Factorial MANCOVA Example

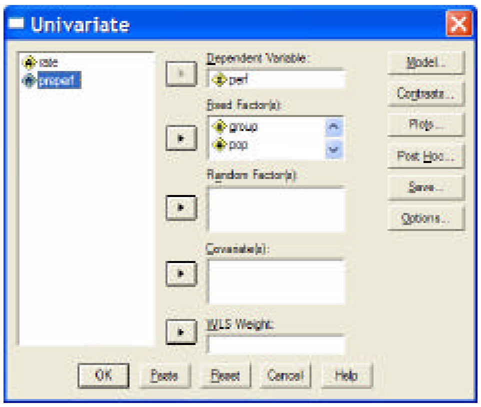
The data are taken from a "minimal" MANOVA design -- 2 2-group IVs, 2 DVs and a single covariate.

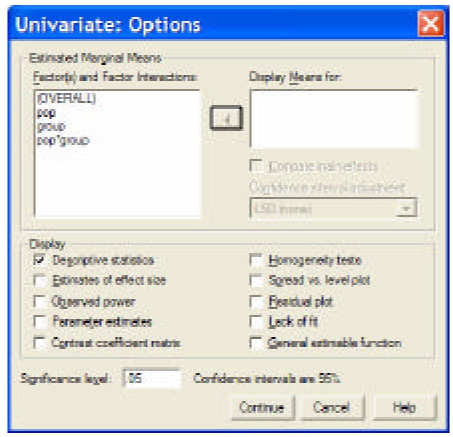
Group*Treatment design. There are two DVs (Performance & Evaluation Rating). A performance pretest is the covariate.

We'll proceed from factorial ANOVAs with each DV and the covariate, through ANCOVAs with each DV-covariate pair, then a factorial MANOVA and finally the factorial MANCOVA analysis. As we work through the progression watch for changes in the "effects" and consider whether or not we learn anything new from each successively more complex analysis.

Factorial ANOVAs of each DV and the Covariate

Factorial ANOVA with Performance as the DV





Descriptive Statistics

Dependent Variable: PERF

POP	GROUP	Mean	Std. Deviation	N
1.00	1.00	35.5097	10.25415	18
	2.00	45.6378	11.13390	20
	Total	40.8403	11.75725	38
2.00	1.00	55.7257	8.06672	29
	2.00	43.6741	11.91757	14
	Total	51.8019	10.95416	43
Total	1.00	47.9834	13.30950	47
	2.00	44.8292	11.32634	34
	Total	46.6594	12.53908	81

Tests of Between-Subjects Effects

Dependent Variable: PERF

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4767.072[a]	3	1589.024	15.664	.000
Intercept	154148.508	1	154148.508	1519.539	.000
GROUP	17.496	1	17.496	.172	.679
POP	1575.415	1	1575.415	15.530	.000
GROUP * POP	2326.318	1	2326.318	22.932	.000
Error	7811.209	77	101.444		
Total	188923.408	81			
Corrected Total	12578.281	80			

a. R Squared = .379 (Adjusted R Squared = .355)

There is an interaction

$df_{error} = 77$ $MS_{error} = 101.44$ n = 81/4 = 20.5   LSDmmd = 6.33

The pattern of the interaction is:

Population 1 G1 < G2   or   Group 1 Pop1 < Pop 2
Population 2 G1 > G2   Group 2 Pop1 = Pop 2

There is no main effect of Group (which is misleading for both populations)

There is a main effect for Population -- Pop 1 < Pop 2 (which is misleading for Group 2)

Factorial ANOVA with Evaluation Rating as the DV

Descriptive Statistics

Dependent Variable: RATE

POP	GROUP	Mean	Std. Deviation	N
1.00	1.00	3.6889	3.06610	18
	2.00	3.2460	3.58948	20
	Total	3.4558	3.31450	38
2.00	1.00	5.8238	2.77815	29
	2.00	5.2374	2.53035	14
	Total	5.6329	2.68412	43
Total	1.00	5.0062	3.04512	47
	2.00	4.0660	3.30609	34
	Total	4.6115	3.17152	81

Tests of Between-Subjects Effects

Dependent Variable: RATE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	100.722[a]	3	33.574	3.672	.016
Intercept	1531.487	1	1531.487	167.52	.000
POP	80.519	1	80.519	8.807	.004
GROUP	5.010	1	5.010	.548	.461
POP * GROUP	.097	1	.097	.011	.918
Error	703.962	77	9.142		
Total	2527.244	81			
Corrected Total	804.684	80			

a. R Squared = .125 (Adjusted R Squared = .091)

There is no interaction.

