# Package 'PowerUpR'

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Type Package

**Title** R version of PowerUp!

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	iption R version of PowerUp! allows calculation of statistical power, minimum detectable effect size, and constrained optimal sample allocation for main, and moderator effects in various multilevel randomized experiments.
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#### **Description**

PowerUp? is an implementation of *PowerUp!*, and *PowerUp!-Moderator* in R environment (R Core Team, 2017). *PowerUp!* series consist of convenient excel based functions to conduct statistical power analysis for various experimental and quasi-experimental designs (Dong & Maynard, 2013). It also enables users to conduct statistical power analysis for moderator effects in two- and three-level cluster randomized trials (Dong, Kelcey, & Spybrook, in press; Spybrook, Kelcey, & Dong, in press), and for mediator effects in two-level cluster randomized trials (Kelcey, Dong, Spybrook, & Cox, 2017; Kelcey, Dong, Spybrook, & Shen, in press).

The PowerUpR package bases its framework on three fundemental concepts in statistical power analysis; statistical power calculation, minimum detectable effect size calculation, and constrained optimal sample allocation (COSA; Hedges & Borenstein, 2014; Raudenbush, 1997; Raudenbush & Liu, 2000). COSA problems can be solved in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power constraints given marginal costs per unit, (iii) under MDES constraints given marginal costs per unit, and (iv) under sample size constraints for one or more levels along with any of the i, ii or iii options.

A design parameter (one of the MDES, power, or COSA) can be requested by using approriate function given design characteristics.

Each function begins with an **output** name, followed by a period, an **effect** (for moderator only), followed by a period, and a **design** name.

There are three types of output; mdes, power, and optimal, and 14 types of design; ira1r1, bira2r1, bira2f1, bira2c1, cra2r2, bira3r1, bcra3r2, bcra3f2, cra3r3, bira4r1, bcra4r2, bcra4r3, bcra4f3, and cra4r4. The first three or four letters of the design stands for the type of assignment, for individual random assignment ira, for blocked individual random assignment bira, for cluster random assignment cra, and for blocked cluster random assignment bcra. It is followed by a number indicating number of levels. A single letter followed by a number indicates whether a block is considered to be r, random; f, fixed; or c, constant and the level at which random assignment takes place.

A function with two keywords (output.design) returns results for main effect. For moderator effect, there is an additional keyword so the function has three keywords (output.effect.design). There are three moderator effects available for design cra2r2 and five moderator effect available for design cra3r3. In total there are six moderator effects; mod1n, mod1r, mod2n, mod2n, mod2r, and mod3. The number and the single letter at the end stands for the level of moderator variable and whether it varies randomly or non-randomly across higher level unit.

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So, to find MDES for main effect in two-level cluster randomized design where random assignment is at level-2, function mdes.cra2r2 is used. Similarly, to find MDES for a non-randoly varying moderator effect at level-1 for the same design, function mdes.mod1n.cra2r2 is used.

Each function requires slightly different arguments depending on the output it produces and the design. Most of the arguments have default values to provide users a starting point, which can be found in *usage* section of the documentation. For all functions default values are

- mdes = .25
- power  $(1 \beta) = .80$
- alpha  $(\alpha) = .05$
- two.tail = TRUE
- P = .50

and depending on the effect and design

- any of one of g1, g2, g3, g4 = 0
- any sequence of R12, R22, R32, R42 = 0
- any sequence of RT22, RT32, RT42 = 0
- Q = NULL, implies continuous moderator

Users should be aware of default values and change them if necessary. Depending on the function minimum required arguments are

- any sequence of rho2, rho3, rho4
- any sequence of omega2, omega3, omega4
- any one of, any sequence of, or any combination of n, J, K, L

For definition of above-mentioned parameters, statistical models and formulas see Dong and Maynard (2013), Dong, Kelcey, and Spybrook (in press), Spybrook, Kelcey, and Dong (in press), Kelcey, Dong, Spybrook, and Cox (2017), and Kelcey, Dong, Spybrook, and Shen (in press).

For reference intraclass correlation (rho2, rho3) values see Dong, Reinke, Herman, Bradshaw, and Murray (2016), Hedberg and Hedges (2014), Hedges and Hedberg (2007, 2013), Kelcey, and Phelps (2013), Schochet (2008), Spybrook, Westine, and Taylor (2016). For reference variance (R12, R22, R32) values see Bloom, Richburg-Hayes, and Black (2007), Deke et al. (2010), Dong et al. (2016), Hedges and Hedberg (2013), Kelcey, and Phelps (2013), Spybrook, Westine, and Taylor (2016), Westine, Spybrook, and Taylor (2013). Users can also obtain design parameters for various levels using publicly available state or district data.

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6 mdes.bcra3f2

mdes.bcra3f2	MDES Calculator for Three-Level Fixed Effects Blocked Cluster Ran-
	dom Assignment Design, Treatment at Level-2

# Description

mdes.bcra3f2 calculates minimum detectable effect size (MDES) for designs with three-levels where level-2 units are randomly assigned to treatment and control groups within level-3 units (fixed blocks).

# Usage

```
mdes.bcra3f2(power=.80, alpha=.05, two.tail=TRUE, rho2, P=.50, g2=0, R12=0, R22=0, n, J, K, ...)
```

# **Arguments**

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
Р	average proportion of level-2 units randomly assigned to treatment within level-3 units.
g2	number of covariates at level-2.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

### Value

fun	function name.
parms	list of parameters used in MDES calculation.
ncp	noncentrality parameter.
mdes	minimum detectable effect size and $(1-\alpha)\%$ lower and upper confidence limits.

# See Also

```
power.bcra3f2, optimal.bcra3f2
```

mdes.bcra3r2

### **Examples**

mdes.bcra3r2

MDES Calculator for Three-Level Random Effects Blocked Cluster Random Assignment Designs, Treatment at Level-2

# Description

mdes.bcra3r2 calculates minimum detectable effect size (MDES) for designs with three-levels where level-2 units are randomly assigned to treatment and control groups within level-3 units (random blocks).

### Usage

```
mdes.bcra3r2(power=.80, alpha=.05, two.tail=TRUE, rho2, rho3, omega3, P=.50, g3=0, R12=0, R22=0, RT32=0, n, J, K, ...)
```

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
omega3	treatment effect heterogeneity as ratio of treatment effect variance among level-3 units to the residual variance at level-3.
Р	average proportion of level-2 units randomly assigned to treatment within level-3 units.
g3	number of covariates at level-3.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
RT32	proportion of treatment effect variance among level-3 units explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

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#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

### See Also

```
power.bcra3r2, optimal.bcra3r2
```

### **Examples**

mdes.bcra4f3

MDES Calculator for Four-Level Fixed Effects Blocked Cluster Random Assignment Designs, Treatment at Level-3

### **Description**

mdes.bcra4f3 calculates minimum detectable effect size (MDES) for designs with four-levels where level-3 units are randomly assigned to treatment and control groups within level-4 units (fixed blocks).

#### Usage

```
mdes.bcra4f3(power=.80, alpha=.05, two.tail=TRUE,
    rho2, rho3,
    P=.50, R12=0, R22=0, R32=0, g3=0,
    n, J, K, L, ...)
```

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
P	average proportion of level-3 units randomly assigned to treatment within level-4 units.
g3	number of covariates at level-3.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.

mdes.bcra4r2

R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average).
L	number of level-4 units.
	to handle extra parameters passed from other functions, do not define any additional parameters.

### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

### See Also

```
power.bcra4f3, optimal.bcra4f3
```

# **Examples**

mdes.bcra4r2

MDES Calculator for Four-Level Random Effects Block Random Assignment Designs, Treatment at Level-2

# Description

mdes.bcra4r2 calculates minimum detectable effect size (MDES) for designs with four-levels where level-2 units are randomly assigned to treatment and control groups within level-3 units (random blocks).

### Usage

```
mdes.bcra4r2(power=.80, alpha=.05, two.tail=TRUE, rho2, rho3, rho4, omega3, omega4, P=.50, R12=0, R22=0, RT32=0, RT42=0, g4=0, n, J, K, L, ...)
```

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# Arguments

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
rho4	proportion of variance in the outcome explained by level-4 units.
omega3	treatment effect heterogeneity as ratio of treatment effect variance among level-3 units to the residual variance at level-3.
omega4	treatment effect heterogeneity as ratio of treatment effect variance among level-4 units to the residual variance at level-4.
Р	average proportion of level-2 units randomly assigned to treatment within level-3 units.
g4	number of covariates at level-4.
g4 R12	number of covariates at level-4. proportion of level-1 variance in the outcome explained by level-1 covariates.
_	
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R12 R22	proportion of level-1 variance in the outcome explained by level-1 covariates. proportion of level-2 variance in the outcome explained by level-2 covariates. proportion of treatment effect variance among level-3 units explained by level-3
R12 R22 RT32	proportion of level-1 variance in the outcome explained by level-1 covariates. proportion of level-2 variance in the outcome explained by level-2 covariates. proportion of treatment effect variance among level-3 units explained by level-3 covariates. proportion of treatment effect variance among level-4 units explained by level-4
R12 R22 RT32 RT42	proportion of level-1 variance in the outcome explained by level-1 covariates. proportion of level-2 variance in the outcome explained by level-2 covariates. proportion of treatment effect variance among level-3 units explained by level-3 covariates. proportion of treatment effect variance among level-4 units explained by level-4 covariates.
R12 R22 RT32 RT42	proportion of level-1 variance in the outcome explained by level-1 covariates. proportion of level-2 variance in the outcome explained by level-2 covariates. proportion of treatment effect variance among level-3 units explained by level-3 covariates. proportion of treatment effect variance among level-4 units explained by level-4 covariates. harmonic mean of level-1 units across level-2 units (or simple average).
R12 R22 RT32 RT42	proportion of level-1 variance in the outcome explained by level-1 covariates. proportion of level-2 variance in the outcome explained by level-2 covariates. proportion of treatment effect variance among level-3 units explained by level-3 covariates. proportion of treatment effect variance among level-4 units explained by level-4 covariates. harmonic mean of level-1 units across level-2 units (or simple average). harmonic mean of level-2 units across level-3 units (or simple average).
R12 R22 RT32 RT42 n J	proportion of level-1 variance in the outcome explained by level-1 covariates. proportion of level-2 variance in the outcome explained by level-2 covariates. proportion of treatment effect variance among level-3 units explained by level-3 covariates. proportion of treatment effect variance among level-4 units explained by level-4 covariates. harmonic mean of level-1 units across level-2 units (or simple average). harmonic mean of level-2 units across level-3 units (or simple average). harmonic mean of level-3 units across level-4 units (or simple average).

### Value

fun function name.

parms list of parameters used in MDES calculation.

tional parameters.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

### See Also

```
power.bcra4r2, optimal.bcra4r2
```

# **Examples**

mdes.bcra4r3

mdes.bcra4r3	MDES Calculator for Four-Level Random Effects Blocked Cluster
	Random Assignment Designs, Treatment at Level-3

# Description

mdes.bcra4r3 calculates minimum detectable effect size (MDES) for designs with four-levels where level-3 units are randomly assigned to treatment and control groups within level-4 units (random blocks).

# Usage

```
mdes.bcra4r3(power=.80, alpha=.05, two.tail=TRUE,
    rho2, rho3, rho4, omega4,
    P=.50, R12=0, R22=0, R32=0, RT42=0, g4=0,
    n, J, K, L, ...)
```

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
rho4	proportion of variance in the outcome explained by level-4 units.
omega4	treatment effect heterogeneity as ratio of treatment effect variance among level-4 units to the residual variance at level-4.
Р	average proportion of level-3 units randomly assigned to treatment within level-4 units.
g4	number of covariates at level-4.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.
RT42	proportion of treatment effect variance among level-4 units explained by level-4 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average).
L	number of level-4 units.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

mdes.bira2c1

#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and 95% lower and upper confidence limits.

