Package ‘BUCSS’

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Type Package

Title Bias and Uncertainty Corrected Sample Size

Version 1.1.0

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Description Implements a method of correcting for publication bias and uncertainty when planning sample sizes in a future study from an original study. See Anderson, Kelley, & Maxwell (2017; Psychological Science, 28, 1547-1562).

License GPL (>= 3)

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BUCSS-package *Bias and Uncertainty Corrected Sample Size (BUCSS)*

Description

BUCSS implements a method of correcting for publication bias anduncertainty when planning sample sizes in a future study from an original study

Details

Note that https://designingexperiments.com uses Shiny R apps that implement, via a web interface, the functions contained in BUCSS.

Author(s)

Samantha Anderson <samantha.f.anderson@asu.edu> and Ken Kelley <kkelley@nd.edu>

References

Anderson, S. & Kelley, K., Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science*, *28*, 1547–1562.

See https://designingexperiments.com/ for Shiny R implementation of the functions.

For suggested updates, please email Samantha Anderson <samantha.f.anderson@asu.edu> or Ken Kelley <kkelley@nd.edu>.

ss.power.ba *Necessary sample size to reach desired power for a one or two-way between-subjects ANOVA using an uncertainty and publication bias correction procedure*

Description

ss.power.ba returns the necessary per-group sample size to achieve a desired level of statistical power for a planned study testing an omnibus effect using a one or two-way fully between-subjects ANOVA, based on information obtained from a previous study. The effect from the previous study can be corrected for publication bias and/or uncertainty to provide a sample size that will achieve more accurate statistical power for a planned study, when compared to approaches that use a sample effect size at face value or rely on sample size only.

Usage

```
ss.power.ba(F.observed, N, levels.A, levels.B = NULL, effect = c("factor.A",
  "factor.B", "interaction"), alpha.prior = 0.05, alpha.planned = 0.05,
  assurance = 0.8, power = 0.8, step = 0.001)
```

Arguments

`F.observed`	Observed F-value from a previous study used to plan sample size for a planned study
`N`	Total sample size of the previous study
`levels.A`	Number of levels for factor A
`levels.B`	Number of levels for factor B, which is NULL if a single factor design
`effect`	Effect most of interest to the planned study: main effect of A (`factor.A`), main effect of B (`factor.B`), interaction (`interaction`)
`alpha.prior`	Alpha-level α for the previous study or the assumed statistical significance necessary for publishing in the field; to assume no publication bias, a value of 1 can be entered (correct for uncertainty only)
`alpha.planned`	Alpha-level (α) assumed for the planned study
`assurance`	Desired level of assurance, or the long run proportion of times that the planned study power will reach or surpass desired level (assurance of .5 corrects for publication bias only; assurance > .5 corrects for uncertainty)
`power`	Desired level of statistical power for the planned study
`step`	Value used in the iterative scheme to determine the noncentrality parameter necessary for sample size planning (0 < step < .01) (users should not generally need to change this value; smaller values lead to more accurate sample size planning results, but unnecessarily small values will add unnecessary computational time)

Details

Researchers often use the sample effect size from a prior study as an estimate of the likely size of an expected future effect in sample size planning. However, sample effect size estimates should not usually be used at face value to plan sample size, due to both publication bias and uncertainty.

The approach implemented in `ss.power.ba` uses the observed F-value and sample size from a previous study to correct the noncentrality parameter associated with the effect of interest for publication bias and/or uncertainty. This new estimated noncentrality parameter is then used to calculate the necessary per-group sample size to achieve the desired level of power in the planned study.

The approach uses a likelihood function of a truncated non-central F distribution, where the truncation occurs due to small effect sizes being unobserved due to publication bias. The numerator of the likelihood function is simply the density of a noncentral F distribution. The denominator is the power of the test, which serves to truncate the distribution. Thus, the ratio of the numerator and the denominator is a truncated noncentral F distribution. (See Taylor & Muller, 1996, Equation 2.1. and Anderson & Maxwell, in press, for more details.)

Assurance is the proportion of times that power will be at or above the desired level, if the experiment were to be reproduced many times. For example, assurance = .5 means that power will be above the desired level half of the time, but below the desired level the other half of the time. Selecting assurance = .5 (selecting the noncentrality parameter at the 50th percentile of the likelihood distribution) results in a median-unbiased estimate of the population noncentrality parameter and corrects for publication bias only. In order to correct for uncertainty, assurance > .5 can be selected, which corresponds to selecting the noncentrality parameter associated with the (1 - assurance) quantile of the likelihood distribution.

If the previous study of interest has not been subjected to publication bias (e.g., a pilot study), `alpha.prior` can be set to 1 to indicate no publication bias. Alternative α-levels can also be accommodated to represent differing amounts of publication bias. For example, setting `alpha.prior=`.20 would reflect less severe publication bias than the default of .05. In essence, setting `alpha.prior` at .20 assumes that studies with p-values less than .20 are published, whereas those with alrger p-values are not.

In some cases, the corrected noncentrality parameter for a given level of assurance will be estimated to be zero. This is an indication that, at the desired level of assurance, the previous study's effect cannot be accurately estimated due to high levels of uncertainty and bias. When this happens, subsequent sample size planning is not possible with the chosen specifications. Two alternatives are recommended. First, users can select a lower value of assurance (e.g. .8 instead of .95). Second, users can reduce the influence of publciation bias by setting `alpha.prior` at a value greater than .05. It is possible to correct for uncertainty only by setting `alpha.prior=`1 and choosing the desired level of assurance. We encourage users to make the adjustments as minimal as possible.

`ss.power.ba` assumes that the planned study will have equal n. Unequal n in the previous study is handled in the following way for between-subjects anova designs. If the user enters an N not equally divisible by the number of cells, the function calculates n by dividing N by the number of cells and both rounding up and rounding down the result, effectively assuming equal n. The suggested sample size for the planned study is calculated using both of these values of n, and the function returns the larger of these two suggestions, to be conservative. Although equal-n previous studies are preferable, this approach will work well as long as the cell sizes are only slightly discrepant.

Value

Suggested per-group sample size for planned study

Author(s)

Samantha F. Anderson <samantha.f.anderson@asu.edu>, Ken Kelley <kkelley@nd.edu>

References

Anderson, S. F., & Maxwell, S. E. (2017). Addressing the 'replication crisis': Using original studies to design replication studies with appropriate statistical power. *Multivariate Behavioral Research, 52,* 305-322.

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science, 28,* 1547-1562.

Taylor, D. J., & Muller, K. E. (1996). Bias in linear model power and sample size calculation due to estimating noncentrality. *Communications in Statistics: Theory and Methods, 25,* 1595-1610.

Examples

```
ss.power.ba(F.observed=5, N=120, levels.A=2, levels.B=3,  effect="factor.B",
alpha.prior=.05, alpha.planned=.05, assurance=.80, power=.80, step=.001)
```

`ss.power.ba.general` *Necessary sample size to reach desired power for a between-subjects ANOVA with any number of factors using an uncertainty and publication bias correction procedure*

Description

`ss.power.ba.general` returns the necessary per-group sample size to achieve a desired level of statistical power for a planned study testing any type of effect (omnibus, contrast) using a fully between-subjects ANOVA with any number of factors, based on information obtained from a previous study. The effect from the previous study can be corrected for publication bias and/or uncertainty to provide a sample size that will achieve more accurate statistical power for a planned study, when compared to approaches that use a sample effect size at face value or rely on sample size only.

