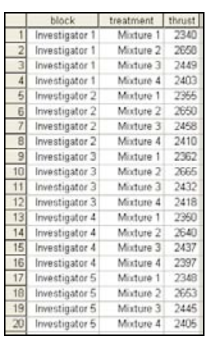
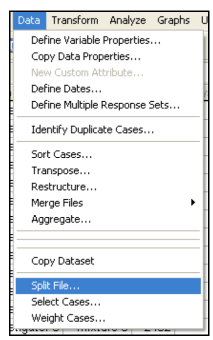
Randomized Block Design ANOVA in SPSS **STAT 314**

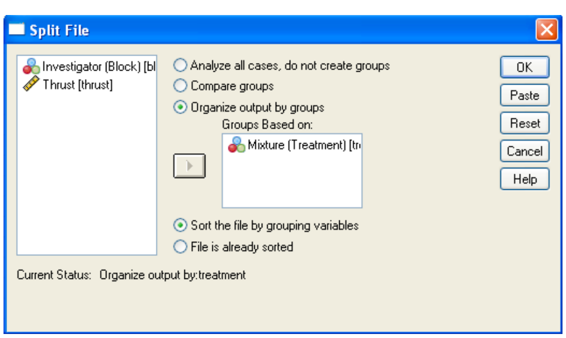
An experiment is conducted to compare four different mixtures of the components oxidizer, binder, and fuel used in the manufacturing of rocket propellant. To compare the four mixtures, five different samples of propellant are prepared from each mixture and readied for testing. Each of five investigators is randomly assigned one sample of each of the four mixtures and asked to measure the propellant thrust. These data are summarized next. Use $\alpha = 0.05$.

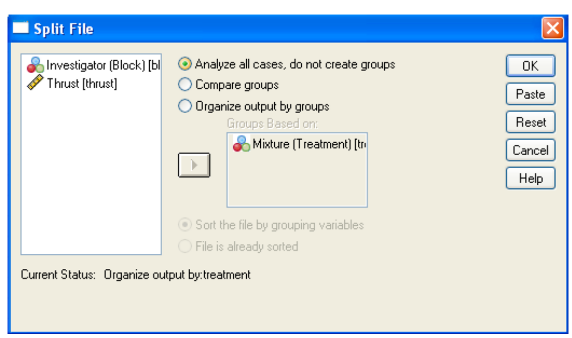
	Investigator				
Mixture	1	2	3	4	5
1	2,340	2,355	2,362	2,350	2,348
2	2,658	2,650	2,665	2,640	2,653
3	2,449	2,458	2,432	2,437	2,445
4	2,403	2,410	2,418	2,397	2,405

1. Enter the investigator number values into one variable (block), the mixture number values into a second variable (treatment), and the corresponding thrust values into a third variable *(see upper-left figure, below)*. Be sure to code your variables appropriately. Now it is time to check the normality assumption. Select "Split File" from the "Data" menu so that we can tell SPSS that we want separate Q–Q Plots for each treatment group *(see upper-right figure, below)*. Select "Organize output by groups" and enter "treatment" as the variable that groups are based upon *(see lower-left figure, below)*. Now create Normal Q–Q Plots to assess the normality of each treatment group *(see separate handout on Normal Q–Q Plots)*. Once you've created your Q–Q Plots and determined that your treatment groups are approximately normally distributed, select "Split File" from the "Data" menu and then select "Analyze all cases, do not create groups" in order to return SPSS to its normal data analysis mode *(see lower-right figure, below)*. We don't need to check the equality of variances since this design requires only one observation per treatment within each block.

