INTERPRETING THE ONE-WAY MANOVA

As a means of checking multicollinearity, the circled correlation (between the dependent variables) should be low to moderate. If the correlation were .60 (some argue .80) or above, we would consider either making a composite variable (in which the highly correlated variables were summed or averaged) or eliminating one of the dependent variables.

Correlations[a]

		Grades in High School	Math Achievement Test	Father's Education Level
Grades in High School	Pearson Correlation	1	.439**	.413**
	Sig. (2-tailed)	.	.000	.000
Math Achievement Test	Pearson Correlation	.439**	1	.449**
	Sig. (2-tailed)	.000	.	.000
Father's Education Level	Pearson Correlation	.413**	.449**	1
	Sig. (2-tailed)	.000	.000	.

**. Correlation is significant at the 0.01 level (2-tailed).

a. Listwise N=75

Ideally, we would like to see a significant relationship between the independent variable(s) and the dependent variables.

To meet the assumptions – it is best to have approximately equal cell sizes. That meaning, the largest cell size (*N*) is not more than 1.5 times larger than the smallest cell size (*N*). For this example, we do not have a concern.

Descriptive Statistics

	Father's Education Level	Mean	Std. Deviation	N
Grades in High School	HS grad or less	5.16	1.375	25
	Some College	5.20	1.555	25
	BS or More	6.76	1.332	25
	Total	5.71	1.592	75
Math Achievement Test	HS grad or less	8.4134	5.49859	25
	Some College	13.5733	5.21092	25
	BS or More	15.7067	7.10659	25
	Total	12.5645	6.67031	75

The Box's Test of Equality of Covariance Matrices checks the assumption of homogeneity of covariance across the groups using $p < .001$ as a criterion. For our example, we do not have a concern – as *Box's M* (4.58) was not significant, p (.624) > α (.001) – indicating that there are no significant differences between the covariance matrices. Therefore, the assumption is not violated and Wilk's Lambda is an appropriate test to use.

Box's Test of Equality of Covariance Matrices[a]

Box's M	4.572
F	.731
df1	6
df2	129201.2
Sig.	.624

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept+FathEduc

The following is the MANOVA using the Wilk's Lambda test. Using an alpha level of .05, we see that this test is significant, *Wilk's* $\Lambda = .66$, $F(4, 142) = 8.12$, $p < .001$, multivariate $\eta^2 = .19$. This significant F indicates that there are significant differences among the Fathers Education (FathEduc) groups on a linear combination of the two dependent variables. If we had violated the assumption of homogeneity of variance-covariance, one could use the Pillai's Trace test (a test statistic that is very robost and not highly linked to assumptions about the normality of the distribution of the data).

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.945	613.377[a]	2.000	71.000	.000	.945
	Wilks' Lambda	.055	613.377[a]	2.000	71.000	.000	.945
	Hotelling's Trace	17.278	613.377[a]	2.000	71.000	.000	.945
	Roy's Largest Root	17.278	613.377[a]	2.000	71.000	.000	.945
FathEduc	Pillai's Trace	.364	8.012	4.000	144.000	.000	.182
	Wilks' Lambda	.662	8.118[a]	4.000	142.000	.000	.186
	Hotelling's Trace	.470	8.219	4.000	140.000	.000	.190
	Roy's Largest Root	.358	12.883[b]	2.000	72.000	.000	.264

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept+FathEduc

The multivariate $\eta^2 = .186$ indicates that approximately 19% of multivariate variance of the dependent variables is associated with the group factor.

The Levene's Test of Equality of Error Variances tests the assumption of MANOVA and ANOVA that the variances of each variable are equal across the groups. If the Levene's test is significant, this means that the assumption has been violated – and data should be viewed with caution – or the data could be transformed so as to equalize the variances. As we see in this example, the assumption is met for both dependent variables (Grades in High School, $p > .05$, and Math Achievement Test, $p > .05$).

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
Grades in High School	.818	2	72	.445
Math Achievement Test	3.105	2	72	.051

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+FathEduc

Because the MANOVA was significant, we will now examine the univariate ANOVA results. Note that these tests are identical to the two separate univariate one-way ANOVAs we would have performed if we opted not to do the MANOVA – provided that there are no missing data. Because the *Grades in High School* and *Math Achievement Test* dependent variables are statistically significant and there are three levels or values of *Fathers Education*, we would need to do post hoc multiple comparisons or contrasts to see which pairs of means are different. The *p* values for the ANOVAs on the MANOVA output do not take into account that multiple ANOVAs have been conducted. To protect against Type I error, we can use a traditional Bonferroni procedure and test each ANOVA at the .025 level (.05 divided by the number of ANOVAs conducted, which should equal the number of dependent variables). As can be seen, both ANOVAs are significant at the .025 adjusted alpha level ($p < .001$ for both).

