Statistical Power, Statistical Significance, Study Design and Decision Making: A Worked Example

Sizing Demand Response Trials in New Zealand

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# About

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## History

Code & report history:

* [Paper history](https://github.com/dataknut/weGotThePower/commits/master)

## Data:

This report uses circuit level extracts for ‘Heat Pumps’ from the NZ GREEN Grid Household Electricity Demand Data (<https://dx.doi.org/10.5255/UKDA-SN-853334> (Anderson et al. 2018)). These have been extracted using the code found in <https://github.com/CfSOtago/GREENGridData/blob/master/examples/code/extractCleanGridSpy1minCircuit.R>

## Acknowledgements

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* The [University of Otago](https://www.otago.ac.nz/);
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# Introduction

This report contains the analysis for a paper of the same name. The text is stored elsewhere for ease of editing.

# Error, power, significance and decision making

# Sample design: statistical power

## Means

## Warning: replacing previous import 'data.table::melt' by 'reshape2::melt'  
## when loading 'weGotThePower'

## Warning: replacing previous import 'data.table::dcast' by 'reshape2::dcast'  
## when loading 'weGotThePower'

Figure 1 shows the initial p = 0.05 plot.

## Scale for 'y' is already present. Adding another scale for 'y', which  
## will replace the existing scale.

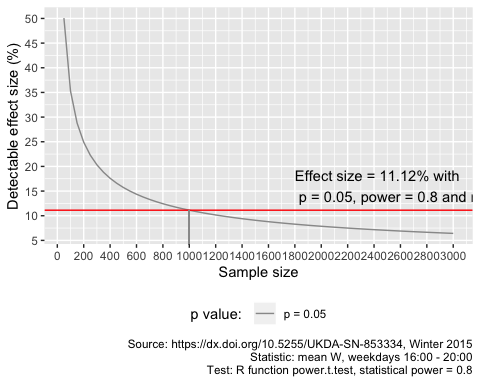


Figure 1 Power analysis results (p = 0.05, power = 0.8)

## Saving 5 x 4 in image

Effect size at n = 1000: 11.12.

Figure 2 shows the plot for all results.

## Scale for 'y' is already present. Adding another scale for 'y', which  
## will replace the existing scale.

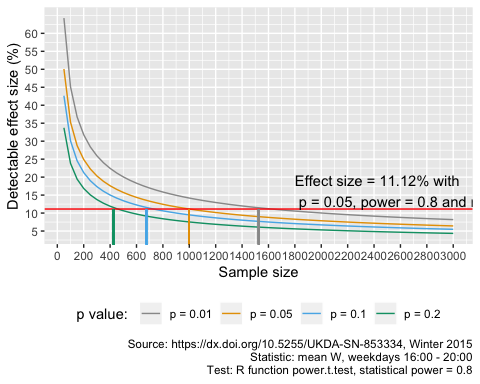


Figure 2 Power analysis results (power = 0.8)

## Saving 5 x 4 in image

Full table of results:

## Using 'effectSize' as value column. Use 'value.var' to override

Table 1 Power analysis for means results table (partial)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| sampleN | p = 0.01 | p = 0.05 | p = 0.1 | p = 0.2 |
| 50 | 64.25 | 50.08 | 42.64 | 33.73 |
| 100 | 45.11 | 35.28 | 30.09 | 23.83 |
| 150 | 36.75 | 28.78 | 24.55 | 19.45 |
| 200 | 31.79 | 24.91 | 21.25 | 16.84 |
| 250 | 28.41 | 22.27 | 19.01 | 15.06 |
| 300 | 25.93 | 20.32 | 17.35 | 13.75 |
| 350 | 23.99 | 18.81 | 16.06 | 12.73 |
| 400 | 22.44 | 17.60 | 15.02 | 11.90 |
| 450 | 21.15 | 16.59 | 14.16 | 11.22 |
| 500 | 20.06 | 15.74 | 13.43 | 10.65 |
| 550 | 19.13 | 15.00 | 12.81 | 10.15 |
| 600 | 18.31 | 14.36 | 12.26 | 9.72 |
| 650 | 17.59 | 13.80 | 11.78 | 9.34 |
| 700 | 16.95 | 13.30 | 11.35 | 9.00 |
| 750 | 16.37 | 12.85 | 10.97 | 8.69 |
| 800 | 15.85 | 12.44 | 10.62 | 8.42 |
| 850 | 15.38 | 12.07 | 10.30 | 8.17 |
| 900 | 14.95 | 11.73 | 10.01 | 7.94 |
| 950 | 14.55 | 11.41 | 9.74 | 7.72 |
| 1000 | 14.18 | 11.12 | 9.50 | 7.53 |

## Proportions

Does not require a sample.

