Comments for MEDB 5501, Week 8

Review multiple comparisons issue

- Type I error: rejecting the null hypothesis when the null hypothesis is true.
  - Multiple simultaneous hypotheses increase the Type I error rate.

Bonferroni inequality for two simultaneous hypotheses

Define

- E_1 = Type I error for Hypothesis 1
- E_2 = Type I error for Hypothesis 2
  - $P[E_1 \cup E_2] = P[E_1] + P[E_2] - P[E_1 \cap E_2]$
  - $P[E_1 \cup E_2] \leq P[E_1] + P[E_2]$
  - $P[E_1 \cup E_2] \leq P[E_1] + P[E_2]$
  - $P[E_1 \cup E_2] \leq 2\alpha$

Bonferroni adjustment

- For m hypotheses
  - $P[E_1 \cup \ldots \cup E_m] \leq m\alpha$
- Test each hypothesis at α/m
  - Preserves overall Type I error rate
- Example, 3 simultaneous hypotheses
  - Reject H0 if p-value < 0.0133

Controversies over Bonferroni adjustment

- Increases Type II errors
- Impractical for large values of m
- Works poorly for highly correlated tests
- Ambiguity in definition of “simultaneous” hypotheses

Alternatives to Bonferroni adjustment

- False discovery rate
- Designation of primary and secondary outcomes
- Subjective assessment of simultaneous hypotheses

Review two-sample t-test

- $H_0: \ \mu_1 = \mu_2$
- $H_1: \ \mu_1 \neq \mu_2$
  - Or a one tailed alternative
- $T = \frac{\bar{X}_1 - \bar{X}_2}{SE(\bar{X}_1 - \bar{X}_2)}$
  - Accept H0 if T is close to zero.

Speaker notes

You saw how to compare two means last week. Here is the general framework.

What to do with three or more groups?

- $H_0: \ \mu_1 = \mu_2 = \ldots = \mu_k$
- $H_1: \ \mu_i \neq \mu_j$ for some i, j
  - Note: one-tailed test is tricky.
- Accept H0 if the F ratio (defined below) is close to 1.

Important assumptions

- Same as independent-samples t-test
  - Normality
  - Equal variances
  - Independence

How to check assumptions

- Boxplots
- Analysis of residuals, e_{ij}
  - e_{ij}= Observed - Predicted
  - $e_{ij} = Y_{ij} - \bar{Y}_i$

Tukey post hoc tests

- If you reject H0, which values are unequal
  - With k groups, there are k(k-1)/2 comparisons
- Studentized range (Tukey test)
  - Requires equal sample sizes per group
  - Uses harmonic mean approximation for unequal sample sizes.
    - Do not use harmonic means if seriously different sample sizes.

Alternatives to Tukey post hoc tests

- Bonferroni adjustment
  - Works for unequal sample sizes per group
  - Works for unequal variances
- Dunnett's test
  - Treatment versus multiple controls
- Scheffe's test
  - Works for complex comparison
    - Example $\mu_1 \ vs. \ \frac{\mu_2+\mu_3+\mu_4}{3}$

