When to use MANOVA

- General linear model (GLM) detects group differences on a single dependent variable.
- Anova- Univariate test (one dependent)
- Manova- Multivariate test (many dependent)
- But when we are interested in several dependent variables?
  - Extension of this technique

Multivariate Analysis of Variance - MANOVA

Similarities and Differences to ANOVA

QUESTION: Why use MANOVA instead of multiple ANOVAS?

ANSWER: The more dependent variables, the more ANOVAS, the greater the chance of making a TYPE I error.

-If separate ANOVAS are conducted on each dependent, then any relationship between the dependent is ignored. So we lose information between the dependent variables.

-MANOVA has the power to detect an effect, because it can detect whether groups differ along a combination of dependent variables, whereas ANOVA can detect only if groups differ along a single variable.

But…

- Use MANOVA when you have a good theoretical or empirical basis for doing it and don’t measure hundreds of dependent variables because the analysis allows you to do it.
- Otherwise run separate analyses

Theory of MANOVA

- The theory of MANOVA is very complex
- You should know matrix algebra, which is beyond the scope of this lecture

Assumptions

- Similar assumptions with ANOVA but extended to the multivariate case
- Independence: Observations should be statistically independence
- Random sampling: Data should be randomly sampled from the population of interest and measured at an interval level.
- Multivariate normality: In ANOVA we assume that our dependent variable is normally distributed within each group. In MANOVA the dependent variables (all together) have multivariate normality within the groups. (**in SPSS check univariate normality for each group, or see Stevens, 2002**)
- Homogeneity of covariance matrices: In ANOVA we assume that the variances in each group are roughly equal (homogeneity of variance). In MANOVA this is true for each dependent variable, but also that the correlation between any two dependent variables is the samel in all groups (**in SPSS check BOX's TEST. This should be non-significant if the matrices are the same**). In large sample sizes Box's test could be significant even when covariance matrices are relatively similar, so if group sample sizes are equal disregard Box's test.

Which statistic to use…

- Test power:
- If group differences are concentrated on the first variate (most of the cases in social sciences) Roy’s statistic more powerful, then Hotteling’s trace, Wilks’s lambda, and Pillai’s trace.
- However, when groups differ along more than one variate the power ordering is the reverse
- Robustness:
- All four relative robust to violations of multivariate normality.
- With unequal group sizes, check the assumption of homogeneity of covariance matrices (Box’s test)/ if this test is non-significant then the Pillai’s trace is accurate.

Follow up analyses

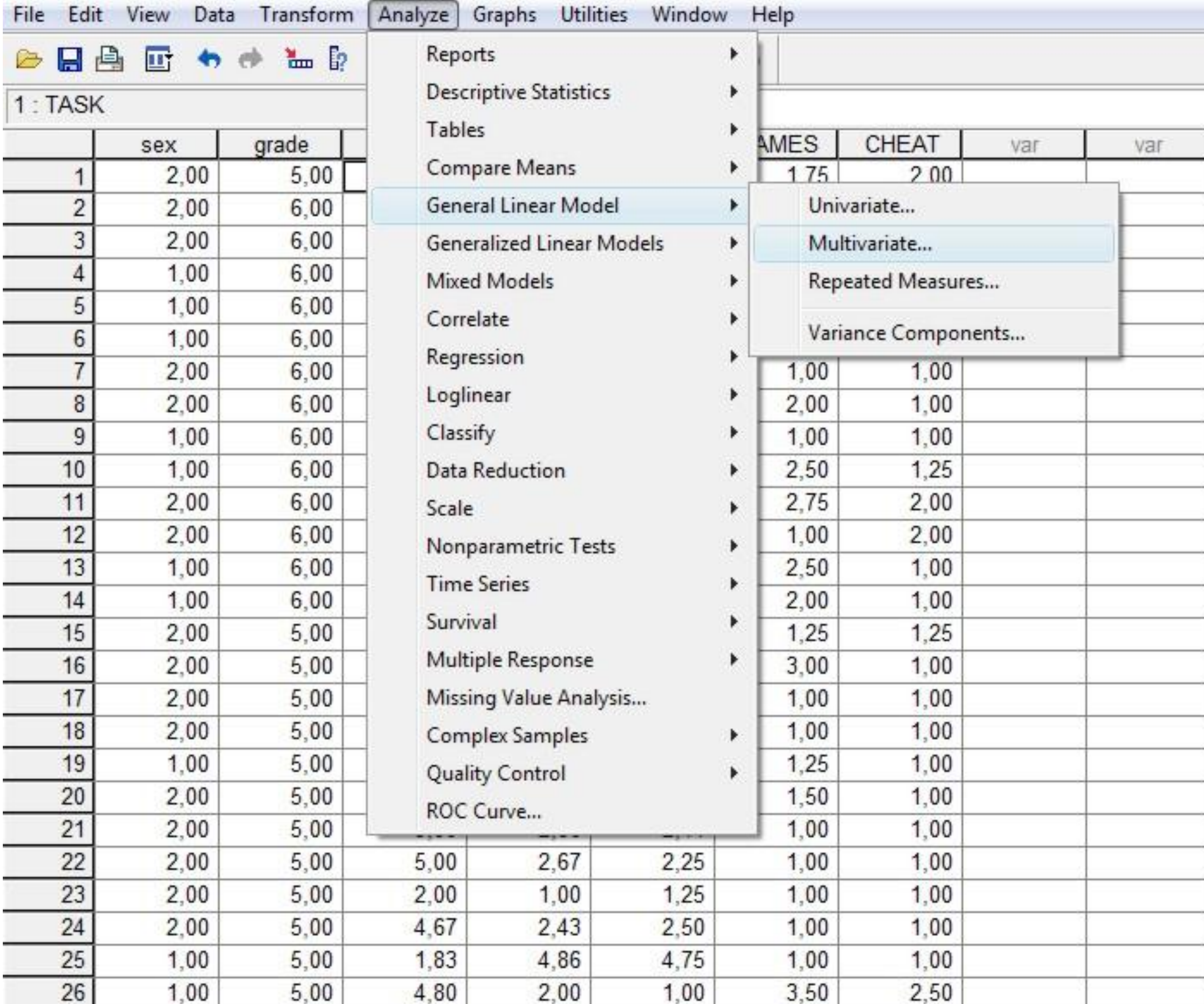
- Follow a significant MANOVA with separate ANOVAs on each of the dependent variables.
- You might consider applying a Bonferroni correction to the subsequent ANOVAs