There is a main effect of Population -- P1< P2

There is no main effect for Group.

Factorial ANOVA with Performance Pretest as the DV -- to check for pattern of initial non-equivalence

Descriptive Statistics

Dependent Variable: PREPERF

POP	GROUP	Mean	Std. Deviation	N
1.00	1.00	21.1190	17.83843	18
	2.00	21.1774	14.81931	20
	Total	21.1497	16.09282	38
2.00	1.00	34.6660	13.51042	29
	2.00	20.5773	13.29106	14
	Total	30.0790	14.86564	43
Total	1.00	29.4778	16.52317	47
	2.00	20.9303	14.00441	34
	Total	25.8899	15.99692	81

Tests of Between-Subjects Effects

Dependent Variable: PREPERF

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3482.556[a]	3	1160.9	5.261	.002
Intercept	44990.448	1	44990	203.906	.000
POP	792.671	1	792.671	3.593	.062
GROUP	930.866	1	930.866	4.219	.043
POP * GROUP	946.429	1	946.429	4.289	.042
Error	16989.550	77	220.644		
Total	74765.529	81			
Corrected Total	20472.106	80			

a. R Squared = .170 (Adjusted R Squared = .138)

There is an interaction

df_{error} = 77 MS_{error} = 220.644 n = 81/4 = 20.5 LSDmmd = 9.279

The pattern of the interaction is:

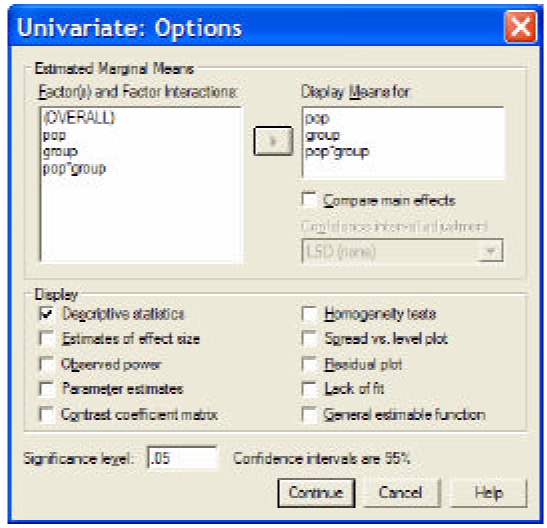
Population 1	G1	=	G2	or	Group 1	Pop1	<	Pop 2
Population 2	G1	>	G2		Group 2	Pop1	=	Pop 2

There is a main effect of Group -- Group 1 > Group 2 (which is descriptive for Pop 2 but misleading for Pop 1)

There is no main effect for Population (which is descriptive for Group 2 but misleading for Group 1)

The presence of covariate “effects” suggests that patterns of corrected means for the DVs will be somewhat different from the patterns of the uncorrected means described above. Let’s see…

ANCOVA with Performance as the DV & Performance Pre-test as the covariate



Tests of Between-Subjects Effects

Dependent Variable: PERF

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8454.906[a]	4	2113.726	38.959	.000
Intercept	23660.274	1	23660.274	436.094	.000
PREPERF	3687.834	1	3687.834	67.972	.000
POP	674.714	1	674.714	12.436	.001
GROUP	95.412	1	95.412	1.759	.189
POP * GROUP	1088.497	1	1088.497	20.063	.000
Error	4123.375	76	54.255		
Total	188923.408	81			
Corrected Total	12578.281	80			

a. R Squared = .672 (Adjusted R Squared = .655)

There is a strong relationship between the covariate (preperf) and the DV (perf), after controlling for the main and interaction effects.

