaction term) on the response.
V2	Value of the estimate of the mediator on the response. Ignored if u1 and u2 are supplied.
V2_VAR	Value of the variance of the estimate of the mediator on the response.. Ignored if u1 and u2 are supplied.
V2_DF	Degrees of freedom for V2. Only needed if t-distribution is used..
V2b	Value of the estimate of the effect of the interaction of the independent and mediator variable on the response. Ignored if u1 and u2 are supplied.
V2b_VAR	Value of the variance of the estimate of the effect of the interaction of the independent and mediator variable on the response. Ignored if u1 and u2 are supplied.
V2bmult	Value indicating the value of the independent variable used for the interaction. Typically 1.
V1_V2_cov	Value of the covariance between V1 and V2. Typically 0 for fully observed data.
V1_V2b_cov	Value of the covariance between V1 and V2b. Typically 0 for fully observed data.
V2_V2b_cov	Value of the covariance between V2 and V2b.
V1_0	Null value for V1.
V2_0	Null value for V2.
V2b_0	Null value for V2b.
numSquares	The number of squares to be used in the asq-test. Always superseded by upLim.
upLim	The allowed extension, between 0 and 1, of the squares towards the center of the region

Value

The smallest significance level that would reject the null hypothesis.

Examples

```
asq_one(c(.05, .01, .001), u1 = .02, u2= .015, upLim = .55)
```

---

asq_ord *ASQ-Test for the indirect effect - Ordered Mediators*

Description

This function takes a vector of significance levels, as well as estimates and covariances, or 3 U values, for the asq-test for an ordered mediation scenario. If estimates are passed to the function, the user must specify what distribution is to be used to find the cumulative probabilities. The smallest significance level for which the test is significant is returned, or 1 if no provided levels are significant. Additionally, the cutoff, either specified by number of squares or the percentage towards the center of the transformation region, can be specified.

Usage

```
asq_ord(
  alpha,
  u1 = NULL,
  u2 = NULL,
  u3 = NULL,
  V1Dist = NULL,
  V1 = NULL,
  V1_VAR = NULL,
  V1_DF = NULL,
  V2Dist = NULL,
  V2 = NULL,
  V2_VAR = NULL,
  V2_DF = NULL,
  V2b = 0,
  V2b_VAR = 0,
  V2bmult = 1L,
  V3Dist = NULL,
  V3 = NULL,
  V3_VAR = NULL,
  V3_DF = NULL,
  V3b = 0,
  V3b_VAR = 0,
  V1_V2_cov = 0,
  V1_V2b_cov = 0,
  V1_V3_cov = 0,
  V1_V3b_cov = 0,
  V2_V2b_cov = 0,
  V2_V3_cov = 0,
  V2_V3b_cov = 0,
```

```
  V2b_V3_cov = 0,
  V2b_V3b_cov = 0,
  V3_V3b_cov = 0,
  V1_0 = 0,
  V2_0 = 0,
  V2b_0 = 0,
  V3_0 = 0,
  V3b_0 = 0,
  numSquares = 4L,
  upLim = 0.5
)
```

Arguments

alpha	Significance levels to be tested.
u1, u2, u3	The U values to be used in the test. Given priority over estimates, but all must be supplied.
V1Dist	String value specifying the distribution of the estimate of the independent variable on the first mediator. Ignored if u1, u2, and u3 are supplied.
V1	Value of the estimate of the independent variable on the first mediator. Ignored if u1, u2, and u3 are supplied.
V1_VAR	Value of the variance of the estimate of the independent variable on the first mediator. Ignored if u1, u2, and u3 are supplied.
V1_DF	Degrees of freedom for V1. Only needed if t-distribution is used.
V2Dist	String value specifying the distribution of the estimate of the first mediator (and interaction term) on the second mediator.
V2	Value of the estimate of the first mediator on the second mediator. Ignored if u1, u2, and u3 are supplied.
V2_VAR	Value of the variance of the estimate of the first mediator on the second mediator. Ignored if u1, u2, and u3 are supplied.
V2_DF	Degrees of freedom for V2.
V2b	Value of the estimate of the effect of the interaction of the independent and first mediator variable on the second mediator. Ignored if u1, u2, and u3 are supplied.
V2b_VAR	Value of the variance of the estimate of the effect of the interaction of the independent and first mediator variable on the second mediator. Ignored if u1, u2, and u3 are supplied.
V2bmult	Value indicating the value of the independent variable used for the interactions. Typically 1.
V3Dist	String value specifying the distribution of the estimate of the second mediator (and interaction term) on the response.
V3	Value of the estimate of the second mediator on the response. Ignored if u1, u2, and u3 are supplied.
V3_VAR	Value of the variance of the estimate of the second mediator on the response. Ignored if u1, u2, and u3 are supplied.

