Multiple Analysis of Variance (MANOVA) or Multiple Analysis of Covariance (MANCOVA).
Kelly Davis

- Goals, assumptions, data required.

Goals

MANOVA can be an appropriate statistical technique when an ANOVA-like analysis is desired for more than one dependent variable. The goal of the MANOVA is to test whether mean differences among the groups (independent variable) on a combination of dependent variables are likely to have occurred by chance. This is achieved by creating a single dependent measure from a combination of all dependent measures that maximizes the between group differences. By including more than one dependent measure, the researcher improves the chance of discovering what can change between different treatments or measures that more clearly defines the groups.

MANCOVA is the multivariate version of ANCOVA. MANCOVA determines whether there are of statistically reliable mean differences among groups, after adjusting the newly created dependent measure on one or more covariates.

Essentially, a wider net is cast to explain between group differences as a result of the dependent measures, and their interactions. It is possible that these interactions can reveal differences that traditional ANOVAs cannot. However, as Tabachnick & Fidell point out, these cases may be rare, and that more often ANOVA is a more powerful technique than MANOVA. This wide net, however, is often at the cost of a larger sample size, as explained further in the assumptions.

Assumptions

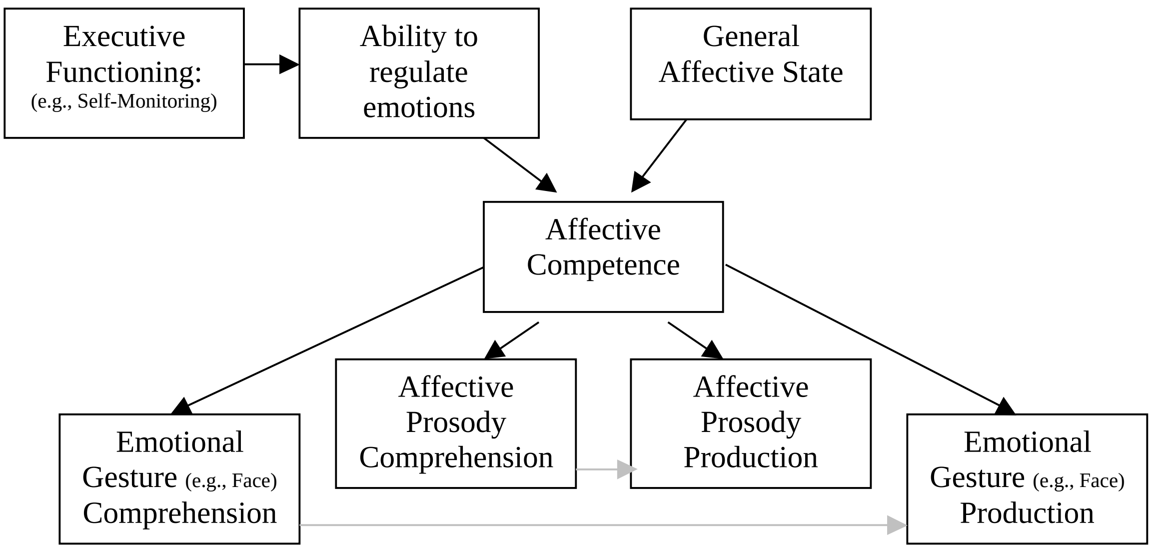
- The observations are independent: that is that random sampling is employed, observations are not susceptible to influence of other observations. This reduces Type I error.
- Multivariate dependent variables are normally distributed for each group. In other words, any linear combination of the variables is normally distributed. This includes evaluating the normality of each level of each variable for each group. This reduces Type I error.
- The covariance matrices for dependent variables are equal. This reduces Type I error and increases statistical power.
- There must be a linear relationship between the dependent variable(s) and the covariate.
- The slope of the regression line for the covariate is the same in each group.

