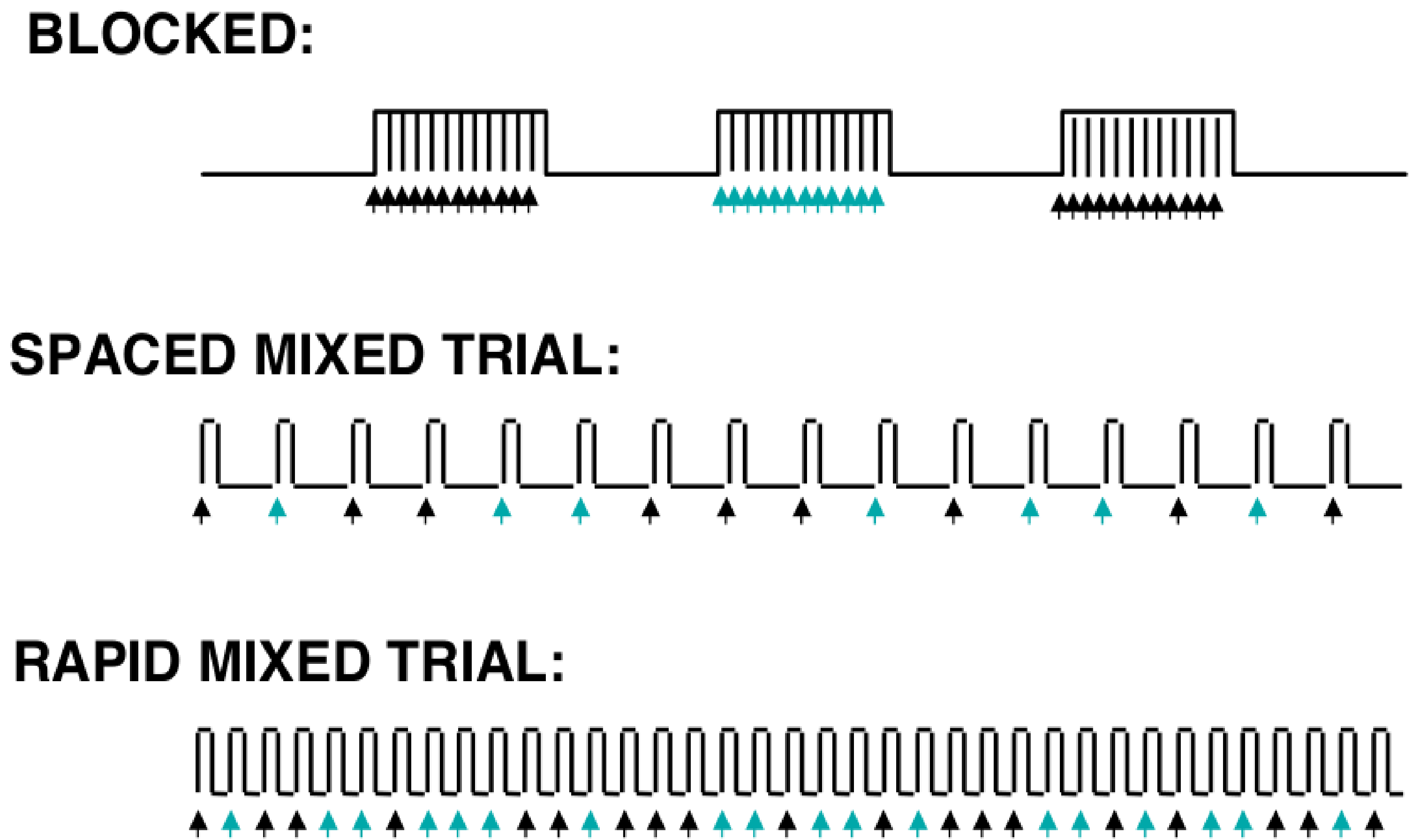
fMRI design efficiency

Aim: to design experiments maximising the power of detecting real effects.
(That is, avoid type-II errors, a.k.a “misses”).

Hard Constraints:
- total duration of acquisition
- max. # of Ss
- psychological paradigm constraints...

Parameters that can be manipulated

- Temporal distribution of the events/conditions



- Should one include null events? (if yes, what proportion)
- Should one add some jitter to the SOA? (if yes, how much)

Power of classic t-test

- To compute the power of an experiment comparing 2 conditions, one needs:

  (1) the Type-I statistical threshold (2) the number of measurements (3) estimates of the effect size (diff. Between conds.) and 'noise' (variability).
- (This allows to compute the distribution of standard error, and therefore that of t-values)