V3_DF	Degrees of freedom for V3.
V3b	Value of the estimate of the effect of the interaction of the independent and second mediator variable on the response. Ignored if u1, u2, and u3 are supplied.
V3b_VAR	Value of the variance of the estimate of the effect of the interaction of the independent and second mediator variable on the response. Ignored if u1, u2, and u3 are supplied.
V1_V2_cov	Value of the covariance between V1 and V2. Typically 0 for fully observed data.
V1_V2b_cov	Value of the covariance between V1 and V2b. Typically 0 for fully observed data.
V1_V3_cov	Value of the covariance between V1 and V3. Typically 0 for fully observed data.
V1_V3b_cov	Value of the covariance between V1 and V3b. Typically 0 for fully observed data.
V2_V2b_cov	Value of the covariance between V2 and V2b.
V2_V3_cov	Value of the covariance between V2 and V3. Typically 0 for fully observed data.
V2_V3b_cov	Value of the covariance between V2 and V3b. Typically 0 for fully observed data.
V2b_V3_cov	Value of the covariance between V2b and V3. Typically 0 for fully observed data.
V2b_V3b_cov	Value of the covariance between V2b and V3b. Typically 0 for fully observed data.
V3_V3b_cov	Value of the covariance between V3 and V3b.
V1_0	Null value for V1.
V2_0	Null value for V2.
V2b_0	Null value for V2b.
V3_0	Null value for V3.
V3b_0	Null value for V3b.
numSquares	The number of squares to be used in the asq-test. Always superseded by upLim.
upLim	The allowed extension, between 0 and 1, of the squares towards the center of the region

Value

The smallest significance level that would reject the null hypothesis.

Examples

```
asq_ord(c(.05, .01, .001), u1 = .02, u2= .015, u3 = .995, upLim = .55)
```

asq_ord_bool *Is the mediation effect significant?*

Description

This function takes 3 U values for the asq-test for 2 ordered mediators, as well as an alpha level. It returns whether the test would reject at the given alpha level. Additionally, the cutoff, either specified by number of squares or the percentage towards the center of the transformation region, can be specified. This function is primarily called by the asq_ord function to determine if the test is significant at one of a chosen set of alpha values.

Usage

```
asq_ord_bool(alpha, u1, u2, u3, numSquares = 4L, upLim = 0.5)
```

Arguments

alpha	Significance level for the test.
u1, u2, u3	The U values to be used in the test
numSquares	The number of squares to be used in the asq-test. Always superceded by upLim
upLim	The allowed extension, between 0 and 1, of the squares towards the center of the region

Value

A boolean variable indicating if the indirect effect null hypothesis is rejected.

Examples

```
asq_ord_bool(.05, .02, .015, .995, upLim = .75)
```

ieTest *Testing the indirect effect.*

Description

This function takes a vector estimates and a matrix of covariances or a vector of U values to be used in various indirect effect tests. Estimate vectors with three parameters will default to single mediator analysis (or one path of unordered mediation), and five parameters will default to the ordered scenario. Values for the interaction term must be provided for this wrapper. The user can then specify the distribution(s) to be used as well as the test to be performed.

Usage

```
ieTest(
  test,
  u = NULL,
  V = NULL,
  cov = NULL,
  df = NULL,
  V_0 = 0,
  V1Dist = NULL,
  V2Dist = NULL,
  V3Dist = NULL,
  numSquares = 10,
  upLim = 0.5,
  alpha = 0.05,
  interMult = 1
)
```