#### See Also

```
power.bcra4r3, optimal.bcra4r3
```

### **Examples**

mdes.bira2c1

MDES Calculator for Two-Level Constant Effects Blocked Individual Random Assignment Designs, Treatment at Level-1

### **Description**

mdes.bira2c1 calculates minimum detectable effect size (MDES) for designs with two-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (school intercepts only).

### Usage

```
mdes.bira2c1(power=.80, alpha=.05, two.tail=TRUE, P=.50, g1=0, R12=0, n, J, ...)
```

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
Р	average proportion of level-1 units randomly assigned to treatment within level-2 units.
g1	number of covariates at level-1.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

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### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

### See Also

```
power.bira2c1, optimal.bira2c1
```

### **Examples**

```
## Not run:
mdes.bira2c1(n=55, J=3)
## End(Not run)
```

mdes.bira2f1

MDES Calculator for Two-Level Fixed Effects Blocked Individual Random Assignment Designs, Treatment at Level-1

# **Description**

mdes.bira2f1 calculates minimum detectable effect size (MDES) for designs with two-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (fixed blocks).

# Usage

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
P	average proportion of level-1 units randomly assigned to treatment within level-2 units.
g1	number of covariates at level-1.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

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#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

#### See Also

```
power.bira2f1, optimal.bira2f1
```

### **Examples**

```
## Not run:

mdes.bira2f1(n=55, J=3)

## End(Not run)
```

mdes.bira2r1

MDES Calculator for Two-Level Random Effects Blocked Individual Random Assignment Designs, Individuals Randomized within Blocks

### **Description**

mdes.bira2r1 calculates minimum detectable effect size (MDES) for designs with two-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (random blocks).

# Usage

```
mdes.bira2r1(power=.80, alpha=.05, two.tail=TRUE, rho2, omega2, P=.50, g2=0, R12=0, RT22=0, n, J, ...)
```

### **Arguments**

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

rho2 proportion of variance in the outcome explained by level-2 units.

omega2 treatment effect heterogeneity as ratio of treatment effect variance among level-2

units to the residual variance at level-2.

P average proportion of level-1 units randomly assigned to treatment within level-

2 units.

g2 number of covariates at level-2.

mdes.bira3r1

R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
RT22	proportion of treatment effect variance among level-2 units explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
	to handle extra parameters passed from other functions, do not define any additional parameters.

### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

### See Also

```
power.bira2r1, optimal.bira2r1
```

# **Examples**

mdes.bira3r1

MDES Calculator for Three-Level Random Effects Blocked Individual Random Assignment Design, Individuals Randomized within Blocks

# Description

mdes.bira3r1 calculates minimum detectable effect size (MDES) for designs with three-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (random blocks).

# Usage

```
mdes.bira3r1(power=.80, alpha=.05, two.tail=TRUE, rho2, rho3, omega2, omega3, P=.50, R12=0, RT22=0, RT32=0, g3=0, n, J, K, ...)
```

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# Arguments

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
omega2	treatment effect heterogeneity as ratio of treatment effect variance among level-2 units to the residual variance at level-2.
omega3	treatment effect heterogeneity as ratio of treatment effect variance among level-3 units to the residual variance at level-3.
Р	average proportion of level-1 units randomly assigned to treatment within level-2 units.
g3	number of covariates at level-3.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
RT22	proportion of treatment effect variance among level-2 units explained by level-2 covariates.
RT32	proportion of treatment effect variance among level-3 units explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
	to handle extra parameters passed from other functions, do not define any addi-
	tional parameters.

# Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

# See Also

```
power.bira3r1, optimal.bira3r1
```

# **Examples**

mdes.bira4r1

mdes.bira4r1	MDES Calculator for Four-Level Random Effects Blocked Individual
	Random Assignment Design, Individuals Randomized within Blocks

# Description

mdes.bira4r1 calculates minimum detectable effect size (MDES) for designs with four-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (random blocks).

# Usage

```
mdes.bira4r1(power=.80, alpha=.05, two.tail=TRUE,
    rho2, rho3, rho4, omega2, omega3, omega4,
    P=.50, R12=0, RT22=0, RT32=0, RT42=0, g4=0,
    n, J, K, L, ...)
```

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
rho4	proportion of variance in the outcome explained by level-4 units.
omega2	treatment effect heterogeneity as ratio of treatment effect variance among level-2 units to the residual variance at level-2.
omega3	treatment effect heterogeneity as ratio of treatment effect variance among level-3 units to the residual variance at level-3.
omega4	treatment effect heterogeneity as ratio of treatment effect variance among level-4 units to the residual variance at level-4.
P	average proportion of level-1 units randomly assigned to treatment within level-2 units.
g4	number of covariates at level-4.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
RT22	proportion of treatment effect variance among level-2 units explained by level-2 covariates.
RT32	proportion of treatment effect variance among level-3 units explained by level-3 covariates.
RT42	proportion of treatment effect variance among level-4 units explained by level-4 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average).
L	number of level-4 units.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

mdes.cra2r2

#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

### See Also

```
power.bira4r1, optimal.bira4r1
```

### **Examples**

mdes.cra2r2

MDES Calculator for Main Effect in Two-Level Cluster Random Assignment Design, Treatment at Level-2

# Description

mdes.cra2r2 calculates minimum detectable effect size (MDES) for main effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups.

# Usage

```
mdes.cra2r2(power=.80, alpha=.05, two.tail=TRUE, rho2, P=.50, g2=0, R12=0, R22=0, n, J, ...)
```

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
P	proportion of level-2 units randomly assigned to treatment.
g2	number of covariates at level-2.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
	to handle extra parameters passed from other functions, do not define any additional parameters.

mdes.cra3r3

#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

#### See Also

```
power.cra2r2, optimal.cra2r2
```

#### **Examples**

mdes.cra3r3

MDES Calculator for Main Effect in Three-Level Cluster Random Assignment Designs, Treatment at Level-3

# Description

mdes.cra3r3 calculates minimum detectable effect size (MDES) for main effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups.

# Usage

```
mdes.cra3r3(power=.80, alpha=.05, two.tail=TRUE, rho2, rho3, P=.50, g3=0, R12=0, R22=0, R32=0, n, J, K, ...)
```

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
Р	proportion of level-3 units randomly assigned to treatment.
g3	number of covariates at level-3.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.

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n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
	to handle extra parameters passed from other functions, do not define any addi-

tional parameters.

#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

#### See Also

```
power.cra3r3, optimal.cra3r3
```

### **Examples**

mdes.cra4r4

MDES Calculator for Four-Level Cluster Random Assignment Designs, Treatment at Level-4

#### **Description**

mdes.cra4r4 calculates minimum detectable effect size (MDES) for designs with four-levels where level-4 units are randomly assigned to treatment and control groups.

### Usage

```
mdes.cra4r4(power=.80, alpha=.05, two.tail=TRUE,
    rho2, rho3, rho4,
    P=.50, R12=0, R22=0, R32=0, R42=0, g4=0,
    n, J, K, L, ...)
```

#### **Arguments**

 $\begin{array}{ll} \mbox{power} & \mbox{statistical power} \ (1-\beta). \\ \mbox{alpha} & \mbox{probability of type I error.} \end{array}$ 

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

rho2 proportion of variance in the outcome explained by level-2 units.

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rho3	proportion of variance in the outcome explained by level-3 units.
rho4	proportion of variance in the outcome explained by level-4 units.
P	proportion of level-4 units randomly assigned to treatment.
g4	number of covariates at level-4.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.
R42	proportion of level-4 variance in the outcome explained by level-4 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average).
L	number of level-4 units.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

#### See Also

```
power.cra4r4, optimal.cra4r4
```

### **Examples**

mdes.ira1r1

MDES Calculator for Individual Random Assignment Designs, Completely Randomized Controlled Trials

# Description

mdes.ira1r1 calculates minimum detectable effect size (MDES) for completely randomized controlled trials where individuals are randomly assigned to treatment or control groups.

# Usage

```
mdes.ira1r1(power=.80, alpha=.05, two.tail=TRUE, P=.50, g1=0, R12=0, n, ...)
```

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### **Arguments**

 $\begin{array}{ll} \mbox{power} & \mbox{statistical power} \ (1-\beta). \\ \mbox{alpha} & \mbox{probability of type I error.} \end{array}$ 

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

P proportion of units randomly assigned to treatment.

g1 number of covariates.

R12 proportion of variance in the outcome explained by covariates.

n sample size.

... to handle extra parameters passed from other functions, do not define any addi-

tional parameters.

#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

#### See Also

```
power.ira1r1, optimal.ira1r1
```

#### **Examples**

```
## Not run:

mdes.ira1r1(n=55)

## End(Not run)
```

mdes.mod1n.cra2r2

MDES Calculator for Non-Randomly Varying Moderator Effect in Two-Level Cluster Random Assignment Design, Treatment at Level-2, Moderator at Level-1

### **Description**

mdes.mod1n.cra2r2 calculates minimum detectable effect size (MDES) for non-randomly varying moderator effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups and moderator is at level-1.

### Usage

```
mdes.mod1n.cra2r2(power=.80, alpha=.05, two.tail=TRUE, rho2, P=.50, Q=NULL, g1=0, R12=0, n, J, ...)
```

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### **Arguments**

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
Р	proportion of level-2 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g1	number of covariates at level-1 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

### See Also

```
power.mod1n.cra2r2, optimal.mod1n.cra2r2
```

# **Examples**

mdes.mod1n.cra3r3

MDES Calculator for Non-Randomly Varying Moderator Effect in Three-Level Cluster Random Assignment Design, Treatment at Level-3, Moderator at Level-1

# Description

mdes.mod1n.cra3r3 calculates minimum detectable effect size (MDES) for non-randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-1.

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### Usage

```
mdes.mod1n.cra3r3(power=.80, alpha=.05, two.tail=TRUE, rho2, rho3, P=.50, Q=NULL, g1=0, R12=0, n, J, K, ...)
```

### **Arguments**

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
P	proportion of level-3 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g1	number of covariates at level-1 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
• • •	to handle extra parameters passed from other functions, do not define any additional parameters.

#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

# See Also

```
power.mod1n.cra3r3, optimal.mod1n.cra3r3
```

# **Examples**

mdes.mod1r.cra2r2 25

mdes.mod1r.cra2r2	MDES Calculator for Randomly Varying Moderator Effect in Two- Level Cluster Random Assignment Design, Treatment at Level-2, Mod- erator at Level-1

# Description

mdes.mod1r.cra2r2 calculates minimum detectable effect size (MDES) for randomly varying moderator effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups and moderator is at level-1.

### Usage

```
mdes.mod1r.cra2r2(power=.80, alpha=.05, two.tail=TRUE, rho2, omega2, RT22=0, P=.50, Q=NULL, g1=0, R12=0, n, J, ...)
```

# Arguments

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
omega2	moderator effect heterogeneity (unconditional) across level-2 units.
Р	proportion of level-2 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g1	number of covariates at level-1 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
RT22	proportion of level-2 variance in the moderator effect explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
	to handle extra parameters passed from other functions, do not define any additional parameters.

### Value

fun	function name.
parms	list of parameters used in MDES calculation.
ncp	noncentrality parameter.
mdes	minimum detectable effect size and $(1-\alpha)\%$ lower and upper confidence limits.

