DataLunch Statistical Power

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23 Jul 2025

Points to think about before starting your power analysis

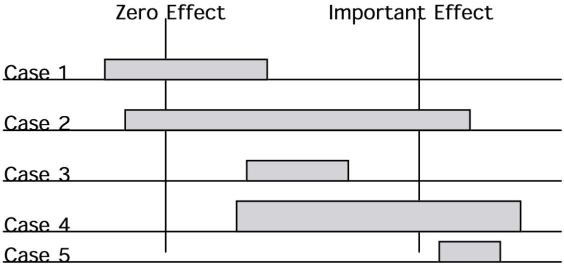


Figure 1. Confidence intervals for five different environmental scenarios.

Figure 1: Effects_Not_Pvalues

Figure 1 from Fox (2001)

Points to think about before starting your power analysis

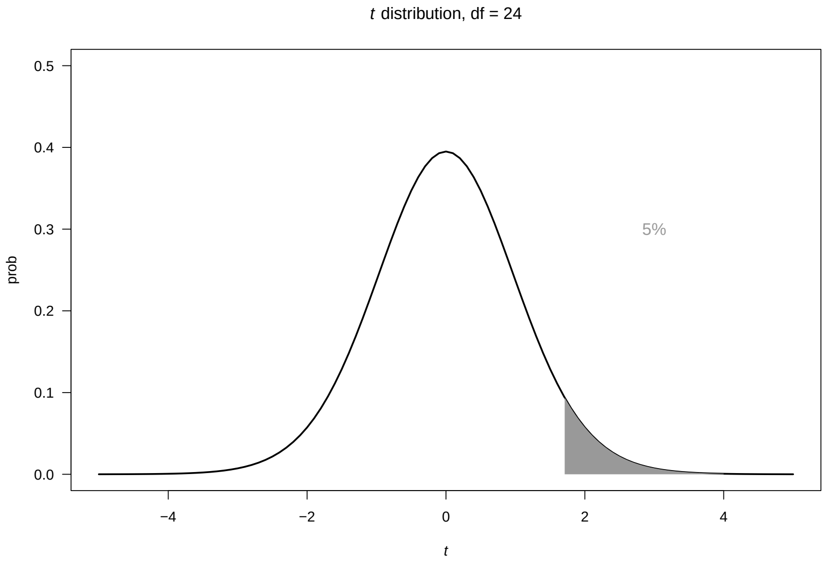
- Power analysis to maximize precision of your quantities of interest
- Lakens (2022) is a good starting place for considering how to determine appropriate/sufficient sample sizes (including a Shiny app!)

the traditional "4 possible outcomes of a statistical test"

	Reject Null	Accept Null
Null True	Type I error, α	Correct, $1-\alpha$
Null False	Correct, $1-\beta$	Type II error, β

- $(1-\beta)$ is **power**, probability of detecting a true difference.
- $(1-\alpha)$ is **confidence**, probability of correctly accepting null.

Critical value for a t distribution, for a one tailed test



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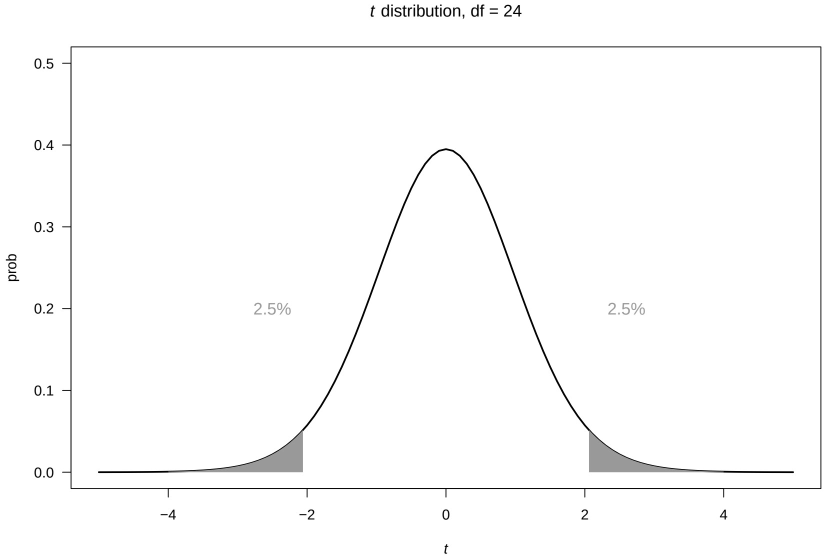

Keep in mind

These kinds of dichotomies lead you to an *"Is there an effect?"* thinking.