Arguments

test	Denotes the test to be performed. ("maxP", "ps-test", "asq-test", "sobel", "sobel unordered")
u	A vector with the U values to be used in the test. Given priority over estimates, but all must be supplied. Order defined in note.
V	A vector containing the estimates to be used in the test. Must follow same order as u.
cov	A matrix of the covariance matrix of the estimates in V. Must be square with dimensions compatible with V. Must follow same order as u.
df	A vector of the degrees of freedom for the effect estimates. Length of 2 for single mediator, 3 for ordered.
V_0	A vector containing the null values of the estimates to be used in the test. Defaults to zero.
V1Dist	String value specifying the distribution of the estimate of the independent variable on the mediator.
V2Dist	String value specifying the distribution of the second estimate.
V3Dist	String value specifying the distribution of the third estimate (only needed for ordered scenario).
numSquares	The number of squares to be used in the asq-test. Always superseded by upLim.
upLim	The allowed extension, between 0 and 1, for the asq and ps-tests.
alpha	A vector for the asq-test of significance levels to test. A value in the ps-test to control type I error.
interMult	Integer indicating the level of the independent variable to use for the interaction terms.

Value

A p-value or p-value cutoff for the specified test for the indirect effect.

Note

Order of parameters Values must be in the correct order within u, V, and the cov matrix.

Single mediator (or single path in unordered scenarios):
Independent variable to mediator, mediator to response, interaction of independent and mediator.

Ordered mediators:
Independent variable to first mediator, first mediator to second mediator, interaction of independent and first mediator on second mediator, second mediator to response, interaction of independent and second mediator on response.

Combined Unordered Mediator:
Independent variable to first mediator, first mediator to response, interaction of independent and first mediator on response, Independent variable to second mediator, second mediator to response, interaction of independent and second mediator on response.

Examples

```
ieTest( test = "ps-test", u = c(.015, .02, .998), alpha = 0.05, upLim = 0.5)
```

`maxp_one` *MaxP test for the indirect effect - Single mediator path*

Description

This function takes estimates and covariances, or 2 U values, for the maxP test for either one mediator of one path of an unordered mediation scenario. If estimates are passed to the function, the user must specify what distribution is to be used to find the cumulative probabilities. The maximum p-value is returned.

Usage

```
maxp_one(
  u1 = NULL,
  u2 = NULL,
  V1Dist = NULL,
  V1 = NULL,
  V1_VAR = NULL,
  V1_DF = NULL,
  V2Dist = NULL,
  V2 = NULL,
  V2_VAR = NULL,
  V2_DF = NULL,
  V2b = 0,
  V2b_VAR = 0,
  V2bmult = 1L,
  V1_V2_cov = 0,
  V1_V2b_cov = 0,
```

```
  V2_V2b_cov = 0,
  V1_0 = 0,
  V2_0 = 0,
  V2b_0 = 0
)
```

Arguments

u1, u2	The U values to be used in the test. Given priority over estimates, but both must be supplied.
V1Dist	String value specifying the distribution of the estimate of the independent variable on the mediator. Ignored if u1 and u2 are supplied.
V1	Value of the estimate of the independent variable on the mediator. Ignored if u1 and u2 are supplied.
V1_VAR	Value of the variance of the estimate of the independent variable on the mediator. Ignored if u1 and u2 are supplied.
V1_DF	Degrees of freedom for V1. Only needed if t-distribution is used.
V2Dist	String value specifying the distribution of the estimate of the mediator (and interaction term) on the response.
V2	Value of the estimate of the mediator on the response. Ignored if u1 and u2 are supplied.
V2_VAR	Value of the variance of the estimate of the mediator on the response.. Ignored if u1 and u2 are supplied.
V2_DF	Degrees of freedom for V2. Only needed if t-distribution is used..
V2b	Value of the estimate of the effect of the interaction of the independent and mediator variable on the response. Ignored if u1 and u2 are supplied.
V2b_VAR	Value of the variance of the estimate of the effect of the interaction of the independent and mediator variable on the response. Ignored if u1 and u2 are supplied.
V2bmult	Value indicating the value of the independent variable used for the interaction. Typically 1.
V1_V2_cov	Value of the covariance between V1 and V2. Typically 0 for fully observed data.
V1_V2b_cov	Value of the covariance between V1 and V2b. Typically 0 for fully observed data.
V2_V2b_cov	Value of the covariance between V2 and V2b.
V1_0	Null value for V1.
V2_0	Null value for V2.
V2b_0	Null value for V2b.

Value

The p-value of the test in the form of the larger of the p-values for the individual parameters.

Examples

```
maxp_one(u1 = .02, u2= .015)
```

maxp_ord *MaxP-Test for the indirect effect - Ordered Mediators*

Description

This function takes estimates and covariances, or 3 U values, for the maxp-test for an ordered mediation scenario. If estimates are passed to the function, the user must specify what distribution is to be used to find the cumulative probabilities. The p-value of the maxp-test is returned.