Data required

Independent variables should be grouped by treatment, or by clear nominal definitions (e.g., patient groups). Dependent variables and covariates should be continuous data derived from ratio/ordinal level measurements. The best choice of a set of dependent measures are those that aren't correlated with each other, because they are more likely to capture unique variance. However, sometimes conceptual reasons for choosing related dependent variables warrant their inclusion. Additionally, covariates should be chosen carefully, from among those variables that have strong correlations with the dependent measure(s) that are statistically significant. However, these covariates should be independent of one another.

Define (conceptually and operationally), the variables of interest.

The data that I present to illustrate the MANCOVA is preliminary data for my dissertation entitled: "Comprehension of Emotion in Neurodegenerative Disorders." I hypothesize that patients in the early stages of Parkinson's disease will be impaired on a measure of emotional prosody comprehension, relative to a measure of non-emotional prosody comprehension (i.e., within group comparison of paired t-test), as well as a neurologically healthy control group. However, I am attempting to support a theoretical model of emotional prosody, and need to assess several background measures to mete out why this hypothesized effect occurs in Parkinson's disease. Although a full explanation of the theoretical model is beyond the scope of this illustration, let me briefly outline the constructs that are of interest to this analysis.



As illustrated in this figure, I hypothesize that emotional prosody comprehension is influenced by "affective competence." Affective competence refers to the ability to feel, express and understand emotions from within and to accurately interpret emotional states of others based on their behaviors (e.g., verbal communication, emotional prosody, affect, facial expressions, gestures). An individual's general affective state, and his ability to appropriately regulate emotions influence affective competence. (An individual's general affective state is controlled for in this study by selecting non-depressed participants without psychiatric history.) The ability to regulate emotions in an appropriate manner is related to executive functioning. The comprehension and expression of emotional prosody is a manifestation of affective competence, and is paralleled by other modes of emotional comprehension and expression. While there are potentially a handful of other modes of emotional expressions, facial expressions have been well examined, and will serve as a non-verbal control condition for the proposed study.

Given that I have found a within group difference between affective and non-affective prosody comprehension, I wish to determine if this can be explained by other known factors present in Parkinson's disease. Essentially the questions of interest are…

Is the emotional prosody comprehension deficit due to:

A general emotional comprehension deficit? If this is the case, one would expect deficits in comprehension of emotion in other modalities. This is evaluated with the Penn Emotion Recognition Test-40 item version (Gur et al., 2001; Moelter et al., 1999). This task presents pictures of emotional faces and asks participants to choose the emotion being expressed among 4 categories or "no emotion." Total correct identifications (out of a possible 40 points) are the operational variable. This variable is suspect for a covariate in the MANCOVA analysis.

Problems in acoustic perception? If this is the case, one would expect deficits in detecting just noticeable differences in pitch, volume, and duration as measured by the Penn Continuum of Emotional Prosody (Davis, Liberman & Grossman, in preparation). Four syllable utterances are played and participants determine whether the pitch, volume, or duration is of greater, lesser, or the same intensity on the least syllable using a 5-point Likert scale. Actual judgements on this scale are subtracted from expected values (as identified measuring the actual acoustic properties of each utterance). The sum of the absolute values of these difference scores creates a continuous variable. As this measure is an estimate of the difference between expected and observed values, it is treated conceptually as an error score (i.e., lower score means better performance). There are three separate levels for this dependent variable, of duration, pitch, and volume, respectively.

Problems in executive functioning? Past research has shown that task demands can account for some prosody comprehension deficits in unilateral lesions. Given that there is executive dysfunction in PD, is that related to the self-monitoring of emotions in orbitofrontal areas disconnected from the striate loops by PD? This is measured by the sum of total correct trials on the Letter-Number Sequencing subtest from the WAIS-3. This variable is a potential covariate in the MANCOVA analysis.