Instead you should ask *"What is the effect?"* and for a power analysis, *"What precision of the effect do I want, given the resources I have?"*

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- Not necessarily. The magnitude of an effect could be similar, and the sample sizes differ (the second data set being much larger).
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- However it could also be that there is a difference in these. You need to examine (and report) all three whenever possible (include confidence intervals on estimates).

Let's compare these three data sets

- We are examining the relationship between body size and fitness.

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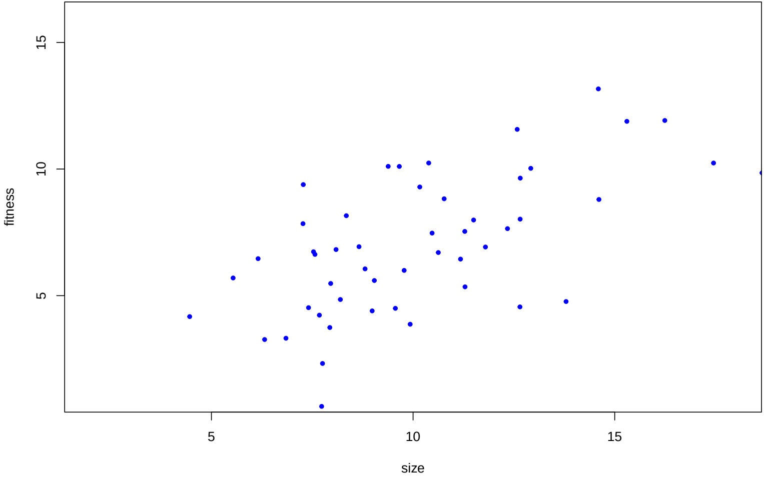
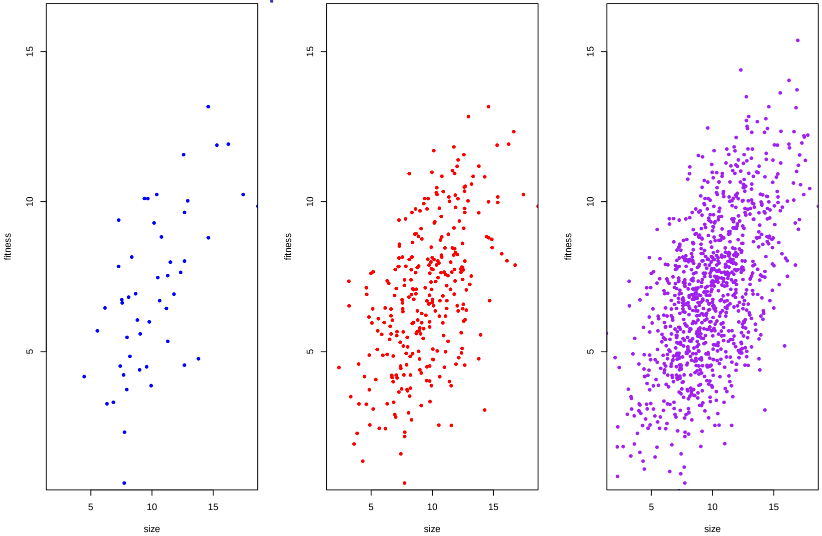
- Is there a relationship?



Is there a relationship?



- In fact they all have the same relationship $fitness \sim N(2 + 0.5 * size, \sigma = 2)$, and only differ in sample size.