Usage

```
maxp_ord(
  u1 = NULL,
  u2 = NULL,
  u3 = NULL,
  V1Dist = NULL,
  V1 = NULL,
  V1_VAR = NULL,
  V1_DF = NULL,
  V2Dist = NULL,
  V2 = NULL,
  V2_VAR = NULL,
  V2_DF = NULL,
  V2b = 0,
  V2b_VAR = 0,
  V2bmult = 1L,
  V3Dist = NULL,
  V3 = NULL,
  V3_VAR = NULL,
  V3_DF = NULL,
  V3b = 0,
  V3b_VAR = 0,
  V1_V2_cov = 0,
  V1_V2b_cov = 0,
  V1_V3_cov = 0,
  V1_V3b_cov = 0,
  V2_V2b_cov = 0,
  V2_V3_cov = 0,
  V2_V3b_cov = 0,
  V2b_V3_cov = 0,
  V2b_V3b_cov = 0,
  V3_V3b_cov = 0,
  V1_0 = 0,
  V2_0 = 0,
  V2b_0 = 0,
  V3_0 = 0,
  V3b_0 = 0
```

)

Arguments

u1, u2, u3	The U values to be used in the test. Given priority over estimates, but all must be supplied.
V1Dist	String value specifying the distribution of the estimate of the independent variable on the first mediator. Ignored if u1, u2, and u3 are supplied.
V1	Value of the estimate of the independent variable on the first mediator. Ignored if u1, u2, and u3 are supplied.
V1_VAR	Value of the variance of the estimate of the independent variable on the first mediator. Ignored if u1, u2, and u3 are supplied.
V1_DF	Degrees of freedom for V1. Only needed if t-distribution is used.
V2Dist	String value specifying the distribution of the estimate of the first mediator (and interaction term) on the second mediator.
V2	Value of the estimate of the first mediator on the second mediator. Ignored if u1, u2, and u3 are supplied.
V2_VAR	Value of the variance of the estimate of the first mediator on the second mediator. Ignored if u1, u2, and u3 are supplied.
V2_DF	Degrees of freedom for V2.
V2b	Value of the estimate of the effect of the interaction of the independent and first mediator variable on the second mediator. Ignored if u1, u2, and u3 are supplied.
V2b_VAR	Value of the variance of the estimate of the effect of the interaction of the independent and first mediator variable on the second mediator. Ignored if u1, u2, and u3 are supplied.
V2bmult	Value indicating the value of the independent variable used for the interactions. Typically 1.
V3Dist	String value specifying the distribution of the estimate of the second mediator (and interaction term) on the response.
V3	Value of the estimate of the second mediator on the response. Ignored if u1, u2, and u3 are supplied.
V3_VAR	Value of the variance of the estimate of the second mediator on the response. Ignored if u1, u2, and u3 are supplied.
V3_DF	Degrees of freedom for V3.
V3b	Value of the estimate of the effect of the interaction of the independent and second mediator variable on the response. Ignored if u1, u2, and u3 are supplied.
V3b_VAR	Value of the variance of the estimate of the effect of the interaction of the independent and second mediator variable on the response. Ignored if u1, u2, and u3 are supplied.
V1_V2_cov	Value of the covariance between V1 and V2. Typically 0 for fully observed data.
V1_V2b_cov	Value of the covariance between V1 and V2b. Typically 0 for fully observed data.
V1_V3_cov	Value of the covariance between V1 and V3. Typically 0 for fully observed data.

V1_V3b_cov	Value of the covariance between V1 and V3b. Typically 0 for fully observed data.
V2_V2b_cov	Value of the covariance between V2 and V2b
V2_V3_cov	Value of the covariance between V2 and V3 Typically 0 for fully observed data.
V2_V3b_cov	Value of the covariance between V2 and V3b Typically 0 for fully observed data.
V2b_V3_cov	Value of the covariance between V2b and V3. Typically 0 for fully observed data.
V2b_V3b_cov	Value of the covariance between V2b and V3b Typically 0 for fully observed data.
V3_V3b_cov	Value of the covariance between V3 and V3b.
V1_0	Null value for V1.
V2_0	Null value for V2.
V2b_0	Null value for V2b.
V3_0	Null value for V3.
V3b_0	Null value for V3b.

