Neuendorf
MANOVA /MANCOVA

Like ANOVA/ANCOVA:

1. Assumes equal variance (equal covariance matrices) across cells (groups defined by the IVS). Box's M tests for this. Once again, this is a "homoscedasticity" issue.

2. Assumes univariate and multivariate normality of the DVs.

3. Assumes independence of observations. Given the heavy use of the ANOVA model with experimental designs, this translates generally to a concern with the threats to internal validity expressed by Campbell and Stanley, a concern over experimental administration variations over time, and a concern over using group administration.

4. Can specify a full or partial model (e.g., full model for a two-factor ANOVA or MANOVA would be: main effects A and B, interaction effect A x B). MANOVA will provide a separate set of tests for each effect. Note that a single-factor MANOVA is very much like discriminant analysis, but with the presumed "causal flow" reversed.

5. You may choose to conduct post hoc tests, such as Scheffe's or Tukey's. See Hair et al., Keppel, or the excellent Winer book (look under "a posteriori tests", same as "post hoc").

6. May include covariates (i.e., conduct MANCOVA)--I/R variables that correlate with the DVs but not the IVs. Including these variables as covariates in the model controls for their effect on the DVs. That is, MANOVA is conducted on the residuals of the DVs after they are regressed on the covariates.

Unlike ANOVA/ANCOVA:

1. Handles multiple DVs, which are correlated. Indeed, if the DVs are not correlated, there's no advantage to MANOVA over conducting a series of ANOVAs with an adjustment for alpha, such as Bonferroni (see below). You should check a correlation matrix (or generate a Bartlett's test with Factor Analysis) to assure that the DVs are significantly correlated.

2 When an effect is significant, it means that the DF(s) (DF=discriminant function, a linear composite of the DVs, sometimes called "canonical root" in MANOVA) is/are significantly different among groups on that effect. . . remember that in MANOVA, as in many multivariate procedures, we become "a step removed" from the original variables, in this case the DVs. Also, note that the DF(s) is/are *different* for each effect (each IV or interaction of IVs; each main effect or interaction). The number of DFs that may be derived is c-1 (where c=# of categories on the IV effect) or k (where k=# of DVs), whichever is smaller.

Statistics:

1. Often, in the report of a piece of research, it is reported that "omnibus MANOVA" is run to verify that the set of DVs enjoys significance on the effect, and then only ANOVAs are tabled. More rarely, <u>true</u> MANOVA stats are presented:

   True MANOVA tests--each of the 4 tests for multivariate differences among the groups *on that particular effect*. They will *generally* (but not always) be either statistically significant as a group, or non-significant as a group. (However, Roy's may be quite different because it considers the first DF only.):

   Pillai's Trace = $V = \sum \frac{\lambda_i}{1 + \lambda_i}$ (sum of explained variances on each of the DFs)

   Wilks' Lambda = $\Lambda = \prod \frac{1}{1 + \lambda_i}$ (product of unexplained variances on each of the DFs)

   Hotelling's Trace = $T = \Sigma\ \lambda_i$ (sum of SS_B/SS_W for DFs)

   Roy's Largest Root = $R = \frac{\lambda_{MAX}}{1 + \lambda_{MAX}}$ (proportion variance explained for the *first* DF only)
   (or, Greatest Characteristic Root)

   where λ_i = the eigenvalue for each discriminant function (or canonical root, i.e., each linear composite of the DVs)

   Also, note that:

   $\lambda_i = \frac{SS_B}{SS_W}$ = ratio of explained to unexplained variances

   $\frac{1}{1 + \lambda_i} = \frac{SS_W}{SS_{TOT}}$ = proportion variance unexplained

   $\frac{\lambda_i}{1 + \lambda_i} = \frac{SS_B}{SS_{TOT}}$ = proportion variance explained

   Each of the above four stats (Pillai's, Wilks', Hotelling's, Roy's) is transformed to an F test, and its significance is assessed. Pillai's is the most robust (resistant to violations of test assumptions).

2. Partial eta squared–The eta squared statistic is generally a measure of the proportion of variance explained in a DV (usually by group differences of a categorical IV). In MANOVA, it is specifically the proportion of the total DVs' variability that is attributable to a given factor (main

effect or interaction). In MANOVA, it is reported as a partial (i.e., the proportion explained by that factor when controlling for all other factors in the equation/model).

3. Power–the GLM procedures in SPSS are the only ones for which power estimates are available!

4. Box's M--Tests the assumption of equality of the covariance matrices across the cells (groups as specified by the IVs). We hope for non-significance, just as in the case of discriminant analysis.

5. Levene's test of Equality of Error Variances–In general, Levene's test assesses whether variances compared across groups are equal. In the MANOVA application, it tests the null hypothesis that the error variance of the DV is equal across groups. We hope for non-significance.

6. Bartlett's Test of Sphericity–In general, this test assesses whether a matrix differs significantly from an identity matrix. In the MANOVA application, it tests the null hypothesis that the residual covariance matrix is proportional to an identity matrix. (i.e., Are there still correlations among the DV's after imposing the model? This is not a test of the original, plain correlation matrix.) We hope for non-significance.

7. Bonferroni correction for cumulative Type I error--When multiple tests are run (in this case, using the same IVS), and capitalization on chance is a real threat, a simple Bonferroni adjustment may be used--

$$\text{Bon } \alpha = \frac{\text{selected } \alpha}{\#\text{ of tests}}$$

8. Stepdown analysis for DVs--like a hierarchical inclusion process, this treats some DVs as covariates (controls) by entering them first in the DF.

9. F tests for each DV separately--found in the SPSS output under "Tests of Between-Subjects Effects." SPSS provides them readily with MANOVA, but they're not truly MANOVA. Still, this seems to be the common method of "making sense" of an overall significant MANOVA model. The means that "go with" the Fs are found under "Descriptive Statistics" on the MANOVA output.

Statistics that can inform a MANOVA analysis. . . but must be obtained via syntax ("old" SPSS):

10. Discriminant function coefficients (standardized and unstandardized)--

$$DF1 = ß_1Y1_z + ß_2Y2_z + ß_3Y3_z \ldots$$

Like regression coefficients, these ßs show unique contributions to the DF (linear composite of DVs, in this case). They help us interpret the DF. By the way, remember that there will be a different set of DFs for each IV effect or covariate. NOTE: What's not directly obtainable is the

DF values for the groups! There's no SAVE function for the MANOVA syntax, so one would have to construct the DFs via COMPUTES. Yikes!

11. Correlations between each DV and DF (or canonical root)--These are the simple relationships between the DV and a given DF; they also help us interpret the DF.

12. Canonical correlation--This is the correlation between a DF (or canonical root) and an IV effect (treated as a set of dummies).

The syntax to get the above:

```
MANOVA   DV1 DV2 DV3 DV4 by IV1 (1,2) IV2 (1,5)
        /discrim=raw stan
        /print=signif (hypoth multiv univ eigen)
        /design.
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[NOTE: 1 and 2, 1 and 5 are min and max for each of the two IVs.]

References

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Keppel, G. (1991). *Design and analysis: A researcher's handbook* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Winer, B. J. (1971). *Statistical principles in experimental design* (2nd ed.). New York: McGraw-Hill Book Co.

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