

# Package ‘APCAnalysis’

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**Title** Analysis of Unreplicated Orthogonal Experiments using All Possible Comparisons

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**Author** Arden Miller and Abu Zar Md. Shafiullah.

**Maintainer** Arden Miller <a.miller@auckland.ac.nz>

**Description** Analysis of data from unreplicated orthogonal experiments such as 2-level factorial and fractional factorial designs and Plackett-Burman designs using the all possible comparisons (APC) methodology developed by Miller (2005) <[doi:10.1198/004017004000000608](https://doi.org/10.1198/004017004000000608)>.

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APCanalysis-package     *Analysis of Unreplicated Orthogonal Experiments using All Possible Comparisons*

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## Description

This package provides functions to analyse data from unreplicated orthogonal experiments such as 2-level factorial and fractional factorial designs and Plackett-Burman designs using the all possible comparisons (APC) methodology.

## Details

`apc()` identifies the active effects from an unreplicated orthogonal experiment using a modified version of the all possible comparisons (APC) procedure proposed by Miller (2005). This function has been designed specifically to analyse data from two-level designs including full factorial designs, regular fractional factorial designs and Plackett-Burman designs.

The APC procedure is based on minimizing an AIC-like criterion:  $APC = \log(\text{ResSS}) + p$  where  $p$  is a penalty term that increases as the size of the candidate model increases. The APC procedure can be adapted to control either the individual error rate (IER), the experimentwise error rate (EER) or the false discovery rate (FDR). The functions `IERpenalties()`, `EERpenalties()` and `FDRpenalties()` can be used to estimate the penalties used in the APC criterion for each type of error control.

## Author(s)

Arden Miller and Abu Zar Md. Shafiullah.

Maintainer: Arden Miller <a.miller@auckland.ac.nz>

## References

Miller A.E. (2005) \_The analysis of unreplicated factorial experiments using all possible comparisons\_ Technometrics, 47, 51-63, 2005.

## See Also

[apc](#), [IERpenalties](#), [EERpenalties](#), [FDRpenalties](#).

## Examples

```
## This example demonstrates the analysis of an artificial data set for a 12-run
## Plackett-Burman design stored in "PB12matrix". The values of "PB12response" were
## generated using the following active effects: B=7, D=5, H=11, I=4 and K=6. The
## remaining columns were all set to be inactive (effects equal 0).
my.apc = apc(PB12response, PB12matrix, maxsize=6, method = 2, level = 0.20, reps = 10000)
summary(my.apc)
plot(my.apc)
```

**Description**

apc() applies the all possible comparisons procedure to identify the active effects.

**Usage**

```
apc(y, x, maxsize, level=0.05, method=1, data=NULL, effnames=NULL, reps=50000, dp=4)
```

**Arguments**

y	Either the response vector or the model formula for the full model.
x	The model matrix for the full model - only used when y is a response vector.
maxsize	The maximum model size.
level	The level of error control.
method	The type of error control: 1 = IER, 2 = EER, 3 = FDR.
data	Optional data frame
effnames	Optional vector containing labels for the candidate effects.
reps	The number of repetitions used by the Monte Carlo simulation algorithm which estimates the set of penalties (default is 50000).
dp	the number of decimal places returned for estimates of effects. Default is 4.

**Details**

The APC procedure is based on minimizing an AIC-like criterion:  $APC = \log(\text{ResSS}) + p$  where  $p$  is a penalty term that increases as the size of the candidate model increases. The penalties can be selected to control either the individual error rate (IER), the experimentwise error rate (EER) or the false discovery rate (FDR) at a specified level. In addition to the type and level of error control, the penalties also depend on the run size of the experiment, the number of candidate effects and the maximum model size.