Other variables of interest include:

Diagnostic Group: Eventually, there will be enough data to have n=20 for three groups, PD, Elderly controls, and young controls. However, there's not that much data collected so far, so I am combining both control groups. Therefore this independent variable of group has two levels, control (n=20) and PD (n=8). ONE SHOULD IMMEDIATELY BE ALARMED THAT THIS ANALYSIS WOULD BE ATTEMPTED WITH SUCH A SMALL NUMBER OF SUBJECTS, and WITH UNEQUAL GROUPS. I ACKNOWLEDGE THIS, YET EMBRACE THE PEDAGOGICAL EXPERIENCE OF EXAMINING THE STATISTICAL TECHNIQUE I WILL EVENTUALLY EMPLOY FOR THESE DATA. ONCE I HAVE COLLECTED DATA FROM MORE SUBJECTS, I WOULD BE HAPPY TO REVISE THIS SECTION USING THE FULL DATA SET FOR ANY WWW POSTINGS.

Prosody Comprehension: This dependent variable includes two levels: the emotional task, and a non-emotional, non-linguistic task that varies interlocutor distance (called "distance condition"). Both of these are evaluated on a 5-point Likert scale, and the sum of the absolute difference scores from expected values (based on normative data) is the operational variable. Both DVs are scaled in the same manner, such that a higher score means poorer performance.

4. Interpret the output file

Before proceeding with the analysis of interest, let's choose the covariates for the MANCOVA.

- - Correlation Coefficients - -

	BDI_2	BENT_FAC	DIST_ABS	DUR_ABS	EDUC	EMO_ABS
BDI_2	1.0000 (30) P= .	.2712 (30) P= .147	.0175 (26) P= .932	-.1022 (23) P= .643	-.1341 (30) P= .480	.1491 (26) P= .467
BENT_FAC	.2712 (30) P= .147	1.0000 (30) P= .	.0343 (26) P= .868	-.3228 (23) P= .133	.0552 (30) P= .772	-.1452 (26) P= .479
DIST_ABS	.0175 (26) P= .932	.0343 (26) P= .868	1.0000 (28) P= .	.2695 (23) P= .214	.0237 (27) P= .906	.5555 (28) P= .002
DUR_ABS	-.1022 (23) P= .643	-.3228 (23) P= .133	.2695 (23) P= .214	1.0000 (24) P= .	-.3567 (23) P= .095	.4896 (23) P= .018
EDUC	-.1341 (30) P= .480	.0552 (30) P= .772	.0237 (27) P= .906	-.3567 (23) P= .095	1.0000 (31) P= .	-.2016 (27) P= .313
EMO_ABS	.1491 (26) P= .467	-.1452 (26) P= .479	.5555 (28) P= .002	.4896 (23) P= .018	-.2016 (27) P= .313	1.0000 (28) P= .
AGE	.1870 (30) P= .323	-.0789 (30) P= .679	.3458 (27) P= .077	.4116 (23) P= .051	.2341 (31) P= .205	.5707 (27) P= .002
LET_NUMB	.0752 (30) P= .693	.3069 (30) P= .099	-.5711 (26) P= .002	-.4873 (23) P= .018	.1074 (30) P= .572	-.5778 (26) P= .002
MMSE	.0318 (15) P= .911	.4289 (15) P= .111	.3455 (13) P= .248	-.2101 (12) P= .512	-.1141 (15) P= .686	-.0816 (13) P= .791
PERT40	.2112 (28) P= .281	.4625 (28) P= .013	-.4231 (24) P= .039	-.2780 (22) P= .210	-.1534 (28) P= .436	-.3624 (24) P= .082
PIT_ABS	.1282 (23) P= .560	-.1746 (23) P= .426	.1758 (23) P= .422	.6815 (24) P= .000	-.3366 (23) P= .116	.4622 (23) P= .026
VOL_ABS	-.0129 (23) P= .954	-.3549 (23) P= .097	-.0744 (23) P= .736	.4943 (24) P= .014	-.3143 (23) P= .144	.1020 (23) P= .643

(Coefficient / (Cases) / 2-tailed Significance)