Value

The p-value of the test in the form of the larger of the p-values for the individual parameters.

Examples

```
maxp_ord( u1 = .02, u2= .015, u3 = .995)
```

---

ps_one *PS-Test for the indirect effect - Single mediator path*

Description

This function takes estimates and covariances, or 2 U values, for the ps-test for either one mediator of one path of an unordered mediation scenario. If estimates are passed to the function, the user must specify what distribution is to be used to find the cumulative probabilities. The p-value of the ps-test is returned. Additionally, the cutoff, specified by the percentage towards the center of the transformation region, can be specified.

Usage

```
ps_one(
  u1 = NULL,
  u2 = NULL,
  V1Dist = NULL,
  V1 = NULL,
  V1_VAR = NULL,
  V1_DF = NULL,
```

```
  V2Dist = NULL,
  V2 = NULL,
  V2_VAR = NULL,
  V2_DF = NULL,
  V2b = 0,
  V2b_VAR = 0,
  V2bmult = 1L,
  V1_V2_cov = 0,
  V1_V2b_cov = 0,
  V2_V2b_cov = 0,
  V1_0 = 0,
  V2_0 = 0,
  V2b_0 = 0,
  upLim = 0.5,
  alpha = NULL
)
```

Arguments

u1, u2	The U values to be used in the test. Given priority over estimates, but both must be supplied.
V1Dist	String value specifying the distribution of the estimate of the independent variable on the mediator. Ignored if u1 and u2 are supplied.
V1	Value of the estimate of the independent variable on the mediator. Ignored if u1 and u2 are supplied.
V1_VAR	Value of the variance of the estimate of the independent variable on the mediator. Ignored if u1 and u2 are supplied.
V1_DF	Degrees of freedom for V1. Only needed if t-distribution is used.
V2Dist	String value specifying the distribution of the estimate of the mediator (and interaction term) on the response.
V2	Value of the estimate of the mediator on the response. Ignored if u1 and u2 are supplied.
V2_VAR	Value of the variance of the estimate of the mediator on the response.. Ignored if u1 and u2 are supplied.
V2_DF	Degrees of freedom for V2. Only needed if t-distribution is used..
V2b	Value of the estimate of the effect of the interaction of the independent and mediator variable on the response. Ignored if u1 and u2 are supplied.
V2b_VAR	Value of the variance of the estimate of the effect of the interaction of the independent and mediator variable on the response. Ignored if u1 and u2 are supplied.
V2bmult	Value indicating the value of the independent variable used for the interaction. Typically 1.
V1_V2_cov	Value of the covariance between V1 and V2. Typically 0 for fully observed data.
V1_V2b_cov	Value of the covariance between V1 and V2b. Typically 0 for fully observed data.

V2_V2b_cov	Value of the covariance between V2 and V2b.
V1_0	Null value for V1.
V2_0	Null value for V2.
V2b_0	Null value for V2b.
upLim	The allowed extension, between 0 and 1, of the band towards the center of the region
alpha	Used to ensure correctly controlled type I error for large values of upLim.

Value

The smallest alpha value for which the generated rejection region leads to rejection of the hypothesis test. Can be used as a p-value.

Examples

```
ps_one(u1 = .02, u2= .015, upLim = .55)
```

---

ps_ord *PS-Test for the indirect effect - Ordered Mediators*

Description

This function takes estimates and covariances, or 3 U values, for the ps-test for an ordered mediation scenario. If estimates are passed to the function, the user must specify what distribution is to be used to find the cumulative probabilities. The p-value of the ps-test is returned. Additionally, the cutoff, specified by the percentage towards the center of the transformation region, can be specified.

Usage

```
ps_ord(
  u1 = NULL,
  u2 = NULL,
  u3 = NULL,
  V1Dist = NULL,
  V1 = NULL,
  V1_VAR = NULL,
  V1_DF = NULL,
  V2Dist = NULL,
  V2 = NULL,
  V2_VAR = NULL,
  V2_DF = NULL,
  V2b = 0,
  V2b_VAR = 0,
  V2bmult = 1L,
  V3Dist = NULL,
  V3 = NULL,
```

```
  V3_VAR = NULL,
  V3_DF = NULL,
  V3b = 0,
  V3b_VAR = 0,
  V1_V2_cov = 0,
  V1_V2b_cov = 0,
  V1_V3_cov = 0,
  V1_V3b_cov = 0,
  V2_V2b_cov = 0,
  V2_V3_cov = 0,
  V2_V3b_cov = 0,
  V2b_V3_cov = 0,
  V2b_V3b_cov = 0,
  V3_V3b_cov = 0,
  V1_0 = 0,
  V2_0 = 0,
  V2b_0 = 0,
  V3_0 = 0,
  V3b_0 = 0,
  upLim = 0.5,
  alpha = NULL
)
```