Figure 3 shows the initial p = 0.05 plot. This shows the difference that would be required

## Scale for 'y' is already present. Adding another scale for 'y', which  
## will replace the existing scale.

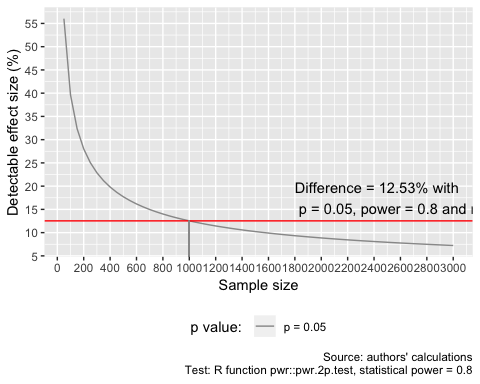


Figure 3 Power analysis results for proportions (p = 0.05, power = 0.8)

## Saving 5 x 4 in image

Figure 4 shows the plot for all results.

## Scale for 'y' is already present. Adding another scale for 'y', which  
## will replace the existing scale.

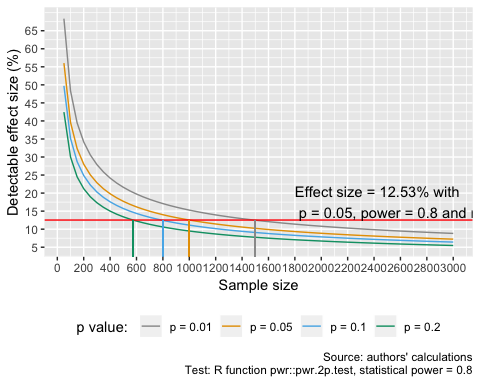


Figure 4 Power analysis results (power = 0.8)

## Saving 5 x 4 in image

Full table of results:

## Using 'effectSize' as value column. Use 'value.var' to override

Table 2 Power analysis for proportions results table (partial)

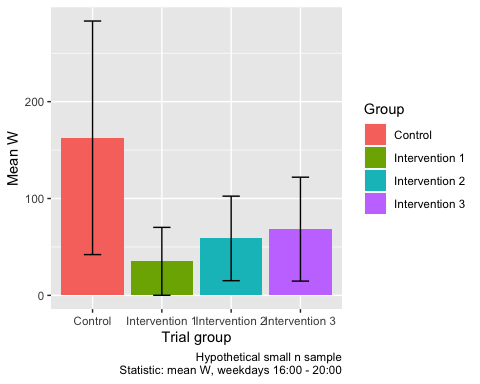
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| sampleN | p = 0.01 | p = 0.05 | p = 0.1 | p = 0.2 |
| 50 | 68.35 | 56.03 | 49.73 | 42.44 |
| 100 | 48.33 | 39.62 | 35.16 | 30.01 |
| 150 | 39.46 | 32.35 | 28.71 | 24.51 |
| 200 | 34.17 | 28.01 | 24.86 | 21.22 |
| 250 | 30.57 | 25.06 | 22.24 | 18.98 |
| 300 | 27.90 | 22.88 | 20.30 | 17.33 |
| 350 | 25.83 | 21.18 | 18.80 | 16.04 |
| 400 | 24.16 | 19.81 | 17.58 | 15.01 |
| 450 | 22.78 | 18.68 | 16.58 | 14.15 |
| 500 | 21.61 | 17.72 | 15.72 | 13.42 |
| 550 | 20.61 | 16.89 | 15.00 | 12.80 |
| 600 | 19.73 | 16.17 | 14.36 | 12.25 |
| 650 | 18.96 | 15.54 | 13.79 | 11.77 |
| 700 | 18.27 | 14.97 | 13.29 | 11.34 |
| 750 | 17.65 | 14.47 | 12.84 | 10.96 |
| 800 | 17.09 | 14.01 | 12.43 | 10.61 |
| 850 | 16.57 | 13.59 | 12.06 | 10.29 |
| 900 | 16.11 | 13.21 | 11.72 | 10.00 |
| 950 | 15.68 | 12.86 | 11.41 | 9.73 |
| 1000 | 15.28 | 12.53 | 11.12 | 9.49 |