	AGE	LET_NUMB	MMSE	PERT40	PIT_ABS	VOL_ABS
BDI_2	.1870 (30) P= .323	.0752 (30) P= .693	.0318 (15) P= .911	.2112 (28) P= .281	.1282 (23) P= .560	-.0129 (23) P= .954
BENT_FAC	-.0789 (30) P= .679	.3069 (30) P= .099	.4289 (15) P= .111	.4625 (28) P= .013	-.1746 (23) P= .426	-.3549 (23) P= .097
DIST_ABS	.3458 (27) P= .077	-.5711 (26) P= .002	.3455 (13) P= .248	-.4231 (24) P= .039	.1758 (23) P= .422	-.0744 (23) P= .736
DUR_ABS	.4116 (23) P= .051	-.4873 (23) P= .018	-.2101 (12) P= .512	-.2780 (22) P= .210	.6815 (24) P= .000	.4943 (24) P= .014
EDUC	.2341 (31) P= .205	.1074 (30) P= .572	-.1141 (15) P= .686	-.1534 (28) P= .436	-.3366 (23) P= .116	-.3143 (23) P= .144
EMO_ABS	.5707 (27) P= .002	-.5778 (26) P= .002	-.0816 (13) P= .791	-.3624 (24) P= .082	.4622 (23) P= .026	.1020 (23) P= .643
AGE	1.0000 (31) P= .	-.4515 (30) P= .012	-.5288 (15) P= .043	-.4244 (28) P= .024	.4856 (23) P= .019	.1671 (23) P= .446
LET_NUMB	-.4515 (30) P= .012	1.0000 (30) P= .	.4220 (15) P= .117	.4871 (28) P= .009	-.3722 (23) P= .080	-.3050 (23) P= .157
MMSE	-.5288 (15) P= .043	.4220 (15) P= .117	1.0000 (15) P= .	.0690 (14) P= .815	-.0708 (12) P= .827	-.1238 (12) P= .701
PERT40	-.4244 (28) P= .024	.4871 (28) P= .009	.0690 (14) P= .815	1.0000 (28) P= .	-.3840 (22) P= .078	-.2588 (22) P= .245
PIT_ABS	.4856 (23) P= .019	-.3722 (23) P= .080	-.0708 (12) P= .827	-.3840 (22) P= .078	1.0000 (24) P= .	.5304 (24) P= .008
VOL_ABS	.1671 (23) P= .446	-.3050 (23) P= .157	-.1238 (12) P= .701	-.2588 (22) P= .245	.5304 (24) P= .008	1.0000 (24) P= .

(Coefficient / (Cases) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

Whew! There are quite a few correlated variables in there. Of those variables that correlate with the dependent variables, let's examine the PERT40, age, and LET_ NUMB. Age correlates with PERT40, LET_NUMB, and some of the DVs, so let's include that as a covariate. I know that this sample is young control heavy at this point, so that may account for some of the correlation in this current sampling. Also, PERT40 correlates with LET_NUMB. Although we think that these may mediate the effect of the DVs, correlations among the covariates is not desirable. It's also possible that the age covariate may really clear things up, so lets stick with age for now. Another "housekeeping" issue would be to collapse a DV. I did a series of one-way repeated measures ANOVA on the acoustic screening for both groups and found that there were no significant differences between duration, pitch and volume for each group. To free up some degrees of freedom (and boy do I need them for this data set), let's combine those scores into one score. Thus the second DV of ACOUSTIC will now have one level, instead of three.

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* * * * * * A n a l y s i s   o f   V a r i a n c e * * * * * *


        19 cases accepted.
         3 cases rejected because of out-of-range factor values.
        10 cases rejected because of missing data.
```

My Goodness, that's a lot of missing data. I know this is because some measures haven't been collected yet. As I mentioned, this is a work in progress. If this were my final data set, I would consider replacing these empty cells with mean values. But that has its drawbacks.

```
         2 non-empty cells.

         1 design will be processed.