Arguments

u1, u2, u3	The U values to be used in the test. Given priority over estimates, but all must be supplied.
V1Dist	String value specifying the distribution of the estimate of the independent variable on the first mediator. Ignored if u1, u2, and u3 are supplied.
V1	Value of the estimate of the independent variable on the first mediator. Ignored if u1, u2, and u3 are supplied.
V1_VAR	Value of the variance of the estimate of the independent variable on the first mediator. Ignored if u1, u2, and u3 are supplied.
V1_DF	Degrees of freedom for V1. Only needed if t-distribution is used.
V2Dist	String value specifying the distribution of the estimate of the first mediator (and interaction term) on the second mediator.
V2	Value of the estimate of the first mediator on the second mediator. Ignored if u1, u2, and u3 are supplied.
V2_VAR	Value of the variance of the estimate of the first mediator on the second mediator. Ignored if u1, u2, and u3 are supplied.
V2_DF	Degrees of freedom for V2.
V2b	Value of the estimate of the effect of the interaction of the independent and first mediator variable on the second mediator. Ignored if u1, u2, and u3 are supplied.
V2b_VAR	Value of the variance of the estimate of the effect of the interaction of the independent and first mediator variable on the second mediator. Ignored if u1, u2, and u3 are supplied.

V2bmult	Value indicating the value of the independent variable used for the interaction. Typically 1.
V3Dist	String value specifying the distribution of the estimate of the second mediator (and interaction term) on the response.
V3	Value of the estimate of the second mediator on the response. Ignored if u1, u2, and u3 are supplied.
V3_VAR	Value of the variance of the estimate of the second mediator on the response. Ignored if u1, u2, and u3 are supplied.
V3_DF	Degrees of freedom for V3.
V3b	Value of the estimate of the effect of the interaction of the independent and second mediator variable on the response. Ignored if u1, u2, and u3 are supplied.
V3b_VAR	Value of the variance of the estimate of the effect of the interaction of the independent and second mediator variable on the response. Ignored if u1, u2, and u3 are supplied.
V1_V2_cov	Value of the covariance between V1 and V2. Typically 0 for fully observed data.
V1_V2b_cov	Value of the covariance between V1 and V2b. Typically 0 for fully observed data.
V1_V3_cov	Value of the covariance between V1 and V3. Typically 0 for fully observed data.
V1_V3b_cov	Value of the covariance between V1 and V3b. Typically 0 for fully observed data.
V2_V2b_cov	Value of the covariance between V2 and V2b
V2_V3_cov	Value of the covariance between V2 and V3 Typically 0 for fully observed data.
V2_V3b_cov	Value of the covariance between V2 and V3b Typically 0 for fully observed data.
V2b_V3_cov	Value of the covariance between V2b and V3. Typically 0 for fully observed data.
V2b_V3b_cov	Value of the covariance between V2b and V3b Typically 0 for fully observed data.
V3_V3b_cov	Value of the covariance between V3 and V3b.
V1_0	Null value for V1.
V2_0	Null value for V2.
V2b_0	Null value for V2b.
V3_0	Null value for V3.
V3b_0	Null value for V3b.
upLim	The allowed extension, between 0 and 1, of the band towards the center of the region.
alpha	Used to ensure correctly controlled type I error for large values of upLim.

Value

The smallest alpha value for which the generated rejection region leads to rejection of the hypothesis test. Can be used as a p-value.

Examples

```
ps_ord( u1 = .02, u2= .015, u3 = .995, upLim = .55)
```

`sobelTest_one` *Sobel test for the indirect effect - Single mediator path*

Description

This function takes the parameter estimates and covariances and performs the Sobel test for one mediator, or a single mediator path for multiple unordered mediators.