# Testing for differences: effect sizes, confidence intervals and p values

## Getting it ‘wrong’

Table 3 Number of households and summary statistics per group

|  |  |  |  |
| --- | --- | --- | --- |
| group | mean W | sd W | n households |
| Control | 162.66915 | 325.51171 | 28 |
| Intervention 1 | 35.13947 | 83.90258 | 22 |
| Intervention 2 | 58.80597 | 113.53102 | 26 |
| Intervention 3 | 68.37439 | 147.37279 | 29 |



T test group 1

Table 4 T test results (Group 1 vs Control)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Control mean | Group 1 mean | Mean difference | statistic | p.value | conf.low | conf.high |
| 162.6691 | 35.13947 | -127.5297 | -1.990661 | 0.0552626 | -258.11 | 3.050644 |

The results show that the mean power demand for the control group was 162.67W and for Intervention 1 was 35.14W. This is a (very) large difference in the mean of 127.53. The results of the t test are:

* effect size = 128W or 78% representing a *substantial bang for buck* for whatever caused the difference;
* 95% confidence interval for the test = -258.11 to 3.05 representing *considerable* uncertainty/variation;
* p value of 0.055 representing a *relatively low* risk of a false positive result but which (just) fails the conventional p < 0.05 threshold.

T test Group 2

Table 5 T test results (Group 2 vs Control)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Control mean | Group 2 mean | Mean difference | statistic | p.value | conf.low | conf.high |
| 162.6691 | 58.80597 | -103.8632 | -1.587604 | 0.1216582 | -236.8285 | 29.10212 |

Now:

* effect size = 104W or 63.85% representing a still *reasonable bang for buck* for whatever caused the difference;
* 95% confidence interval for the test = -236.83 to 29.1 representing *even greater* uncertainty/variation;
* p value of 0.122 representing a *higher* risk of a false positive result which fails the conventional p < 0.05 threshold and also the less conservative p < 0.1.

To detect Intervention Group 2’s effect size of 63.85% would have required control and trial group sizes of 47 respectively.

## Getting it ‘right’

Table 6 Number of households and summary statistics per group

|  |  |  |  |
| --- | --- | --- | --- |
| group | mean W | sd W | n households |
| Control | 163.15129 | 324.06971 | 1110 |
| Intervention 1 | 40.50084 | 86.63044 | 910 |
| Intervention 2 | 57.53867 | 110.14187 | 1020 |
| Intervention 3 | 69.55935 | 144.98786 | 1160 |

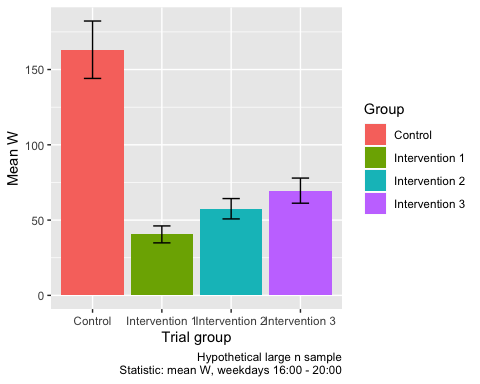


Figure 5 Mean W demand per group for large sample (Error bars = 95% confidence intervals for the sample mean)

re-run T tests Group 1

Table 7 T test results (Group 1 vs Control)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Control mean | Group 1 mean | Mean difference | statistic | p.value | conf.low | conf.high |
| 163.1513 | 57.53867 | -105.6126 | -10.23356 | 0 | -125.8576 | -85.36762 |

In this case:

* effect size = 105.6126252W or 64.73% representing a still *reasonable bang for buck* for whatever caused the difference;
* 95% confidence interval for the test = -125.86 to -85.37 representing *much less* uncertainty/variation;
* p value of 0 representing a *very low* risk of a false positive result as it passes all conventional thresholds.