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
               CELL NUMBER
                 1    2
 Variable
   GR_DX         1    2

 Univariate Homogeneity of Variance Tests
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I included this option to address one of the assumptions of the MANCOVA. Looks like I'm OK on this assumption (although I've violated about everything else!)

```
 Variable .. ACOUSTIC

       Cochrans C(9,2) =                          .73750, P =  .140
(approx.)
       Bartlett-Box F(1,226) =                   1.44964, P =  .230

 Variable .. DIST_ABS

       Cochrans C(9,2) =                          .73279, P =  .149
(approx.)
       Bartlett-Box F(1,226) =                    .90150, P =  .343

 Variable .. EMO_ABS

       Cochrans C(9,2) =                          .77346, P =  .082
(approx.)
       Bartlett-Box F(1,226) =                   1.27427, P =  .260
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 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Cell Number .. 1

 Determinant of Covariance matrix of dependent variables =  202239524.68143
 LOG(Determinant) =                                                19.12496

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 Cell Number .. 2

 Determinant of Covariance matrix of dependent variables =    1581712.03704
 LOG(Determinant) =                                                14.27402

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 Determinant of pooled Covariance matrix of dependent vars. = 284461734.59697
 LOG(Determinant) =                                                  19.46611
```

That was for another assumption. These look pretty well distributed so far.

```
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* * * * * * A n a l y s i s   o f   V a r i a n c e -- design   1 * * * * * *


 Multivariate test for Homogeneity of Dispersion matrices


 Boxs M =                         20.35232
 F WITH (6,168) DF =               2.00006, P =   .068 (Approx.)
 Chi-Square with 6 DF =           12.72495, P =   .048 (Approx.)


 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -



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* * * * * * A n a l y s i s   o f   V a r i a n c e -- design   1 * * * * * *

 Combined Observed Means for GR_DX
 Variable .. ACOUSTIC
         GR_DX
             1        WGT.    56.46667
                    UNWGT.    56.46667
             2        WGT.    75.50000
                    UNWGT.    75.50000

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 Variable .. DIST_ABS
         GR_DX
```

```
            1        WGT.    25.33333
                   UNWGT.    25.33333
            2        WGT.    28.75000
                   UNWGT.    28.75000

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 Variable .. EMO_ABS
         GR_DX
            1        WGT.    38.26667
                   UNWGT.    38.26667
            2        WGT.    40.75000
                   UNWGT.    40.75000
```

Huh- didn't expect the emotion and distance to be so similar. Also, it seems that the PD group (#2) is doing poorly on the acoustic measure. But those are just the means. Let's look further.

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 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Variable .. AGE
         GR_DX
            1        WGT.    32.20000
                   UNWGT.    32.20000
            2        WGT.    66.50000
                   UNWGT.    66.50000

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```


* * * * * * A n a l y s i s   o f   V a r i a n c e -- design   1 * * * * * *

EFFECT .. WITHIN+RESIDUAL Regression
Multivariate Tests of Significance (S = 1, M = 1/2, N = 6)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.55155	5.73966	3.00	14.00	.009
Hotellings	1.22993	5.73966	3.00	14.00	.009
Wilks	.44845	5.73966	3.00	14.00	.009
Roys	.55155				

Note.. F statistics are exact.

OK- that's more like it. This can be interpreted as a main effect of acoustic and prosody measures differentiating my diagnostic groups.

- -

EFFECT .. WITHIN+RESIDUAL Regression (Cont.)
Univariate F-tests with (1,16) D. F.

Variable	Hypoth. SS	Error SS	Hypoth. MS	Error MS	F
ACOUSTIC	2076.88885	19985.84448	2076.88885	1249.11528	1.66269
DIST_ABS	1557.86542	5986.21791	1557.86542	374.13862	4.16387
EMO_ABS	10442.77480	8636.90853	10442.77480	539.80678	19.34539

Variable	Sig. of F
ACOUSTIC	.216
DIST_ABS	.058

EMO_ABS .000

This tells me that the main effect appears to be "driven" by the emotional prosody scores, and nothing else.