Usage

```
ss.power.ba.general(F.observed, N, cells, df.numerator, df.denominator,
  alpha.prior = 0.05, alpha.planned = 0.05, assurance = 0.8,
  power = 0.8, step = 0.001)
```

Arguments

`F.observed`	Observed F-value from a previous study used to plan sample size for a planned study
`N`	Total sample size of the previous study
`cells`	Number of cells for the design (the product of the number of levels of each factor)
`df.numerator`	Numerator degrees of freedom for the effect of interest
`df.denominator`	Denominator degrees of freedom for the effect of interest
`alpha.prior`	Alpha-level α for the previous study or the assumed statistical significance necessary for publishing in the field; to assume no publication bias, a value of 1 can be entered (correct for uncertainty only)
`alpha.planned`	Alpha-level (α) assumed for the planned study
`assurance`	Desired level of assurance, or the long run proportion of times that the planned study power will reach or surpass desired level (assurance of .5 corrects for publication bias only; assurance > .5 corrects for uncertainty)
`power`	Desired level of statistical power for the planned study
`step`	Value used in the iterative scheme to determine the noncentrality parameter necessary for sample size planning (0 < step < .01) (users should not generally need to change this value; smaller values lead to more accurate sample size planning results, but unnecessarily small values will add unnecessary computational time)

Details

Researchers often use the sample effect size from a prior study as an estimate of the likely size of an expected future effect in sample size planning. However, sample effect size estimates should not usually be used at face value to plan sample size, due to both publication bias and uncertainty.

The approach implemented in `ss.power.ba.general` uses the observed F-value and sample size from a previous study to correct the noncentrality parameter associated with the effect of interest for publication bias and/or uncertainty. This new estimated noncentrality parameter is then used to calculate the necessary per-group sample size to achieve the desired level of power in the planned study.

The approach uses a likelihood function of a truncated non-central F distribution, where the truncation occurs due to small effect sizes being unobserved due to publication bias. The numerator of the likelihood function is simply the density of a noncentral F distribution. The denominator is the power of the test, which serves to truncate the distribution. Thus, the ratio of the numerator and the denominator is a truncated noncentral F distribution. (See Taylor & Muller, 1996, Equation 2.1. and Anderson & Maxwell, in press, for more details.)

Assurance is the proportion of times that power will be at or above the desired level, if the experiment were to be reproduced many times. For example, assurance = .5 means that power will be above the desired level half of the time, but below the desired level the other half of the time. Selecting assurance = .5 (selecting the noncentrality parameter at the 50th percentile of the likelihood distribution) results in a median-unbiased estimate of the population noncentrality parameter and corrects for publication bias only. In order to correct for uncertainty, assurance > .5 can be selected, which corresponds to selecting the noncentrality parameter associated with the (1 - assurance) quantile of the likelihood distribution.

If the previous study of interest has not been subjected to publication bias (e.g., a pilot study), `alpha.prior` can be set to 1 to indicate no publication bias. Alternative α-levels can also be accommodated to represent differing amounts of publication bias. For example, setting `alpha.prior`=.20 would reflect less severe publication bias than the default of .05. In essence, setting `alpha.prior` at .20 assumes that studies with p-values less than .20 are published, whereas those with alrger p-values are not.

In some cases, the corrected noncentrality parameter for a given level of assurance will be estimated to be zero. This is an indication that, at the desired level of assurance, the previous study's effect cannot be accurately estimated due to high levels of uncertainty and bias. When this happens, subsequent sample size planning is not possible with the chosen specifications. Two alternatives are recommended. First, users can select a lower value of assurance (e.g. .8 instead of .95). Second, users can reduce the influence of publciation bias by setting `alpha.prior` at a value greater than .05. It is possible to correct for uncertainty only by setting `alpha.prior`=1 and choosing the desired level of assurance. We encourage users to make the adjustments as minimal as possible.

`ss.power.ba.general` assumes that the planned study will have equal n. Unequal n in the previous study is handled in the following way for between-subjects anova designs. If the user enters an N not equally divisible by the number of cells, the function calculates n by dividing N by the number of cells and both rounding up and rounding down the result, effectively assuming equal n. The suggested sample size for the planned study is calculated using both of these values of n, and the function returns the larger of these two suggestions, to be conservative. Although equal-n previous studies are preferable, this approach will work well as long as the cell sizes are only slightly discrepant.

Value

Suggested per-group sample size for planned study

Author(s)

Samantha F. Anderson <samantha.f.anderson@asu.edu>, Ken Kelley <kkelley@nd.edu>

References

Anderson, S. F., & Maxwell, S. E. (2017). Addressing the 'replication crisis': Using original studies to design replication studies with appropriate statistical power. *Multivariate Behavioral Research, 52,* 305-322.

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science, 28,* 1547-1562.

Taylor, D. J., & Muller, K. E. (1996). Bias in linear model power and sample size calculation due to estimating noncentrality. *Communications in Statistics: Theory and Methods, 25,* 1595-1610.

Examples

```
ss.power.ba.general(F.observed=5, N=120, cells=6,  df.numerator=2,
df.denominator=117, alpha.prior=.05, alpha.planned=.05, assurance=.80,
power=.80, step=.001)
```

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ss.power.dt — *Necessary sample size to reach desired power for a dependent t-test using an uncertainty and publication bias correction procedure*

Description

ss.power.dt returns the necessary per-group sample size to achieve a desired level of statistical power for a planned study using a dependent t-test, based on information obtained from a previous study. The effect from the previous study can be corrected for publication bias and/or uncertainty to provide a sample size that will achieve more accurate statistical power for a planned study, when compared to approaches that use a sample effect size at face value or rely on sample size only.

Usage

```
ss.power.dt(t.observed, N, alpha.prior = 0.05, alpha.planned = 0.05,
  assurance = 0.8, power = 0.8, step = 0.001)
```

Arguments

`t.observed`	Observed t-value from a previous study used to plan sample size for a planned study
`N`	Total sample size of the previous study
`alpha.prior`	Alpha-level α for the previous study or the assumed statistical significance necessary for publishing in the field; to assume no publication bias, a value of 1 can be entered (correct for uncertainty only)
`alpha.planned`	Alpha-level (α) assumed for the planned study
`assurance`	Desired level of assurance, or the long run proportion of times that the planned study power will reach or surpass desired level (assurance of .5 corrects for publication bias only; assurance > .5 corrects for uncertainty)
`power`	Desired level of statistical power for the planned study
`step`	Value used in the iterative scheme to determine the noncentrality parameter necessary for sample size planning (0 < step < .01) (users should not generally need to change this value; smaller values lead to more accurate sample size planning results, but unnecessarily small values will add unnecessary computational time)

Details

Researchers often use the sample effect size from a prior study as an estimate of the likely size of an expected future effect in sample size planning. However, sample effect size estimates should not usually be used at face value to plan sample size, due to both publication bias and uncertainty.

The approach implemented in `ss.power.dt` uses the observed t-value and sample size from a previous study to correct the noncentrality parameter associated with the effect of interest for publication bias and/or uncertainty. This new estimated noncentrality parameter is then used to calculate the necessary per-group sample size to achieve the desired level of power in the planned study.

The approach uses a likelihood function of a truncated non-central F distribution, where the truncation occurs due to small effect sizes being unobserved due to publication bias. The numerator of the likelihood function is simply the density of a noncentral F distribution. The denominator is the power of the test, which serves to truncate the distribution. In the two-group case, this formula reduces to the density of a truncated noncentral t-distribution.(See Taylor & Muller, 1996, Equation 2.1. and Anderson & Maxwell, in press, for more details.)