# See Also

```
power.mod1r.cra2r2, optimal.mod1r.cra2r2
```

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### **Examples**

```
## Not run:

mdes.mod1r.cra2r2(rho2=.2, omega2=.2, RT22=.2, n=4, J=20)

## End(Not run)

mdes.mod1r.cra3r3

MDES Calculator for Randomly Varying Moderator Effect in Three-Level Cluster Random Assignment Designs, Treatment at Level-3, Moderator at Level-1
```

# Description

mdes.mod1r.cra3r3 calculates minimum detectable effect size (MDES) for randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-1.

# Usage

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
omega2	moderator effect heterogeneity (unconditional) across level-2 units.
omega3	moderator effect heterogeneity (unconditional) across level-3 units.
Р	proportion of level-3 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g1	number of covariates at level-1 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
RT22	proportion of level-2 variance in the moderator effect explained by level-2 covariates.
RT32	proportion of level-3 variance in the moderator effect explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
• • •	to handle extra parameters passed from other functions, do not define any additional parameters.

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#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

#### See Also

```
power.mod1r.cra3r3, optimal.mod1r.cra3r3
```

#### **Examples**

mdes.mod2.cra2r2

MDES Calculator for Moderator Effect in Two-Level Cluster Random Assignment Design, Treatment and Moderator at Level-2

### **Description**

mdes.mod2.cra2r2 calculates minimum detectable effect size (MDES) for moderator effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups and moderator is at level-2.

### Usage

```
mdes.mod2.cra2r2(power=.80, alpha=.05, two.tail=TRUE, rho2, P=.50, Q=NULL, g2=0, R12=0, R22=0, n, J, ...)
```

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
Р	proportion of level-2 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g2	number of covariates at level-2 excluding moderator.

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R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
• • •	to handle extra parameters passed from other functions, do not define any additional parameters.

### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

### See Also

```
power.mod2.cra2r2, optimal.mod2.cra2r2
```

#### **Examples**

```
## Not run:
mdes.mod2.cra2r2(rho2=.20, n=4, J=20, Q=.5)
## End(Not run)
```

mdes.mod2n.cra3r3

MDES Calculator for Non-Randomly Varying Moderator Effect in Three-Level Cluster Random Assignment Design, Treatment at Level-3, Moderator at Level-2

### **Description**

mdes.mod2n.cra3r3 calculates minimum detectable effect size (MDES) for non-randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-2.

### Usage

```
mdes.mod2n.cra3r3(power=.80, alpha=.05, two.tail=TRUE, rho2, rho3, P=.50, Q=NULL, g2=0, R12=0, R22=0, n, J, K, ...)
```

mdes.mod2n.cra3r3

# Arguments

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
Р	proportion of level-3 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g2	number of covariates at level-2 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
	to handle extra parameters passed from other functions, do not define any additional parameters.

# Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

# See Also

```
power.mod 2n.cra 3r3,\ optimal.mod 2n.cra 3r3
```

# **Examples**

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mdes.mod2r.cra3r3 MDES Calculator for Randomly Varying Moderator Effect in Three- Level Cluster Random Assignment Designs, Treatment at Level-3, Moderator at Level-2
---

# Description

mdes.mod2r.cra3r3 calculates minimum detectable effect size (MDES) for randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-2.

### Usage

```
mdes.mod2r.cra3r3(power=.80, alpha=.05, two.tail=TRUE, rho2, rho3, omega3, P=.50, Q=NULL, g2=0, R12=0, R22=0, R732=0, n, J, K, ...)
```

# Arguments

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
omega3	moderator effect heterogeneity (unconditional) across level-3 units.
Р	proportion of level-3 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g2	number of covariates at level-2 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
RT32	proportion of level-3 variance in the moderator effect explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
• • •	to handle extra parameters passed from other functions, do not define any additional parameters.

### Value

fun	function name.
parms	list of parameters used in MDES calculation.
ncp	noncentrality parameter.
mdes	minimum detectable effect size and $(1-\alpha)\%$ lower and upper confidence limits.

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#### See Also

```
power.mod2r.cra3r3, optimal.mod2r.cra3r3
```

#### **Examples**

```
## Not run:

mdes.mod2r.cra3r3(rho3=.10, rho2=.10, omega3=.05, Q=.5, g2=1, R12=.30, R22=.40, RT32=0, n=20, J=4, K=60)

## End(Not run)
```

mdes.mod3.cra3r3

MDES Calculator for Moderator Effect in Three-Level Cluster Random Assignment Designs, Treatment and Moderator at Level-3

# Description

mdes.mod3.cra3r3 calculates minimum detectable effect size (MDES) for moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-3.

### Usage

```
mdes.mod3.cra3r3(power=.80, alpha=.05, two.tail=TRUE, rho2, rho3, P=.50, Q=NULL, g3=0, R12=0, R22=0, R32=0, n, J, K, ...)
```

power	statistical power $(1 - \beta)$ .
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
Р	proportion of level-3 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g3	number of covariates at level-3 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

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#### Value

fun function name.

parms list of parameters used in MDES calculation.

ncp noncentrality parameter.

mdes minimum detectable effect size and  $(1-\alpha)\%$  lower and upper confidence limits.

### See Also

```
power.mod3.cra3r3, optimal.mod3.cra3r3
```

### **Examples**

mdes.to.pctl

MDES to Percentiles

### **Description**

mdes.to.pctl converts MDES values returned from mdes function into percentile values.

# Usage

```
mdes.to.pctl(x)
```

### **Arguments**

Х

an object returned from mdes function or a numeric value in standard deviation units.

### **Details**

mdes.to.pctl converts MDES values returned from mdes function into percentile values. Values should be interpreted as percentile increase with reference to 50th percentile.

### See Also

```
optimal.to.mdes
```

mdes.to.power 33

### **Examples**

mdes.to.power

MDES to power

### **Description**

mdes.to.power converts an object returned from mdes function into an object returned from power function.

# Usage

```
mdes.to.power(x)
```

### **Arguments**

Х

an object returned from one of the mdes functions.

### Details

mdes.to.power converts an object returned from mdes function into an object returned from power function by passing parameters through power function.

#### See Also

```
optimal.to.mdes, power.to.mdes
```

### **Examples**

```
## Not run:

# object returned from power function
  design1 <- mdes.bira2r1(rho2=.35, omega2=.10, n=83, J=10)
  # convert the object into an object returned from mdes function
  design2 <- mdes.to.power(design1)

## End(Not run)</pre>
```

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optimal.bcra3f2	COSA Solver for Main Effect in Three-Level Fixed Effects Blocked
	Cluster Random Assignment Designs, Treatment at Level-2

# Description

optimal.bcra3f2 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with three-levels where level-2 units are randomly assigned to treatment and control groups within level-3 units (fixed blocks). COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

### Usage

# **Arguments**

rho2

cn	marginal cost per level-1 unit.
сJ	marginal cost per level-2 unit.
cK	marginal cost per level-3 unit.
cost	total cost or budget.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
power	statistical power (1 - type II error).
mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
nJK0	vector with a length of three to specify starting values for level-1, level-2, and level-3 sample sizes.
ncase	number of cases to show in the output.
gm	grid multiplier to increase the range of sample size search for each level.
constrain	one of the followings can be constrained at a specified cost or value: "cost", "power", or "mdes".
optimizer	algorithm to find optimal sample sizes given total cost, power, or MDES. Available algorithms: "auglag_cobyla", "auglag_lbfgs", "auglag_mma", or "auglag_slsqp".

proportion of variance in the outcome explained by level-2 units.

optimal.bcra3r2

P	average proportion of level-2 units randomly assigned to treatment within level-3 units.
g2	number of covariates at level-2.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.

#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

### See Also

```
mdes.bcra3f2, power.bcra3f2
```

# **Examples**

COSA Solver for Main Effect in Three-Level Random Effects Blocked Cluster Random Assignment Designs, Treatment at Level-2

#### **Description**

optimal.bcra3r2

optimal.bcra3r2 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with three-levels where level-2 units are randomly assigned to treatment and control groups within level-3 units (random blocks). COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

#### Usage

```
optimal.bcra3r2(cn=0, cJ=0, cK=0, cost=NULL, n=NULL, J=NULL, K=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJK0=c(10,10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", rho2, rho3, omega3, P=.50, g3=0, R12=0, R22=0, RT32=0)
```

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### **Arguments**

cn marginal cost per level-1 unit.
cJ marginal cost per level-2 unit.
cK marginal cost per level-3 unit.

cost total cost or budget.

n harmonic mean of level-1 units across level-2 units (or simple average).

J harmonic mean of level-2 units across level-3 units (or simple average).

K level-3 sample size.

power statistical power (1 - type II error).

mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

nJK0 vector with a length of three to specify starting values for level-1, level-2, and

level-3 sample sizes.

ncase number of cases to show in the output.

gm grid multiplier to increase the range of sample size search for each level.

constrain one of the followings can be constrained at a specified cost or value: "cost",

"power", or "mdes".

optimizer algorithm to find optimal sample sizes given total cost, power, or MDES. Avail-

able algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp".

rho2 proportion of variance in the outcome explained by level-2 units.
rho3 proportion of variance in the outcome explained by level-3 units.

omega3 treatment effect heterogeneity as ratio of treatment effect variance among level-3

units to the residual variance at level-3.

P average proportion of level-2 units randomly assigned to treatment within level-

3 units.

g3 number of covariates at level-3.

R12 proportion of level-1 variance in the outcome explained by level-1 covariates.

R22 proportion of level-2 variance in the outcome explained by level-2 covariates.

RT32 proportion of treatment effect variance among level-3 units explained by level-3

covariates.

#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

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#### See Also

```
mdes.bcra3r2, power.bcra3r2
```

#### **Examples**

optimal.bcra4f3

COSA Solver for Main Effect in Four-Level Fixed Effects Blocked Cluster Random Assignment Designs, Treatment at Level-3

# Description

optimal.bcra4f3 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with four-levels where level-3 units are randomly assigned to treatment and control groups within level-4 units (fixed blocks). COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

# Usage

```
optimal.bcra4f3(cn=0, cJ=0, cK=0, cL=0, cost=NULL, n=NULL, J=NULL, K=NULL, L=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJKL0=c(10,10,10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", rho3, rho2, P=.50, g3=0, R32=0, R22=0, R12=0)
```

#### **Arguments**

cn	marginal cost per level-1 unit.
сJ	marginal cost per level-2 unit.
cK	marginal cost per level-3 unit.
cL	marginal cost per level-4 unit.
cost	total cost or budget.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average). $ \\$
L	number of level-4 units.
power	statistical power (1 - type II error).

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mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
nJKL0	vector with a length of four to specify starting values for level-1, level-2, level-3, and level-4 sample sizes.
ncase	number of cases to show in the output.
gm	grid multiplier to increase the range of sample size search for each level.
constrain	one of the followings can be constrained at a specified cost or value: "cost", "power", or "mdes".
optimizer	algorithm to find optimal sample sizes given total cost, power, or MDES. Available algorithms: "auglag_cobyla", "auglag_lbfgs", "auglag_mma", or "auglag_slsqp".
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
P	average proportion of level-3 units randomly assigned to treatment within level-4 units.
g3	number of covariates at level-3.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.

## Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

#### See Also

```
mdes.bcra4f3, power.bcra4f3
```

# **Examples**

optimal.bcra4r2

optimal.bcra4r2	COSA Solver for Main Effect in Four-Level Random Effects Block
	Random Assignment Designs, Treatment at Level-2

# Description

optimal.bcra4r2 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with four-levels where level-2 units are randomly assigned to treatment and control groups within level-3 units (random blocks). COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

# Usage

```
optimal.bcra4r2(cn=0, cJ=0, cK=0, cL=0, cost=NULL, n=NULL, J=NULL, K=NULL, L=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJKL0=c(10,10,10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", rho4, rho3, rho2, omega4, omega3, P=.50, g4=0, RT42=0, RT32=0, R22=0, R12=0)
```

# **Arguments**

cn	marginal cost per level-1 unit.
сJ	marginal cost per level-2 unit.
cK	marginal cost per level-3 unit.
cL	marginal cost per level-4 unit.
cost	total cost or budget.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average).
L	number of level-4 units.
power	statistical power (1 - type II error).
mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
nJKL0	vector with a length of four to specify starting values for level-1, level-2, level-3, and level-4 sample sizes.
ncase	number of cases to show in the output.
gm	grid multiplier to increase the range of sample size search for each level.
constrain	one of the followings can be constrained at a specified cost or value: "cost", "power", or "mdes".

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optimizer	algorithm to find optimal sample sizes given total cost, power, or MDES. Available algorithms: "auglag_cobyla", "auglag_lbfgs", "auglag_mma", or "auglag_slsqp".
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
rho4	proportion of variance in the outcome explained by level-4 units.
omega3	treatment effect heterogeneity as ratio of treatment effect variance among level-3 units to the residual variance at level-3.
omega4	treatment effect heterogeneity as ratio of treatment effect variance among level-4 units to the residual variance at level-4.
P	average proportion of level-2 units randomly assigned to treatment within level-3 units.
g4	number of covariates at level-4.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
RT32	proportion of treatment effect variance among level-3 units explained by level-3 covariates.
RT42	proportion of treatment effect variance among level-4 units explained by level-4 covariates.

## Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

 $integer.optim \quad best integer solutions \ around \ round.optim \ solution. \ MDES \ is \ calculated \ at \ the$ 

specified power (default .80), and power is calculated at the specified MDES

(default .25).

#### See Also

```
mdes.bcra4r2, power.bcra4r2
```

# **Examples**

optimal.bcra4r3 41

optimal.bcra4r3	COSA Solver for Main Effect in Four-Level Random Effects Blocked
	Cluster Random Assignment Designs, Treatment at Level-3

# Description

optimal.bcra4r3 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with four-levels where level-3 units are randomly assigned to treatment and control groups within level-4 units (random blocks). COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

# Usage

```
optimal.bcra4r3(cn=0, cJ=0, cK=0, cL=0, cost=NULL, n=NULL, J=NULL, K=NULL, L=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJKL0=c(10,10,10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", rho4, rho3, rho2, omega4, P=.50, g4=0, RT42=0, R32=0, R22=0, R12=0)
```

# **Arguments**

cn	marginal cost per level-1 unit.
сJ	marginal cost per level-2 unit.
cK	marginal cost per level-3 unit.
cL	marginal cost per level-4 unit.
cost	total cost or budget.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average).
L	number of level-4 units.
power	statistical power (1 - type II error).
mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
nJKL0	vector with a length of four to specify starting values for level-1, level-2, level-3, and level-4 sample sizes.
ncase	number of cases to show in the output.
gm	grid multiplier to increase the range of sample size search for each level.
constrain	one of the followings can be constrained at a specified cost or value: "cost", "power", or "mdes".

optimal.bcra4r3

optimiz	algorithm to find optimal sample sizes given total cost, power, or MDES. Available algorithms: "auglag_cobyla", "auglag_lbfgs", "auglag_mma", or "auglag_slsqp"
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
rho4	proportion of variance in the outcome explained by level-4 units.
omega4	treatment effect heterogeneity as ratio of treatment effect variance among level-4 units to the residual variance at level-4.
Р	average proportion of level-3 units randomly assigned to treatment within level-4 units.
g4	number of covariates at level-4.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.
RT42	proportion of treatment effect variance among level-4 units explained by level-4 covariates.

## Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

### See Also

```
mdes.bcra4r3, power.bcra4r3
```

# **Examples**

optimal.bira2c1 43

optimal.bira2c1	COSA Solver for Main Effect in Two-Level Constant Effects Blocked
	Individual Random Assignment Designs, Treatment at Level-2

# Description

optimal.bira2c1 finds constrained optimal sample allocation (COSA) solutions for main effct in designs with two-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (school intercepts only). COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

# Usage

```
optimal.bira2c1(cn=0, cJ=0, cost=NULL, n=NULL, J=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJ0=c(10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", P=.50, g1=0, R12=0)
```

## **Arguments**

R12

2	, differences	
	cn	marginal cost per level-1 unit.
	сJ	marginal cost per level-2 unit.
	cost	total cost or budget.
	n	harmonic mean of level-1 units across level-2 units (or simple average).
	J	level-2 sample size.
	power	statistical power (1 - type II error).
	mdes	minimum detectable effect size.
	alpha	probability of type I error.
	two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
	nJ0	vector with a length of two to specifiy starting values for level-1 and level-2 sample sizes.
	ncase	number of cases to show in the output.
	gm	grid multiplier to increase the range of sample size search for each level.
	constrain	one of the followings can be constrained at a specified cost or value: "cost", "power", or "mdes".
	optimizer	algorithm to find optimal sample sizes given total cost, power, or MDES. Available algorithms: "auglag_cobyla", "auglag_lbfgs", "auglag_mma", or "auglag_slsqp".
	Р	average proportion of level-1 units randomly assigned to treatment within level-2 units.
	g1	number of covariates at level-1.

proportion of level-1 variance in the outcome explained by level-1 covariates.

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#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

### See Also

```
mdes.bira2c1, power.bira2c1
```

### **Examples**

optimal.bira2f1

COSA Solver for Main Effect in Two-Level Fixed Effects Blocked Individual Random Assignment Designs, Treatment at Level-1

# **Description**

optimal.bira2f1 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with two-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (fixed blocks). COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

# Usage

```
optimal.bira2f1(cn=0, cJ=0, cost=NULL, n=NULL, J=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJ0=c(10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", P=.50, g1=0, R12=0)
```

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#### **Arguments**

cn marginal cost per level-1 unit. cJ marginal cost per level-2 unit.

cost total cost or budget.

n harmonic mean of level-1 units across level-2 units (or simple average).

J level-2 sample size.

power statistical power (1 - type II error).

mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

nJ0 vector with a length of four to specify starting values for level-1 and level-2

sample sizes.

ncase number of cases to show in the output.

gm grid multiplier to increase the range of sample size search for each level.

constrain one of the followings can be constrained at a specified cost or value: "cost",

"power", or "mdes".

optimizer algorithm to find optimal sample sizes given total cost, power, or MDES. Avail-

able algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp".

P average proportion of level-1 units randomly assigned to treatment within level-

2 units.

g1 number of covariates at level-1.

R12 proportion of level-1 variance in the outcome explained by level-1 covariates.

#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

# See Also

```
mdes.bira2f1, power.bira2f1
```

# **Examples**

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optimal.bira2r1	COSA Solver for Main Effect in Two-Level Random Effects Blocked Individual Random Assignment Designs, Individuals Randomized within Blocks

# Description

optimal.bira2r1 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with two-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (random blocks). COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

# Usage

```
optimal.bira2r1(cn=0, cJ=0, cost=NULL, n=NULL, J=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJ0=c(10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", rho2, omega2, P=.50, g2=0, R12=0, RT22=0)
```

## **Arguments**

cn	marginal cost per level-1 unit.
сJ	marginal cost per level-2 unit.
cost	total cost or budget.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
power	statistical power (1 - type II error).
mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
nJ0	vector with a length of two to specifiy starting values for level-1 and level-2 sample sizes.
ncase	number of cases to show in the output.
gm	grid multiplier to increase the range of sample size search for each level.
constrain	one of the followings can be constrained at a specified cost or value: "cost", "power", or "mdes".
optimizer	algorithm to find optimal sample sizes given total cost, power, or MDES. Available algorithms: "auglag_cobyla", "auglag_lbfgs", "auglag_mma", or "auglag_slsqp".
rho2	proportion of variance in the outcome explained by level-2 units.
omega2	treatment effect heterogeneity as ratio of treatment effect variance among level-2 units to the residual variance at level-2.

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Р	average proportion of level-1 units randomly assigned to treatment within level-2 units.
g2	number of covariates at level-2.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
RT22	proportion of treatment effect variance among level-2 units explained by level-2 covariates.

#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

#### See Also

```
mdes.bira2r1, power.bira2r1
```

# Examples

optimal.bira3r1

COSA Solver for Main Effect in Three-Level Random Effects Blocked Individual Random Assignment Design, Individuals Randomized within Blocks

### **Description**

optimal.bira3r1 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with three-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (random blocks). COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

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#### **Usage**

```
optimal.bira3r1(cn=0, cJ=0, cK=0, cost=NULL, n=NULL, J=NULL, K=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJK0=c(10,10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", rho2, rho3, omega2, omega3, P=.50, g3=0, R12=0, RT22=0, RT32=0)
```

# **Arguments**

cn marginal cost per level-1 unit.
cJ marginal cost per level-2 unit.
cK marginal cost per level-3 unit.

cost total cost or budget.

n harmonic mean of level-1 units across level-2 units (or simple average).

J harmonic mean of level-2 units across level-3 units (or simple average).

K level-3 sample size.

power statistical power (1 - type II error).

mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

nJK0 vector with a length of three to specify starting values for level-1, level-2, and

level-3 sample sizes.

ncase number of cases to show in the output.

gm grid multiplier to increase the range of sample size search for each level.

constrain one of the followings can be constrained at a specified cost or value: "cost",

"power", or "mdes".

optimizer algorithm to find optimal sample sizes given total cost, power, or MDES. Avail-

 $able\ algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp".$ 

rho2 proportion of variance in the outcome explained by level-2 units.
rho3 proportion of variance in the outcome explained by level-3 units.

omega2 treatment effect heterogeneity as ratio of treatment effect variance among level-2

units to the residual variance at level-2.

omega3 treatment effect heterogeneity as ratio of treatment effect variance among level-3

units to the residual variance at level-3.

P average proportion of level-1 units randomly assigned to treatment within level-

2 units.

g3 number of covariates at level-3.

R12 proportion of level-1 variance in the outcome explained by level-1 covariates.

RT22 proportion of treatment effect variance among level-2 units explained by level-2

covariates.

RT32 proportion of treatment effect variance among level-3 units explained by level-3

covariates.

optimal.bira4r1 49

#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

#### See Also

```
mdes.bira3r1, power.bira3r1
```

### **Examples**

```
## Not run:
```

```
optimal.bira3r1(cn=1, cJ=10, cK=100, cost=5600,
constrain="cost",
rho3=.20, rho2=.15, omega3=.10, omega2=.10)
```

## End(Not run)

optimal.bira4r1

COSA Solver for Main Effect in Four-Level Random Effects Blocked Individual Random Assignment Design, Individuals Randomized within Blocks

## **Description**

optimal.bira4r1 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with four-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (random blocks). COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

## Usage

```
optimal.bira4r1(cn=0, cJ=0, cK=0, cL=0, cost=NULL, n=NULL, J=NULL, K=NULL, L=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJKL0=c(10,10,10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", rho4, rho3, rho2, omega4, omega3, omega2, P=.50, g4=0, RT42=0, RT32=0, RT22=0, R12=0)
```

50 optimal.bira4r1

#### **Arguments**

cn marginal cost per level-1 unit.
cJ marginal cost per level-2 unit.
cK marginal cost per level-3 unit.
cL marginal cost per level-4 unit.

cost total cost or budget.

n harmonic mean of level-1 units across level-2 units (or simple average).