Notice that the MSerror is much smaller in this ANCOVA than it was in the ANOVA with perf as the DV.

This analysis also shows a significant interaction and a significant main effect for population.

The patterns of these effects can be described based on the corrected means.

3. POP * GROUP

Dependent Variable: PERF

POP	GROUP	Mean	Std. Error
1.00	1.00	37.732[a]	1.757
	2.00	47.833[a]	1.668
2.00	1.00	47.637[a]	1.455
	2.00	46.149[a]	1.991

a. Covariates appearing in the model are evaluated at the following values: PREPERF = 25.8899.

$df_{error} = 76$ $MS_{error} = 54.255$ n = 81/4 = 20.5 LSDmmd = 4.601

The interaction corrected interaction pattern is…

Population 1	G1 < G2	or	Group 1	Pop1 < Pop 2
Population 2	G1 = G2*		Group 2	Pop1 = Pop 2

* is different from the uncorrected interaction pattern in what is likely to be an important way! A cross-over interaction pattern is importantly different from a pattern of one simple effect and one null!

1. POP

Dependent Variable: PERF

POP	Mean	Std. Error
1.00	42.783[a]	1.226
2.00	46.893[a]	1.203

a. Covariates appearing in the model are evaluatec at the following values: PREPERF = 25.8899.

The corrected population effect is Pop 1 < Pop 2, which is descriptive for Group 1 but misleading for Group 2.

The corrected and uncorrected versions of this effect are equivalent.

2. GROUP

Dependent Variable: PERF

GROUP	Mean	Std. Error
1.00	44.685[a]	1.111
2.00	46.991[a]	1.314

a. Covariates appearing in the model are evaluatec at the following values: PREPERF = 25.8899.

There is corrected main effect of Group, which is descriptive for Pop 2 but misleading for Pop 1.

The corrected and uncorrected versions of this effect are equivalent.

ANCOVA with Evaluation Rating as the DV & Performance Pre-test as the covariate

Tests of Between-Subjects Effects

Dependent Variable: RATE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	478.593[a]	4	119.648	27.89	.000
Intercept	15.424	1	15.424	3.595	.062
PREPERF	377.872	1	377.872	88.07	.000
POP	21.779	1	21.779	5.076	.027
GROUP	5.067	1	5.067	1.181	.281
POP * GROUP	17.319	1	17.319	4.036	.048
Error	326.090	76	4.291		
Total	2527.244	81			
Corrected Total	804.684	80			

a. R Squared = .595 (Adjusted R Squared = .573)

The ANOVA with this DV had only a Population main effect.

This ANCOVA also has a Population main effect, but also has a Interaction.

3. POP * GROUP

Dependent Variable: RATE

POP	GROUP	Mean	Std. Error
1.00	1.00	4.400[a]	.494
	2.00	3.949[a]	.469
2.00	1.00	4.515[a]	.409
	2.00	6.030[a]	.560

a. Covariates appearing in the model are evaluated at the following values: PREPERF = 25.8899.

$df_{error} = 76$ $MS_{error} = 4.291$ n = 81/4 = 20.5   LSDmmd = 1.294

The interaction corrected interaction pattern is…

Population 1	G1 = G2	or	Group 1	Pop1 = Pop 2
Population 2	G1 < G2		Group 2	Pop1 < Pop 2

The simple effect of group for population 2 was numerically larger than in the ANOVA and that MS_{error} was substantially larger -- together these differences led to a significant ANCOVA interaction.

1. POP

Dependent Variable: RATE

POP	Mean	Std. Error
1.00	4.175[a]	.345
2.00	5.272[a]	.338

a. Covariates appearing in the model are evaluated at the following values: PREPERF = 25.8899.

The corrected population main effect is equivalent to the uncorrected main effect.

2. GROUP

Dependent Variable: RATE

GROUP	Mean	Std. Error
1.00	4.458[a]	.312
2.00	4.989[a]	.370

a. Covariates appearing in the model are evaluatec at the following values: PREPERF = 25.8899.