Assurance is the proportion of times that power will be at or above the desired level, if the experiment were to be reproduced many times. For example, assurance = .5 means that power will be above the desired level half of the time, but below the desired level the other half of the time. Selecting assurance = .5 (selecting the noncentrality parameter at the 50th percentile of the likelihood distribution) results in a median-unbiased estimate of the population noncentrality parameter and corrects for publication bias only. In order to correct for uncertainty, assurance > .5 can be selected, which corresponds to selecting the noncentrality parameter associated with the (1 - assurance) quantile of the likelihood distribution.

If the previous study of interest has not been subjected to publication bias (e.g., a pilot study), `alpha.prior` can be set to 1 to indicate no publication bias. Alternative α-levels can also be accommodated to represent differing amounts of publication bias. For example, setting `alpha.prior=.20` would reflect less severe publication bias than the default of .05. In essence, setting `alpha.prior` at .20 assumes that studies with p-values less than .20 are published, whereas those with alrger p-values are not.

In some cases, the corrected noncentrality parameter for a given level of assurance will be estimated to be zero. This is an indication that, at the desired level of assurance, the previous study's effect cannot be accurately estimated due to high levels of uncertainty and bias. When this happens, subsequent sample size planning is not possible with the chosen specifications. Two alternatives are recommended. First, users can select a lower value of assurance (e.g. .8 instead of .95). Second, users can reduce the influence of publciation bias by setting `alpha.prior` at a value greater than .05. It is possible to correct for uncertainty only by setting `alpha.prior=1` and choosing the desired level of assurance. We encourage users to make the adjustments as minimal as possible.

Value

Suggested per-group sample size for planned study

Author(s)

Samantha F. Anderson <samantha.f.anderson@asu.edu>, Ken Kelley <kkelley@nd.edu>

References

Anderson, S. F., & Maxwell, S. E. (2017). Addressing the 'replication crisis': Using original studies to design replication studies with appropriate statistical power. *Multivariate Behavioral Research, 52,* 305-322.

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science, 28,* 1547-1562.

Taylor, D. J., & Muller, K. E. (1996). Bias in linear model power and sample size calculation due to estimating noncentrality. *Communications in Statistics: Theory and Methods, 25,* 1595-1610.

Examples

```
ss.power.dt(t.observed=3, N=40, alpha.prior=.05, alpha.planned=.05,
assurance=.80, power=.80, step=.001)
```

`ss.power.it` *Necessary sample size to reach desired power for an independent t-test using an uncertainty and publication bias correction procedure*

Description

`ss.power.it` returns the necessary per-group sample size to achieve a desired level of statistical power for a planned study using an independent t-test, based on information obtained from a previous study. The effect from the previous study can be corrected for publication bias and/or uncertainty to provide a sample size that will achieve more accurate statistical power for a planned study, when compared to approaches that use a sample effect size at face value or rely on sample size only.

Usage

```
ss.power.it(t.observed, n, N, alpha.prior = 0.05, alpha.planned = 0.05,
  assurance = 0.8, power = 0.8, step = 0.001)
```

Arguments

`t.observed`	Observed t-value from a previous study used to plan sample size for a planned study
`n`	Per group sample size (if equal) or the two group sample sizes of the previous study (enter either a single number or a vector of length 2)
`N`	Total sample size of the previous study, assumed equal across groups if specified
`alpha.prior`	Alpha-level α for the previous study or the assumed statistical significance necessary for publishing in the field; to assume no publication bias, a value of 1 can be entered (correct for uncertainty only)
`alpha.planned`	Alpha-level (α) assumed for the planned study
`assurance`	Desired level of assurance, or the long run proportion of times that the planned study power will reach or surpass desired level (assurance of .5 corrects for publication bias only; assurance > .5 corrects for uncertainty)
`power`	Desired level of statistical power for the planned study
`step`	Value used in the iterative scheme to determine the noncentrality parameter necessary for sample size planning (0 < step < .01) (users should not generally need to change this value; smaller values lead to more accurate sample size planning results, but unnecessarily small values will add unnecessary computational time)

Details

Researchers often use the sample effect size from a prior study as an estimate of the likely size of an expected future effect in sample size planning. However, sample effect size estimates should not usually be used at face value to plan sample size, due to both publication bias and uncertainty.

The approach implemented in `ss.power.it` uses the observed t-value and sample size from a previous study to correct the noncentrality parameter associated with the effect of interest for publication bias and/or uncertainty. This new estimated noncentrality parameter is then used to calculate the necessary per-group sample size to achieve the desired level of power in the planned study.

The approach uses a likelihood function of a truncated non-central F distribution, where the truncation occurs due to small effect sizes being unobserved due to publication bias. The numerator of the likelihood function is simply the density of a noncentral F distribution. The denominator is the power of the test, which serves to truncate the distribution. In the two-group case, this formula reduces to the density of a truncated noncentral t-distribution.(See Taylor & Muller, 1996, Equation 2.1. and Anderson & Maxwell, in press, for more details.)

Assurance is the proportion of times that power will be at or above the desired level, if the experiment were to be reproduced many times. For example, assurance = .5 means that power will be above the desired level half of the time, but below the desired level the other half of the time. Selecting assurance = .5 (selecting the noncentrality parameter at the 50th percentile of the likelihood distribution) results in a median-unbiased estimate of the population noncentrality parameter and corrects for publication bias only. In order to correct for uncertainty, assurance > .5 can be selected, which corresponds to selecting the noncentrality parameter associated with the (1 - assurance) quantile of the likelihood distribution.

If the previous study of interest has not been subjected to publication bias (e.g., a pilot study), `alpha.prior` can be set to 1 to indicate no publication bias. Alternative α-levels can also be accommodated to represent differing amounts of publication bias. For example, setting `alpha.prior=`.20 would reflect less severe publication bias than the default of .05. In essence, setting `alpha.prior` at .20 assumes that studies with p-values less than .20 are published, whereas those with alrger p-values are not.

In some cases, the corrected noncentrality parameter for a given level of assurance will be estimated to be zero. This is an indication that, at the desired level of assurance, the previous study's effect cannot be accurately estimated due to high levels of uncertainty and bias. When this happens, subsequent sample size planning is not possible with the chosen specifications. Two alternatives are recommended. First, users can select a lower value of assurance (e.g. .8 instead of .95). Second, users can reduce the influence of publciation bias by setting `alpha.prior` at a value greater than .05. It is possible to correct for uncertainty only by setting `alpha.prior=`1 and choosing the desired level of assurance. We encourage users to make the adjustments as minimal as possible.

`ss.power.it` assumes that the planned study will have equal n. Unequal n in the previous study is handled in the following way for the independent-t. If the user enters an odd value for N, no information is available on the exact group sizes. The function calculates n by dividing N by 2 and both rounding up and rounding down the result, thus assuming equal n. The suggested sample size for the planned study is calculated using both of these values of n, and the function returns the larger of these two suggestions, t be conservative. If the user enters a vector for n with two different values, specific information is available on the exact group sizes. n is calcualted as the harmonic mean of these two values (a measure of effective sample size). Again, this is rounded both up and down. The suggested sample size for the planned study is calculated using both of these values of n, and the function returns the larger of these two suggestions, to be conservative. When the individual group sizes of an unequal-n previous study are known, we highly encourage entering these explicitly, especially if the sample sizes are quite discrepant, as this allows for the greatest precision in estimating an appropriate planned study n.

Value

Suggested per-group sample size for planned study

Author(s)

Samantha F. Anderson <samantha.f.anderson@asu.edu>, Ken Kelley <kkelley@nd.edu>

References

Anderson, S. F., & Maxwell, S. E. (2017). Addressing the 'replication crisis': Using original studies to design replication studies with appropriate statistical power. *Multivariate Behavioral Research, 52,* 305-322.