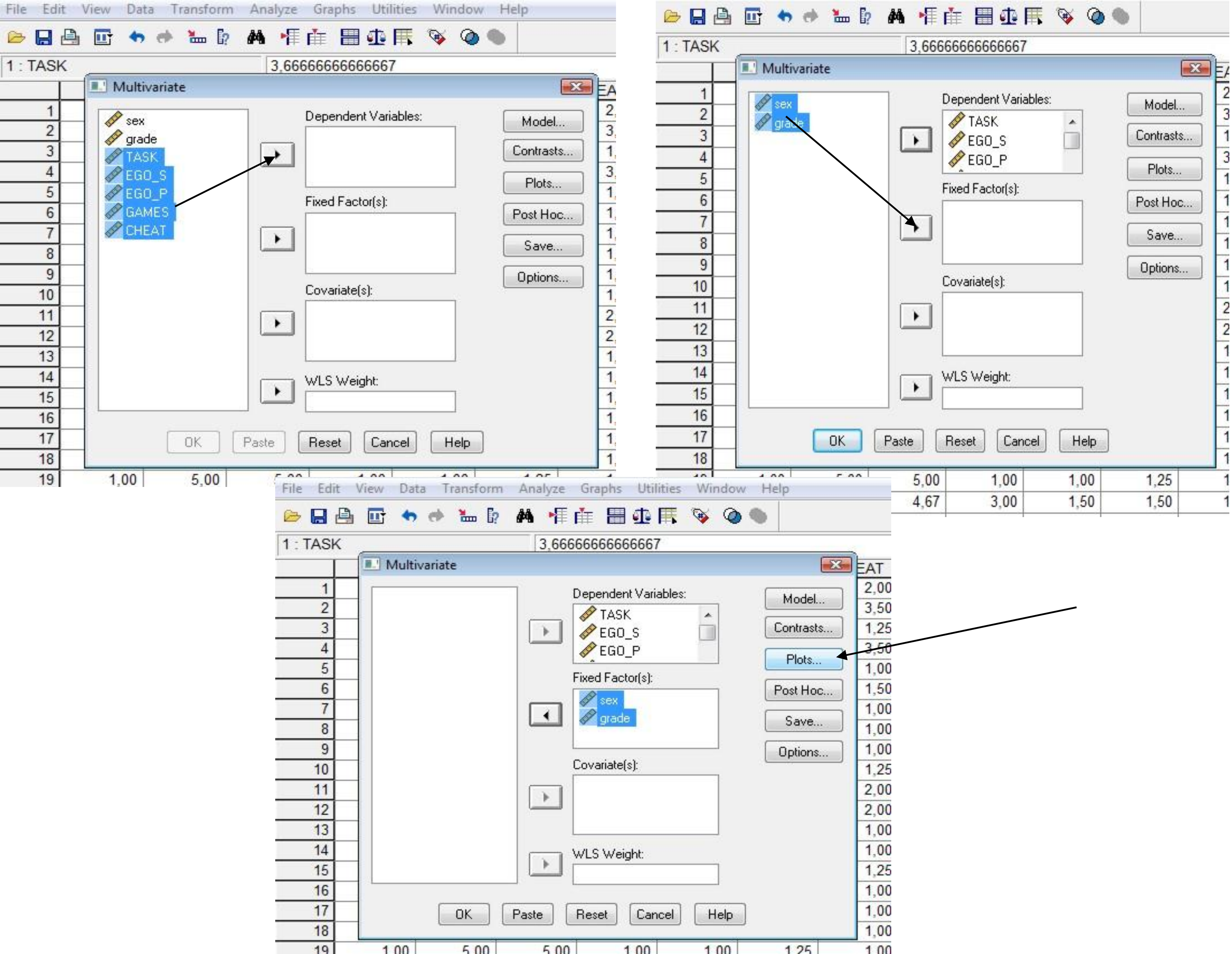
Example of MANOVA

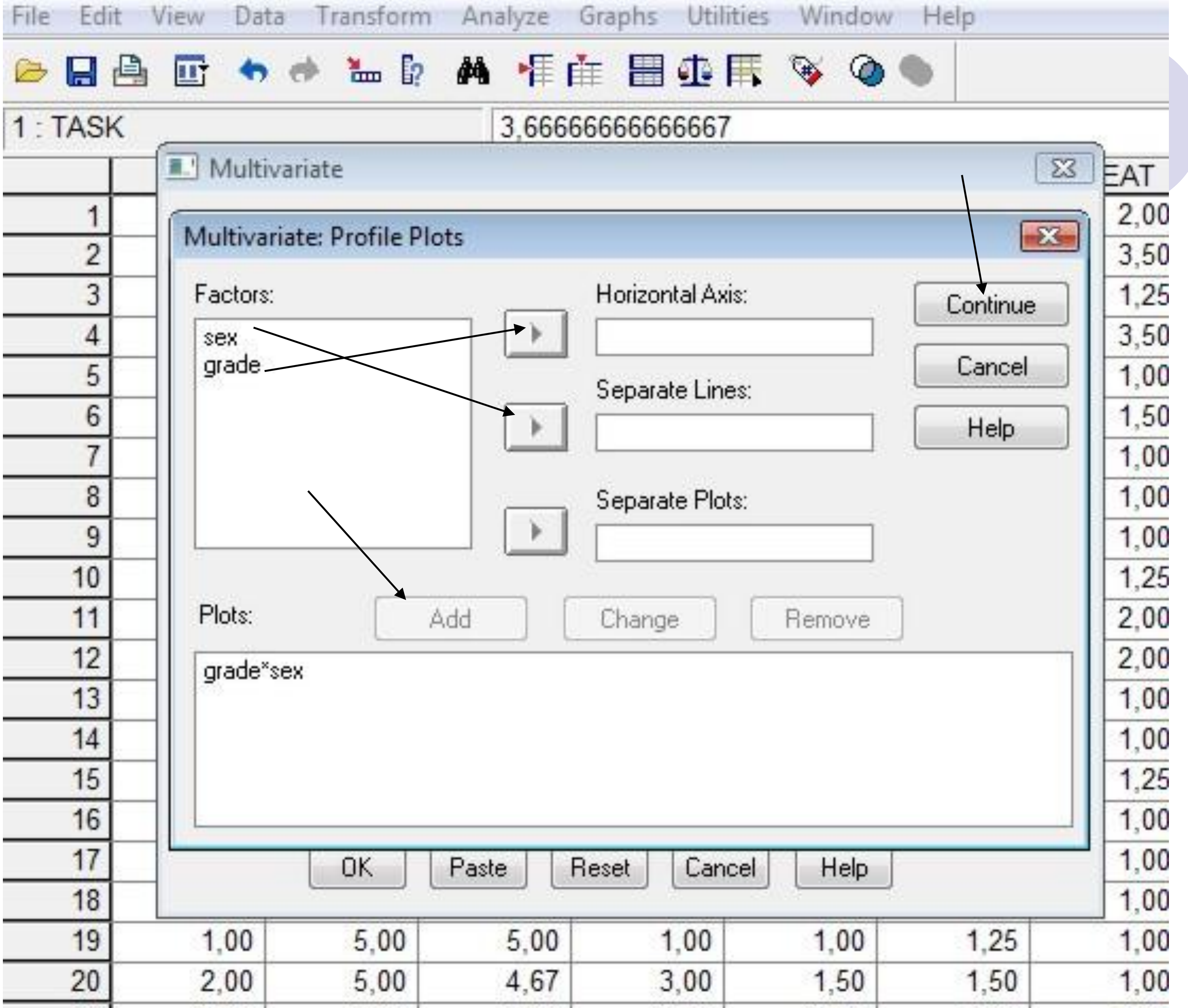
- Examine the effects of gender and classroom level on achievement goals and unfair-play