The null corrected group main effect is equivalent to the uncorrected main effect.

MANOVA with Performance and Evaluation Rating as DVs

GLM and MANOVA give very similar output except that only MANOVA gives the beta and structure weights that define the canonical variate. Here's the code (which must be run from the syntax window) and results using SPSS MANOVA.

```
manova  perf rate by pop (1,2) group (1,2)     ← tells the DVs and IVs (with group values)
  / print = signif (multiv, eigen, dimenr)     ← gets significance tests and effect sizes
  / discrim stan cor.                          ← gets the ß & structure weights
```

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

 EFFECT .. POP BY GROUP
 Multivariate Tests of Significance (S = 1, M = 0, N = 37 )

 Test Name         Value    Exact F Hypoth. DF   Error DF  Sig. of F

 Pillais          .22954   11.32144       2.00      76.00       .000
 Hotellings       .29793   11.32144       2.00      76.00       .000
 Wilks            .77046   11.32144       2.00      76.00       .000
 Roys             .22954
 Note.. F statistics are exact.

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 Eigenvalues and Canonical Correlations

 Root No.    Eigenvalue        Pct.   Cum. Pct.  Canon Cor.

       1          .298     100.000     100.000        .479

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 EFFECT .. POP BY GROUP (Cont.)
 Standardized discriminant function coefficients
          Function No.

 Variable            1

 PERF             .963
 RATE            -.020

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 Correlations between DEPENDENT and canonical variables
          Canonical Variable

 Variable            1

 PERF             .971
 RATE             .022
```

The significant interaction canonical variate is predominantly perf, which is consistent with the significant ANOVA interaction for perf and nonsignificant ANOVA interaction for rate.

Always compare multivariate and univariate effects and patterns for congruence!

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

EFFECT .. GROUP
Multivariate Tests of Significance (S = 1, M = 0, N = 37)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.00896	.34363	2.00	76.00	.710
Hotellings	.00904	.34363	2.00	76.00	.710
Wilks	.99104	.34363	2.00	76.00	.710
Roys	.00896				

Note.. F statistics are exact.

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Eigenvalues and Canonical Correlations

Root No.	Eigenvalue	Pct.	Cum. Pct.	Canon Cor.
1	.009	100.000	100.000	.095

The nonsignificant MANOVA group main effect is consistent with there being no ANOVA group main effects.

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EFFECT .. GROUP (Cont.)

>Note # 12188
>Because there are no functions significant at level alpha, MANOVA will not
>report any canonical discriminant or correlation analysis for this effect.

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

EFFECT .. POP
Multivariate Tests of Significance (S = 1, M = 0, N = 37)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.23318	11.55503	2.00	76.00	.000
Hotellings	.30408	11.55503	2.00	76.00	.000
Wilks	.76682	11.55503	2.00	76.00	.000
Roys	.23318				

Note.. F statistics are exact.

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Eigenvalues and Canonical Correlations

Root No.	Eigenvalue	Pct.	Cum. Pct.	Canon Cor.
1	.304	100.000	100.000	.483

- -

EFFECT .. POP (Cont.)
Standardized discriminant function coefficients
Function No.

Variable	1
PERF	.791
RATE	.581

The significant MANOVA population main effect is contributed to by both perf and rate, which is consistent with the significant ANOVA main effects for both DVs.

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Correlations between DEPENDENT and canonical variables
Canonical Variable

Variable	1
PERF	.814
RATE	.613

Examining the Multivariate Means

To make the "MANOVA variates" for each significant multivariate effect we first obtain Z-score versions of each DV, then apply the standardized discriminant function coefficients for each.