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Grades in High School	41.627[a]	2	20.813	10.270	.000	.222
	Math Achievement Test	703.079[b]	2	351.539	9.775	.000	.214
Intercept	Grades in High School	2442.453	1	2442.453	1205.158	.000	.944
	Math Achievement Test	11839.912	1	11839.912	329.216	.000	.821
FathEduc	Grades in High School	41.627	2	20.813	10.270	.000	.222
	Math Achievement Test	703.079	2	351.539	9.775	.000	.214
Error	Grades in High School	145.920	72	2.027			
	Math Achievement Test	2589.402	72	35.964			
Total	Grades in High School	2630.000	75				
	Math Achievement Test	15132.393	75				
Corrected Total	Grades in High School	187.547	74				
	Math Achievement Test	3292.481	74				

a. R Squared = .222 (Adjusted R Squared = .200)

b. R Squared = .214 (Adjusted R Squared = .192)

Follow-up univariate ANOVAs (shown above) indicated that both Grades in High School and Math Achievement Test were significantly different for children of fathers with different degrees of education, $F(2, 72) = 10.27$, $p < .001$, $\eta^2 = .22$ and $F(2, 72) = 9.78$, $p < .001$, $\eta^2 = .21$, respectively.

The results of the pairwise comparisons are shown below. We had previously controlled for Type I error across the two univariate ANOVAs by testing each at the .025 alpha level. To be consistent with this decision, we also need to control the probability of committing one or more Type I errors across the multiple pairwise comparisons for the dependent variable at the .025 alpha level. We are able to maintain this familywise error rate across comparisons for a dependent variable by selecting .025 for the Significance Level in the Multivariate: Options dialog box in SPSS. Although (arguably) more powerful methods are available, the Bonferroni approach is commonly used to control for Type I error across the pairwise comparisons (for Grades in High School and Math Achievement – in our example). With the Bonferroni method, each comparison is tested at the alpha level for the ANOVA divided by the number of comparisons; for our example, .025/3 = .0083. Because the assumption of homogeneity of variance-covariance was met – we could choose to use the Tukey HSD post hoc procedure. As we see below, for Grades in High School – there is a significant pairwise difference between High School Graduate or less and BS or more, and Some College and BS or more – both significant at the .0083 alpha level. For Math Achievement – there is a significant pairwise difference between High School Graduate or less and BS or more – at the .0083 alpha level.

Multiple Comparisons

Dependent Variable		(I) Father's Education Level	(J) Father's Education Level	Mean Difference (I-J)	Std. Error	Sig.	97.5% Confidence Interval Lower Bound	Upper Bound
Grades in High School	Tukey HSD	HS grad or less	Some College	-.04	.403	.995	-1.12	1.04
			BS or More	-1.60*	.403	.000	-2.68	-.52
		Some College	HS grad or less	.04	.403	.995	-1.04	1.12
			BS or More	-1.56*	.403	.001	-2.64	-.48
		BS or More	HS grad or less	1.60*	.403	.000	.52	2.68
			Some College	1.56*	.403	.001	.48	2.64
	Games-Howell	HS grad or less	Some College	-.04	.415	.995	-1.16	1.08
			BS or More	-1.60*	.383	.000	-2.64	-.56
		Some College	HS grad or less	.04	.415	.995	-1.08	1.16
			BS or More	-1.56*	.409	.001	-2.67	-.45
		BS or More	HS grad or less	1.60*	.383	.000	.56	2.64
			Some College	1.56*	.409	.001	.45	2.67
Math Achievement Test	Tukey HSD	HS grad or less	Some College	-5.1599*	1.69621	.009	-9.6913	-.6285
			BS or More	-7.2934*	1.69621	.000	-11.8248	-2.7620
		Some College	HS grad or less	5.1599*	1.69621	.009	.6285	9.6913
			BS or More	-2.1334	1.69621	.424	-6.6648	2.3980
		BS or More	HS grad or less	7.2934*	1.69621	.000	2.7620	11.8248
			Some College	2.1334	1.69621	.424	-2.3980	6.6648
	Games-Howell	HS grad or less	Some College	-5.1599*	1.51510	.004	-9.2610	-1.0589
			BS or More	-7.2934*	1.79709	.001	-12.1692	-2.4176
		Some College	HS grad or less	5.1599*	1.51510	.004	1.0589	9.2610
			BS or More	-2.1334	1.76247	.453	-6.9205	2.6536
		BS or More	HS grad or less	7.2934*	1.79709	.001	2.4176	12.1692
			Some College	2.1334	1.76247	.453	-2.6536	6.9205

Based on observed means.

*. The mean difference is significant at the .025 level.