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singcar: Comparing single cases to small samples in R

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Summary

Case-control comparisons are a class of statistical tests allowing researchers to compare single cases to populations estimated from a sample. Such tests have wide potential utility, but historically have been applied mostly in the fields of cognitive and clinical neuropsychology, to infer whether individuals have suffered significant cognitive changes as the consequence of a brain lesion. One may wish to estimate whether that individual has abnormally low performance on some cognitive ability, or if one cognitive ability is abnormally discrepant with respect to another cognitive ability. John Crawford, Paul Garthwaite and colleagues have developed several related methods to statistically test for abnormality on a single variate and abnormality of the difference between two variates when a single case is compared to a small sample, while controlling the Type I error rate (Crawford et al., 2011; Crawford & Garthwaite, 2002, 2007, 2005; e.g., Crawford & Howell, 1998). This paper presents the R package singcar in which they are implemented. Due to recent discussion on the fundamental power limits of these tests (McIntosh & Rittmo, 2020) the package also includes associated power calculators.

Statement of need

There are many reasons why researchers and clinicians might want to look at single cases instead of at the average of some group. In certain fields, such as neuropsychology, this need arises because the pattern of naturally-occurring brain damage will be unique in each individual case. From a theoretical perspective, this means that a single patient might be the only available source of data for a given phenomenon. From a practical, clinical perspective, diagnosis and description of the pattern of cognitive impairment is done at the individual level. Individual brain-damaged patients are thus often compared to the healthy population to assess changes in cognitive functioning. If we want to assess the patient score on some variate Y, for which we do not know the population parameters, these must be estimated from a sample. Thus, the single-case of interest is compared to a control sample. There are many other areas where the application of such methods could also be useful, for example studies of uncommon human expertise.

As it represents the canonical field for the application of these methods, the nomenclature of neuropsychology is adopted. An abnormally low score on a single variate is referred to as a *deficit*, an important concept for clinical and basic neuropsychology alike. For the latter area another concept is also considered to be of cardinal importance: the ability to test for an abnormally large discrepancy between two variates. This is referred to as a *dissociation*, which is taken to provide evidence for some degree of functional independence between two cognitive abilities. By charting dissociations, a cognitive architecture of the mind can be theorized (Shallice, 1988).

During the last 20 years, a class of related methods have been developed for case-control comparisons, allowing researchers to estimate abnormality and test for deficits and dissociations in the single case, while controlling the Type I error rate. These tests have been

developed mainly by John Crawford and Paul Garthwaite (Crawford et al., 2011; Crawford & Garthwaite, 2002, 2007, 2005; e.g., Crawford & Howell, 1998). John Crawford has provided free software packages to perform these tests, making them available at https://homepages.abdn.ac.uk/j.crawford/pages/dept/psychom.htm. However, these are available only as standalone compiled computer programs for Windows operating systems. Many of these programs require manual input of summary statistics, and output a static text file and for thorough documentation one must consult the original publications.

Our aim is to encourage and simplify usage of these methods by implementing them in the package `singcar` for the `R` environment (R Core Team, 2020), bringing them together in a fully documented package with open source code that works across platforms. Further advantages of `singcar` include an API that has more modifiable test parameters. It is also possible to automate these tests if multiple analyses need to be run for the purposes of data analysis or simulation studies. The development of Crawford and Garthwaite's methods has been focused around limiting Type I errors, but to emphasise the importance of considering Type II errors we also provide power calculators for each test function. Our hope in doing so is to increase awareness of power for this methodology as well as to aid in the planning and design of experiments (McIntosh & Rittmo, 2020).

Note that the `R` package `singlecase` (Dubois, 2008) contains some overlapping functionality with `singcar`, but it has not been maintained since 2008 and lacks core functionality such as tests allowing for the inclusion of covariates, and power calculators. A recent study by Mitchell et al. (2020) investigating peripheral reaching in Alzheimer's disease and mild cognitive impairment exemplifies the uses of these novel functionalities in `singcar`.

Functionality

`singcar` contains seven functions to estimate a case's abnormality compared to a normal population estimated from a small sample, three of them with regards to a single variate and four with regards to the discrepancy between two variates. Both frequentist and Bayesian methods are provided, all developed originally by Crawford and colleagues (Crawford et al., 2011; Crawford & Garthwaite, 2002, 2007, 2005; Crawford & Howell, 1998). Of special note for psychological research are the methods allowing the inclusion of covariates (Crawford et al., 2011) using Bayesian regression techniques. These methods make matching the control sample to the case less cumbersome. For rationale as well as mathematical and contextual background of the methods consult the package vignette.

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