J harmonic mean of level-2 units across level-3 units (or simple average).

K harmonic mean of level-3 units across level-4 units (or simple average).

L number of level-4 units.

power statistical power (1 - type II error).

mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

nJKL0 vector with a length of four to specify starting values for level-1, level-2, level-

3, and level-4 sample sizes.

ncase number of cases to show in the output.

gm grid multiplier to increase the range of sample size search for each level.

constrain one of the followings can be constrained at a specified cost or value: "cost",

"power", or "mdes".

optimizer algorithm to find optimal sample sizes given total cost, power, or MDES. Avail-

 $able\ algorithms:\ "auglag\_cobyla",\ "auglag\_lbfgs",\ "auglag\_mma",\ or\ "auglag\_slsqp".$ 

rho2 proportion of variance in the outcome explained by level-2 units.
rho3 proportion of variance in the outcome explained by level-3 units.
rho4 proportion of variance in the outcome explained by level-4 units.

omega2 treatment effect heterogeneity as ratio of treatment effect variance among level-2

units to the residual variance at level-2.

omega3 treatment effect heterogeneity as ratio of treatment effect variance among level-3

units to the residual variance at level-3.

omega4 treatment effect heterogeneity as ratio of treatment effect variance among level-4

units to the residual variance at level-4.

P average proportion of level-1 units randomly assigned to treatment within level-

2 units.

g4 number of covariates at level-4.

R12 proportion of level-1 variance in the outcome explained by level-1 covariates.

RT22 proportion of treatment effect variance among level-2 units explained by level-2

covariates.

RT32 proportion of treatment effect variance among level-3 units explained by level-3

covariates.

RT42 proportion of treatment effect variance among level-4 units explained by level-4

covariates.

optimal.cra2r2 51

#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

#### See Also

```
mdes.bira4r1, power.bira4r1
```

#### **Examples**

optimal.cra2r2

COSA Solver for Main Effect in Two-Level Cluster Random Assignment Design, Treatment at Level-2

## **Description**

optimal.cra2r2 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups. COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

## Usage

```
optimal.cra2r2(cn=0, cJ=0, cost=NULL, n=NULL, J=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJ0=c(10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", rho2, P=.50, g2=0, R12=0, R22=0)
```

52 optimal.cra2r2

#### **Arguments**

cn marginal cost per level-1 unit. cJ marginal cost per level-2 unit.

cost total cost or budget.

n harmonic mean of level-1 units across level-2 units (or simple average).

J level-2 sample size.

power statistical power (1 - type II error).

mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

nJ0 vector with a length of two to specifiy starting values for level-1 and level-2

sample sizes.

ncase number of cases to show in the output.

gm grid multiplier to increase the range of sample size search for each level.

constrain one of the followings can be constrained at a specified cost or value: "cost",

"power", or "mdes".

optimizer algorithm to find optimal sample sizes given total cost, power, or MDES. Avail-

able algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp".

rho2 proportion of variance in the outcome explained by level-2 units.

P proportion of level-2 units randomly assigned to treatment.

g2 number of covariates at level-2.

R12 proportion of level-1 variance in the outcome explained by level-1 covariates.
R22 proportion of level-2 variance in the outcome explained by level-2 covariates.

# Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

### See Also

```
mdes.cra2r2, power.cra2r2
```

# Examples

optimal.cra3r3 53

optimal.cra3r3	COSA Solver for Main Effect in Three-Level Cluster Random Assign-
	ment Designs, Treatment at Level-3

# Description

optimal.cra3r3 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups. COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

# Usage

```
optimal.cra3r3(cn=0, cJ=0, cK=0, cost=NULL, n=NULL, J=NULL, K=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJK0=c(10,10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", rho2, rho3, P=.50, g3=0, R12=0, R22=0, R32=0)
```

#### **Arguments**

rho2

`		
	cn	marginal cost per level-1 unit.
	сJ	marginal cost per level-2 unit.
	сК	marginal cost per level-3 unit.
	cost	total cost or budget.
	n	harmonic mean of level-1 units across level-2 units (or simple average).
	J	harmonic mean of level-2 units across level-3 units (or simple average).
	K	level-3 sample size.
	power	statistical power (1 - type II error).
	mdes	minimum detectable effect size.
	alpha	probability of type I error.
	two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
	nJK0	vector with a length of three to specify starting values for level-1, level-2, and level-3 sample sizes.
	ncase	number of cases to show in the output.
	gm	grid multiplier to increase the range of sample size search for each level.
	constrain	one of the followings can be constrained at a specified cost or value: "cost", "power", or "mdes".
	optimizer	algorithm to find optimal sample sizes given total cost, power, or MDES. Available algorithms: "auglag_cobyla", "auglag_lbfgs", "auglag_mma", or "auglag_slsqp".

proportion of variance in the outcome explained by level-2 units.

54 optimal.cra4r4

rho3	proportion of variance in the outcome explained by level-3 units.
Р	proportion of level-3 units randomly assigned to treatment.
g3	number of covariates at level-3.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.

#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

#### See Also

```
mdes.cra3r3, power.cra3r3
```

## **Examples**

optimal.cra4r4

COSA Solver for Main Effect in Four-Level Cluster Random Assignment Designs, Treatment at Level-4

# Description

optimal.cra4r4 finds constrained optimal sample allocation (COSA) solutions for main effect in designs with four-levels where level-4 units are randomly assigned to treatment and control groups. COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

55 optimal.cra4r4

# Usage

```
optimal.cra4r4(cn=0, cJ=0, cK=0, cL=0, cost=NULL,
               n=NULL, J=NULL, K=NULL, L=NULL,
               power=.80, mdes=.25, alpha=.05, two.tail=TRUE,
               nJKL0=c(10,10,10,10), ncase=10, gm=2,
               constrain="power", optimizer="auglag_cobyla",
               rho4, rho3, rho2,
               P=.50, g4=0, R42=0, R32=0, R22=0, R12=0)
```

# Arg

R32

R42

guments		
cn	marginal cost per level-1 unit.	
сJ	marginal cost per level-2 unit.	
cK	marginal cost per level-3 unit.	
cL	marginal cost per level-4 unit.	
cost	total cost or budget.	
n	harmonic mean of level-1 units across level-2 units (or simple average).	
J	harmonic mean of level-2 units across level-3 units (or simple average).	
K	harmonic mean of level-3 units across level-4 units (or simple average).	
L	number of level-4 units.	
power	statistical power (1 - type II error).	
mdes	minimum detectable effect size.	
alpha	probability of type I error.	
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.	
nJKL0	vector with a length of four to specifiy starting values for level-1, level-2, level-3, and level-4 sample sizes.	
ncase	number of cases to show in the output.	
gm	grid multiplier to increase the range of sample size search for each level.	
constrain	one of the followings can be constrained at a specified cost or value: "cost", "power", or "mdes".	
optimizer	algorithm to find optimal sample sizes given total cost, power, or MDES. Available algorithms: "auglag_cobyla", "auglag_lbfgs", "auglag_mma", or "auglag_slsqp".	
rho2	proportion of variance in the outcome explained by level-2 units.	
rho3	proportion of variance in the outcome explained by level-3 units.	
rho4	proportion of variance in the outcome explained by level-4 units.	
Р	proportion of level-4 units randomly assigned to treatment.	
g4	number of covariates at level-4.	
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.	
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.	

proportion of level-3 variance in the outcome explained by level-3 covariates.

proportion of level-4 variance in the outcome explained by level-4 covariates.

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#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

#### See Also

```
mdes.cra4r4, power.cra4r4
```

# **Examples**

```
## Not run:
```

```
optimal.cra4r4(cn=1, cJ=10, cK=100, cL=1000, cost=75600, constrain="cost", rho4=.05, rho3=.05, rho2=.10)
```

## End(Not run)

optimal.ira1r1

Sample Size Calculator for Main Effect in Individual Random Assignment Designs, Completely Randomized Controlled Trials

## **Description**

optimal.ira1r1 calculates minimum required sample size for main effect in completely randomized controlled trials where individuals are randomly assigned to treatment or control groups.

#### Usage

```
optimal.ira1r1(mdes=.25, power=.80, alpha=.05, two.tail=TRUE, n0=10, tol=.10, P=.50, g1=0, R12=0)
```

# Arguments

power statistical power (1 - type II error).

mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

n0 starting value for sample size.

tol tolerance.

optimal.mod1n.cra2r2 57

D	average t	roportion	of unite	randomly	accioned t	to treatment.
Г	average	лорогион	or units	randoniny	assigned	o ucamen.

g1 number of covariates.

R12 proportion of variance in the outcome explained by covariates.

#### Value

fun function name.

parms list of parameters used in the function.

n sample size.

#### See Also

```
mdes.ira1r1, power.ira1r1
```

# **Examples**

```
## Not run:
     optimal.ira1r1(R12=.50)
## End(Not run)
```

optimal.mod1n.cra2r2 COSA Solver for Non-randomly Varying Moderator Effect in Two-Level Cluster Random Assignment Design, Treatment at level-2 and Moderator at Level-1

## **Description**

optimal.mod1n.cra2r2 finds constrained optimal sample allocation (COSA) solutions for non-randomly varying moderator effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups and moderator is at level-1. COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

# Usage

### **Arguments**

cn marginal cost per level-1 unit.
cJ marginal cost per level-2 unit.

cost total cost or budget.

n harmonic mean of level-1 units across level-2 units (or simple average).

J level-2 sample size.

power statistical power (1 - type II error).
mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

nJ0 vector with a length of two to specifiy starting values for level-1 and level-2

sample sizes.

ncase number of cases to show in the output.

gm grid multiplier to increase the range of sample size search for each level.

constrain one of the followings can be constrained at a specified cost or value: "cost",

"power", or "mdes".

optimizer algorithm to find optimal sample sizes given total cost, power, or MDES. Avail-

able algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp".

rho2 proportion of variance in the outcome explained by level-2 units.

P proportion of level-2 units randomly assigned to treatment.

Q proportion of level-1 units within moderator subgroup. NULL implies continuous

moderator.

g1 number of covariates at level-1 excluding moderator.

R12 proportion of level-1 variance in the outcome explained by level-1 covariates.

#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

#### See Also

mdes.mod1n.cra2r2, power.mod1n.cra2r2

optimal.mod1n.cra3r3 59

#### **Examples**

optimal.mod1n.cra3r3 CO

COSA Solver for Non-randomly Varying Moderator Effect in Three-Level Cluster Random Assignment Designs, Treatment at Level-3 and Moderator at Level-1

## **Description**

optimal.mod1n.cra3r3 finds constrained optimal sample allocation (COSA) solutions for non-randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-1. COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

### Usage

## **Arguments**

cn	marginal cost per level-1 unit.
сJ	marginal cost per level-2 unit.
cK	marginal cost per level-3 unit.
cost	total cost or budget.

n harmonic mean of level-1 units across level-2 units (or simple average).

J harmonic mean of level-2 units across level-3 units (or simple average).

K level-3 sample size.

power statistical power (1 - type II error).

mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

nJK0 vector with a length of three to specify starting values for level-1, level-2, and

level-3 sample sizes.

ncase number of cases to show in the output.

gm grid multiplier to increase the range of sample size search for each level.

constrain one of the followings can be constrained at a specified cost or value: "cost",

"power", or "mdes".

optimizer algorithm to find optimal sample sizes given total cost, power, or MDES. Avail-

able algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp".

rho2 proportion of variance in the outcome explained by level-2 units.
rho3 proportion of variance in the outcome explained by level-3 units.

P proportion of level-3 units randomly assigned to treatment.