Statistical Power Analysis in R

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```
qt(p = 0.975, df = 24)
```

```
## [1] 2.063899
```

- Why do we have df $= 24$, not 25?

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## [1] 2.063899
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- Why do we have $\text{df} = 24$, not 25?
- Why is $\text{p} = 0.975$, not 0.95 (with $\alpha = 0.05$)?

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```
curve(qt(p = 0.975,df = x), 2, 25,
    col = "red", lwd = 3, cex.lab = 2,
    main = "Critical values of t for different sample sizes
    xlab = "Sample Size",
    ylab = expression(paste("t value (two tailed), ", alpha
```

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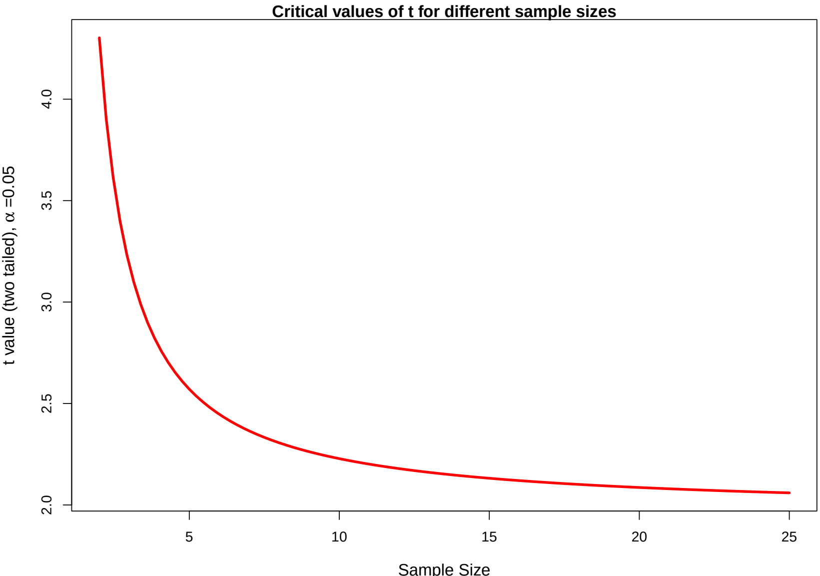

Critical values for other distributions

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- `qf()` for the F distribution, `qchisq()` for χ^2 etc..

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- See this draft task view for power
- I will show just a couple here.

Some of the functions in base R

```
## [1] "power"              "power.anova.test" "power.prop.te
```

`power.t.test`

- What goes into a t-test?

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$$\frac{\bar{x}_A - \bar{x}_B}{\hat{\sigma}\frac{1}{\sqrt{n}}}$$

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- The denominator is just the *pooled standard error of the mean*
- So we see that there are 4 critical things:
- α, the difference between means $\Delta = \bar{x}_A - \bar{x}_B$, n and $\hat{\sigma}$

power.t.test

```
pwr_t_check <- power.t.test(delta = 0.5, sd = 2,
                            sig.level = 0.05,
                            power = 0.8)
pwr_t_check
```

```
##
##      Two-sample t test power calculation
##
##               n = 252.1281
##           delta = 0.5
##              sd = 2
##       sig.level = 0.05
##           power = 0.8
##     alternative = two.sided
##
## NOTE: n is number in *each* group
```

```
str(pwr_t_check)
```

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- what sample sizes we would need for a range of differences, Δ, on the interval $[0.1, 0.5]$.

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- $(1-\beta) = 0.8$, $\hat{\sigma} = 2$, $\alpha = 0.05$

power.t.test

- $\Delta = 0.5$, $\hat{\sigma} = 2$, $\alpha = 0.05$

```
delta_vals = seq(from = 0.1, to = 0.5, by = 0.01)
delta_vals
```

```
##  [1] 0.10 0.11 0.12 0.13 0.14 0.15 0.16 0.17 0.18 0.19 0
## [16] 0.25 0.26 0.27 0.28 0.29 0.30 0.31 0.32 0.33 0.34 0
## [31] 0.40 0.41 0.42 0.43 0.44 0.45 0.46 0.47 0.48 0.49 0
```

- This creates a vector from 0.1 - 0.5

power.t.test

```
pow.test <- function(x) {
  pow2 <- power.t.test(delta = x, sd = 2,
                       sig.level = 0.05,
                       power = 0.8) # We only allow delta t
  return(pow2$n) # Pull out the sample size we need
}
```