- -

Regression analysis for WITHIN+RESIDUAL error term
--- Individual Univariate .9500 confidence intervals
Dependent variable .. ACOUSTIC

COVARIATE	B	Beta	Std. Err.	t-Value	Sig. of t
AGE	.56520	.37502	.438	1.289	.216

COVARIATE	Lower -95%	CL- Upper
AGE	-.364	1.494

Dependent variable .. DIST_ABS

COVARIATE	B	Beta	Std. Err.	t-Value	Sig. of t
AGE	.48951	.56827	.240	2.041	.058

COVARIATE	Lower -95%	CL- Upper
AGE	-.019	.998

These seem to be congruent with the univariate tests. It didn't seem to print a regression of the covariate (age) on emotion though. I don't know why. If you think I really should, gimme a "B". ☺

* * * * * * A n a l y s i s o f V a r i a n c e -- design 1 * * * * * *

Regression analysis for WITHIN+RESIDUAL error term (Cont.)
Dependent variable .. EMO_ABS

COVARIATE	B	Beta	Std. Err.	t-Value	Sig. of t
AGE	1.26737	.92694	.288	4.398	.000

COVARIATE	Lower -95%	CL- Upper
AGE	.657	1.878

- -

Oh- there it is… just on the next page. Now you have no excuse to give me a "B" ☺ This tells me that I was probably on the right track for choosing age as a covariate. I doubt I could get more variance from the PERT40 or NUMB_LET.

* * * * * * A n a l y s i s o f V a r i a n c e -- design 1 * * * * * *

EFFECT .. GR_DX

Multivariate Tests of Significance (S = 1, M = 1/2, N = 6)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.32535	2.25045	3.00	14.00	.127
Hotellings	.48224	2.25045	3.00	14.00	.127
Wilks	.67465	2.25045	3.00	14.00	.127
Roys	.32535				

Note.. F statistics are exact.

- -

EFFECT .. GR_DX (Cont.)
Univariate F-tests with (1,16) D. F.

Variable	Hypoth. SS	Error SS	Hypoth. MS	Error MS	F	Sig. of F
ACOUSTIC	.25051	19985.8445	.25051	1249.11528	.00020	.989
DIST_ABS	359.40869	5986.21791	359.40869	374.13862	.96063	.342
EMO_ABS	3375.98943	8636.90853	3375.98943	539.80678	6.25407	.024

Same deal as before: Emotion seems to be playing a big factor, yet the main effect has vanished now that the covariate is figured in.

- -

Adjusted and Estimated Means
Variable .. ACOUSTIC

CELL	Obs. Mean	Adj. Mean	Est. Mean	Raw Resid.	Std. Resid.
1	56.467	66.160	56.467	.000	.000
2	75.500	65.807	75.500	.000	.000

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Adjusted and Estimated Means (Cont.)
Variable .. DIST_ABS

CELL	Obs. Mean	Adj. Mean	Est. Mean	Raw Resid.	Std. Resid.
1	25.333	33.728	25.333	.000	.000
2	28.750	20.355	28.750	.000	.000

- -

Adjusted and Estimated Means (Cont.)
Variable .. EMO_ABS

CELL	Obs. Mean	Adj. Mean	Est. Mean	Raw Resid.	Std. Resid.
1	38.267	60.002	38.267	.000	.000
2	40.750	19.015	40.750	.000	.000

* * * * * * A n a l y s i s   o f   V a r i a n c e -- design   1 * * * * * *

Combined Adjusted Means for GR_DX
Variable .. ACOUSTIC

```
        GR_DX
            1      UNWGT.    66.15987
            2      UNWGT.    65.80680

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 Variable .. DIST_ABS
        GR_DX
            1      UNWGT.    33.72843
            2      UNWGT.    20.35490

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 Variable .. EMO_ABS
        GR_DX
            1      UNWGT.    60.00212
            2      UNWGT.    19.01455

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