Q proportion of level-1 units within moderator subgroup. NULL implies continuous

moderator.

g1 number of covariates at level-1 excluding moderator.

R12 proportion of level-1 variance in the outcome explained by level-1 covariates.

#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

# See Also

```
mdes.mod1n.cra3r3, power.mod1n.cra3r3
```

#### **Examples**

optimal.mod1r.cra2r2 COSA Solver for Randomly Varying Moderator Effect in Two-Level

Cluster Random Assignment Design, Treatment at level-2 and Moder-

ator at Level-1

optimal.mod1r.cra2r2 61

### **Description**

optimal.mod1r.cra2r2 finds constrained optimal sample allocation (COSA) solutions for randomly varying moderator effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups and moderator is at level-1. COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

## Usage

```
optimal.mod1r.cra2r2(cn=0, cJ=0, cost=NULL, n=NULL, J=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJ0=c(10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", rho2, omega2, P=.50, Q=NULL, g1=0, R12=0, RT22=0)
```

#### **Arguments**

cn	marginal cost per level-1 unit.
сJ	marginal cost per level-2 unit.
cost	total cost or budget.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
power	statistical power (1 - type II error).
mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
nJ0	vector with a length of two to specifiy starting values for level-1 and level-2 sample sizes.

ncase number of cases to show in the output.

gm grid multiplier to increase the range of sample size search for each level.

constrain one of the followings can be constrained at a specified cost or value: "cost",

"power", or "mdes".

optimizer algorithm to find optimal sample sizes given total cost, power, or MDES. Avail-

able algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp".

rho2 proportion of variance in the outcome explained by level-2 units.

omega2 moderator effect heterogeneity (unconditional) across level-2 units.

P proportion of level-2 units randomly assigned to treatment.

Q proportion of level-1 units within moderator subgroup. NULL implies continuous

moderator.

g1 number of covariates at level-1 excluding moderator.

R12 proportion of level-1 variance in the outcome explained by level-1 covariates.

RT22 proportion of level-2 variance in the moderator effect explained by level-2 co-

variates.

62 optimal.mod1r.cra3r3

#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

#### See Also

```
mdes.mod1r.cra2r2, power.mod1r.cra2r2
```

## **Examples**

optimal.mod1r.cra3r3 COSA Solver for Randomly Varying Moderator Effect in Three-Level

Cluster Random Assignment Designs, Treatment at Level-3 and Moderator at Level-1

### **Description**

optimal.mod1r.cra3r3 finds constrained optimal sample allocation (COSA) solutions for randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-1. COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

### Usage

```
optimal.mod1r.cra3r3(cn=0, cJ=0, cK=0, cost=NULL, n=NULL, J=NULL, K=NULL, power=.80, mdes=.25, alpha=.05, two.tail=TRUE, nJK0=c(10,10,10), ncase=10, gm=2, constrain="power", optimizer="auglag_cobyla", rho2, rho3, omega2, omega3, P=.50, Q=NULL, g1=0, R12=0, RT22=0, RT32=0)
```

optimal.mod1r.cra3r3 63

#### **Arguments**

cn marginal cost per level-1 unit.
cJ marginal cost per level-2 unit.
cK marginal cost per level-3 unit.

cost total cost or budget.

n harmonic mean of level-1 units across level-2 units (or simple average).

J harmonic mean of level-2 units across level-3 units (or simple average).

K level-3 sample size.

power statistical power (1 - type II error).

mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

nJK0 vector with a length of three to specify starting values for level-1, level-2, and

level-3 sample sizes.

ncase number of cases to show in the output.

gm grid multiplier to increase the range of sample size search for each level.

constrain one of the followings can be constrained at a specified cost or value: "cost",

"power", or "mdes".

optimizer algorithm to find optimal sample sizes given total cost, power, or MDES. Avail-

able algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp".

rho2 proportion of variance in the outcome explained by level-2 units.
rho3 proportion of variance in the outcome explained by level-3 units.
omega2 moderator effect heterogeneity (unconditional) across level-2 units.
omega3 moderator effect heterogeneity (unconditional) across level-3 units.

P proportion of level-3 units randomly assigned to treatment.

Q proportion of level-1 units within moderator subgroup. NULL implies continuous

moderator.

g1 number of covariates at level-1 excluding moderator.

R12 proportion of level-1 variance in the outcome explained by level-1 covariates.

RT22 proportion of level-2 variance in the moderator effect explained by level-2 co-

variates.

RT32 proportion of level-3 variance in the moderator effect explained by level-3 co-

variates.

## Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

#### See Also

```
mdes.mod1r.cra3r3, power.mod1r.cra3r3
```

# **Examples**

optimal.mod2.cra2r2

COSA Solver for Moderator Effect in Two-Level Cluster Random Assignment Design, Treatment and Moderator at Level-2

#### **Description**

optimal.mod2.cra2r2 finds constrained optimal sample allocation (COSA) solutions for moderator effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups and moderator is at level-2. COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

### Usage

### Arguments

cn	marginal cost per level-1 unit.
сJ	marginal cost per level-2 unit.

cost total cost or budget.

n harmonic mean of level-1 units across level-2 units (or simple average).

J level-2 sample size.

power statistical power (1 - type II error).
mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

nJ0 vector with a length of two to specifiy starting values for level-1 and level-2

sample sizes.

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ncase number of cases to show in the output. grid multiplier to increase the range of sample size search for each level. gm one of the followings can be constrained at a specified cost or value: "cost", constrain "power", or "mdes". optimizer algorithm to find optimal sample sizes given total cost, power, or MDES. Available algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp". proportion of variance in the outcome explained by level-2 units. rho2 proportion of level-2 units randomly assigned to treatment. 0 proportion of level-1 units within moderator subgroup. NULL implies continuous moderator. g2 number of covariates at level-2 excluding moderator. R12 proportion of level-1 variance in the outcome explained by level-1 covariates.

proportion of level-2 variance in the outcome explained by level-2 covariates.

#### Value

R22

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

#### See Also

```
mdes.mod2.cra2r2, power.mod2.cra2r2
```

# **Examples**

optimal.mod2n.cra3r3 COSA Solver for Non-Randomly Varying Moderator Effect in Three-

Level Cluster Random Assignment Designs, Treatment at Level-3 and

Moderator at Level-2

### **Description**

optimal.mod2n.cra3r3 finds constrained optimal sample allocation (COSA) solutions for non-randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-2. COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

#### **Usage**

```
optimal.mod2n.cra3r3(cn=0, cJ=0, cK=0, cost=NULL,
               n=NULL, J=NULL, K=NULL,
               power=.80, mdes=.25, alpha=.05, two.tail=TRUE,
               nJK0=c(10,10,10), ncase=10, gm=2,
               constrain="power", optimizer="auglag_cobyla",
               rho2, rho3, P=.50, Q=NULL, g2=0, R12=0, R22=0)
```

### **Arguments**

marginal cost per level-1 unit. cn сJ marginal cost per level-2 unit. marginal cost per level-3 unit. cK

total cost or budget. cost

harmonic mean of level-1 units across level-2 units (or simple average). n J harmonic mean of level-2 units across level-3 units (or simple average).

Κ level-3 sample size.

power statistical power (1 - type II error). minimum detectable effect size. mdes probability of type I error. alpha

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

vector with a length of three to specify starting values for level-1, level-2, and nJK0

level-3 sample sizes.

ncase number of cases to show in the output.

grid multiplier to increase the range of sample size search for each level. gm

one of the followings can be constrained at a specified cost or value: "cost", constrain

"power", or "mdes".

algorithm to find optimal sample sizes given total cost, power, or MDES. Availoptimizer

able algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp".

proportion of variance in the outcome explained by level-2 units. rho2 rho3 proportion of variance in the outcome explained by level-3 units.

Ρ proportion of level-3 units randomly assigned to treatment.

proportion of level-1 units within moderator subgroup. NULL implies continuous 0

moderator.

g2 number of covariates at level-2 excluding moderator.

R12 proportion of level-1 variance in the outcome explained by level-1 covariates. R22 proportion of level-2 variance in the outcome explained by level-2 covariates.

### Value

fun function name.

parms list of parameters used in the function.

list of nloptr log and output. nloptr

optimal.mod2r.cra3r3 67

round.optim solution after rounding. MDES is calculated at the specified power (default .80), and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES (default .25).

### See Also

```
mdes.mod2n.cra3r3, power.mod2n.cra3r3
```

### **Examples**

optimal.mod2r.cra3r3

COSA Solver for Randomly Varying Moderator Effect in Three-Level Cluster Random Assignment Designs, Treatment at Level-3 and Moderator at Level-2

## **Description**

optimal.mod2r.cra3r3 finds constrained optimal sample allocation (COSA) solutions for randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-2. COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

### Usage

#### **Arguments**

cn	marginal cost per level-1 unit.
сJ	marginal cost per level-2 unit.
cK	marginal cost per level-3 unit.
cost	total cost or budget.
n	harmonic mean of level-1 units across level-2 units (or simple average).

J harmonic mean of level-2 units across level-3 units (or simple average).

K level-3 sample size.

power statistical power (1 - type II error).

mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

nJK0 vector with a length of three to specify starting values for level-1, level-2, and

level-3 sample sizes.

ncase number of cases to show in the output.

gm grid multiplier to increase the range of sample size search for each level.

constrain one of the followings can be constrained at a specified cost or value: "cost",

"power", or "mdes".

optimizer algorithm to find optimal sample sizes given total cost, power, or MDES. Avail-

able algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp".

rho2 proportion of variance in the outcome explained by level-2 units.

rho3 proportion of variance in the outcome explained by level-3 units.

omega3 moderator effect heterogeneity (unconditional) across level-3 units.

P proportion of level-3 units randomly assigned to treatment.

Q proportion of level-1 units within moderator subgroup. NULL implies continuous

moderator.

g2 number of covariates at level-2 excluding moderator.

R12 proportion of level-1 variance in the outcome explained by level-1 covariates.

R22 proportion of level-2 variance in the outcome explained by level-2 covariates.

RT32 proportion of level-3 variance in the moderator effect explained by level-3 co-

variates.

#### Value

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

integer.optim best integer solutions around round.optim solution. MDES is calculated at the

specified power (default .80), and power is calculated at the specified MDES

(default .25).

### See Also

```
mdes.mod2r.cra3r3, power.mod2r.cra3r3
```

optimal.mod3.cra3r3 69

#### **Examples**

```
## Not run:

optimal.mod2r.cra3r3(cn=1, cJ=10, cK=100, n=10, constrain="mdes", rho2=.20, rho3=.10, omega3=.10)

## End(Not run)
```

optimal.mod3.cra3r3

COSA Solver for Moderator Effect in Three-Level Cluster Random Assignment Designs, Treatment and Moderator at Level-3

### **Description**

optimal.mod3.cra3r3 finds constrained optimal sample allocation (COSA) solutions for moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-3. COSA can be found in the following forms, (i) under budgetary constraints given marginal costs per unit, (ii) under power contraints given marginal costs per unit, (iii) under MDES contraints given marginal costs per unit, and (iv) under sample size contraints for one or more levels along with any of the i,ii, or iii options.

### Usage

#### **Arguments**

cn	marginal cost per level-1 unit.
сJ	marginal cost per level-2 unit.
cK	marginal cost per level-3 unit.
cost	total cost or budget.

n harmonic mean of level-1 units across level-2 units (or simple average).

J harmonic mean of level-2 units across level-3 units (or simple average).

K level-3 sample size.

power statistical power (1 - type II error).

mdes minimum detectable effect size.

alpha probability of type I error.

two.tail logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis

testing.

nJK0 vector with a length of three to specify starting values for level-1, level-2, and

level-3 sample sizes.

