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pwranova: An R package for power analysis of flexible ANOVA designs and related tests

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Software

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Summary

Researchers often need to determine how large a sample is required before collecting data. A common way to address this question is through statistical power analysis. In many psychological and behavioral experiments, as well as other experimental studies using factorial designs, the data are typically analyzed with analysis of variance (ANOVA). However, existing tools for power analysis often lack the flexibility needed to accommodate complex ANOVA designs.

`pwranova` is an R package that performs power analysis for between-, within-, and mixed-factor ANOVA designs, with full support for main effects, interactions, and planned contrasts (user-defined contrast weights). The package allows researchers to calculate statistical power, required total sample size, significance level, or minimal detectable effect sizes expressed as partial eta squared (η_p^2) or Cohen's f (Cohen, 1988).

In addition to ANOVA, `pwranova` provides complementary functions for common related tests, including t-tests (one-sample, paired, and two-sample) and tests of Pearson correlation (using either the t-distribution or Fisher's z-transformation approach). This makes the package a convenient toolkit for planning experimental studies in psychology and related fields.

Statement of need

Researchers in psychology and the behavioral sciences frequently rely on analysis of variance (ANOVA) to analyze factorial designs with multiple between- and within-participant factors. To support such analyses, several software tools provide analytic solutions for statistical power analysis, including G*Power (Faul et al., 2007) and several R packages (R Core Team, 2025) such as `pwr` (Champely, 2020), `pwr2` (Lu et al., 2017), `pwrss` (Bulus & Jentschke, 2025), and `WebPower` (Zhang & Yuan, 2018). However, existing analytic tools offer only limited flexibility when it comes to handling such complex ANOVA designs. For example, specifying interactions in multi-factor mixed ANOVA designs is difficult or not directly supported in these tools. These analytic tools also generally do not allow direct specification of user-defined contrasts. In addition, although effect sizes can be specified via Cohen's f (Cohen, 1988), they do not directly support partial eta squared, which is more commonly reported in psychological research. While flexible simulation-based packages such as `simr` (Green & MacLeod, 2016) and `Superpower` (Lakens & Caldwell, 2021) are available, such approaches may require substantial computational time and can be less straightforward to specify for routine experimental planning. Similarly, tools such as `InteractionPoweR` (Baranger et al., 2023) require more detailed information about expected correlations and interaction effects, which may be difficult to specify when little prior information is available. By contrast, `pwranova` requires only minimal inputs (e.g., design characteristics and standardized effect sizes), while providing fast analytic power calculations for complex factorial ANOVA designs, including higher-order interactions and user-defined contrasts.

pwranova provides the following features:

- Support for between-, within-, and mixed-factor ANOVA designs, including both main effects and interactions.
- Power analysis for planned contrasts with flexible, user-defined weight specification.
- Methods based on standard noncentral F-distribution power calculations. The numerator degrees of freedom are determined by the specified design, whereas the denominator degrees of freedom depend on both the design and sample size. The noncentrality parameter is defined as the product of Cohen's f squared and the total sample size. These formulations are consistent with those implemented in G*Power (Faul et al., 2007).
- Integrated functions for related t-tests and Pearson correlations, based on corresponding noncentral t-distribution and Fisher's z-transformation methods. Detailed descriptions are provided in the package documentation.
- A unified and extensible R implementation designed for reproducible research workflows.

All analyses assume balanced designs with equal cell sizes, as extending power calculations to unbalanced designs generally requires additional assumptions about group sizes and variance structures.

pwranova not only extends power analysis to complex factorial ANOVA designs but also incorporates related t-tests and correlation tests within the same framework. This integration allows researchers to conduct power analysis for a wide range of commonly used statistical tests in a consistent and reproducible way. This combination of flexibility and reproducibility makes pwranova especially useful for experimental psychologists and cognitive scientists, as well as researchers in the behavioral, social, and biological sciences designing studies with complex factorial structures.

Example use case

To illustrate a realistic application, consider a visual search experiment investigating age-related differences in search efficiency. In this type of task, participants search for a target item among distractors on a screen. They indicate whether the target is present or absent by pressing a key, and response time is recorded. The study includes one between-participant factor, age group (young vs. older adults), and two within-participant factors: target presence (present vs. absent) and set size (8, 16, or 24 items displayed), forming a 2 $\times$ 2 $\times$ 3 mixed design. In this example, the three-way interaction reflects whether age-related differences in search efficiency depend on target presence. Suppose the researcher wishes to detect a three-way interaction effect size of $f = 0.25$ with 80% power at $\alpha = .05$. The required total sample size can be estimated as follows:

```
pwranova(
  nlevels_b = 2,
  nlevels_w = c(2, 3),
  cohensf   = 0.25,
  alpha     = 0.05,
  power     = 0.80,
  target    = "B1:W1:W2"
)
```

The output indicates that a total sample size of 156 is required to achieve the desired statistical power (assuming equal group sizes). If the target argument is omitted, the function returns results for all main effects and interactions under the specified design. Although Cohen's f is used here, η_p^2 (peta2) can also be specified. If a planned contrast is of interest, power analysis can be conducted with pwrcontrast(), which uses a similar interface to pwranova() and specifies contrast weights via the weights argument (e.g., weights = c(1, -1, 0)). For paired data, set `paired = TRUE`. More detailed examples and tutorials are available on the package website: https://mutopsy.github.io/pwranova/

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