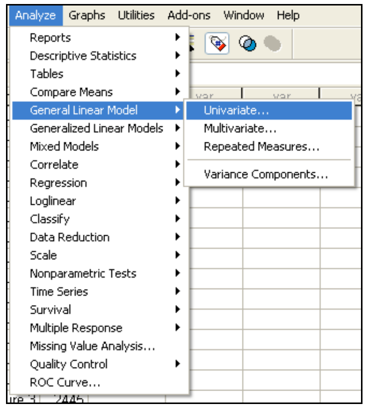




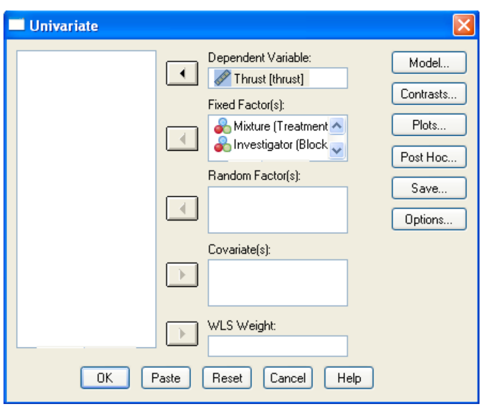


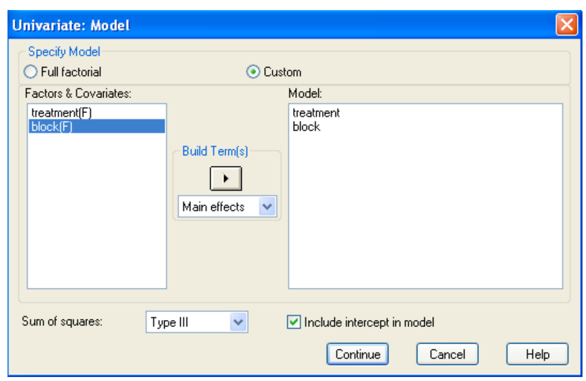


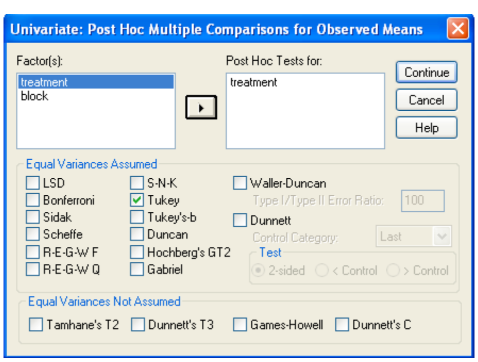
2. Select Analyze → General Linear Model → Univariate… *(see figure, below)*.

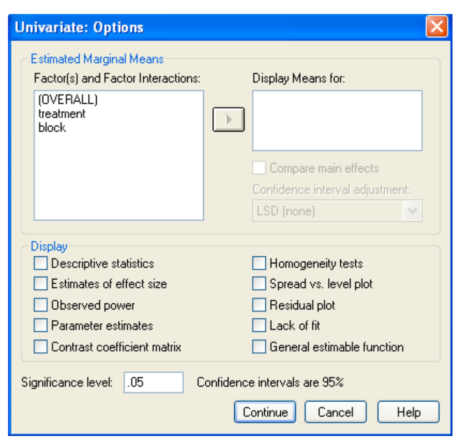


3. Select "Thrust" as the dependent variable, and select "Mixture" (treatments) and "Investigator" (blocks) as the fixed factors *(see upper-left figure, below)*. Click the "Model…" button. In the Univariate:Model window, select the "Custom" option and then the pull-down option in the center for "Main effects". Select "Mixture" (treatments) and "Investigator" (blocks) and move them to be in the Model. Be sure "Type III" sum of squares and "Include intercept in model" are selected, and click "Continue" *(see upper-right figure, below)*. Click the "Post Hoc…" button, select the "Tukey" procedure, enter "Mixture" (treatments) as the Post Hoc Tests variable, and click "Continue" *(see lower-left figure, below)*. Click the "Options…" button, enter 0.05 for the significance level (95% CI corresponds to a 5% (0.05) significance level), and click "Continue" *(see lower-right figure, below)*. Now click the "OK" button in the main Univariate analysis window.









4. Your output should look like this.

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Mixture (Treatment)	1	Mixture 1	5
	2	Mixture 2	5
	3	Mixture 3	5
	4	Mixture 4	5
Investigator (Block)	1	Investigator 1	4
	2	Investigator 2	4
	3	Investigator 3	4
	4	Investigator 4	4
	5	Investigator 5	4

Tests of Between-Subjects Effects

Dependent Variable: Thrust

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	261713.4500[a]	7	37387.6357	542.9646	.0000
Intercept	121401281	1	121401281.3	1763059	.0000
treatment	261260.9500	3	87086.9833	1264.7269	.0000
block	452.5000	4	113.1250	1.6429	.2273
Error	826.3000	12	68.8583		
Total	121663821	20			
Corrected Total	262539.7500	19			

a. R Squared = .997 (Adjusted R Squared = .995)

Post Hoc Tests

Mixture (Treatment)