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science, 28,* 1547-1562.

Taylor, D. J., & Muller, K. E. (1996). Bias in linear model power and sample size calculation due to estimating noncentrality. *Communications in Statistics: Theory and Methods, 25,* 1595-1610.

Examples

```
ss.power.it(t.observed=3, n=20, alpha.prior=.05, alpha.planned=.05,
assurance=.80, power=.80, step=.001)
```

---

ss.power.reg.all — *Necessary sample size to reach desired power for a test of model R2 in a multiple regression using an uncertainty and publication bias correction procedure*

Description

`ss.power.reg.all` returns the necessary total sample size to achieve a desired level of statistical power for a test of model R2 in a planned study using multiple regression, based on information obtained from a previous study.The effect from the previous study can be corrected for publication bias and/or uncertainty to provide a sample size that will achieve more accurate statistical power for a planned study, when compared to approaches that use a sample effect size at face value or rely on sample size only.

Usage

```
ss.power.reg.all(F.observed, N, p, alpha.prior = 0.05, alpha.planned = 0.05,
  assurance = 0.8, power = 0.8, step = 0.001)
```

Arguments

`F.observed`	Observed F-value from a previous study used to plan sample size for a planned study
`N`	Total sample size of the previous study
`p`	Number of predictors; be sure to include any product terms or polynomials that are in the model
`alpha.prior`	Alpha-level α for the previous study or the assumed statistical significance necessary for publishing in the field; to assume no publication bias, a value of 1 can be entered (correct for uncertainty only)
`alpha.planned`	Alpha-level (α) assumed for the planned study
`assurance`	Desired level of assurance, or the long run proportion of times that the planned study power will reach or surpass desired level (assurance of .5 corrects for publication bias only; assurance > .5 corrects for uncertainty)
`power`	Desired level of statistical power for the planned study
`step`	Value used in the iterative scheme to determine the noncentrality parameter necessary for sample size planning (0 < step < .01) (users should not generally need to change this value; smaller values lead to more accurate sample size planning results, but unnecessarily small values will add unnecessary computational time)

Details

Researchers often use the sample effect size from a prior study as an estimate of the likely size of an expected future effect in sample size planning. However, sample effect size estimates should not usually be used at face value to plan sample size, due to both publication bias and uncertainty.

The approach implemented in `ss.power.reg.all` uses the observed F-value and sample size from a previous study to correct the noncentrality parameter associated with the effect of interest for publication bias and/or uncertainty. This new estimated noncentrality parameter is then used to calculate the necessary total sample size to achieve the desired level of power in the planned study.

The approach uses a likelihood function of a truncated non-central F distribution, where the truncation occurs due to small effect sizes being unobserved due to publication bias. The numerator of the likelihood function is simply the density of a noncentral F distribution. The denominator is the power of the test, which serves to truncate the distribution. In the single predictor case, this formula reduces to the density of a truncated noncentral t-distribution.(See Taylor & Muller, 1996, Equation 2.1. and Anderson & Maxwell, 2017, for more details.)

Assurance is the proportion of times that power will be at or above the desired level, if the experiment were to be reproduced many times. For example, assurance = .5 means that power will be above the desired level half of the time, but below the desired level the other half of the time. Selecting assurance = .5 (selecting the noncentrality parameter at the 50th percentile of the likelihood distribution) results in a median-unbiased estimate of the population noncentrality parameter and corrects for publication bias only. In order to correct for uncertainty, assurance > .5 can be selected, which corresponds to selecting the noncentrality parameter associated with the (1 - assurance) quantile of the likelihood distribution.

If the previous study of interest has not been subjected to publication bias (e.g., a pilot study), `alpha.prior` can be set to 1 to indicate no publication bias. Alternative α-levels can also be accommodated to represent differing amounts of publication bias. For example, setting `alpha.prior`=.20 would reflect less severe publication bias than the default of .05. In essence, setting `alpha.prior` at .20 assumes that studies with p-values less than .20 are published, whereas those with alrger p-values are not.

In some cases, the corrected noncentrality parameter for a given level of assurance will be estimated to be zero. This is an indication that, at the desired level of assurance, the previous study's effect cannot be accurately estimated due to high levels of uncertainty and bias. When this happens, subsequent sample size planning is not possible with the chosen specifications. Two alternatives are recommended. First, users can select a lower value of assurance (e.g. .8 instead of .95). Second, users can reduce the influence of publciation bias by setting `alpha.prior` at a value greater than .05. It is possible to correct for uncertainty only by setting `alpha.prior`=1 and choosing the desired level of assurance. We encourage users to make the adjustments as minimal as possible.

Value

Suggested total sample size for planned study

Author(s)

Samantha F. Anderson <samantha.f.anderson@asu.edu>, Ken Kelley <kkelley@nd.edu>

References

Anderson, S. F., & Maxwell, S. E. (2017). Addressing the 'replication crisis': Using original studies to design replication studies with appropriate statistical power. *Multivariate Behavioral Research, 52,* 305-322.

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science, 28,* 1547-1562.

Taylor, D. J., & Muller, K. E. (1996). Bias in linear model power and sample size calculation due to estimating noncentrality. *Communications in Statistics: Theory and Methods, 25,* 1595-1610.

Examples

```
ss.power.reg.all(F.observed=5, N=150, p=4, alpha.prior=.05, alpha.planned=.05,
assurance=.80, power=.80, step=.001)
```

`ss.power.reg.joint` *Necessary sample size to reach desired power for a test of multiple predictors in a multiple regression using an uncertainty and publication bias correction procedure*

Description

`ss.power.reg.joint` returns the necessary total sample size to achieve a desired level of statistical power for a test of multiple predictors in a planned study using multiple regression, based on information obtained from a previous study.The effect from the previous study can be corrected for publication bias and/or uncertainty to provide a sample size that will achieve more accurate statistical power for a planned study, when compared to approaches that use a sample effect size at face value or rely on sample size only.

Usage

```
ss.power.reg.joint(F.observed, N, p, p.joint, alpha.prior = 0.05,
  alpha.planned = 0.05, assurance = 0.8, power = 0.8, step = 0.001)
```

Arguments

`F.observed`	Observed F-value from a previous study used to plan sample size for a planned study
`N`	Total sample size of the previous study
`p`	Number of predictors; be sure to include any product terms or polynomials that are in the model
`p.joint`	Number of predictors tested jointly for significance
`alpha.prior`	Alpha-level α for the previous study or the assumed statistical significance necessary for publishing in the field; to assume no publication bias, a value of 1 can be entered (correct for uncertainty only)

alpha.planned	Alpha-level (α) assumed for the planned study
assurance	Desired level of assurance, or the long run proportion of times that the planned study power will reach or surpass desired level (assurance of .5 corrects for publication bias only; assurance > .5 corrects for uncertainty)
power	Desired level of statistical power for the planned study
step	Value used in the iterative scheme to determine the noncentrality parameter necessary for sample size planning (0 < step < .01) (users should not generally need to change this value; smaller values lead to more accurate sample size planning results, but unnecessarily small values will add unnecessary computational time)

Details

Researchers often use the sample effect size from a prior study as an estimate of the likely size of an expected future effect in sample size planning. However, sample effect size estimates should not usually be used at face value to plan sample size, due to both publication bias and uncertainty.

