MANOVA – Multivariate analysis of variance

- Multivariate analysis of variance (MANOVA) is simply an ANOVA with several dependent variables.
    - ANOVA tests for the difference in means between two or more groups, while MANOVA tests for the difference in two or more vectors of means.
- Can involve 1 IV or more than 1
- Requires ***parametric*** DVs.

Why do you need MANOVA?

Can use it when there are multiple DVs and IVs in the model to be tested

- ***Type I error probability*** increases with number of variables (i.e. falsely rejecting H_0 – finding an effect when there isn't one)
- More than 1 DV may lead to multiple correlated responses
    - i.e. examines relationships between DVs, which ANOVA doesn't do.
- MANOVA provides a joint test for any significant effects among a set of variables
    - i.e. has a greater power to detect any effects on a group of a *combination* of variables, rather than just one
- Also can be used instead of a repeated measures ANOVA when assumptions of sphericity are violated (i.e. equal variances among the different levels of the groups of IVs – tested with Mauchly's sphericity test).

Assumptions in MANOVA

Similar to ANOVA, but extended for multivariate case

1. ***Independence*** – observations should be statistically independent
2. ***Random sampling*** – data should be randomly sampled from the population of interest and measured at the ***interval*** level.
3. ***Multivariate normality*** – in ANOVA we assume the DV is normally distributed within each group; in MANOVA, we assume that the DVs (collectively) have multivariate normality within groups.
    a. *F*-test is robust to non-normality, if it's caused by skewness rather than outliers
    b. Run tests for, and remove or transform any outliers before doing a MANOVA
4. ***Homogeneity of covariance matrices –*** in an ANOVA we assume homogeneity of variance (the variances in each group are roughly equal). In MANOVA we assume it's true for
    a. Each DV and
    b. The correlation between any 2 DVs is the same in all groups (i.e. level of the $IV_{(s)}$).
    c. Test whether the population variance-covariance matrices of the different groups of analysis are equal
        i. Test univariate equality of variances between the groups – *Levene's test* – shouldn't be significant for any of the DVs

ii. Compare variance-covariance matrices between groups using *Box's test* – should be non-significant if the matrices are the same. Data must show multivariate normality, or lead to erroneous results in Box's test.

Example

- Effect of 2 different text books (IV – 2 levels) on students' improvements in maths and physics (2 DVs)
- Hypothesis – both DVs will be affected by difference in text book
    - Use MANOVA to test this
- Calculate a ***multivariate F-value (Wilks' λ)*** based on the comparison of the error variance / covariance matrix and the effect variance / covariance matrix, instead of univariate *F*.
    - Can also use Hotelling's trace and Pillai's criterion (robust to violations of assumptions).

- The "covariance" here is included because the two measures are probably correlated and we must take this correlation into account when performing the significance test.
- Test the multiple DVs by creating new DVs that maximize group differences. These artificial DVs are linear combinations of the measured DVs.

Aim of a MANOVA

- To establish if response variables (e.g. the students' maths and physics results) are altered by manipulation of the IVs.

e.g.

1. What are the main effects of each IV?
2. What is the interaction between the IVs?
3. What is the importance of the DVs?
4. How are the DVs related?
5. What are the effects of the covariates and how can they be used?

Limitations

1. ***Outliers –***
    - **a.** MANOVA's very sensitive to outliers, which may produce Type I or Type II errors, but not give an indication as to which is occurring.
    - b. Can test for outliers or examine plots.
2. ***Multicollinearity and Singularity***:
    - a. High correlation between DVs, results in one DV becoming a near-linear combination of the other DVs.
    - b. It would then become statistically redundant and suspect to include both combinations.