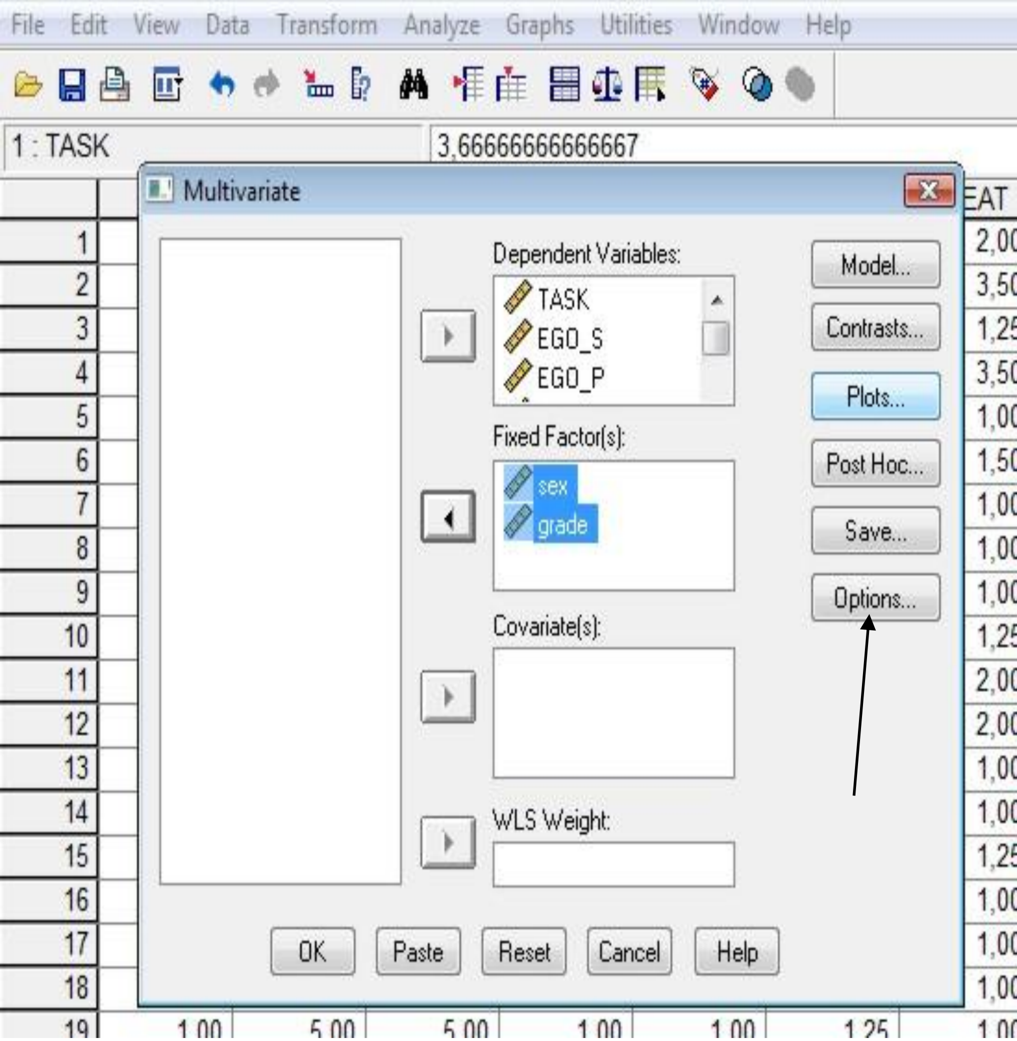
Two-way MANOVA (2 independent): gender – classroom

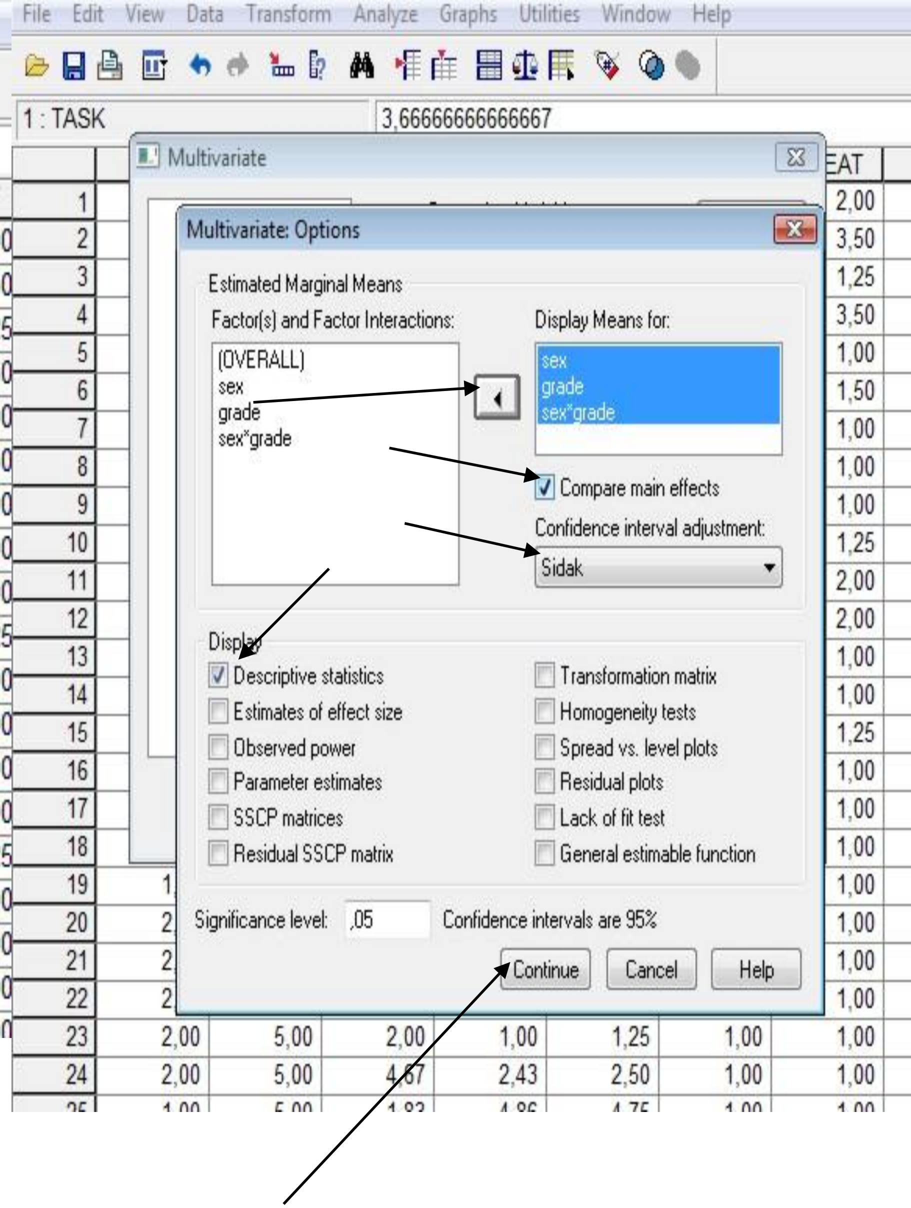
Dependent: achievement goals and unfair-play