**Value**

A list with components

Results	A data frame that summarizes the results of the APC analysis. The best model of each size is indicated along with its ResSS and value for the APC criterion.
Penalties	A vector containing the penalties used for the APC procedure.
level	The level of error control.
ErrorType	The type of error control used.
k	The number of candidate effects.
m	The maximum model size.

apc	The value of APC for the selected model
Ests	A vector containing the estimated effects
ActEffs	A vector containing the names of the effects included in the selected model.
NonActEffs	A vector containing the names of the effects not included in the selected model.

**Note**

Penalties are estimated using Monte Carlo simulations and thus the estimates will not be exactly the same each time the function is run. The precision of the estimates can be increased by increasing the number of reps but the function will take longer to run. The amount of time needed to run this programme increases as the values of n, k and m increase. For larger experiments it may be necessary to reduce the number of reps.

**Author(s)**

Arden Miller and Abu Zar Md. Shafiullah

**References**

Miller A.E. (2005) \_The analysis of unreplicated factorial experiments using all possible comparisons\_ Technometrics, 47, 51-63, 2005.

**See Also**

[IERpenalties](#), [EERpenalties](#), [FDRpenalties](#).

**Examples**

```
## This example demonstrates the analysis of an artificial data set for a unreplicated
## factorial design for four two-level factors. The values of "resp" were generated as
## "resp<-round(10+8*x1+5*x3+7*x4+6*x1*x4+rnorm(16), 2)". The data is contained in the
## data frame "testdata". A maximum model size of 6 and an IER of .05 are used.
apc(resp~x1*x2*x3*x4, maxsize=6, data=testdata, method=1, level=.05, reps=9000)
```

---

EERpenalties

*EER Penalties for APC*

---

**Description**

EERpenalties() generates the set of penalties used for the APC criterion so that the experimentwise error rate (EER) is controlled at the specified level. The values of the penalties are estimated using a Monte Carlo simulation procedure and also depend on the run size of the experiment, the number of candidate effects and the maximum model size.

**Usage**

```
EERpenalties(n, k = n - 1, m = min(n - 2, k), eer = 0.2, reps = 50000, rnd = 3)
```

**Arguments**

n	The number of experimental runs in the study, i.e. the row dimension of the design matrix (for orthogonal 2-level designs n must be a multiple of 4).
k	The number of candidate effects under study, i.e., the column dimension of the design matrix ( $1 < k \leq n-1$ ).
m	The maximum size of the candidate models ( $0 < m < \min(n-2, k)$ ).
eer	The level ( $0 < eer < 1$ ) at which the experimentwise error rate will be controlled (default is $eer = 0.2$ ).
reps	The number of repetitions used by the Monte Carlo simulation algorithm which estimates the set of penalties (default is 50000).
rnd	The number of decimal places returned for the estimated penalties (default is $rnd = 3$ ).

**Value**

A vector of containing the  $m + 1$  penalties for the APC procedure that controls the EER at the specified level.

**Note**

Penalties are estimated using Monte Carlo simulations and thus the estimates will not be exactly the same each time the function is run. The precision of the estimates can be increased by increasing the number of reps but the function will take longer to run. The amount of time needed to run this programme increases as the values of n, k and m increase. For larger experiments it may be necessary to reduce the number of reps.

**Author(s)**

Arden Miller and Abu Zar Md. Shafiullah

**References**

Miller A.E. (2005) \_The analysis of unreplicated factorial experiments using all possible comparisons\_ Technometrics, 47, 51-63, 2005.

**See Also**

[apc](#), [IERpenalties](#), [FDRpenalties](#)

**Examples**

```
## Penalties for a 8-run experiment that has 5 candidate effects are generated.  
## The maximum model size is set to 5 and an experimentwise error rate of .25 is used.  
EERpenalties(n = 8, k = 5, m = 5, eer = .25, reps = 15000)
```

---

FDRpenalties

*FDR Penalties for APC*


---

### Description

FDRpenalties() generates the set of penalties used for the APC criterion so that the false discovery rate (FDR) is controlled at the specified level. The values of the penalties are estimated using a Monte Carlo simulation procedure and also depend on the run size of the experiment, the number of candidate effects and the maximum model size.

