

New Statistical Methods in P8

Most of the methods in the list below are unique to PRIMER 8 and are not available in any other software package. Some of the methods are not new (such as the non-parametric univariate Mann-Whitney U test), but are implemented in a novel way in P8.

- **Expanded summary statistics** - Summarise your variables (or samples) with ease, using a host of standard statistics (e.g., average, median, range, min, max, nominated quantiles, skewness, kurtosis, etc.) and/or using several other bespoke diagnostic measures, such as frequencies of occurrence, the number of singletons or doubletons, or the smallest value above a given threshold, etc. You can also calculate summaries on data split by a factor (or indicator).
- **Empirical distributions** - Create raw or cumulative empirical distributions and view them graphically.
- **Dot plots and violin plots** - Dot plots and violin plots offer a great way to visualise the empirical shape of distributions of sample values across multiple groups for any individual variable.
- **Univariate non-parametric methods** - In P8 you can now implement many standard non-parametric univariate statistical tests. PRIMER's implementation of these tests is novel in that all of these rely on robust permutation algorithms and automatically output relevant graphics as well. Available tests include:
 - *Wilcoxon Signed-Rank test* (paired 2-sample);
 - *Mann-Whitney U test* (unpaired 2-sample);
 - *Kruskal-Wallis test* (compare multiple groups);
 - *Kolmogorov-Smirnov test* (compare empirical distributions); and
 - *Test of Association* (between 2 variables).
- **New PERMANOVA Design file** - The interface for specifying a given study design and various defaults for PERMANOVA have been re-vamped. In P8 it is now easier to specify or modify the design and to fine-tune the model, to add/remove or pool terms, to include/exclude interactions with or among covariates, or to reset the full list of terms implied by a given study design.

- **Allow heterogeneous dispersions** - We have provided some solutions to the multivariate Behrens-Fisher problem for dissimilarity-based analyses ([Anderson et al. \(2017\)](#)). PERMANOVA in P8 now allows you to test for differences in multivariate centroids while allowing for heterogeneity in multivariate dispersions.
- **Finite factors** - The notion of a fixed vs a random factor need not be seen as a strict dichotomy, but rather as a progression ([Anderson et al. \(2025\)](#)). With PERMANOVA in P8, there is a new factor type called 'Finite', in which the user can specify the number of levels in the population from which sampled levels have been drawn. Doing this can greatly increase the power of inferential tests, and is especially useful for tests in broad-scale environmental impact study designs.
- **Split-plot and repeated measures designs** - PERMANOVA in P8 has a new factor type called 'Subject/Whole-plot error', so you can specify sources of error at multiple levels in the study design. This enables repeated measures, split-plot (and split-split-plot, etc.) study designs to be analysed easily and directly.
- **Tests for cyclicity: grouping covariates** - PERMANOVA in P8 allows you to group multiple covariates together (using an indicator), which opens the door to new ways of analysing multivariate patterns of periodicity, cyclicity and other spatio-temporal models.
- **Centroid plots** - New centroid plots allow you to visualise the relative importance of main effects from a multi-factorial PERMANOVA model (**Main Effects Plot**) and to explore the patterns among cell centroids from complex PERMANOVA study designs (**Interaction Plot**), all constructed in the space of your chosen resemblance measure.
- **Residual distances/dissimilarities** - Remove the effects of one or more dominant factors (*via* PERMANOVA) or regressors (*via* DISTLM) and output a residual distance/dissimilarity matrix among the sampling units. Ordination of a residual distance matrix permits visualisation of non-dominant factors.
- **Multivariate control charts** - Create a multivariate control chart on the basis of a chosen resemblance measure. You can build a chart through time (using progressive, baseline or moving-window criteria) and detect when an individual observation is 'out-of-control', given previous observations. This is a fantastic tool for monitoring applications.
- **New standardisation options** - Perform standardisations of samples (or variables) separately within groups (or levels) of indicators (or factors), output values as raw or cumulative percentages or proportions, with ordering specified by you.
- **Create ordered groups from a continuous variable** - Generate a new factor which consists of ordered groups, based on any chosen continuous variable, with a plethora of

optional criteria for defining suitable group boundaries. For example, you can specify quantiles as 'breaks', or create a given number of groups with equal sample sizes per group, or minimise the within-group sum-of-squares, etc.

- **Multi-factor means plots** - Create univariate bar plots or point plots of mean values for factors, with error bars corresponding to standard errors/deviations, or your choice of confidence interval, using either bootstrap percentiles or classical methods. Split your data by additional factors, either within a plot or across different plots, and customise the colours, symbols and/or joining lines.
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