The approach implemented in `ss.power.reg.joint` uses the observed F-value and sample size from a previous study to correct the noncentrality parameter associated with the effect of interest for publication bias and/or uncertainty. This new estimated noncentrality parameter is then used to calculate the necessary total sample size to achieve the desired level of power in the planned study.

The approach uses a likelihood function of a truncated non-central F distribution, where the truncation occurs due to small effect sizes being unobserved due to publication bias. The numerator of the likelihood function is simply the density of a noncentral F distribution. The denominator is the power of the test, which serves to truncate the distribution. In the single predictor case, this formula reduces to the density of a truncated noncentral t-distribution.(See Taylor & Muller, 1996, Equation 2.1. and Anderson & Maxwell, 2017, for more details.)

Assurance is the proportion of times that power will be at or above the desired level, if the experiment were to be reproduced many times. For example, assurance = .5 means that power will be above the desired level half of the time, but below the desired level the other half of the time. Selecting assurance = .5 (selecting the noncentrality parameter at the 50th percentile of the likelihood distribution) results in a median-unbiased estimate of the population noncentrality parameter and corrects for publication bias only. In order to correct for uncertainty, assurance > .5 can be selected, which corresponds to selecting the noncentrality parameter associated with the (1 - assurance) quantile of the likelihood distribution.

If the previous study of interest has not been subjected to publication bias (e.g., a pilot study), `alpha.prior` can be set to 1 to indicate no publication bias. Alternative α-levels can also be accommodated to represent differing amounts of publication bias. For example, setting `alpha.prior`=.20 would reflect less severe publication bias than the default of .05. In essence, setting `alpha.prior` at .20 assumes that studies with p-values less than .20 are published, whereas those with alrger p-values are not.

In some cases, the corrected noncentrality parameter for a given level of assurance will be estimated to be zero. This is an indication that, at the desired level of assurance, the previous study's effect cannot be accurately estimated due to high levels of uncertainty and bias. When this happens, subsequent sample size planning is not possible with the chosen specifications. Two alternatives are recommended. First, users can select a lower value of assurance (e.g. .8 instead of .95). Second, users can reduce the influence of publciation bias by setting `alpha.prior` at a value greater than .05. It is possible to correct for uncertainty only by setting `alpha.prior`=1 and choosing the desired level of assurance. We encourage users to make the adjustments as minimal as possible.

Value

Suggested total sample size for planned study

Author(s)

Samantha F. Anderson <samantha.f.anderson@asu.edu>, Ken Kelley <kkelley@nd.edu>

References

Anderson, S. F., & Maxwell, S. E. (2017). Addressing the 'replication crisis': Using original studies to design replication studies with appropriate statistical power. *Multivariate Behavioral Research, 52,* 305-322.

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science, 28,* 1547-1562.

Taylor, D. J., & Muller, K. E. (1996). Bias in linear model power and sample size calculation due to estimating noncentrality. *Communications in Statistics: Theory and Methods, 25,* 1595-1610.

Examples

```
ss.power.reg.joint(F.observed=5, N=150, p=4, p.joint=2, alpha.prior=.05,
alpha.planned=.05, assurance=.80, power=.80, step=.001)
```

---

ss.power.reg1 — *Necessary sample size to reach desired power for a single coefficient in a multiple regression using an uncertainty and publication bias correction procedure*

Description

`ss.power.reg1` returns the necessary total sample size to achieve a desired level of statistical power for a single regression coefficient in a planned study using multiple regression, based on information obtained from a previous study.The effect from the previous study can be corrected for publication bias and/or uncertainty to provide a sample size that will achieve more accurate statistical power for a planned study, when compared to approaches that use a sample effect size at face value or rely on sample size only.

Usage

```
ss.power.reg1(t.observed, N, p, alpha.prior = 0.05, alpha.planned = 0.05,
  assurance = 0.8, power = 0.8, step = 0.001)
```

Arguments

`t.observed`	Observed t-value from a previous study used to plan sample size for a planned study
`N`	Total sample size of the previous study
`p`	Number of predictors; be sure to include any product terms or polynomials that are in the model
`alpha.prior`	Alpha-level α for the previous study or the assumed statistical significance necessary for publishing in the field; to assume no publication bias, a value of 1 can be entered (correct for uncertainty only)
`alpha.planned`	Alpha-level (α) assumed for the planned study
`assurance`	Desired level of assurance, or the long run proportion of times that the planned study power will reach or surpass desired level (assurance of .5 corrects for publication bias only; assurance > .5 corrects for uncertainty)
`power`	Desired level of statistical power for the planned study
`step`	Value used in the iterative scheme to determine the noncentrality parameter necessary for sample size planning (0 < step < .01) (users should not generally need to change this value; smaller values lead to more accurate sample size planning results, but unnecessarily small values will add unnecessary computational time)

Details

Researchers often use the sample effect size from a prior study as an estimate of the likely size of an expected future effect in sample size planning. However, sample effect size estimates should not usually be used at face value to plan sample size, due to both publication bias and uncertainty.

The approach implemented in `ss.power.reg1` uses the observed t-value and sample size from a previous study to correct the noncentrality parameter associated with the effect of interest for publication bias and/or uncertainty. This new estimated noncentrality parameter is then used to calculate the necessary total sample size to achieve the desired level of power in the planned study.

The approach uses a likelihood function of a truncated non-central F distribution, where the truncation occurs due to small effect sizes being unobserved due to publication bias. The numerator of the likelihood function is simply the density of a noncentral F distribution. The denominator is the power of the test, which serves to truncate the distribution. In the single predictor case, this formula reduces to the density of a truncated noncentral t-distribution.(See Taylor & Muller, 1996, Equation 2.1. and Anderson & Maxwell, 2017, for more details.)

Assurance is the proportion of times that power will be at or above the desired level, if the experiment were to be reproduced many times. For example, assurance = .5 means that power will be above the desired level half of the time, but below the desired level the other half of the time. Selecting assurance = .5 (selecting the noncentrality parameter at the 50th percentile of the likelihood distribution) results in a median-unbiased estimate of the population noncentrality parameter and corrects for publication bias only. In order to correct for uncertainty, assurance > .5 can be selected, which corresponds to selecting the noncentrality parameter associated with the (1 - assurance) quantile of the likelihood distribution.

If the previous study of interest has not been subjected to publication bias (e.g., a pilot study), `alpha.prior` can be set to 1 to indicate no publication bias. Alternative α-levels can also be accommodated to represent differing amounts of publication bias. For example, setting `alpha.prior`=.20

would reflect less severe publication bias than the default of .05. In essence, setting `alpha.prior` at .20 assumes that studies with p-values less than .20 are published, whereas those with alrger p-values are not.

In some cases, the corrected noncentrality parameter for a given level of assurance will be estimated to be zero. This is an indication that, at the desired level of assurance, the previous study's effect cannot be accurately estimated due to high levels of uncertainty and bias. When this happens, subsequent sample size planning is not possible with the chosen specifications. Two alternatives are recommended. First, users can select a lower value of assurance (e.g. .8 instead of .95). Second, users can reduce the influence of publciation bias by setting `alpha.prior` at a value greater than .05. It is possible to correct for uncertainty only by setting `alpha.prior=1` and choosing the desired level of assurance. We encourage users to make the adjustments as minimal as possible.

Value

Suggested total sample size for planned study

Author(s)

Samantha F. Anderson <samantha.f.anderson@asu.edu>, Ken Kelley <kkelley@nd.edu>

References

Anderson, S. F., & Maxwell, S. E. (2017). Addressing the 'replication crisis': Using original studies to design replication studies with appropriate statistical power. *Multivariate Behavioral Research, 52,* 305-322.