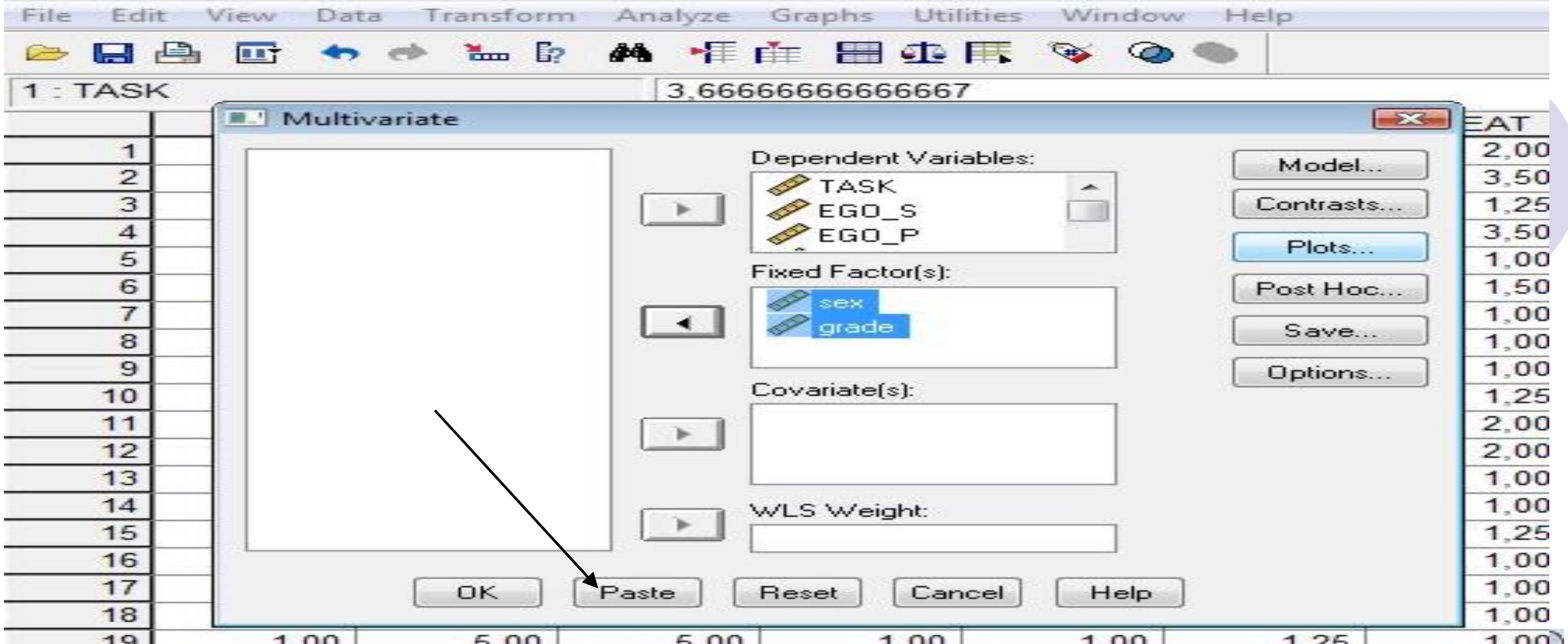

File Edit View Data Transform Analyze Graphs Utilities Window Help
1 : TASK
sex
grade
AMES
CHEAT
var
var
Reports
Descriptive Statistics
Tables
Compare Means
General Linear Model
Generalized Linear Models
Mixed Models
Correlate
Regression
Loglinear
Classify
Data Reduction
Scale
Nonparametric Tests
Time Series
Survival
Multiple Response
Missing Value Analysis...
Complex Samples
Quality Control
ROC Curve...
Univariate...
Multivariate...
Repeated Measures...
Variance Components...


