

MANOVA Basics

Lecture 10

Psy 524

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What is MANOVA

Multivariate Analysis of Variance

- an extension of ANOVA in which main effects and interactions are assessed on a combination of DVs
- MANOVA tests whether mean differences among groups on a combination of DVs is likely to occur by chance

MANOVA

- A new DV is created that is a linear combination of the individual DVs that maximizes the difference between groups.
- In factorial designs a different linear combination of the DVs is created for each main effect and interaction that maximizes the group difference separately.
- Also when the IVs have more than one level the DVs can be recombined to maximize paired comparisons

MANCOVA

- is the multivariate extension of ANCOVA where the linear combination of DVs is adjusted for by one or more continuous covariates.
- A covariate is a variable that is related to the DV, which you can't manipulate, but you want to remove its (their) relationship from the DV before assessing differences on the IVs.

Basic requirements

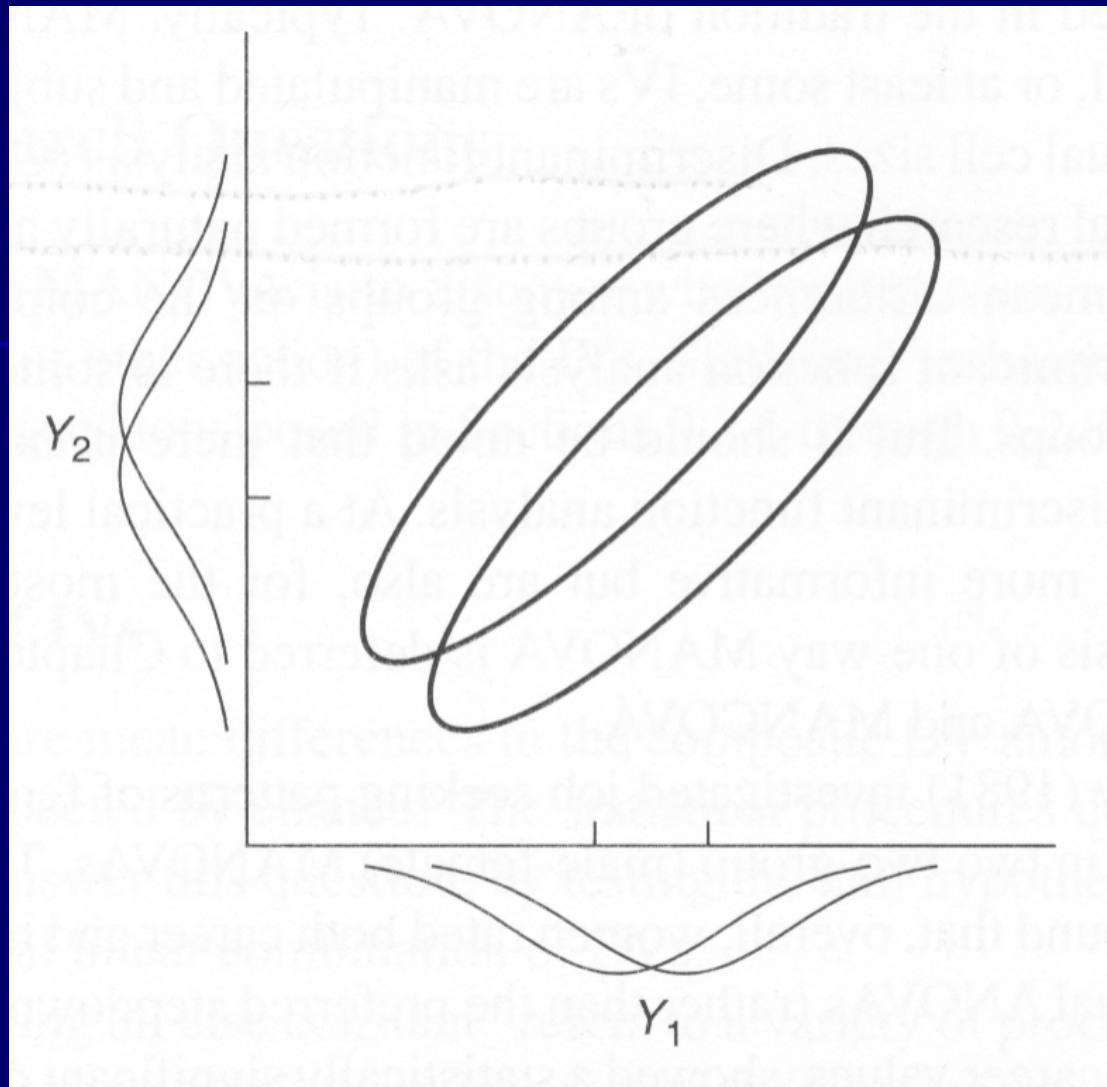
- 2 or more DVs (I, R)
- 1 or more categorical IVs (N, O)
- for MANCOVA you also need 1 or more continuous CVs (I, R)