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science, 28,* 1547-1562.

Taylor, D. J., & Muller, K. E. (1996). Bias in linear model power and sample size calculation due to estimating noncentrality. *Communications in Statistics: Theory and Methods, 25,* 1595-1610.

Examples

```
ss.power.reg1(t.observed=3, N=150, p=3, alpha.prior=.05, alpha.planned=.05,
assurance=.80, power=.80, step=.001)
```

`ss.power.spa` *Necessary sample size to reach desired power for two-factor split-plot (mixed) ANOVA using an uncertainty and publication bias correction procedure*

Description

`ss.power.spa` returns the necessary per-group sample size to achieve a desired level of statistical power for a planned study testing an omnibus effect using a two-factor split-plot (mixed) ANOVA, based on information obtained from a previous study. The effect from the previous study can be corrected for publication bias and/or uncertainty to provide a sample size that will achieve more accurate statistical power for a planned study, when compared to approaches that use a sample effect size at face value or rely on sample size only.

Usage

```
ss.power.spa(F.observed, N, levels.between, levels.within,
  effect = c("between", "within", "interaction"), alpha.prior = 0.05,
  alpha.planned = 0.05, assurance = 0.8, power = 0.8, step = 0.001)
```

Arguments

`F.observed`	Observed F-value from a previous study used to plan sample size for a planned study
`N`	Total sample size of the previous study
`levels.between`	Number of levels for the between-subjects factor
`levels.within`	Number of levels for the within-subjects factor
`effect`	Effect most of interest to the planned study: between main effect (between), within main effect (within), interaction
`alpha.prior`	Alpha level assumed for the previous study. If the previous study is unpublished, this a value of 1 can be entered to correct for uncertainty only.
`alpha.planned`	Alpha level assumed for the planned study
`assurance`	Desired level of assurance, or the percent of confidence that the planned study power will reach or surpass desired level. Assurance of .5 corrects for publication bias only. Assurance > .5 corrects for uncertainty.
`power`	Desired level of statistical power for the planned study
`step`	Value used in the iterative scheme to determine the noncentral parameters necessary for sample size planning (0 < step < .01) (users should not generally need to change this value; smaller values lead to more accurate sample size planning results, but unnecessarily small values will add unnecessary computational time)

Details

Researchers often use the sample effect size from a prior study as an estimate of the likely size of an expected future effect in sample size planning. However, sample effect size estimates should not usually be used at face value to plan sample size, due to both publication bias and uncertainty.

The approach implemented in `ss.power.spa` uses the observed F-value and sample size from a previous study to correct the noncentrality parameter associated with the effect of interest for publication bias and/or uncertainty. This new estimated noncentrality parameter is then used to calculate the necessary per-group sample size to achieve the desired level of power in the planned study.

The approach uses a likelihood function of a truncated non-central F distribution, where the truncation occurs due to small effect sizes being unobserved due to publication bias. The numerator of the likelihood function is simply the density of a noncentral F distribution. The denominator is the power of the test, which serves to truncate the distribution. Thus, the ratio of the numerator and the denominator is a truncated noncentral F distribution. (See Taylor & Muller, 1996, Equation 2.1. and Anderson & Maxwell, in press, for more details.)

Assurance is the proportion of times that power will be at or above the desired level, if the experiment were to be reproduced many times. For example, assurance = .5 means that power will be above the desired level half of the time, but below the desired level the other half of the time. Selecting assurance = .5 (selecting the noncentrality parameter at the 50th percentile of the likelihood distribution) results in a median-unbiased estimate of the population noncentrality parameter and corrects for publication bias only. In order to correct for uncertainty, assurance > .5 can be selected, which corresponds to selecting the noncentrality parameter associated with the (1 - assurance) quantile of the likelihood distribution.

If the previous study of interest has not been subjected to publication bias (e.g., a pilot study), `alpha.prior` can be set to 1 to indicate no publication bias. Alternative α-levels can also be accommodated to represent differing amounts of publication bias. For example, setting `alpha.prior`=.20 would reflect less severe publication bias than the default of .05. In essence, setting `alpha.prior` at .20 assumes that studies with p-values less than .20 are published, whereas those with alrger p-values are not.

In some cases, the corrected noncentrality parameter for a given level of assurance will be estimated to be zero. This is an indication that, at the desired level of assurance, the previous study's effect cannot be accurately estimated due to high levels of uncertainty and bias. When this happens, subsequent sample size planning is not possible with the chosen specifications. Two alternatives are recommended. First, users can select a lower value of assurance (e.g. .8 instead of .95). Second, users can reduce the influence of publciation bias by setting `alpha.prior` at a value greater than .05. It is possible to correct for uncertainty only by setting `alpha.prior`=1 and choosing the desired level of assurance. We encourage users to make the adjustments as minimal as possible.

`ss.power.spa` assumes that the planned study will have equal n. Unequal n in the previous study is handled in the following way for split plot designs. If the user enters an N not equally divisible by the number of between-subjects cells, the function calculates n by dividing N by the number of cells and both rounding up and rounding down the result, effectively assuming equal n. The suggested sample size for the planned study is calculated using both of these values of n, and the function returns the larger of these two suggestions, to be conservative. Although equal-n previous studies are preferable, this approach will work well as long as the cell sizes are only slightly discrepant.

`ss.power.spa` assumes sphericity for the within-subjects effects.

Value

Suggested per-group sample size for planned study

Author(s)

Samantha F. Anderson <samantha.f.anderson@asu.edu>, Ken Kelley <kkelley@nd.edu>

References

Anderson, S. F., & Maxwell, S. E. (2017). Addressing the 'replication crisis': Using original studies to design replication studies with appropriate statistical power. *Multivariate Behavioral Research, 52,* 305-322.

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science, 28,* 1547-1562.

Taylor, D. J., & Muller, K. E. (1996). Bias in linear model power and sample size calculation due to estimating noncentrality. *Communications in Statistics: Theory and Methods, 25,* 1595-1610.

Examples

```
ss.power.spa(F.observed=5, N=60, levels.between=2, levels.within=3,
effect="within", alpha.prior=.05, alpha.planned=.05, assurance=.80,
power=.80, step=.001)
```

---

ss.power.spa.general *Necessary sample size to reach desired power for a split-plot (mixed) ANOVA with any number of factors using an uncertainty and publication bias correction procedure*

Description

`ss.power.spa.general` returns the necessary per-group sample size to achieve a desired level of statistical power for a planned study testing any type of effect (omnibus, contrast) using a split-plot (mixed) ANOVA with any number of factors, based on information obtained from a previous study. The effect from the previous study can be corrected for publication bias and/or uncertainty to provide a sample size that will achieve more accurate statistical power for a planned study, when compared to approaches that use a sample effect size at face value or rely on sample size only.