Usage

```
sobelTest_one(
  mu1,
  sig1,
  mu2,
  sig2,
  sig12,
  indL = 1,
  mu3 = 0L,
  sig3 = 0L,
  sig13 = 0L,
  sig23 = 0L,
  mu1_0 = 0,
  mu2_0 = 0,
  mu3_0 = 0
)
```

Arguments

`mu1`	Value of the estimate of the independent variable on the mediator.
`sig1`	Value of the variance of the estimate of the independent variable on the mediator.
`mu2`	Value of the estimate of the mediator on the response.
`sig2`	Value of the variance of the estimate of the mediator on the response.
`sig12`	Value of the covariance between mu1 and mu2.
`indL`	Value indicating the value of the independent variable used for the interaction. Typically 1.
`mu3`	Value of the estimate of the effect of the interaction of the independent and mediator variable on the response.
`sig3`	Value of the variance of the estimate of the effect of the interaction of the independent and mediator variable on the response.
`sig13`	Value of the covariance between mu1 and mu3.
`sig23`	Value of the covariance between mu2 and mu3.
`mu1_0`	Null value for mu1.
`mu2_0`	Null value for mu2.
`mu3_0`	Null value for mu3.

Value

A p-value for the test for the indirect effect.

Examples

```
sobelTest_one(1, .1, .25, .01, .05)
```

`sobelTest_ord` *Sobel test for the indirect effect - Two ordered mediator path*

Description

This function takes the parameter estimates and covariances and performs the Sobel test for two ordered mediators.

Usage

```
sobelTest_ord(
  mu1,
  sig1,
  mu2,
  sig2,
  mu3,
  sig3,
  mu2b = 0L,
  sig2b = 0L,
  mu3b = 0L,
  sig3b = 0L,
  sig12 = 0L,
  sig12b = 0L,
  sig13 = 0L,
  sig13b = 0L,
  sig22b = 0L,
  sig23 = 0L,
  sig23b = 0L,
  sig2b3 = 0L,
  sig2b3b = 0L,
  sig33b = 0L,
  indL = 1L,
  mu1_0 = 0,
  mu2_0 = 0,
  mu3_0 = 0,
  mu2b_0 = 0,
  mu3b_0 = 0
)
```

Arguments

mu1	Value of the estimate of the independent variable on the first mediator.
sig1	Value of the variance of the estimate of the independent variable on the first mediator.
mu2	Value of the estimate of the first mediator on the second mediator.
sig2	Value of the variance of the estimate of the first mediator on the second mediator.
mu3	Value of the estimate of the second mediator on the response.
sig3	Value of the variance of the estimate of the second mediator on the response.
mu2b	Value of the estimate of the effect of the interaction of the independent and first mediator variable on the second mediator.
sig2b	Value of the variance of the estimate of the effect of the interaction of the independent and first mediator variable on the second mediator.
mu3b	Value of the estimate of the effect of the interaction of the independent and second mediator variable on the response.
sig3b	Value of the variance of the estimate of the effect of the interaction of the independent and second mediator variable on the response.
sig12	Value of the covariance between mu1 and mu2.
sig12b	Value of the covariance between mu1 and mu2b.
sig13	Value of the covariance between mu1 and mu3.
sig13b	Value of the covariance between mu1 and mu3b.
sig22b	Value of the covariance between mu2 and mu2b.
sig23	Value of the covariance between mu2 and mu3.
sig23b	Value of the covariance between mu2 and mu2b.
sig2b3	Value of the covariance between mu2b and mu3.
sig2b3b	Value of the covariance between mu2b and mu3b.
sig33b	Value of the covariance between mu3 and mu3b.
indL	Value indicating the value of the independent variable used for the interaction. Typically 1.
mu1_0	Null value for mu1.
mu2_0	Null value for mu2.
mu3_0	Null value for mu3.
mu2b_0	Null value for mu2b.
mu3b_0	Null value for mu3b.

Value

A p-value for the test for the indirect effect.

Examples

```
sobelTest_ord(1, .1, .25, .01, 0, 0, .15, .01, 0, 0)
```

`sobelTest_unord` *Sobel test for the indirect effect - Two ordered mediator path*

Description

This function takes the parameter estimates and covariances and performs the Sobel test for two ordered mediators.