### Usage

```
FDRpenalties(n, k = n - 1, m = min(n - 2, k), fdr = .1, reps = 50000, rnd = 3)
```

### Arguments

n	The number of experimental runs in the study, i.e. the row dimension of the design matrix (for orthogonal 2-level designs n must be a multiple of 4).
k	The number of candidate effects under study, i.e., the column dimension of the design matrix ( $1 < k \leq n-1$ ).
m	The maximum size of the candidate models ( $0 < m < \min(n-2, k)$ ).
fdr	The level ( $0 < \text{fdr} < 1$ ) at which the experimentwise error rate will be controlled (default is $\text{fdr} = 0.1$ ).
reps	The number of repetitions used by the Monte Carlo simulation algorithm which estimates the set of penalties (default is 50000).
rnd	The number of decimal places returned for the estimated penalties (default is $\text{rnd} = 3$ ).

### Value

A vector of containing the  $m + 1$  penalties for the APC procedure that controls the FDR at the specified level.

### Note

Penalties are estimated using Monte Carlo simulations and thus the estimates will not be exactly the same each time the function is run. The precision of the estimates can be increased by increasing the number of reps but the function will take longer to run. The amount of time needed to run this programme increases as the values of n, k and m increase. For larger experiments it may be necessary to reduce the number of reps.

### Author(s)

Arden Miller and Abu Zar Md. Shafiullah

**References**

Miller A.E. (2005) \_The analysis of unreplicated factorial experiments using all possible comparisons\_ Technometrics, 47, 51-63, 2005.

**See Also**

[apc](#), [IERpenalties](#), [EERpenalties](#).

**Examples**

```
## Penalties for a 8-run experiment that has 5 candidate effects are generated.
## The maximum model size is set to 5 and a false discovery rate of .05 is used.
FDRpenalties(n = 8, k = 5, m = 5, fdr = .05, reps = 12000)
```

---

IERpenalties

*IER Penalties for APC*

---

**Description**

IERpenalties() generates the set of penalties used for the APC criterion so that the individual error rate (IER) is controlled at the specified level. The values of the penalties are estimated using a Monte Carlo simulation procedure and also depend on the run size of the experiment, the number of candidate effects and the maximum model size.

**Usage**

```
IERpenalties(n, k = n - 1, m = min(n - 2, k), ier = 0.05, reps = 50000, rnd = 3)
```

**Arguments**

n	The number of experimental runs in the study, i.e. the row dimension of the design matrix (for orthogonal 2-level designs n must be a multiple of 4).
k	The number of candidate effects under study, i.e., the column dimension of the design matrix ( $1 < k \leq n-1$ ).
m	The maximum size of the candidate models ( $0 < m < \min(n-2, k)$ ).
ier	The level ( $0 < ier < 1$ ) at which the experimentwise error rate will be controlled (default is $ier = 0.05$ ).
reps	The number of repetitions used by the Monte Carlo simulation algorithm which estimates the set of penalties (default is 50000).
rnd	The number of decimal places returned for the estimated penalties (default is $rnd = 3$ ).

**Value**

A vector of containing the  $m + 1$  penalties for the APC procedure that controls the IER at the specified level.

**Note**

Penalties are estimated using Monte Carlo simulations and thus the estimates will not be exactly the same each time the function is run. The precision of the estimates can be increased by increasing the number of reps but the function will take longer to run. The amount of time needed to run this programme increases as the values of n, k and m increase. For larger experiments it may be necessary to reduce the number of reps.

**Author(s)**

Arden Miller and Abu Zar Md. Shafiullah

**References**

Miller A.E. (2005) \_The analysis of unreplicated factorial experiments using all possible comparisons\_ Technometrics, 47, 51-63, 2005.