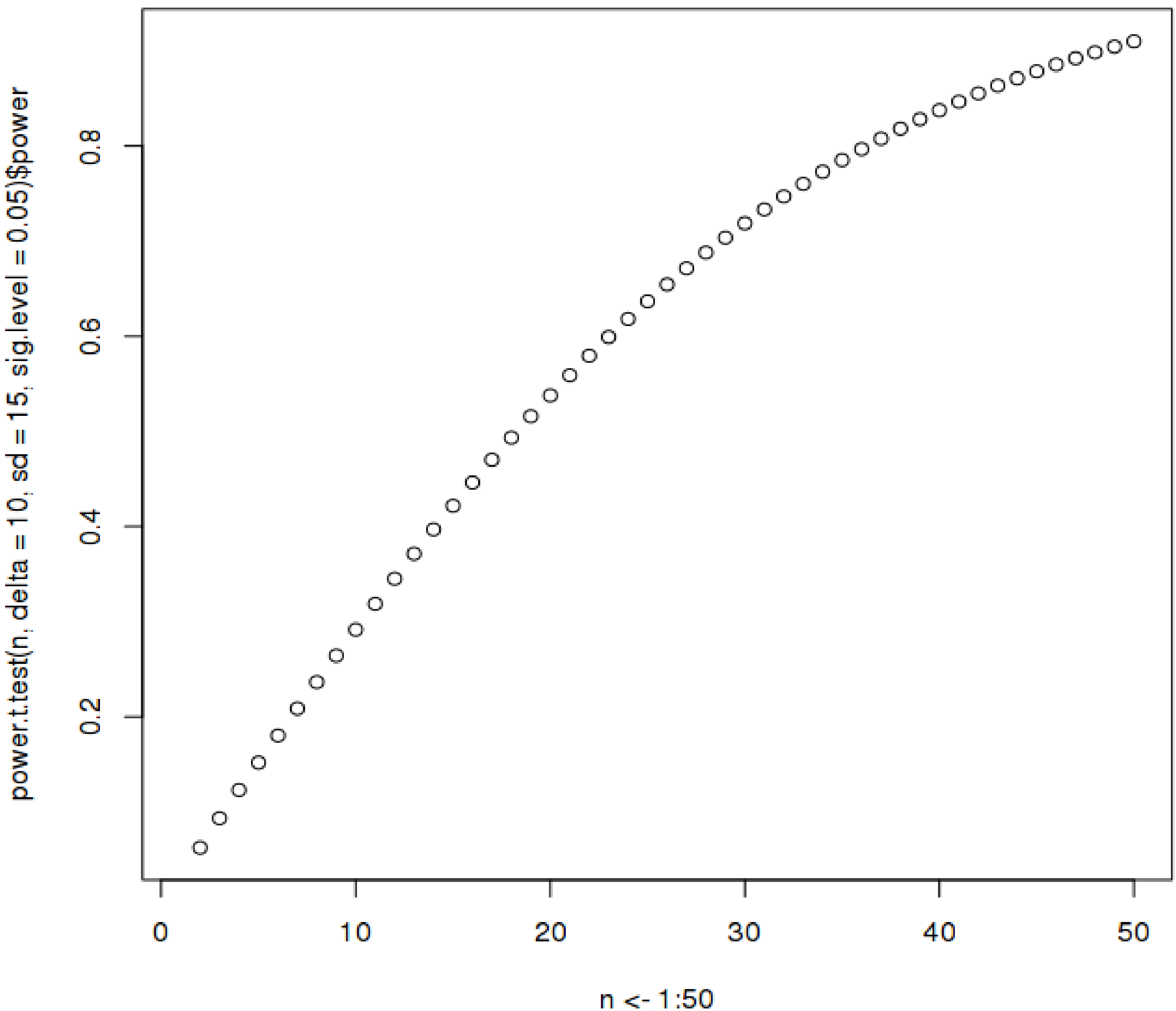
- Example:
- we want to test the hypothesis that men are taller than women.
- Let's suppose the population difference is ~10cm, and the standard dev. is ~15cm.

```
> power.t.test(n=10, delta=10, sd=15, sig.level=.05)
          power = 0.2917418
```

```
> power.t.test(delta=10, sd=15, sig.level=.05,
power=.80)
              n = 36.3058
```

NOTE: n is number in *each* group

- `plot(n<-1:50,power.t.test(n, delta=10, sd=15, sig.level=.05)$power)`



Computation of power for fMRI

Use **simulations**:

- Suppose that you have 2 conditions A & B, and that you expect that a 'A' event elicits a response of 1% response in a given ROI while a 'B' event elicits a 0.5% response.
- **Given a description of the experiment, one can simulate the timecourse of activations in the ROI.**
- Then, repeat the following many times:
  - Generate random noise and add it to the theoretical timecourse;
  - run the GLM;
  - check if the difference between A and B is significant.

- power is simply the proportion of cases where the contrast A>B is significant.

To estimate power, one needs a good model of noise AND of its parameters

Several sources:

- Thermal noise
- MRI system noise, including low freq. drifts
- Physiological noise (heart beats, breathing (aliased))
- Neural/Psychological noise

The noise is temporally autocorrelated (therefore gaussian iid noise is not very statisfactory)

In the absence of a precise estimation of the noise, one can still compare the **relative power** of two designs:

The most efficient design is the one that **minimizes the confidence intervals** of the constrasts of interest

Efficiency of a design

In a GLM setting ($y=E(X\beta)$), the standard error of a contrast $C\beta$ is proportional (when noise is iid) to

$$C' (X' X)^{-1} C$$

The inverse of this quantity is the **efficiency of X for the C contrast**

(Here C is is one d.f. Contrast; This formula can be generalisated to a F contrast, see Dale (1999))

R code to generate designs and compute the efficiencies of contrasts

See http://www.pallier.org/ressources/power_fmri_design.html

The code is a Rmarkdown document:

http://www.pallier.org/ressources/power_fmri_design.Rmd

(can be run from rstudio).

My Intention: put a R-package on github

Optimal sequences

Even when a design has been selected, some random permutations can have better efficiency than others; this code can be used to select the best permutations.

See also:

- optseq (http://surfer.nmr.mgh.harvard.edu/optseq/), a generator of 'optimal sequences'

- M-sequences: Buračas, Giedrius T., and Geoffrey M. Boynton. 2002. “Efficient Design of Event-Related fMRI Experiments Using M-Sequences.” NeuroImage 16 (3): 801–13.

Going further

- A relevant paper:

Welvaert, Durnez, Moerkerke, Verdoolaege, and Rosseel. (2011). "neuRosim: An R Package for Generating fMRI Data." *Journal of Statistical Software* 44 (10): 1–18.

Better model for noise & Generation of 4D volumes

- Must read:

Human Brain Function, chap.15 by Rik Hanson. Efficient Experimental Design for fMRI. (and the CBU wiki)