Usage

```
ss.power.spa.general(F.observed, N, df.numerator, num.groups,
  effect = c("between.only", "within.only", "between.within"), df.num.within,
  alpha.prior = 0.05, alpha.planned = 0.05, assurance = 0.8,
  power = 0.8, step = 0.001)
```

Arguments

`F.observed`	Observed F-value from a previous study used to plan sample size for a planned study
`N`	Total sample size of the previous study
`df.numerator`	Numerator degrees of freedom for the effect of interest
`num.groups`	Number of distinct groups (product of the number of levels of between-subjects factors)

`effect`	Effect of interest: involves only between-subjects effects (`between.only`), involves only within-subjects effects (`within.only`), involves both between and within effects (`between.within`)
`df.num.within`	Numerator degrees of freedom only for the within subjects components of the effect of interest. Only needed when effect = `between.within`.
`alpha.prior`	Alpha-level α for the previous study or the assumed statistical significance necessary for publishing in the field; to assume no publication bias, a value of 1 can be entered (correct for uncertainty only)
`alpha.planned`	Alpha-level (α) assumed for the planned study
`assurance`	Desired level of assurance, or the long run proportion of times that the planned study power will reach or surpass desired level (assurance of .5 corrects for publication bias only; assurance > .5 corrects for uncertainty)
`power`	Desired level of statistical power for the planned study
`step`	Value used in the iterative scheme to determine the noncentrality parameter necessary for sample size planning (0 < step < .01) (users should not generally need to change this value; smaller values lead to more accurate sample size planning results, but unnecessarily small values will add unnecessary computational time)

Details

Researchers often use the sample effect size from a prior study as an estimate of the likely size of an expected future effect in sample size planning. However, sample effect size estimates should not usually be used at face value to plan sample size, due to both publication bias and uncertainty.

The approach implemented in `ss.power.spa.general` uses the observed F-value and sample size from a previous study to correct the noncentrality parameter associated with the effect of interest for publication bias and/or uncertainty. This new estimated noncentrality parameter is then used to calculate the necessary per-group sample size to achieve the desired level of power in the planned study.

The approach uses a likelihood function of a truncated non-central F distribution, where the truncation occurs due to small effect sizes being unobserved due to publication bias. The numerator of the likelihood function is simply the density of a noncentral F distribution. The denominator is the power of the test, which serves to truncate the distribution. Thus, the ratio of the numerator and the denominator is a truncated noncentral F distribution. (See Taylor & Muller, 1996, Equation 2.1. and Anderson & Maxwell, in press, for more details.)

Assurance is the proportion of times that power will be at or above the desired level, if the experiment were to be reproduced many times. For example, assurance = .5 means that power will be above the desired level half of the time, but below the desired level the other half of the time. Selecting assurance = .5 (selecting the noncentrality parameter at the 50th percentile of the likelihood distribution) results in a median-unbiased estimate of the population noncentrality parameter and corrects for publication bias only. In order to correct for uncertainty, assurance > .5 can be selected, which corresponds to selecting the noncentrality parameter associated with the (1 - assurance) quantile of the likelihood distribution.

If the previous study of interest has not been subjected to publication bias (e.g., a pilot study), `alpha.prior` can be set to 1 to indicate no publication bias. Alternative α-levels can also be accommodated to represent differing amounts of publication bias. For example, setting `alpha.prior`=.20 would reflect less severe publication bias than the default of .05. In essence, setting `alpha.prior` at .20 assumes that studies with p-values less than .20 are published, whereas those with alrger p-values are not.

In some cases, the corrected noncentrality parameter for a given level of assurance will be estimated to be zero. This is an indication that, at the desired level of assurance, the previous study's effect cannot be accurately estimated due to high levels of uncertainty and bias. When this happens, subsequent sample size planning is not possible with the chosen specifications. Two alternatives are recommended. First, users can select a lower value of assurance (e.g. .8 instead of .95). Second, users can reduce the influence of publciation bias by setting `alpha.prior` at a value greater than .05. It is possible to correct for uncertainty only by setting `alpha.prior=1` and choosing the desired level of assurance. We encourage users to make the adjustments as minimal as possible.

`ss.power.spa.general` assumes that the planned study will have equal n. Unequal n in the previous study is handled in the following way for split plot designs. If the user enters an N not equally divisible by the number of between-subjects cells, the function calculates n by dividing N by the number of cells and both rounding up and rounding down the result, effectively assuming equal n. The suggested sample size for the planned study is calculated using both of these values of n, and the function returns the larger of these two suggestions, to be conservative. Although equal-n previous studies are preferable, this approach will work well as long as the cell sizes are only slightly discrepant.

`ss.power.spa.general` assumes sphericity for the within-subjects effects.

Value

Suggested per-group sample size for planned study

Author(s)

Samantha F. Anderson `<samantha.f.anderson@asu.edu>`, Ken Kelley `<kkelley@nd.edu>`

References

Anderson, S. F., & Maxwell, S. E. (2017). Addressing the 'replication crisis': Using original studies to design replication studies with appropriate statistical power. *Multivariate Behavioral Research, 52,* 305-322.

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science, 28,* 1547-1562.

Taylor, D. J., & Muller, K. E. (1996). Bias in linear model power and sample size calculation due to estimating noncentrality. *Communications in Statistics: Theory and Methods, 25,* 1595-1610.

Examples

```
ss.power.spa.general(F.observed=5, N=90,  df.numerator=2, num.groups=3,
effect="between.only", df.num.within=3, alpha.prior=.05, alpha.planned=.05,
assurance=.80, power=.80, step=.001)
```

ss.power.wa *Necessary sample size to reach desired power for a one or two-way within-subjects ANOVA using an uncertainty and publication bias correction procedure*

Description

ss.power.wa returns the necessary per-group sample size to achieve a desired level of statistical power for a planned study testing an omnibus effect using a one or two-way fully within-subjects ANOVA, based on information obtained from a previous study. The effect from the previous study can be corrected for publication bias and/or uncertainty to provide a sample size that will achieve more accurate statistical power for a planned study, when compared to approaches that use a sample effect size at face value or rely on sample size only.

Usage

```
ss.power.wa(F.observed, N, levels.A, levels.B = NULL, effect = c("factor.A",
  "factor.B", "interaction"), alpha.prior = 0.05, alpha.planned = 0.05,
  assurance = 0.8, power = 0.8, step = 0.001)
```

Arguments

F.observed	Observed F-value from a previous study used to plan sample size for a planned study
N	Total sample size of the previous study
levels.A	Number of levels for factor A
levels.B	Number of levels for factor B, which is NULL if a single factor design
effect	Effect most of interest to the planned study: main effect of A (factor.A), main effect of B (factor.B), interaction (interaction)
alpha.prior	Alpha-level α for the previous study or the assumed statistical significance necessary for publishing in the field; to assume no publication bias, a value of 1 can be entered (correct for uncertainty only)
alpha.planned	Alpha-level (α) assumed for the planned study
assurance	Desired level of assurance, or the long run proportion of times that the planned study power will reach or surpass desired level (assurance of .5 corrects for publication bias only; assurance > .5 corrects for uncertainty)
power	Desired level of statistical power for the planned study
step	Value used in the iterative scheme to determine the noncentrality parameter necessary for sample size planning (0 < step < .01) (users should not generally need to change this value; smaller values lead to more accurate sample size planning results, but unnecessarily small values will add unnecessary computational time)

Details

Researchers often use the sample effect size from a prior study as an estimate of the likely size of an expected future effect in sample size planning. However, sample effect size estimates should not usually be used at face value to plan sample size, due to both publication bias and uncertainty.

The approach implemented in `ss.power.wa` uses the observed F-value and sample size from a previous study to correct the noncentrality parameter associated with the effect of interest for publication bias and/or uncertainty. This new estimated noncentrality parameter is then used to calculate the necessary per-group sample size to achieve the desired level of power in the planned study.

The approach uses a likelihood function of a truncated non-central F distribution, where the truncation occurs due to small effect sizes being unobserved due to publication bias. The numerator of the likelihood function is simply the density of a noncentral F distribution. The denominator is the power of the test, which serves to truncate the distribution. Thus, the ratio of the numerator and the denominator is a truncated noncentral F distribution. (See Taylor & Muller, 1996, Equation 2.1. and Anderson & Maxwell, in press, for more details.)