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```
power.n <- sapply(delta_vals, pow.test)
```

- This uses one of the `*apply` functions to repeat the function `pow.test` for each element of the vector `delta_vals`.

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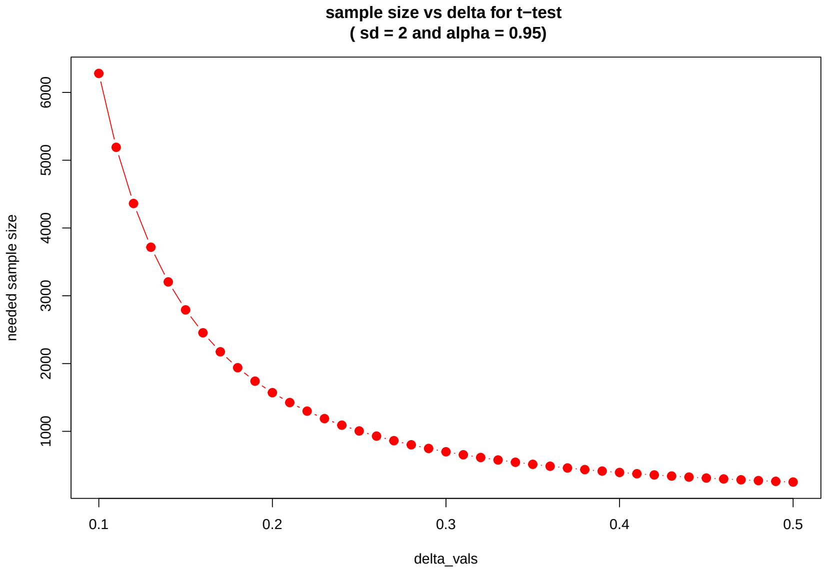
power.n <- sapply(delta_vals, pow.test)
```

- This uses one of the `*apply` functions to repeat the function `pow.test` for each element of the vector `delta_vals`.
- Thus for each value in the vector `delta_vals` (from 0.1 to 0.5), it puts this value into `pow.test()` and then returns the estimated `n` (# of observations needed to achieve this power).

power.t.test



sample size vs delta for t−test
(sd = 2 and alpha = 0.95)
needed sample size
1000
2000
3000
4000
5000
6000
0.1
0.2
0.3
0.4
0.5
delta_vals

Similarly, there are functions in base R for 1-way ANOVA

`power.anova.test` example

More complex power analyses

- `pwr` has many useful functions for experimental designs of simple to moderate complexity.
- `pwrss` does as well, and can generate some very helpful figures to help understand
- If you are designing experiments and you think it is likely you are going to use mixed models, the `simr` is a good choice to learn (relatively straightforward)
- `EMSS` has useful sample size calculators.

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- It is relatively straightforward to put this in a `for` loop to generate power analyses for more complicated designs/analyses

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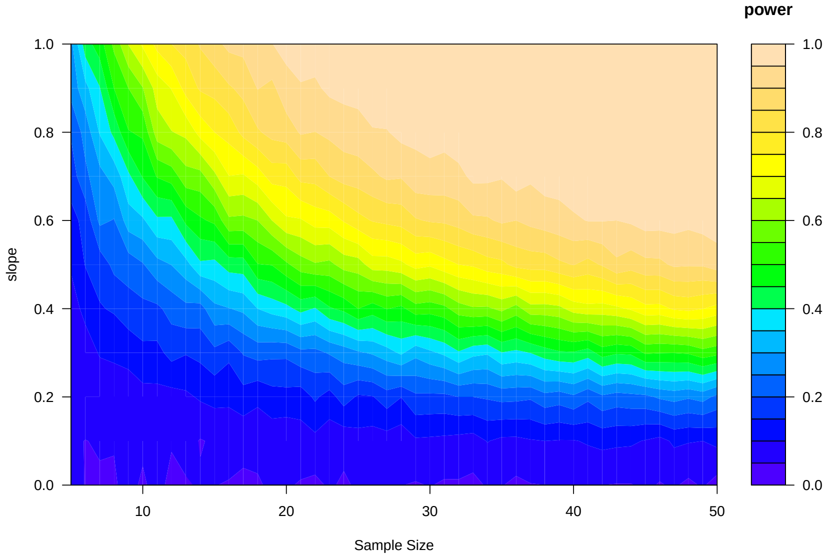
- Learning how to do simple *Monte Carlo* simulations gives you lots of flexibility
- I have posted a series of screencasts on YouTube, starting here that will teach you the basics.