**See Also**

[apc](#), [EERpenalties](#), [FDRpenalties](#).

**Examples**

```
## Penalties for a 8-run experiment that has 5 candidate effects are generated.  
## The maximum model size is set to 5 and an individual error rate of .01 is used.  
IERpenalties(n = 8, k = 5, m = 5, ier = .01, reps = 15000)
```

---

PB12matrix

*Plackett-Burman 12-run design matrix*

---

**Description**

A binary matrix (-1 or +1) for a 12-run Plackett Burman design

**Usage**

```
data("PB12matrix")
```

**Format**

PB12matrix has 12 rows and 11 columns labelled A through K.

**Examples**

```
data(PB12matrix)
```

---

PB12response	<i>Response Vector for PB12 design</i>
--------------	--

---

**Description**

A constructed response vector for a 12-run Plackett-Burman design

**Usage**

```
data("PB12response")
```

**Format**

PB12response is a vector of length 12.

**Details**

The values of "PB12response" were generated using the following active effects: B=7, D=5, H=11, I=4 and K=6. The remaining columns were all set to be inactive (effects equal 0).

**Examples**

```
data(PB12response)
```

---

plot.apc	<i>Graphical Summary of an APC Analysis</i>
----------	---

---

**Description**

Produces a scatterplot of minimum APC versus model size. This is useful for visualizing the relative values of APC for the best models of each size.

**Usage**

```
## S3 method for class 'apc'  
plot(x, elabs = TRUE, ...)
```

**Arguments**

x	apc object
elabs	use effect labels as plotting characters
...	other arguments

**Value**

none

**Author(s)**

Arden Miller and Abu Zar Md. Shafiullah

**See Also**

[apc](#), [summary.apc](#)

**Examples**

```
## This example demonstrates the analysis of an artificial data set for a unreplicated
## factorial design for four two-level factors. The values of "resp" were generated as
## "resp<-round(10+8*x1+5*x3+7*x4+6*x1*x4+rnorm(16),2)". The data is contained in the
## data frame "testdata". A maximum model size of 6 and an IER of .05 are used.
my.apc = apc(resp~x1*x2*x3*x4, maxsize=6, data=testdata, method=1, level=.05, reps=9000)
plot(my.apc)
```

---

summary.apc

*Summary for an apc object*

---

**Description**

Produces a useful summary of an apc object

**Usage**

```
## S3 method for class 'apc'
summary(object, ...)
```

**Arguments**

object	apc object
...	other arguments

**Value**

none

**Author(s)**

Arden Miller and Abu Zar Md. Shafiullah

**See Also**

[apc](#), [plot.apc](#)

## Examples

```
## This example demonstrates the analysis of an artificial data set for a unreplicated
## factorial design for four two-level factors. The values of "resp" were generated as
## "resp<-round(10+8*x1+5*x3+7*x4+6*x1*x4+rnorm(16), 2)". The data is contained in the
## data frame "testdata". A maximum model size of 6 and an IER of .05 are used.
my.apc = apc(resp~x1*x2*x3*x4, maxsize=6, data=testdata, method=1, level=.05, reps=9000)
summary(my.apc)
```

---

testdata	<i>testdata data frame</i>
----------	----------------------------

---

## Description

A constructed data frame to illustrate the use of the functions in the APC package.

## Usage

```
data("testdata")
```

## Format

The "testdata" data frame has 16 rows and 5 columns:

- resp response variable.
- x1 binary (-1 or +1) explanatory variable 1.
- x2 binary (-1 or +1) explanatory variable 2.
- x3 binary (-1 or +1) explanatory variable 3.
- x4 binary (-1 or +1) explanatory variable 4.

## Details

The values of "resp" were generated as  $\text{resp} = \text{round}(10+8*x1+5*x3+7*x4+6*x1*x4+rnorm(16), 2)$ .

## Examples

```
data(testdata)
```

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