# Taking the pulse on **single case** neuropsychology

# **Single case neuropsychology:** Validity and reliability in a power-wise pinioned field


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## Introduction

- Single case research in neuropsychology.
  - Functional deficits or dissociations in brain damaged patients.
    - Only valid way to map functions to brain areas?
  - Inherently low power which gives rise to:
    - Low probability of finding an effect.
    - Decrease in positive predictive value.
    - The winner's curse.
      - This is an overestimation of effect sizes stemming from only the studies that by chance draws a sample with a large effect will be able to detect it.

## Gaps in the literature

- Little work has been done on evaluating power for the statistical methods used in single case research.
- The extent of the winner's curse in single case research has not been evaluated.
- Multivariate methods are known for their higher power and reliability for explaining latent functions (e.g. intelligence).
  - No standard for such methods has been proposed.

## Outline

Evaluate power of tests for discovering deficits and dissociations with regards to sample sizes, effect sizes and correlations between functions.

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Evaluate the extent to which single case studies are affected by the winner's curse and possible ways to compensate for this overestimation.

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Construct and evaluate single case multivariate approaches and compare power and usability to simpler but possibly less valid univariate methods.

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Judge whether the confirmatory crown of single case neuropsychology can be retained.

## Method and Results

- Power evaluation can be done in two ways:
  - Analytically (symbol manipulation), which is exact.
  - Numerically (e.g. simulations), which is approximate.
    - Simulations provide an intuition of how statistical issues will affect a field "in the long run".
      - Winner's curse - especially suited for this approach.
      - See example code below and results in figure 1.

```
win_sim <- function (nsim, deficit, ncon) {
# Matrix where each row represents observations
# on a variable from controls plus a patient
  ranmat <- matrix(rnorm((ncon + 1) * nsim),
                   nrow = nsim,
                   ncol = ncon + 1)
# Induce a deficit on the first obs of each row
# and compare to the other obs on that row.
# Save the median of all found deficits.
  med_def <- median(
    apply(cl, ranmat, 1,
       function(x) {if (pt(
              ((x[1] - def) - mean(x[2:ncon+1]))
              /(sd(x[2:ncon+1])*sqrt(length(x)
                                     /(length(x) -
  1))),
             df =  length(x) - 2)<0.05) {
             (x[1] - def)
                   } else { NA } }),
             na.rm = TRUE)
# Return the average overestimation
  return(- def -med_def)
}
```

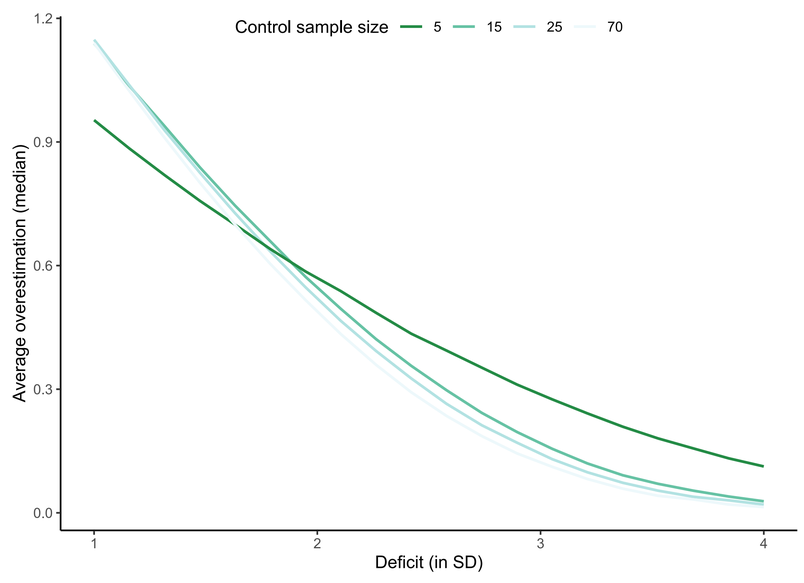


*Figure 1: Median overestimation with Crawford and Howell (1998) method, $10^6$ simulations for every parameter combination.*

### Test construction

- The test used in the simulation above by **Crawford and Howell (1998)** can be seen in eq. (1).
- Building on this I successfully generalised it for multivariate use, as outlined below.

$$t_{n-1} = \frac{X^* - \overline{X}}{s\sqrt{\frac{n+1}{n}}} \tag{1}$$

Where $X^*$ is the patient score, $\overline{X}$, $s$ and $n$ the mean, standard deviation and size of the control sample, i.e. a two sample t test with $n_1 = 1$. The multivariate generalisation of a two sample t test is the Hotelling's $t^2$ test:

$$t^2 = \frac{n_x n_y}{n_x + n_y}(\bar{\boldsymbol{x}} - \bar{\boldsymbol{y}})'\hat{\Sigma}_p^{-1}(\bar{\boldsymbol{x}} - \bar{\boldsymbol{y}}) \tag{2}$$

$\bar{\boldsymbol{x}}$ and $\bar{\boldsymbol{y}}$ being the mean *vectors* of the two groups and $\hat{\Sigma}_p$ the unbiased pooled covariance *matrix* and, if we let $p = no.\ of\ variates$, where

$$\frac{n_x + n_y - p - 1}{(n_x + n_y - 2)p}t^2 \sim F(p, n_x + n_y - 1 - p) \tag{3}$$