# Summary and recommendations

## Statistical power and sample design

## Reporting statistical tests of difference (effects)

## Making inferences and taking decisions

# Acknowledgments

# Runtime

Analysis completed in 35.65 seconds ( 0.59 minutes) using [knitr](https://cran.r-project.org/package=knitr) in [RStudio](http://www.rstudio.com) with R version 3.5.1 (2018-07-02) running on x86\_64-apple-darwin15.6.0.

# R environment

R packages used:

* base R - for the basics (R Core Team 2016)
* data.table - for fast (big) data handling (Dowle et al. 2015)
* lubridate - date manipulation (Grolemund and Wickham 2011)
* ggplot2 - for slick graphics (Wickham 2009)
* readr - for csv reading/writing (Wickham, Hester, and Francois 2016)
* dplyr - for select and contains (Wickham and Francois 2016)
* progress - for progress bars (Csárdi and FitzJohn 2016)
* knitr - to create this document & neat tables (Xie 2016)
* GREENGrid - for local NZ GREEN Grid project utilities

Session info:

## R version 3.5.1 (2018-07-02)  
## Platform: x86\_64-apple-darwin15.6.0 (64-bit)  
## Running under: macOS High Sierra 10.13.6  
##   
## Matrix products: default  
## BLAS: /Library/Frameworks/R.framework/Versions/3.5/Resources/lib/libRblas.0.dylib  
## LAPACK: /Library/Frameworks/R.framework/Versions/3.5/Resources/lib/libRlapack.dylib  
##   
## locale:  
## [1] en\_NZ.UTF-8/en\_NZ.UTF-8/en\_NZ.UTF-8/C/en\_NZ.UTF-8/en\_NZ.UTF-8  
##   
## attached base packages:  
## [1] stats graphics grDevices utils datasets methods base   
##   
## other attached packages:  
## [1] knitr\_1.20 dkUtils\_0.0.0.9000 broom\_0.5.0   
## [4] lubridate\_1.7.4 readr\_1.1.1 ggplot2\_3.1.0   
## [7] dplyr\_0.7.7 data.table\_1.11.8 myUtils\_0.0.0.9000  
##   
## loaded via a namespace (and not attached):  
## [1] Rcpp\_0.12.19 highr\_0.7 pillar\_1.3.0   
## [4] compiler\_3.5.1 plyr\_1.8.4 bindr\_0.1.1   
## [7] tools\_3.5.1 digest\_0.6.18 lattice\_0.20-35   
## [10] nlme\_3.1-137 evaluate\_0.12 tibble\_1.4.2   
## [13] gtable\_0.2.0 pkgconfig\_2.0.2 rlang\_0.3.0.1   
## [16] cli\_1.0.1 yaml\_2.2.0 xfun\_0.4   
## [19] bindrcpp\_0.2.2 pwr\_1.2-2 withr\_2.1.2   
## [22] stringr\_1.3.1 hms\_0.4.2 rprojroot\_1.3-2   
## [25] grid\_3.5.1 tidyselect\_0.2.5 glue\_1.3.0   
## [28] R6\_2.3.0 fansi\_0.4.0 rmarkdown\_1.10   
## [31] bookdown\_0.7 reshape2\_1.4.3 weGotThePower\_0.1  
## [34] tidyr\_0.8.1 purrr\_0.2.5 magrittr\_1.5   
## [37] backports\_1.1.2 scales\_1.0.0 htmltools\_0.3.6   
## [40] assertthat\_0.2.0 colorspace\_1.3-2 labeling\_0.3   
## [43] utf8\_1.1.4 stringi\_1.2.4 lazyeval\_0.2.1   
## [46] munsell\_0.5.0 crayon\_1.3.4

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Xie, Yihui. 2016. *Knitr: A General-Purpose Package for Dynamic Report Generation in R*. <https://CRAN.R-project.org/package=knitr>.