Usage

```
sobelTest_unord(
  mu1,
  sig1,
  mu2,
  sig2,
  mu3,
  sig3,
  mu4,
  sig4,
  mu2b,
  sig2b,
  mu4b,
  sig4b,
  sig12 = 0L,
  sig12b = 0L,
  sig13 = 0L,
  sig14 = 0L,
  sig14b = 0L,
  sig22b = 0L,
  sig23 = 0L,
  sig24 = 0L,
  sig24b = 0L,
  sig2b3 = 0L,
  sig2b4 = 0L,
  sig2b4b = 0L,
  sig34 = 0L,
  sig34b = 0L,
  sig44b = 0L,
  indL = 1L,
  mu1_0 = 0,
  mu2_0 = 0,
  mu3_0 = 0,
  mu4_0 = 0,
  mu2b_0 = 0,
  mu4b_0 = 0
)
```

Arguments

mu1	Value of the estimate of the independent variable on the first mediator.
sig1	Value of the variance of the estimate of the independent variable on the first mediator.
mu2	Value of the estimate of the first mediator on the response.
sig2	Value of the variance of the estimate of the first mediator on the response.
mu3	Value of the estimate of the independent variable on the second mediator.
sig3	Value of the variance of the estimate of the independent variable on the second mediator.
mu4	Value of the estimate of the second mediator on the response.
sig4	Value of the variance of the estimate of the second mediator on the response.
mu2b	Value of the estimate of the effect of the interaction of the independent and first mediator variable on the response.
sig2b	Value of the variance of the estimate of the effect of the interaction of the independent and first mediator variable on the response.
mu4b	Value of the estimate of the effect of the interaction of the independent and second mediator variable on the response.
sig4b	Value of the variance of the estimate of the effect of the interaction of the independent and second mediator variable on the response.
sig12	Value of the covariance between mu1 and mu2.
sig12b	Value of the covariance between mu1 and mu2b.
sig13	Value of the covariance between mu1 and mu3.
sig14	Value of the covariance between mu1 and mu4.
sig14b	Value of the covariance between mu1 and mu4b.
sig22b	Value of the covariance between mu1 and mu2b.
sig23	Value of the covariance between mu2 and mu3.
sig24	Value of the covariance between mu2 and mu4.
sig24b	Value of the covariance between mu2 and mu4b.
sig2b3	Value of the covariance between mu2b and mu3.
sig2b4	Value of the covariance between mu2b and mu4.
sig2b4b	Value of the covariance between mu2b and mu4b.
sig34	Value of the covariance between mu3 and mu4.
sig34b	Value of the covariance between mu3 and mu4b.
sig44b	Value of the covariance between mu4 and mu4b.
indL	Value indicating the value of the independent variable used for the interaction. Typically 1.
mu1_0	Null value for mu1.
mu2_0	Null value for mu2.
mu3_0	Null value for mu3.
mu4_0	Null value for mu4.
mu2b_0	Null value for mu2b.
mu4b_0	Null value for mu4b.

Value

A p-value for the test for the indirect effect.

Examples

```
sobelTest_unord(1, .1, .25, .01, 0, 0, .15, .01, 0, 0, 0, 0)
```

`sTest_one` *S test for Indirect Effect for a single mediator*

Description

This function takes the estimate of the effect of the independent variable on the mediator and the effect of the mediator on the effect as well as their variances and performs the S test. Alternative null hypothesis can be specified as well. Additionally, covariances of the parameters can be specified for cases involving missing data where the estimates may be correlated.

Usage

```
sTest_one(alpha, x1, s11, df1, x2, s22, df2, x10 = 0, x20 = 0, s12 = 0)
```

Arguments

`alpha`	Significance level for the test of significance
`x1`	Numeric value of the estimated first effect of interest
`s11`	Numeric value of the estimated first effect variance
`df1`	Degrees of freedom for estimate x1
`x2`	Numeric value of estimated second effect of interest
`s22`	Numeric value of the estimated second effect variance
`df2`	Degrees of freedom for estimate x2. Often the same as x1
`x10`	Optional numeric value of alternative null hypothesis value for the first effect
`x20`	Optional numeric value of alternative null hypothesis value for the second effect
`s12`	Specification of covariance between x1 and x2. Typically 0, but may be non-zero in the prescence of missing data

Value

Boolean True/False value of whether the test rejects the Null hypothesis

Note

The function for the S-test does not incorporate interactions between the independent and mediating variables. The user must first calculate the mean and variance of the second product term to be used in the function call.

References

Berger, Roger L. Likelihood Ratio Tests and Intersection-Union Tests. Advances in Statistical Decision Theory and Applications, 2011.

Examples

```
sTest_one(0.05, .5, 1, 100, -.25, .1, 100)
```

Index