MANOVA advantages over ANOVA

- By measuring multiple DVs you increase your chances for finding a group difference
- With a single DV you “put all of your eggs in one basket”
- Multiple measures usually do not “cost” a great deal more and you are more likely to find a difference on at least one.

MANOVA advantages over ANOVA

- Using multiple ANOVAs inflates type 1 error rates and MANOVA helps control for the inflation
- Under certain (rare) conditions MANOVA may find differences that do not show up under ANOVA



- Under most circumstance the more complex an analysis becomes the less power there is

Kinds of Research Questions asked by MANOVA

- The questions are mostly the same as ANOVA just on the linearly combined DVs instead just one DV.

Are there any main effects?

- Holding all other effects constant, is a difference among groups greater than expected by chance?

Are there any main effects?

- Holding constant can mean:
 - Controlling for other effects by averaging over them in a factorial design
 - Holding extraneous variables constant or counterbalancing/randomizing their effects
 - Using covariates to adjust the composite DV in order to create a state of “pseudo equality”

Are there any main effects?

- Tests of main effects are orthogonal if they are completely crossed and equal samples in each cell, they are only linked by a common error term

Are there any interactions among the IVs?

- Does change in the linearly combined DV for one IV depend on the levels of another IV?
- For example: Given three types of treatment, does one treatment work better for men and another work better for women?
- If equal samples in each cell then one interaction is independent of main effects and other interactions.

Which DVs are most important?

- If there are any significant main effects or interactions, on which individual DV is there the most change (difference), if any, "caused" by the levels of the IV?
- You can follow a significant MANOVA with individual ANOVAs in order to see on which DV is there large, medium, small or no effect.

Which DVs are most important?

- Another procedure is the Roy-Bargman step-down procedure which uses ANCOVA on each individual DV, with higher priority DVs as covariates.

What are the parameter estimates?

- Marginal means are the best population estimates for the main effects and cell mean are the best estimates of interactions
- When the Roy-Bargman step procedure is used then the interpretation is the best estimates of adjusted population values
- All parameters are accompanied by standard error and/or confidence intervals.

Which levels of the IV are significantly different?

- If there are significant main effects on IVs with more than two levels then you need to test which levels are different from each other
- And if there are interactions the interactions need to be taken apart so that the specific causes of the interaction can be uncovered.

How strong is the IV(s)/composite DV association?

- What is the proportion of the composite DV explained by each IV?
- You can also then pick out the strength of association between the IVs and each DV separately.

- Does use of covariates significantly adjust the composite DV scores?

Can MANOVA be used when assumptions are violated in repeated measure ANOVA?