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ncase number of cases to show in the output. grid multiplier to increase the range of sample size search for each level. gm one of the followings can be constrained at a specified cost or value: "cost", constrain "power", or "mdes". algorithm to find optimal sample sizes given total cost, power, or MDES. Availoptimizer able algorithms: "auglag\_cobyla", "auglag\_lbfgs", "auglag\_mma", or "auglag\_slsqp". rho2 proportion of variance in the outcome explained by level-2 units. rho3 proportion of variance in the outcome explained by level-3 units. Р proportion of level-3 units randomly assigned to treatment. Q proportion of level-1 units within moderator subgroup. NULL implies continuous moderator. g3 number of covariates at level-3 excluding moderator. R12 proportion of level-1 variance in the outcome explained by level-1 covariates. R22 proportion of level-2 variance in the outcome explained by level-2 covariates.

#### Value

R32

fun function name.

parms list of parameters used in the function.

nloptr list of nloptr log and output.

round.optim solution after rounding. MDES is calculated at the specified power (default .80),

and power is calculated at the specified MDES (default .25).

 $integer.optim \quad best integer solutions \ around \ round.optim \ solution. \ MDES \ is \ calculated \ at \ the$ 

specified power (default .80), and power is calculated at the specified MDES

proportion of level-3 variance in the outcome explained by level-3 covariates.

(default .25).

#### See Also

```
mdes.mod3.cra3r3, power.mod3.cra3r3
```

#### **Examples**

optimal.to.mdes 71

optimal.to.mdes

Optimal to MDES

## **Description**

optimal.to.mdes converts an object returned from optimal function into an object returned from mdes function.

## Usage

```
optimal.to.mdes(x)
```

# **Arguments**

Χ

an object returned from one of the optimal functions.

#### **Details**

optimal.to.mdes converts an object returned from optimal function into an object returned from mdes function by passing parameters through mdes function.

# See Also

```
optimal.to.power
```

## **Examples**

optimal.to.power

Optimal to Power

# **Description**

optimal.to.power converts an object returned from optimal function into an object returned from power function.

# Usage

```
optimal.to.power(x)
```

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### **Arguments**

Х

an object returned from one of the optimal functions.

#### **Details**

optimal.to.power converts an object returned from optimal function into an object returned from power function by passing parameters through power function.

#### See Also

```
optimal.to.mdes
```

## **Examples**

power.bcra3f2

Statistical Power Calculator for Three-Level Fixed Effects Blocked Cluster Random Assignment Design, Treatment at Level-2

# **Description**

power.bcra3f2 calculates statistical power for designs with three-levels where level-2 units are randomly assigned to treatment and control groups within level-3 units (fixed blocks).

## Usage

### **Arguments**

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
P	average proportion of level-2 units randomly assigned to treatment within level-3 units.
g2	number of covariates at level-2.

power.bcra3r2 73

R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
	to handle extra parameters passed from other functions, do not define any additional parameters.

#### Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1 - \beta)$ .

## See Also

```
mdes.bcra3f2, optimal.bcra3f2
```

## **Examples**

power.bcra3r2

Statistical Power Calculator for Three-Level Random Effects Blocked Cluster Random Assignment Designs, Treatment at Level-2

## Description

power.bcra3r2 calculates statistical power for designs with three-levels where level-2 units are randomly assigned to treatment and control groups within level-3 units (random blocks).

# Usage

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# Arguments

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
omega3	treatment effect heterogeneity as ratio of treatment effect variance among level-3 units to the residual variance at level-3.
P	average proportion of level-2 units randomly assigned to treatment within level-3 units.
g3	number of covariates at level-3.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
RT32	proportion of treatment effect variance among level-3 units explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters. $$

# Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1-\beta)$ .

## See Also

```
mdes.bcra3r2, optimal.bcra3r2
```

power.bcra4f3 75

power.bcra4f3	Statistical Power Calculator for Four-Level Fixed Effects Blocked
	Cluster Random Assignment Designs, Treatment at Level-3

# Description

power.bcra4f3 calculates statistical power for designs with four-levels where level-3 units are randomly assigned to treatment and control groups within level-4 units (fixed blocks).

# Usage

```
power.bcra4f3(mdes=.25, alpha=.05, two.tail=TRUE,
    rho2, rho3,
    P=.50, R12=0, R22=0, R32=0, g3=0,
    n, J, K, L, ...)
```

## Arguments

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
P	average proportion of level-3 units randomly assigned to treatment within level-4 units.
g3	number of covariates at level-3.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average).
L	number of level-4 units.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun	function name.
parms	list of parameters used in power calculation.
ncp	noncentrality parameter.
power	statistical power $(1 - \beta)$ .

# See Also

```
mdes.bcra4f3, optimal.bcra4f3
```

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## **Examples**

power.bcra4r2

Statistical Power Calculator for Four-Level Random Effects Block Random Assignment Designs, Treatment at Level-2

## Description

power.bcra4r2 calculates statistical power for designs with four-levels where level-2 units are randomly assigned to treatment and control groups within level-3 units (random blocks).

## Usage

```
power.bcra4r2(mdes=.25, alpha=.05, two.tail=TRUE,
    rho2, rho3, rho4, omega3, omega4,
    P=.50, R12=0, R22=0, RT32=0, RT42=0, g4=0,
    n, J, K, L, ...)
```

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
rho4	proportion of variance in the outcome explained by level-4 units.
omega3	treatment effect heterogeneity as ratio of treatment effect variance among level-3 units to the residual variance at level-3.
omega4	treatment effect heterogeneity as ratio of treatment effect variance among level-4 units to the residual variance at level-4.
Р	average proportion of level-2 units randomly assigned to treatment within level-3 units.
g4	number of covariates at level-4.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
RT32	proportion of treatment effect variance among level-3 units explained by level-3 covariates.
RT42	proportion of treatment effect variance among level-4 units explained by level-4 covariates.

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n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average).
L	number of level-4 units.
	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1 - \beta)$ .

## See Also

```
mdes.bcra4r2, optimal.bcra4r2
```

## **Examples**

power.bcra4r3

Statistical Power Calculator for Four-Level Random Effects Blocked Cluster Random Assignment Designs, Treatment at Level-3

## **Description**

power.bcra4r3 calculates statistical power for designs with four-levels where level-3 units are randomly assigned to treatment and control groups within level-4 units (random blocks).

# Usage

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# Arguments

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
rho4	proportion of variance in the outcome explained by level-4 units.
omega4	treatment effect heterogeneity as ratio of treatment effect variance among level-4 units to the residual variance at level-4.
Р	average proportion of level-3 units randomly assigned to treatment within level-4 units.
g4	number of covariates at level-4.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.
RT42	proportion of treatment effect variance among level-4 units explained by level-4 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average).
L	number of level-4 units.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

# Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1 - \beta)$ .

# See Also

```
mdes.bcra4r3, optimal.bcra4r3
```

power.bira2c1 79

power.bira2c1	Statistical Power Calculator for Two-Level Constant Effects Blocked
	Individual Random Assignment Designs, Treatment at Level-1

## Description

power.bira2c1 calculates statistical power for designs with two-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (school intercepts only).

## Usage

```
power.bira2c1(mdes=.25, alpha=.05, two.tail=TRUE, P=.50, g1=0, R12=0, n, J, ...)
```

# Arguments

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
Р	average proportion of level-1 units randomly assigned to treatment within level-2 units.
g1	number of covariates at level-1.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

# Value

fun	function name.
-----	----------------

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1-\beta)$ .

## See Also

```
mdes.bira2c1, optimal.bira2c1
```

```
## Not run:
   power.bira2c1(n=55, J=3)
## End(Not run)
```

power.bira2f1

power.bira2f1	Statistical Power Calculator for Two-Level Fixed Effects Blocked In-
	dividual Random Assignment Designs, Treatment at Level-1

## Description

power.bira2f1 calculates statistical power for designs with two-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (fixed blocks).

## Usage

```
power.bira2f1(mdes=.25, alpha=.05, two.tail=TRUE, P=.50, g1=0, R12=0, n, J, ...)
```

## Arguments

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
P	average proportion of level-1 units randomly assigned to treatment within level-2 units.
g1	number of covariates at level-1.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

•	
fun	function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1-\beta)$ .

## See Also

```
mdes.bira2f1, optimal.bira2f1
```

```
## Not run:
   power.bira2f1(n=55, J=3)
## End(Not run)
```

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power.bira2r1	Statistical Power Calculator for Two-Level Random Effects Blocked Individual Random Assignment Designs, Individuals Randomized within Blocks

# Description

power.bira2r1 calculates statistical power for designs with two-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (random blocks).

## Usage

# Arguments

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
omega2	treatment effect heterogeneity as ratio of treatment effect variance among level-2 units to the residual variance at level-2.
Р	average proportion of level-1 units randomly assigned to treatment within level-2 units.
g2	number of covariates at level-2.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
RT22	proportion of treatment effect variance among level-2 units explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun	function name.
parms	list of parameters used in power calculation.
ncp	noncentrality parameter.
power	statistical power $(1 - \beta)$ .

## See Also

```
mdes.bira2r1, optimal.bira2r1
```

power.bira3r1

## **Examples**

power.bira3r1

Statistical Power Calculator for Three-Level Random Effects Blocked Individual Random Assignment Design, Individuals Randomized within Blocks

## Description

power.bira3r1 calculates statistical power for designs with three-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (random blocks).

## Usage

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
omega2	treatment effect heterogeneity as ratio of treatment effect variance among level-2 units to the residual variance at level-2.
omega3	treatment effect heterogeneity as ratio of treatment effect variance among level-3 units to the residual variance at level-3.
Р	average proportion of level-1 units randomly assigned to treatment within level-2 units.
g3	number of covariates at level-3.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
RT22	proportion of treatment effect variance among level-2 units explained by level-2 covariates.
RT32	proportion of treatment effect variance among level-3 units explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).

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K level-3 sample size.

.. to handle extra parameters passed from other functions, do not define any addi-

tional parameters.

#### Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1 - \beta)$ .

## See Also

```
mdes.bira3r1, optimal.bira3r1
```

## **Examples**

power.bira4r1

Statistical Power Calculator for Four-Level Random Effects Blocked Individual Random Assignment Design, Individuals Randomized within Blocks

## Description

power.bira4r1 calculates statistical power for designs with four-levels where level-1 units are randomly assigned to treatment and control groups within level-2 units (random blocks).

## Usage

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.

power.bira4r1

rho4	proportion of variance in the outcome explained by level-4 units.
omega2	treatment effect heterogeneity as ratio of treatment effect variance among level-2 units to the residual variance at level-2.
omega3	treatment effect heterogeneity as ratio of treatment effect variance among level-3 units to the residual variance at level-3.
omega4	treatment effect heterogeneity as ratio of treatment effect variance among level-4 units to the residual variance at level-4.
Р	average proportion of level-1 units randomly assigned to treatment within level-2 units.
g4	number of covariates at level-4.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
RT22	proportion of treatment effect variance among level-2 units explained by level-2 covariates.
RT32	proportion of treatment effect variance among level-3 units explained by level-3 covariates.
RT42	proportion of treatment effect variance among level-4 units explained by level-4 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average).
L	number of level-4 units.
	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1-\beta)$ .

## See Also

```
mdes.bira4r1, optimal.bira4r1
```

power.cra2r2 85

power.cra2r2	Statistical Power Calculator for Main Effect in Two-Level Cluster
	Random Assignment Design, Treatment at Level-2

# Description

power.cra2r2 calculates statistical power for main effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups.