File Edit View Data Transform Analyze Graphs Utilities Window Help
1 : TASK
3,66666666666667
Multivariate
sex
grade
TASK
EGO_S
EGO_P
GAMES
CHEAT
Dependent Variables:
Fixed Factor(s):
Covariate(s):
WLS Weight:
Model...
Contrasts...
Plots...
Post Hoc...
Save...
Options...
OK
Paste
Reset
Cancel
Help

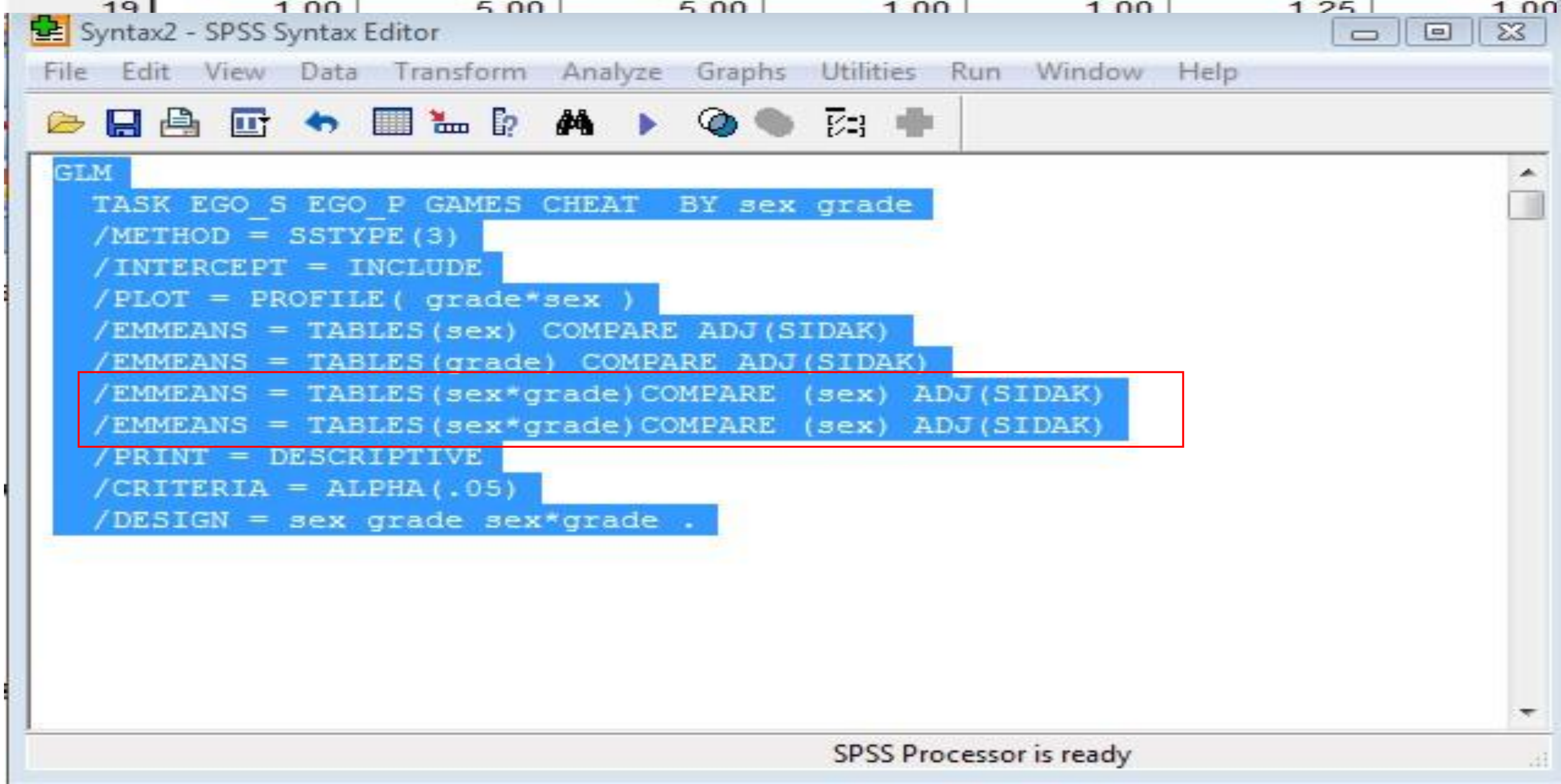

File Edit View Data Transform Analyze Graphs Utilities Window Help
1 : TASK
3,66666666666667
Multivariate
Multivariate: Profile Plots
Factors:
sex
grade
Horizontal Axis:
Separate Lines:
Separate Plots:
Continue
Cancel
Help
Plots:
Add
Change
Remove
grade*sex
OK
Paste
Reset
Cancel
Help


File Edit View Data Transform Analyze Graphs Utilities Window Help
1 : TASK
3,66666666666667
Multivariate
Dependent Variables:
TASK
EGO_S
EGO_P
Fixed Factor(s):
sex
grade
Covariate(s):
WLS Weight:
Model...
Contrasts...
Plots...
Post Hoc...
Save...
Options...
OK
Paste
Reset
Cancel
Help