Monte carlo power analysis example

- `R` code is hidden (but you can see it with the .Rmd file)

Plotting results from a power analysis



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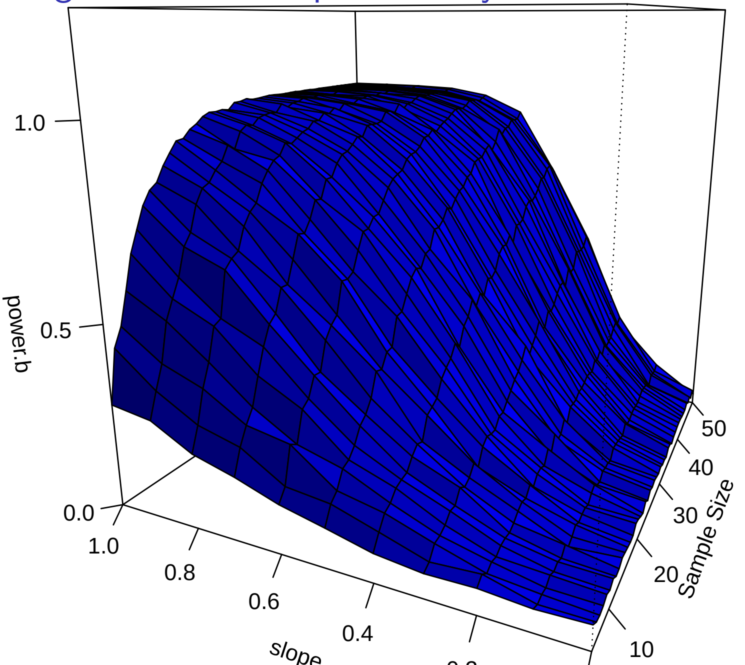

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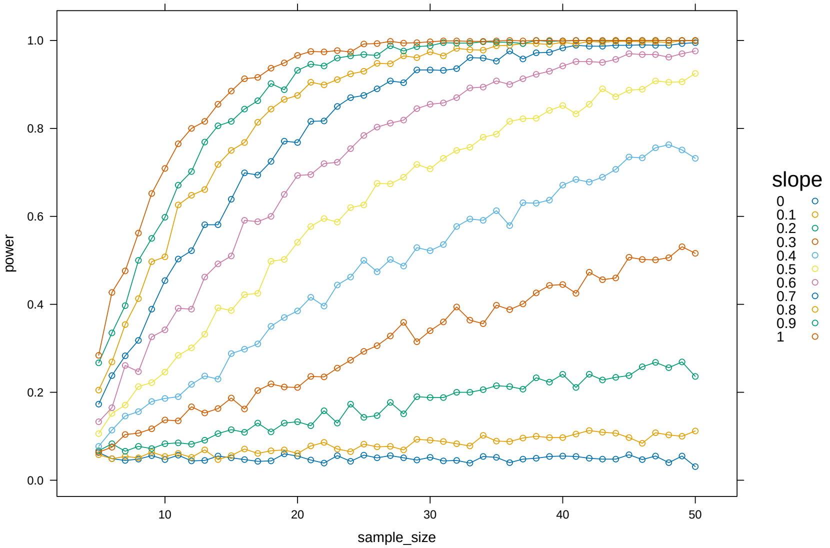

References

Fox, David R. 2001. "Environmental Power Analysis – a New Perspective." *Environmetrics* 12 (5): 437–49. https://doi.org/10.1002/env.470.

Lakens, Daniël. 2022. "Sample Size Justification." *Collabra: Psychology* 8 (1): 33267. https://doi.org/10.1525/collabra.33267.