```
compute int_mv   = (zperf * .963)  + (zrate * -.020).
compute pop_mv   = (zperf * .791)  + (zrate * .581).
```

Remember that each variate is specific to one effect!

Descriptive Statistics

Dependent Variable: INT_MV

POP	GROUP	Mean	Std. Deviation	N
1.00	1.00	-.8505	.77664	18
	2.00	-.0698	.86189	20
	Total	-.4396	.90257	38
2.00	1.00	.6886	.61872	29
	2.00	-.2332	.91650	14
	Total	.3885	.84039	43
Total	1.00	.0992	1.01385	47
	2.00	-.1371	.87479	34
	Total	.0000	.95942	81

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For the Interaction (Hang on -- this is cool!)

We have a significant interaction, but need an LSDmmd to discern the pattern. MSerror is not given in the multivariate results -- but is available in a roundabout way.

Use the interaction manova variate as the DV in a factorial ANOVA. The results give the proper SS, but the MS and F are based on univariate degrees of freedom. We have to adjust the df to represent the multivariate design, compute the mean square (SS / df) and then recomputed F.

The Interaction df needs to be 2 = (#groups -1)*#dvs
The error df needs to be 76 -- as given on the MANOVA output

So…

MS_{int} = 13.707 / 2 = 6.854 MS_{error} = 46.007 / 76 = .605

Check → F = 6.854 / .605 = 11.329 ˜ 11.321 from MANOVA

With that dferror and MSerror LSDmmd = .485

For Pop 1 Group 1 < Group 2
For Pop 2 Group 1 > Group 2

The canonical variate for the interaction that is dominated by perf has the same pattern as did the ANOVA interaction of perf

Tests of Between-Subjects Effects

Dependent Variable: INT_MV

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	27.631[a]	3	9.210	15.415	.000
Intercept	1.022	1	1.022	1.711	.195
POP	8.950	1	8.950	14.980	.000
GROUP	.094	1	.094	.158	.692
POP * GROUP	13.707	1	13.707	22.940	.000
Error	46.007	77	.597		
Total	73.638	81			
Corrected Total	73.638	80			

a. R Squared = .375 (Adjusted R Squared = .351)

For the population main effect

The canonical variate for population main effect has the same pattern as the perf and rate main ANOVA effects

Descriptives

POP_MV

	N	Mean	Std. Deviation
1.00	38	-.5788	.97254
2.00	43	.5115	.87286
Total	81	.0000	1.06640

The MANOVA didn't have any "surprises" -- the effects and the composition of the canonical variates were predictable from the corresponding univariate effects. However, this is not always the case and careful comparisons should always be made.

MANCOVA with Performance and Evaluation Rating as DVs and Performance Pre-test as the Covariate

Again we'll use the MANOVA code (run from the syntax window).

```
manova  perf rate by pop (1,2) group (1,2) with preperf  ← DVs by IVs with COVs
  / print = signif (multiv, eigen, dimenr)               ← gets sig tests & effect sizes
  / discrim stan cor.                                    ← gets the ß & structure weights
```

Covariate -- relationship between the covariate and the dependent variables

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

 EFFECT .. WITHIN CELLS Regression
 Multivariate Tests of Significance (S = 1, M = 0, N = 36 1/2)

 Test Name         Value    Exact F Hypoth. DF   Error DF  Sig. of F

 Pillais          .96910 1176.25430       2.00      75.00       .000
 Hotellings     31.36678 1176.25430       2.00      75.00       .000
 Wilks            .03090 1176.25430       2.00      75.00       .000
 Roys             .96910
 Note.. F statistics are exact.

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 Eigenvalues and Canonical Correlations

 Root No.    Eigenvalue        Pct.   Cum. Pct.  Canon Cor.     Sq. Cor

        1        31.367     100.000     100.000        .984        .969

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 Standardized canonical coefficients for DEPENDENT variables
           Function No.

 Variable            1
 PERF             .668
 RATE             .717
```

This shows there is a very strong relationship between the covariate and canonical variate that is made up of both perf and rate.

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

 Correlations between DEPENDENT and canonical variables
           Function No.

 Variable            1
 PERF             .698
 RATE             .744

  - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Standardized canonical coefficients for COVARIATES
           CAN. VAR.

 COVARIATE           1
 PREPERF         1.000
```

If there were multiple covariates these weights would help to identify which variables define the associated covariate.