# Usage

# Arguments

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
P	proportion of level-2 units randomly assigned to treatment.
g2	number of covariates at level-2.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun	function name.
parms	list of parameters used in power calculation.
пср	noncentrality parameter.
power	statistical power $(1 - \beta)$ .

## See Also

```
mdes.cra2r2, optimal.cra2r2
```

power.cra3r3

## **Examples**

power.cra3r3

Statistical Power Calculator for Main Effect in Three-Level Cluster Random Assignment Designs, Treatment at Level-3

# Description

power.cra3r3 calculates statistical power for main effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups.

## Usage

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
Р	proportion of level-3 units randomly assigned to treatment.
g3	number of covariates at level-3.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

power.cra4r4 87

## Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1 - \beta)$ .

#### See Also

```
mdes.cra3r3, optimal.cra3r3
```

## **Examples**

power.cra4r4

Statistical Power Calculator for Four-Level Cluster Random Assignment Designs, Treatment at Level-4

## Description

power.cra4r4 calculates statistical power for designs with four-levels where level-4 units are randomly assigned to treatment and control groups.

# Usage

```
power.cra4r4(mdes=.25, alpha=.05, two.tail=TRUE,
    rho2, rho3, rho4,
    P=.50, R12=0, R22=0, R32=0, R42=0, g4=0,
    n, J, K, L, ...)
```

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
rho4	proportion of variance in the outcome explained by level-4 units.
P	proportion of level-4 units randomly assigned to treatment.
g4	number of covariates at level-4.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.

power.ira1r1

R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.
R42	proportion of level-4 variance in the outcome explained by level-4 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	harmonic mean of level-3 units across level-4 units (or simple average).
L	number of level-4 units.
	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1-\beta)$ .

## See Also

```
mdes.cra4r4, optimal.cra4r4
```

## **Examples**

power.ira1r1

Statistical Power Calculator for Individual Random Assignment Designs, Completely Randomized Controlled Trials

## Description

power.ira1r1 calculates statistical power for completely randomized controlled trials where individuals are randomly assigned to treatment or control groups.

## Usage

power.mod1n.cra2r2 89

## **Arguments**

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
Р	proportion of units randomly assigned to treatment.
g1	number of covariates.
R12	proportion of variance in the outcome explained by covariates.
n	sample size.
• • •	to handle extra parameters passed from other functions, do not define any additional parameters.

#### Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1-\beta)$ .

#### See Also

```
mdes.ira1r1, optimal.ira1r1
```

## **Examples**

```
## Not run:
   power.ira1r1(n=55)
## End(Not run)
```

power.mod1n.cra2r2

Statistical Power Calculator for for Non-Randomly Varying Moderator Effect in Two-Level Cluster Random Assignment Design, Treatment at Level-2, Moderator at Level-1

## **Description**

power.mod1n.cra2r2 calculates statistical power for non-randomly varying moderator effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups and moderator is at level-1.

## Usage

90 power.mod1n.cra3r3

## **Arguments**

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
Р	proportion of level-2 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g1	number of covariates at level-1 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1 - \beta)$ .

## See Also

```
mdes.mod1n.cra2r2, optimal.mod1n.cra2r2
```

## **Examples**

power.mod1n.cra3r3

Statistical Power Calculator for Non-Randomly Varying Moderator Effect in Three-Level Cluster Random Assignment Design, Treatment at Level-3, Moderator at Level-1

# Description

power.mod1n.cra3r3 calculates statistical power for non-randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-1.

power.mod1n.cra3r3 91

## Usage

## **Arguments**

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
P	proportion of level-3 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g1	number of covariates at level-1 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
• • •	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1-\beta)$ .

## See Also

```
mdes.mod1n.cra3r3, optimal.mod1n.cra3r3
```

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	power.mod1r.cra2r2	Statistical Power Calculator for Randomly Varying Moderator Effect in Two-Level Cluster Random Assignment Design, Treatment at Level- 2, Moderator at Level-1
--	--------------------	---

# Description

power.mod1r.cra2r2 calculates statistical power for randomly varying moderator effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups and moderator is at level-1.

## Usage

## Arguments

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
omega2	moderator effect heterogeneity (unconditional) across level-2 units.
Р	proportion of level-2 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g1	number of covariates at level-1 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
RT22	proportion of level-2 variance in the moderator effect explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun	function name.
parms	list of parameters used in power calculation.
ncp	noncentrality parameter.
power	statistical power $(1 - \beta)$ .

## See Also

```
mdes.mod1r.cra2r2, optimal.mod1r.cra2r2
```

power.mod1r.cra3r3 93

## **Examples**

## Description

power.mod1r.cra3r3 calculates statistical power for randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-1.

## Usage

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
omega2	moderator effect heterogeneity (unconditional) across level-2 units.
omega3	moderator effect heterogeneity (unconditional) across level-3 units.
P	proportion of level-3 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g1	number of covariates at level-1 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
RT22	proportion of level-2 variance in the moderator effect explained by level-2 covariates.
RT32	proportion of level-3 variance in the moderator effect explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
	to handle extra parameters passed from other functions, do not define any additional parameters.

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#### Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1 - \beta)$ .

#### See Also

```
mdes.mod1r.cra3r3, optimal.mod1r.cra3r3
```

## **Examples**

power.mod2.cra2r2

Statistical Power Calculator for Moderator Effect in Two-Level Cluster Random Assignment Design, Treatment and Moderator at Level-2

## **Description**

power.mod2.cra2r2 calculates statistical power for moderator effect in designs with two-levels where level-2 units are randomly assigned to treatment and control groups and moderator is at level-2.

## Usage

```
power.mod2.cra2r2(mdes=.25, alpha=.05, two.tail=TRUE, rho2, P=.50, Q=NULL, g2=0, R12=0, R22=0, n, J, \dots)
```

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
P	proportion of level-2 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g2	number of covariates at level-2 excluding moderator.

power.mod2n.cra3r3 95

R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	level-2 sample size.
	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1 - \beta)$ .

## See Also

```
mdes.mod2.cra2r2, optimal.mod2.cra2r2
```

#### **Examples**

```
## Not run:
    power.mod2.cra2r2(rho2=.20, n=4, J=20, Q=.5)
## End(Not run)
```

power.mod2n.cra3r3

Statistical Power Calculator for Non-Randomly Varying Moderator Effect in Three-Level Cluster Random Assignment Design, Treatment at Level-3, Moderator at Level-2

## **Description**

power.mod2n.cra3r3 calculates statistical power for non-randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-2.

## Usage

```
power.mod2n.cra3r3(mdes=.25, alpha=.05, two.tail=TRUE, rho2, rho3, P=.50, Q=NULL, g2=0, R12=0, R22=0, n, J, K, ...)
```

96 power.mod2n.cra3r3

# Arguments

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
Р	proportion of level-3 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g2	number of covariates at level-2 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter.  $power \qquad statistical \ power \ (1-\beta).$ 

## See Also

```
mdes.mod2n.cra3r3, optimal.mod2n.cra3r3
```

power.mod2r.cra3r3 97

power.mod2r.cra3r3	Statistical Power Calculator for Randomly Varying Moderator Effect in Three-Level Cluster Random Assignment Designs, Treatment at Level-3, Moderator at Level-2
	Level 3, Moderator at Level 2

# Description

power.mod2r.cra3r3 calculates statistical power for randomly varying moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-2.

## Usage

## Arguments

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
omega3	moderator effect heterogeneity (unconditional) across level-3 units.
Р	proportion of level-3 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g2	number of covariates at level-2 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
RT32	proportion of level-3 variance in the moderator effect explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

## Value

fun	function name.
parms	list of parameters used in power calculation.
ncp	noncentrality parameter.
power	statistical power $(1 - \beta)$ .

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#### See Also

```
mdes.mod2r.cra3r3, optimal.mod2r.cra3r3
```

#### **Examples**

power.mod3.cra3r3

Statistical Power Calculator for Moderator Effect in Three-Level Cluster Random Assignment Designs, Treatment and Moderator at Level-3

## Description

power.mod3.cra3r3 calculates statistical power for moderator effect in designs with three-levels where level-3 units are randomly assigned to treatment and control groups and moderator is at level-3.

## Usage

mdes	minimum detectable effect size.
alpha	probability of type I error.
two.tail	logical; TRUE for two-tailed hypothesis testing, FALSE for one-tailed hypothesis testing.
rho2	proportion of variance in the outcome explained by level-2 units.
rho3	proportion of variance in the outcome explained by level-3 units.
Р	proportion of level-3 units randomly assigned to treatment.
Q	proportion of level-1 units within moderator subgroup. NULL implies continuous moderator.
g3	number of covariates at level-3 excluding moderator.
R12	proportion of level-1 variance in the outcome explained by level-1 covariates.
R22	proportion of level-2 variance in the outcome explained by level-2 covariates.
R32	proportion of level-3 variance in the outcome explained by level-3 covariates.
n	harmonic mean of level-1 units across level-2 units (or simple average).
J	harmonic mean of level-2 units across level-3 units (or simple average).
K	level-3 sample size.
•••	to handle extra parameters passed from other functions, do not define any additional parameters.

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## Value

fun function name.

parms list of parameters used in power calculation.

ncp noncentrality parameter. power statistical power  $(1 - \beta)$ .

#### See Also

```
mdes.mod3.cra3r3, optimal.mod3.cra3r3
```

#### **Examples**

power.to.mdes

power to MDES

## **Description**

power.to.mdes converts an object returned from power function into an object returned from mdes function.

## Usage

```
power.to.mdes(x)
```

## **Arguments**

Х

an object returned from one of the power functions.

## **Details**

power.to.mdes converts an object returned from power function into an object returned from mdes function by passing parameters through mdes function.

## See Also

```
optimal.to.mdes
```

#### **Examples**

```
## Not run:

# object returned from power function
  design1 <- power.bira2r1(mdes=.15, rho2=.35, omega2=.10, n=83, J=10)
  # convert the object into an object returned from mdes function
  design2 <- power.to.mdes(design1)

## End(Not run)</pre>
```

PowerUpR-deprecated

Deprecated and Defunct functions in 'PowerUpR'

## **Description**

Deprecated functions are provided for compatibility purposes and will be defunct in the next 'PowerUpR' release. Defunct functions are no longer supported.

#### **Format**

Deprecated functions are no longer documented, please use documentation for new functions.

#### **Details**

Deprecated and defunct functions and their replacement are as follows:

- mrss.ira1r1 is deprecated, use optimal.ira1r1
- mrss.cra2r2 is deprecated, use optimal.cra2r2
- mrss.cra3r3 is deprecated, use optimal.cra3r3
- mrss.cra4r4 is deprecated, use optimal.cra4r4
- mrss.bcra3f2 is deprecated, use optimal.bcra3f2
- mrss.bcra3r2 is deprecated, use optimal.bcra3r2
- mrss.bcra4r2 is deprecated, use optimal.bcra4r2
- mrss.bcra4f3 is deprecated, use optimal.bcra4f3
- mrss.bcra4r2 is deprecated, use optimal.bcra4r2
- mrss.bira4r1 is deprecated, use optimal.bira4r1
- mrss.bira3r1 is deprecated, use optimal.bira3r1
- mrss.bira2c1 is deprecated, use optimal.bira2c1
- mrss.bira2f1 is deprecated, use optimal.bira2f1
- mrss.bira2r1 is deprecated, use optimal.bira2r1
- mrss.to.mdes is defunct, use optimal.to.mdes
- mrss.to.power is defunct, use optimal.to.power
- t1t2.error is defunct, there is no replacement function
- plot.pars is defunct, there is no replacement function

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