It should be possible to generalise eq. (1) $p$ number of variates as follows:

$$t^2 = \frac{n}{n+1}(\boldsymbol{x}^* - \bar{\boldsymbol{x}})'\hat{\boldsymbol{\Sigma}}^{-1}(\boldsymbol{x}^* - \bar{\boldsymbol{x}}) \tag{4}$$

Where $\boldsymbol{x}^*$ is a vector of observations on each variate from the individual of interest, $\bar{\boldsymbol{x}}$, $\hat{\boldsymbol{\Sigma}}$ and $n$ the mean vector, covariance matrix and size of the control sample. Simulations for evaluation of Type I errors and power is seen in figure 2

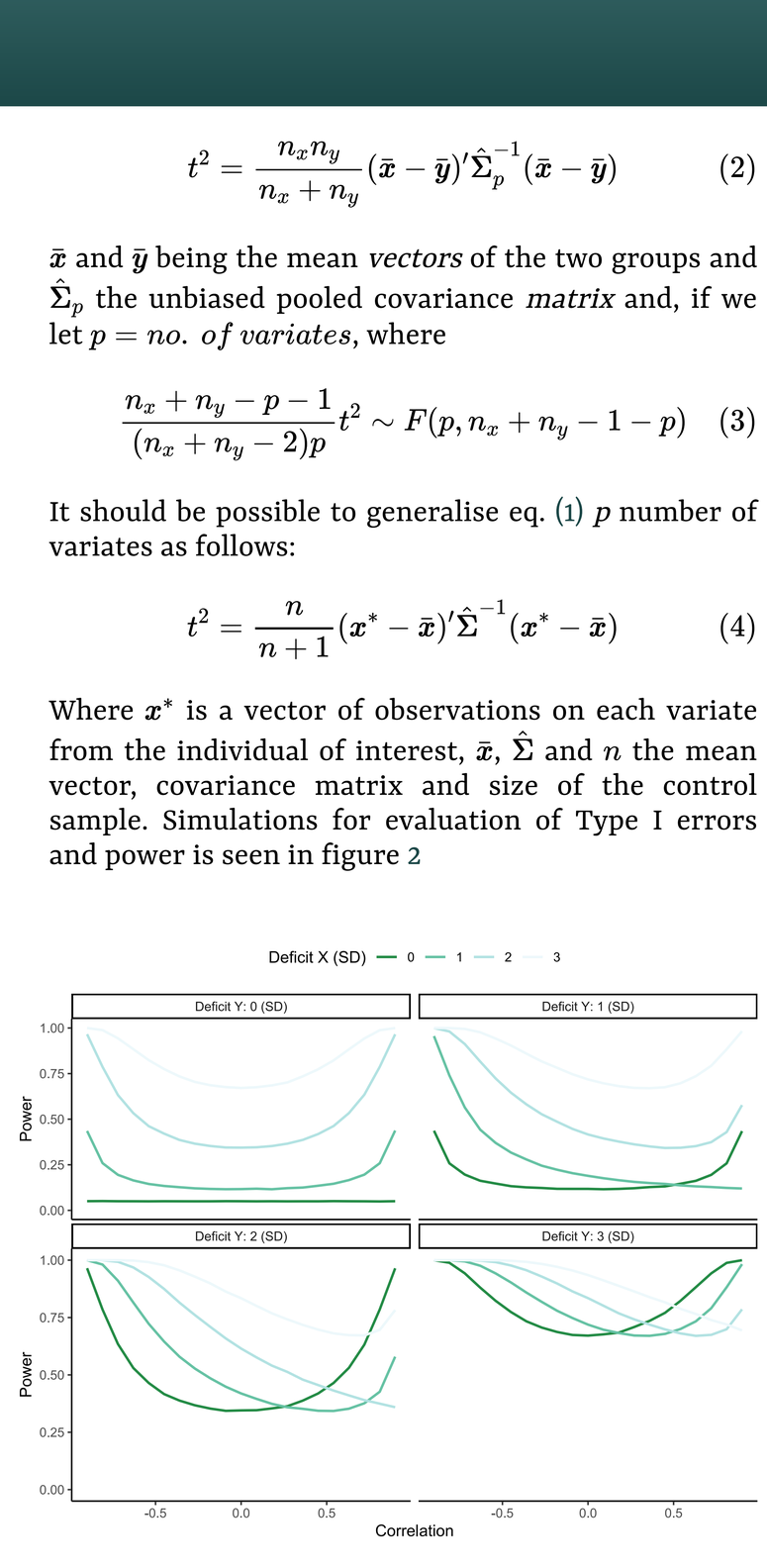


*Figure 2: Power for single case Hotellings $t^2$ over correlation, $10^5$ simulations for every combination. Deficits in standard deviations. Type I errors when deficit X=0 and deficit Y=0*

## Next Steps

- Not only functional deficits but importantly *dissociations* are of interest
  - Evaluation of power and winner's curse
  - Construction of multivariate methods.
- Compare reliability of the multivariate tests with univariate counterparts.
- Development of R package ("singcar").


### Acknowledgements

Poster created with posterdown **(Thorne 2019)**.


## References


Crawford, J. R., and David C. Howell. 1998. "Comparing an Individual's Test Score Against Norms Derived from Small Samples." *The Clinical Neuropsychologist* 12 (4): 482–86. https://doi.org/10.1076/clin.12.4.482.7241.

Thorne, Brent. 2019. *Posterdown: Generate Pdf Conference Posters Using R Markdown*. https://CRAN.R-project.org/package=posterdown.