```
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 Correlations between COVARIATES and canonical variables
           CAN. VAR.

 Covariate           1
 PREPERF         1.000

 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

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

EFFECT .. POP BY GROUP
Multivariate Tests of Significance (S = 1, M = 0, N = 36 1/2)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.43144	28.45661	2.00	75.00	.000
Hotellings	.75884	28.45661	2.00	75.00	.000
Wilks	.56856	28.45661	2.00	75.00	.000
Roys	.43144				

Note.. F statistics are exact.

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Eigenvalues and Canonical Correlations

Root No.	Eigenvalue	Pct.	Cum. Pct.	Canon Cor.
1	.759	100.000	100.000	.657

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EFFECT .. POP BY GROUP (Cont.)
Standardized discriminant function coefficients
Function No.

Variable	1
PERF	.715
RATE	-.274

There is a significant multivariate interaction, after accounting for the covariate. The associated canonical variate is dominated by perf. We will have to compute the canonical variate to determine the corrected means and the pattern of that interaction.,

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Correlations between DEPENDENT and canonical variables
Canonical Variable

Variable	1
PERF	.590
RATE	-.265

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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 .. GROUP
Multivariate Tests of Significance (S = 1, M = 0, N = 36 1/2)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.37016	22.03898	2.00	75.00	.000
Hotellings	.58771	22.03898	2.00	75.00	.000
Wilks	.62984	22.03898	2.00	75.00	.000
Roys	.37016				

Note.. F statistics are exact.

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Eigenvalues and Canonical Correlations

Root No.	Eigenvalue	Pct.	Cum. Pct.	Canon Cor.
1	.588	100.000	100.000	.608

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EFFECT .. GROUP (Cont.)
Standardized discriminant function coefficients
Function No.

Variable	1
PERF	.478
RATE	.460

The canonical variate for the multivariate group main effect involves both perf and rate. We'll have to compute the variate to obtain the corrected means and the pattern of the main effect.

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Correlations between DEPENDENT and canonical variables
Canonical Variable

Variable	1
PERF	.598
RATE	.563

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

EFFECT .. POP
Multivariate Tests of Significance (S = 1, M = 0, N = 36 1/2)

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillais	.77149	126.60959	2.00	75.00	.000
Hotellings	3.37626	126.60959	2.00	75.00	.000
Wilks	.22851	126.60959	2.00	75.00	.000
Roys	.77149				

Note.. F statistics are exact.

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Eigenvalues and Canonical Correlations

Root No.	Eigenvalue	Pct.	Cum. Pct.	Canon Cor.
1	3.376	100.000	100.000	.878

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EFFECT .. POP (Cont.)
Standardized discriminant function coefficients
Function No.

Variable	1
PERF	.788
RATE	.747

The canonical variate for the multivariate population main effect involves both perf and rate. We'll have to compute the variate to obtain the corrected means and the pattern of the main effect.

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Correlations between DEPENDENT and canonical variables
Canonical Variable

Variable	1
PERF	.520
RATE	.441

Examining the Corrected Multivariate Means

Interaction

There is a significant Group * Population interaction. To find the pattern of that interaction we must compute the associated canonical variate, find the corrected cell means for that variate and compute an LSDmmd (for which we will need the MSerror).

We can compute the canonical variate for the interaction in the syntax window

```
compute int_cmv   = (zperf * .715)  + (zrate *  -.274).
```

We obtain an ANCOVA with this as the DV and preperf as the covariate. The corrected means for the interaction from that analysis are shown below, along with the summary table. The effect tests shown in the summary table are meaningless, but the MS $_{error}$ will be necessary.

3. POP * GROUP

Dependent Variable: INT_CMV

POP	GROUP	Mean	Std. Error
1.00	1.00	-.491[a]	.141
	2.00	.124[a]	.134
2.00	1.00	.192[a]	.117
	2.00	.152[a]	.160

a. Covariates appearing in the model are evaluated at the following values: PREPERF = 25.8899.