Assurance is the proportion of times that power will be at or above the desired level, if the experiment were to be reproduced many times. For example, assurance = .5 means that power will be above the desired level half of the time, but below the desired level the other half of the time. Selecting assurance = .5 (selecting the noncentrality parameter at the 50th percentile of the likelihood distribution) results in a median-unbiased estimate of the population noncentrality parameter and corrects for publication bias only. In order to correct for uncertainty, assurance > .5 can be selected, which corresponds to selecting the noncentrality parameter associated with the (1 - assurance) quantile of the likelihood distribution.

If the previous study of interest has not been subjected to publication bias (e.g., a pilot study), `alpha.prior` can be set to 1 to indicate no publication bias. Alternative α-levels can also be accommodated to represent differing amounts of publication bias. For example, setting `alpha.prior`=.20 would reflect less severe publication bias than the default of .05. In essence, setting `alpha.prior` at .20 assumes that studies with p-values less than .20 are published, whereas those with alrger p-values are not.

In some cases, the corrected noncentrality parameter for a given level of assurance will be estimated to be zero. This is an indication that, at the desired level of assurance, the previous study's effect cannot be accurately estimated due to high levels of uncertainty and bias. When this happens, subsequent sample size planning is not possible with the chosen specifications. Two alternatives are recommended. First, users can select a lower value of assurance (e.g. .8 instead of .95). Second, users can reduce the influence of publciation bias by setting `alpha.prior` at a value greater than .05. It is possible to correct for uncertainty only by setting `alpha.prior`=1 and choosing the desired level of assurance. We encourage users to make the adjustments as minimal as possible.

`ss.power.wa` assumes sphericity for the within-subjects effects.

Value

Suggested per-group sample size for planned study

Author(s)

Samantha F. Anderson `<samantha.f.anderson@asu.edu>`, Ken Kelley `<kkelley@nd.edu>`

References

Anderson, S. F., & Maxwell, S. E. (2017). Addressing the 'replication crisis': Using original studies to design replication studies with appropriate statistical power. *Multivariate Behavioral Research, 52,* 305-322.

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science, 28,* 1547-1562.

Taylor, D. J., & Muller, K. E. (1996). Bias in linear model power and sample size calculation due to estimating noncentrality. *Communications in Statistics: Theory and Methods, 25,* 1595-1610.

Examples

```
ss.power.wa(F.observed=5, N=60, levels.A=2, levels.B=3,  effect="factor.B",
alpha.prior=.05, alpha.planned=.05, assurance=.80, power=.80, step=.001)
```

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ss.power.wa.general — *Necessary sample size to reach desired power for a within-subjects ANOVA with any number of factors using an uncertainty and publication bias correction procedure*

Description

`ss.power.wa.general` returns the necessary per-group sample size to achieve a desired level of statistical power for a planned study testing any type of effect (omnibus, contrast) using a fully within-subjects ANOVA with any number of factors, based on information obtained from a previous study. The effect from the previous study can be corrected for publication bias and/or uncertainty to provide a sample size that will achieve more accurate statistical power for a planned study, when compared to approaches that use a sample effect size at face value or rely on sample size only.

Usage

```
ss.power.wa.general(F.observed, N, df.numerator, alpha.prior = 0.05,
  alpha.planned = 0.05, assurance = 0.8, power = 0.8, step = 0.001)
```

Arguments

`F.observed`	Observed F-value from a previous study used to plan sample size for a planned study
`N`	Total sample size of the previous study
`df.numerator`	Numerator degrees of freedom for the effect of interest
`alpha.prior`	Alpha-level α for the previous study or the assumed statistical significance necessary for publishing in the field; to assume no publication bias, a value of 1 can be entered (correct for uncertainty only)
`alpha.planned`	Alpha-level (α) assumed for the planned study

`assurance` Desired level of assurance, or the long run proportion of times that the planned study power will reach or surpass desired level (assurance of .5 corrects for publication bias only; assurance > .5 corrects for uncertainty)

`power` Desired level of statistical power for the planned study

`step` Value used in the iterative scheme to determine the noncentrality parameter necessary for sample size planning (0 < step < .01) (users should not generally need to change this value; smaller values lead to more accurate sample size planning results, but unnecessarily small values will add unnecessary computational time)

Details

Researchers often use the sample effect size from a prior study as an estimate of the likely size of an expected future effect in sample size planning. However, sample effect size estimates should not usually be used at face value to plan sample size, due to both publication bias and uncertainty.

The approach implemented in `ss.power.wa.general` uses the observed F-value and sample size from a previous study to correct the noncentrality parameter associated with the effect of interest for publication bias and/or uncertainty. This new estimated noncentrality parameter is then used to calculate the necessary per-group sample size to achieve the desired level of power in the planned study.

The approach uses a likelihood function of a truncated non-central F distribution, where the truncation occurs due to small effect sizes being unobserved due to publication bias. The numerator of the likelihood function is simply the density of a noncentral F distribution. The denominator is the power of the test, which serves to truncate the distribution. Thus, the ratio of the numerator and the denominator is a truncated noncentral F distribution. (See Taylor & Muller, 1996, Equation 2.1. and Anderson & Maxwell, in press, for more details.)

Assurance is the proportion of times that power will be at or above the desired level, if the experiment were to be reproduced many times. For example, assurance = .5 means that power will be above the desired level half of the time, but below the desired level the other half of the time. Selecting assurance = .5 (selecting the noncentrality parameter at the 50th percentile of the likelihood distribution) results in a median-unbiased estimate of the population noncentrality parameter and corrects for publication bias only. In order to correct for uncertainty, assurance > .5 can be selected, which corresponds to selecting the noncentrality parameter associated with the (1 - assurance) quantile of the likelihood distribution.

If the previous study of interest has not been subjected to publication bias (e.g., a pilot study), `alpha.prior` can be set to 1 to indicate no publication bias. Alternative α-levels can also be accommodated to represent differing amounts of publication bias. For example, setting `alpha.prior`=.20 would reflect less severe publication bias than the default of .05. In essence, setting `alpha.prior` at .20 assumes that studies with p-values less than .20 are published, whereas those with alrger p-values are not.

In some cases, the corrected noncentrality parameter for a given level of assurance will be estimated to be zero. This is an indication that, at the desired level of assurance, the previous study's effect cannot be accurately estimated due to high levels of uncertainty and bias. When this happens, subsequent sample size planning is not possible with the chosen specifications. Two alternatives are recommended. First, users can select a lower value of assurance (e.g. .8 instead of .95). Second, users can reduce the influence of publciation bias by setting `alpha.prior` at a value greater than .05. It is possible to correct for uncertainty only by setting `alpha.prior`=1 and choosing the desired level of assurance. We encourage users to make the adjustments as minimal as possible.

`ss.power.wa.general` assumes sphericity for the within-subjects effects.

Value

Suggested per-group sample size for planned study

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References

Anderson, S. F., & Maxwell, S. E. (2017). Addressing the 'replication crisis': Using original studies to design replication studies with appropriate statistical power. *Multivariate Behavioral Research, 52,* 305-322.

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample size planning for more accurate statistical power: A method correcting sample effect sizes for uncertainty and publication bias. *Psychological Science, 28,* 1547-1562.

Taylor, D. J., & Muller, K. E. (1996). Bias in linear model power and sample size calculation due to estimating noncentrality. *Communications in Statistics: Theory and Methods, 25,* 1595-1610.

Examples

```
ss.power.wa.general(F.observed=6.5, N=80,  df.numerator=1,
alpha.prior=.05, alpha.planned=.05, assurance=.50, power=.80, step=.001)
```

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