File Edit View Data Transform Analyze Graphs Utilities Window Help
1 : TASK
3,66666666666667
Multivariate
Multivariate: Options
Estimated Marginal Means
Factor(s) and Factor Interactions:
(OVERALL)
sex
grade
sex*grade
Display Means for:
sex
grade
sex*grade
Compare main effects
Confidence interval adjustment:
Sidak
Display
Descriptive statistics
Estimates of effect size
Observed power
Parameter estimates
SSCP matrices
Residual SSCP matrix
Transformation matrix
Homogeneity tests
Spread vs. level plots
Residual plots
Lack of fit test
General estimable function
Significance level: ,05
Confidence intervals are 95%
Continue
Cancel
Help



File Edit View Data Transform Analyze Graphs Utilities Window Help
1 : TASK
3,66666666666667
Multivariate
Dependent Variables:
TASK
EGO_S
EGO_P
Fixed Factor(s):
sex
grade
Covariate(s):
WLS Weight:
Model...
Contrasts...
Plots...
Post Hoc...
Save...
Options...
OK
Paste
Reset
Cancel
Help



Syntax2 - SPSS Syntax Editor
File Edit View Data Transform Analyze Graphs Utilities Run Window Help
GLM
TASK EGO_S EGO_P GAMES CHEAT BY sex grade
/METHOD = SSTYPE(3)
/INTERCEPT = INCLUDE
/PLOT = PROFILE(grade*sex)
/EMMEANS = TABLES(sex) COMPARE ADJ(SIDAK)
/EMMEANS = TABLES(grade) COMPARE ADJ(SIDAK)
/EMMEANS = TABLES(sex*grade)COMPARE (sex) ADJ(SIDAK)
/EMMEANS = TABLES(sex*grade)COMPARE (sex) ADJ(SIDAK)
/PRINT = DESCRIPTIVE
/CRITERIA = ALPHA(.05)
/DESIGN = sex grade sex*grade .
SPSS Processor is ready

$F(5,151) = 6.41, p < .001$

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	,985	1926,709[a]	5,000	151,000	,000
	Wilks' Lambda	,015	1926,709[a]	5,000	151,000	,000
	Hotelling's Trace	63,798	1926,709[a]	5,000	151,000	,000
	Roy's Largest Root	63,798	1926,709[a]	5,000	151,000	,000
sex	Pillai's Trace	,175	6,411[a]	5,000	151,000	,000
	Wilks' Lambda	,825	6,411[a]	5,000	151,000	,000
	Hotelling's Trace	,212	6,411[a]	5,000	151,000	,000
	Roy's Largest Root	,212	6,411[a]	5,000	151,000	,000
grade	Pillai's Trace	,145	5,124[a]	5,000	151,000	,000
	Wilks' Lambda	,855	5,124[a]	5,000	151,000	,000
	Hotelling's Trace	,170	5,124[a]	5,000	151,000	,000
	Roy's Largest Root	,170	5,124[a]	5,000	151,000	,000
sex * grade	Pillai's Trace	,095	3,172[a]	5,000	151,000	,009
	Wilks' Lambda	,905	3,172[a]	5,000	151,000	,009
	Hotelling's Trace	,105	3,172[a]	5,000	151,000	,009
	Roy's Largest Root	,105	3,172[a]	5,000	151,000	,009

a. Exact statistic

b. Design: Intercept+sex+grade+sex * grade

F (1,155) = 3.93, p <. 05)

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	TASK	4,077[a]	3	1,359	2,288	,081
	EGO_S	6,546[b]	3	2,182	2,542	,058
	EGO_P	,784[c]	3	,261	,386	,763
	GAMES	33,323[d]	3	11,108	14,003	,000
	CHEAT	18,377[e]	3	6,126	11,466	,000
Intercept	TASK	2727,086	1	2727,086	4590,964	,000
	EGO_S	1021,795	1	1021,795	1190,499	,000
	EGO_P	847,762	1	847,762	1251,109	,000
	GAMES	609,359	1	609,359	768,175	,000
	CHEAT	389,513	1	389,513	729,080	,000
sex	TASK	2,332	1	2,332	3,925	,049
	EGO_S	2,498	1	2,498	2,910	,090
	EGO_P	,170	1	,170	,251	,617
	GAMES	14,444	1	14,444	18,209	,000
	CHEAT	13,929	1	13,929	26,073	,000
grade	TASK	1,294	1	1,294	2,179	,142
	EGO_S	,274	1	,274	,319	,573
	EGO_P	,065	1	,065	,097	,756
	GAMES	17,053	1	17,053	21,498	,000
	CHEAT	4,418	1	4,418	8,269	,005
sex * grade	TASK	,915	1	,915	1,540	,216
	EGO_S	3,400	1	3,400	3,961	,048
	EGO_P	,573	1	,573	,846	,359
	GAMES	5,919	1	5,919	7,462	,007
	CHEAT	1,447	1	1,447	2,708	,102
Error	TASK	92,072	155	,594		
	EGO_S	133,035	155	,858		
	EGO_P	105,029	155	,678		
	GAMES	122,955	155	,793		
	CHEAT	82,809	155	,534		