Tests of Between-Subjects Effects

Dependent Variable: INT_CMV

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	14.450[a]	4	3.613	10.352	.000
Intercept	3.499	1	3.499	10.027	.002
PREPERF	3.180	1	3.180	9.114	.003
POP	1.162	1	1.162	3.330	.072
GROUP	.131	1	.131	.377	.541
POP * GROUP	5.021	1	5.021	14.389	.000
Error	26.521	76	.349		
Total	40.971	81			
Corrected Total	40.971	80			

a. R Squared = .353 (Adjusted R Squared = .319)

To get the LSDmmd df_{error} = 75   MS $_{error}$ = .349   n = 81/4 = 20.5   LSDmmd = .369

Based on these values, the corrected pattern of the interaction is   For Pop 1   Group 1 < Group 2
For Pop 2   Group 1 = Group 2

Remember that the canonical variate is dominated by perf, and so it makes sense that the corrected multivariate interaction pattern would correspond with the interaction pattern from the ANCOVA with perf as the DV (and preperf as the covariate).

So, our conclusion from the ANCOVA using perf as the DV and preperf as the covariate and from this MANCOVA converge to support that there is an interaction of group and population for performance. Importantly, the pattern of the interaction from the ANCOVA and MANCOVA are different from the interaction pattern revealed in the ANOVA with perf as the DV. Specifically, the simple effect of group found in population 2 in that ANOVA seems to be "spurious" and to have been produced by the initial nonequivalence for preperf between these cells. When this initial non-equivalence is "corrected for" using the ANCOVA and MANCOVA we see a different and presumably more descriptive interaction pattern.

Please note: The process shown here of using ANCOVA with the canonical variate does not give exact values of the corrected mean pattern or of the MSerror. I know of no way to get exact computations of these values from SPSS - but this approach provides a useful approximation.

Group Main Effect

There is a significant Group main effect. To find the pattern of that effect we must compute the associated canonical variate and find the corrected marginal means for that variate.

We can compute the canonical variate for the interaction in the syntax window

```
compute grp_cmv   = (zperf * .478)  + (zrate *  .460).
```

We obtain an ANCOVA with this as the DV and preperf as the covariate. The corrected marginal means from that analysis are shown below.

2. GROUP

Dependent Variable: GRP_CMV

GROUP	Mean	Std. Error
1.00	-.098[a]	.016
2.00	.067[a]	.019

a. Covariates appearing in the model are evaluated at the following values: PREPERF = 25.8899.

Based on these values, the corrected pattern of the Group main effect is Group 1 < Group 2

Remember that the canonical variate for this main effect is a nearly equal combination of perf and rate. Both of these DVs had nonsignificant corrected effects in the same direction (see the ANCOVAs of each with preperf as the covariate) and so this seems to be a case of "multivariate power," in which the DVs without significant univariate differences combine to reveal a multivariate effect.

Population Main Effect

There is a significant Population main effect. To find the pattern of that effect we must compute the associated canonical variate and find the corrected marginal means for that variate.

We can compute the canonical variate for the interaction in the syntax window

```
compute pop_cmv   = (zperf * .788)  + (zrate *  .747).
```

We obtain an ANCOVA with this as the DV and preperf as the covariate. The corrected marginal means from that analysis are shown below.

1. POP

Dependent Variable: POP_MV

POP	Mean	Std. Error
1.00	-.325[a]	.029
2.00	.262[a]	.028

a. Covariates appearing in the model are evaluated at the following values: PREPERF = 25.8899.

Based on these values, the corrected pattern of the Population main effect is Pop 1 < Pop 2

Remember that the canonical variate for this main effect is a nearly equal combination of perf and rate. Both of these had significant corrected effects in the same direction (see the ANCOVAs of each with preperf as the covariate) and so it makes sense that the corrected multivariate pattern would correspond with the patterns from the ANCOVAs of each DV when preperf was the covariate.

Please note: The process shown here of using ANCOVA with the canonical variate does not give exact values of the corrected mean pattern. I know of no way to get exact computations of these values from SPSS - but this approach provides a useful approximation.