Multiple Comparisons

Dependent Variable: Thrust
Tukey HSD

(I) Mixture (Treatment)	(J) Mixture (Treatment)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Mixture 1	Mixture 2	-302.2000*	5.2482	.0000	-317.7813	-286.6187
	Mixture 3	-93.2000*	5.2482	.0000	-108.7813	-77.6187
	Mixture 4	-55.6000*	5.2482	.0000	-71.1813	-40.0187
Mixture 2	Mixture 1	302.2000*	5.2482	.0000	286.6187	317.7813
	Mixture 3	209.0000*	5.2482	.0000	193.4187	224.5813
	Mixture 4	246.6000*	5.2482	.0000	231.0187	262.1813
Mixture 3	Mixture 1	93.2000*	5.2482	.0000	77.6187	108.7813
	Mixture 2	-209.0000*	5.2482	.0000	-224.5813	-193.4187
	Mixture 4	37.6000*	5.2482	.0001	22.0187	53.1813
Mixture 4	Mixture 1	55.6000*	5.2482	.0000	40.0187	71.1813
	Mixture 2	-246.6000*	5.2482	.0000	-262.1813	-231.0187
	Mixture 3	-37.6000*	5.2482	.0001	-53.1813	-22.0187

Based on observed means.

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

Homogeneous Subsets

Thrust

Tukey HSD[a,b]

Mixture (Treatment)	N	Subset 1	2	3	4
Mixture 1	5	2351.0000			
Mixture 4	5		2406.6000		
Mixture 3	5			2444.2000	
Mixture 2	5				2653.2000
Sig.		1.0000	1.0000	1.0000	1.0000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 68.858.

a. Uses Harmonic Mean Sample Size = 5.000.

b. Alpha = .05.

5. You should use the output information in the following manner to answer the question.

Step 1: **Hypotheses *(for treatments…not blocks)***

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4$

H_a: at least one μ_i is different

Step 2: **Significance Level**

$\alpha = 0.05$

Step 3: **Rejection Region**

Reject the null hypothesis if p-value ≤ 0.05.

Step 4: **Construct the ANOVA Table *(re-formatted from original SPSS output)***

Tests of Between-Subjects Effects

Dependent Variable: Thrust

Source	df	Type III Sum of Squares	Mean Square	F	Sig.
treatment	3	261260.9500	87086.9833	1264.7269	.0000
block	4	452.5000	113.1250	1.6429	.2273
Error	12	826.3000	68.8583		
Corrected Total	19	262539.7500			

From the output, $F = 1264.7269$ with 3 and 12 degrees of freedom.

p-value = Sig. ≈ 0.0000

Step 5: **Conclusion**

Since p-value $\approx 0.0000 \leq 0.05 = \alpha$, we shall reject the null hypothesis.

Step 6: **State conclusion in words**

At the $\alpha = 0.05$ significance level, there is enough evidence to conclude that the mean thrust differs among the four mixtures.

6. Since we rejected the null hypothesis (we found differences in the treatment means), we should perform a Tukey-Kramer (Tukey's W) multiple comparison analysis to determine which treatment means are similar and which are different. Using the previous output, here is how such an analysis might appear.

Multiple Comparisons

Dependent Variable: Thrust
Tukey HSD

(I) Mixture (Treatment)	(J) Mixture (Treatment)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Mixture 1	Mixture 2	-302.2000*	5.2482	.0000	-317.7813	-286.6187
	Mixture 3	-93.2000*	5.2482	.0000	-108.7813	-77.6187
	Mixture 4	-55.6000*	5.2482	.0000	-71.1813	-40.0187
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	Mixture 2	-246.6000*	5.2482	.0000	-262.1813	-231.0187
	Mixture 3	-37.6000*	5.2482	.0001	-53.1813	-22.0187

Based on observed means.

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

Note that none of the confidence intervals contain zero; thus, we are 95% confident that all mixtures differ with Mixture 2 yielding the highest mean thrust.

Thrust

Tukey HSD[a,b]

Mixture (Treatment)	N	Subset 1	Subset 2	Subset 3	Subset 4
Mixture 1	5	2351.0000			
Mixture 4	5		2406.6000		
Mixture 3	5			2444.2000	
Mixture 2	5				2653.2000
Sig.		1.0000	1.0000	1.0000	1.0000

This table corresponds to our "underline diagram". Note that all four treatment means are grouped separately; thus, all four means appear to be different (with Mixture 2 yielding the highest mean thrust).