- The test of sphericity in repeated measures ANOVA is often violated
- Corrections include:
 - adjustments of the degrees of freedom (e.g. Huynh-Feldt adjustment)
 - decomposing the test into multiple paired tests (e.g. trend analysis) or
 - treating the repeated levels as multiple DVs (e.g. profile analysis which we will talk about next)

Assumptions of MANOVA

Theoretical Considerations

- The interpretation of MANOVA results are always taken in the context of the research design.
- Once again, fancy statistics do not make up for poor design
- Use of IVs change the interpretation of other IVs, so choice of IVs to include needs to be thought about carefully

Theoretical Considerations

- Choice of DVs also needs to be carefully considered, highly correlated DVs severely weaken the power of the analysis.
- Choice of the order in which DVs are entered in the stepdown analysis has an impact on interpretation, DVs that are causally (in theory) more important need to be given higher priority
- Generalizability is limited to the population studied

Missing data, unequal samples, number of subjects and power

- Missing data needs to be handled in the usual ways
- Unequal samples cause non-orthogonality and the total sums of squares is less than all of the effects and error added up. This is handled by using either:
 - Type 3 sums of squares assumes the data was intended to be equal and the lack of balance does not reflect anything meaningful
 - Type 1 sums of square which weights the samples by size and emphasizes the difference in samples is meaningful

Missing data, unequal samples, number of subjects and power

- You need more cases than DVs in every cell of the design and this can become difficult when the design becomes complex
- If there are more DVs than cases in any cell the cell will become singular and cannot be inverted. If there are only a few cases more than DVs the assumption of equality of covariance matrices is likely to be rejected.

Missing data, unequal samples, number of subjects and power

- Plus, with a small cases/DV ratio power is likely to be very small and the chance of finding a significant effect, even when there is one, is very unlikely
- you can use programs like GANOVA to calculate power in MANOVA designs or you can estimate it by picking the DV with the smallest effect expected and calculate power on that variable in a univariate method

Missing data, unequal samples, number of subjects and power

- Power in MANOVA also depends on the relationships among the DVs.
 - Power is highest when the pooled within cell correlation is high and negative. If the pooled within correlation is positive, zero or moderately negative the power is much less

Multivariate normality

- assumes that the means of the various DVs in each cell and all linear combinations of them are normally distributed.
- Difficult to show explicitly

Multivariate normality

- In univariate tests robustness against violation of the assumption is assured when the degrees of freedom for error is 20 or more and equal samples
- If there is at least 20 cases in the smallest cell the test is robust to violations of multivariate normality even when there is unequal n .
- If you have smaller unbalanced designs than the assumption is assessed on the basis of researcher judgment.

Absence of outliers

- univariate and multivariate outliers need to be assessed in every cell of the design

Linearity

- MANOVA and MANCOVA assume linear relationships between all DVs, all CVs and all DV/CV pairs

Linearity

- Deviations from linearity reduce the power of the test because:
 - the linear combination of DVs does not maximize the difference between the groups
 - the CVs do not maximally adjust the error.

Homogeneity of regression

- no IV by CV interaction

Reliability of CVs and DVs

- reliability of CVs discussed previously.
- In the stepdown procedure in order for proper interpretation of the DVs as CVs the DVs should also have reliability in excess of .8

Absence of Multicollinearity/Singularity

- in each cell of the design.
- You do not want redundant DVs or CVs

Homogeneity of Covariance Matrices

- this is the multivariate equivalent of homogeneity of variance.
- Assumes that the variance/covariance matrix in each cell of the design is sampled from the same population so they can be reasonably pooled together to make an error term

Homogeneity of Covariance Matrices

- If sample sizes are equal MANOVA has been shown to be robust to violations so Box's M test can be ignored (it is highly sensitive anyway)

Homogeneity of Covariance Matrices

- If sample sizes are unequal than evaluate Box's M test at $\alpha < .001$. If this is met than a violation has occurred and the robustness of the test is questionable.

Homogeneity of Covariance Matrices

- Look than at the data:
 - If cells with larger samples have larger variances than the test is most likely robust
 - If the cells with fewer cases have larger variances than only null hypotheses are retained with confidence but to reject them is questionable. Use of a more stringent criterion (Pillai's criteria instead of Wilk's; more on this later)