Sex

Pairwise Comparisons

Dependent Variable	(I) sex	(J) sex	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
TASK	male	female	-,245*	,124	,049	-,489	-,001
	female	male	,245*	,124	,049	,001	,489
EGO_S	male	female	,254	,149	,090	-,040	,547
	female	male	-,254	,149	,090	-,547	,040
EGO_P	male	female	,066	,132	,617	-,195	,327
	female	male	-,066	,132	,617	-,327	,195
GAMES	male	female	,610*	,143	,000	,328	,892
	female	male	-,610*	,143	,000	-,892	-,328
CHEAT	male	female	,599*	,117	,000	,367	,831
	female	male	-,599*	,117	,000	-,831	-,367

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

a. Adjustment for multiple comparisons: Sidak.

Grade

Pairwise Comparisons

Dependent Variable	(I) grade	(J) grade	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
TASK	5,00	6,00	,183	,124	,142	-,062	,427
	6,00	5,00	-,183	,124	,142	-,427	,062
EGO_S	5,00	6,00	,084	,149	,573	-,210	,378
	6,00	5,00	-,084	,149	,573	-,378	,210
EGO_P	5,00	6,00	,041	,132	,756	-,220	,302
	6,00	5,00	-,041	,132	,756	-,302	,220
GAMES	5,00	6,00	-,663*	,143	,000	-,945	-,380
	6,00	5,00	,663*	,143	,000	,380	,945
CHEAT	5,00	6,00	-,337*	,117	,005	-,569	-,106
	6,00	5,00	,337*	,117	,005	,106	,569

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

a. Adjustment for multiple comparisons: Sidak.

Sex* grade (με syntax)

Pairwise Comparisons

Dependent Variable	grade	(I) sex	(J) sex	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
TASK	5,00	male	female	-,092	,173	,598	-,434	,251
		female	male	,092	,173	,598	-,251	,434
	6,00	male	female	-,399*	,177	,025	-,748	-,050
		female	male	,399*	,177	,025	,050	,748
EGO_S	5,00	male	female	-,042	,208	,839	-,454	,369
		female	male	,042	,208	,839	-,369	,454
	6,00	male	female	,550*	,212	,011	,130	,969
		female	male	-,550*	,212	,011	-,969	-,130
EGO_P	5,00	male	female	,188	,185	,312	-,178	,553
		female	male	-,188	,185	,312	-,553	,178
	6,00	male	female	-,055	,189	,770	-,428	,317
		female	male	,055	,189	,770	-,317	,428
GAMES	5,00	male	female	,219	,200	,275	-,176	,615
		female	male	-,219	,200	,275	-,615	,176
	6,00	male	female	1,000*	,204	,000	,597	1,404
		female	male	-1,000*	,204	,000	-1,404	-,597
CHEAT	5,00	male	female	,406*	,164	,015	,081	,730
		female	male	-,406*	,164	,015	-,730	-,081
	6,00	male	female	,792*	,168	,000	,461	1,123
		female	male	-,792*	,168	,000	-1,123	-,461

Based on estimated marginal means

*. The mean difference is significant at the ,05 level.

a. Adjustment for multiple comparisons: Sidak.

One-way MANOVA

significant interaction and non-significant main effects

We conducted one-way MANOVA to examine the effects of gender in goal orientations and unfair play. The results showed significant interaction effect, $F(4,154) = 6.46$, $p < .01$. Univariate analyses showed that there was a significant effect in deception, $F(1,157) = 14.06$, $p < .01$, and cheating, $F(1,157) = 23.43$, $p < .01$, and non-significant effect in task goal, $F(1,157) = 3.58$, $p = .06$, and ego goal, $F(1,157) = 2.87$, $p = .09$. Regarding deception and cheating the examination of the means showed that boys had larger scores than girls.

Two-way MANOVA
significant main effects
significant and non significant interaction effects

We conducted Two-way MANOVA to examine the effects of gender and grade (5^{th} and 6^{th} grade) on unfair play (deception and cheating). The results showed a multivariate effect for gender, $F(2,154) = 14.78$, $p < .01$, and grade, $F(2,154) = 10.85$, $p < .01$, and the interaction between gender and grade, $F(2,154) = 3.75$, $p < .05$. Univariate analyses showed a significant effect of gender in deception, $F(1,155) = 18.21$, $p < .01$, and cheating, $F(1,155) = 26.07$, $p < .01$, a significant effect of grade in deception, $F(1,155) = 21.50$, $p < .01$, and cheating, $F(1,155) = 8.27$, $p < .01$, and a significant interaction effect of gender and grade in deception, $F(1,155) = 7.46$, $p < .01$. However, a non-significant interaction effect of gender and grade was found in cheating, $F(1,155) = 1.45$, $p = .10$. The examination of the means showed that boys had larger scores than girls in deception and cheating and that students of the 6^{th} grade had larger scores in deception and cheating than students of the 5^{th} grade. However the examination of the interaction showed that although in the 5^{th} grade boys and girls didn’t differ in deception, in the 6^{th} grade boys had larger scores than girls.