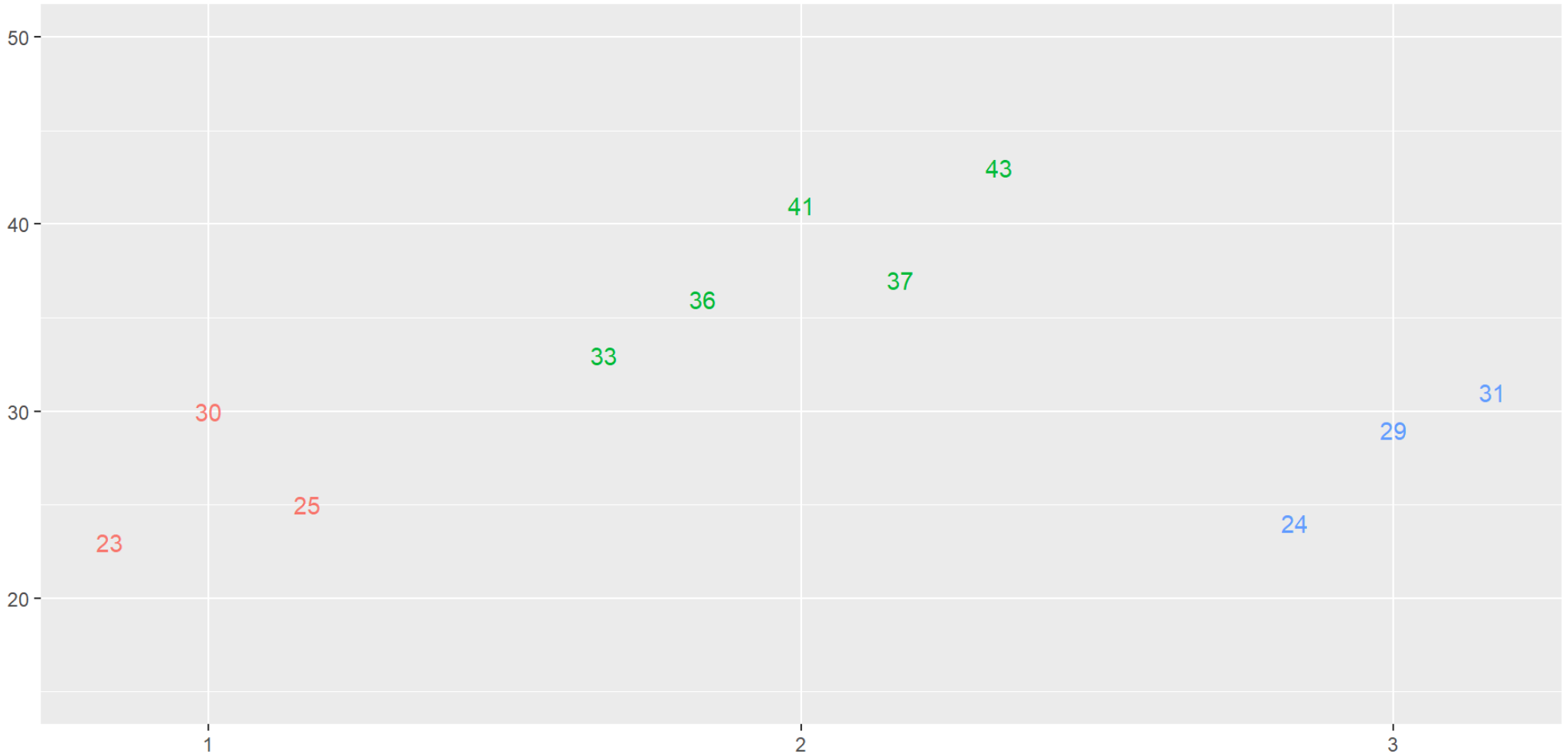
Artificial data

	g	y
1	1	23
2	1	30
3	1	25
4	2	33
5	2	36
6	2	41
7	2	37
8	2	43
9	3	24
10	3	29
11	3	31

Speaker notes

To motivate some of the calculations in Analysis of Variance, I created an artificial data set with numbers that are easy to work with.

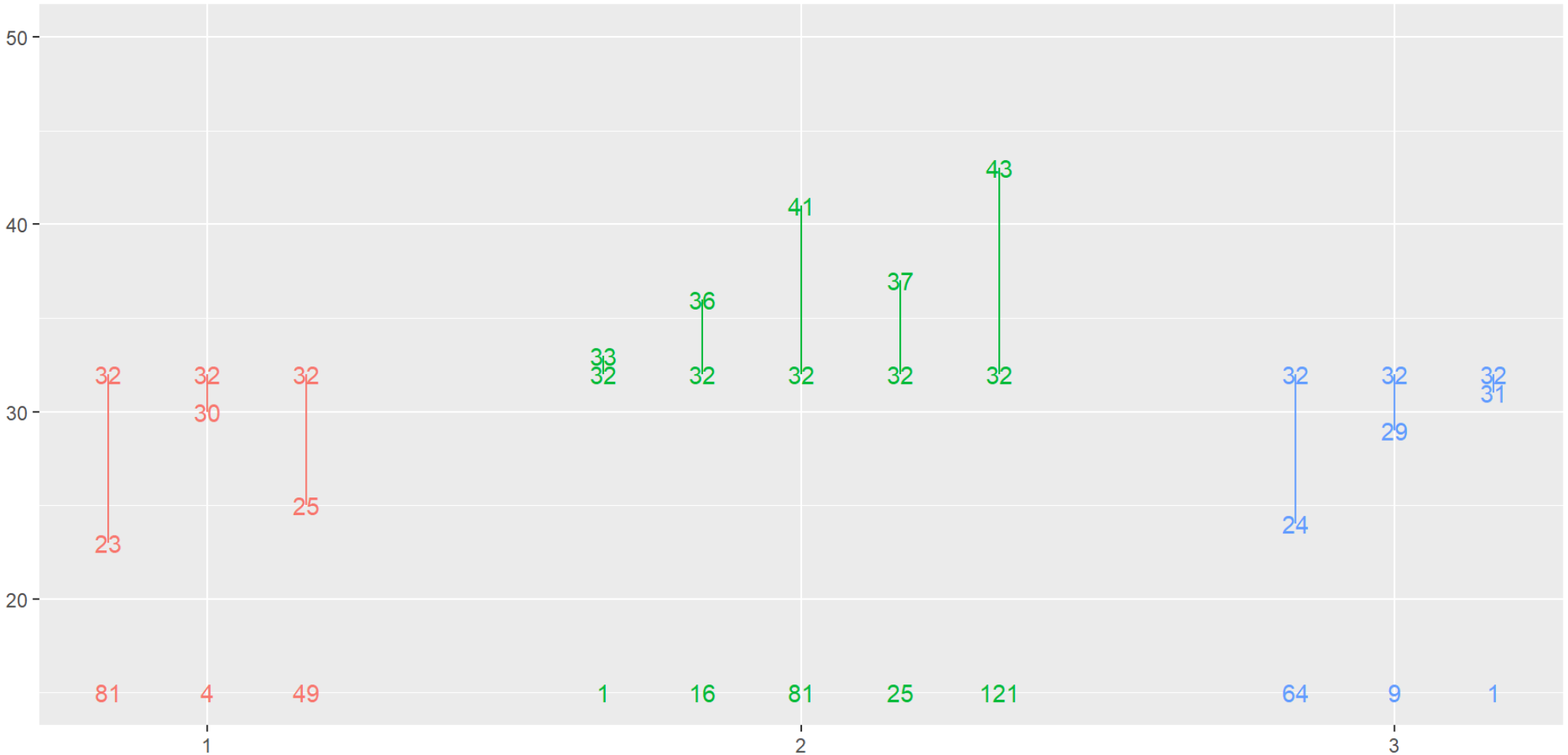
Scatterplot



Speaker notes

Here is a plot of the data.

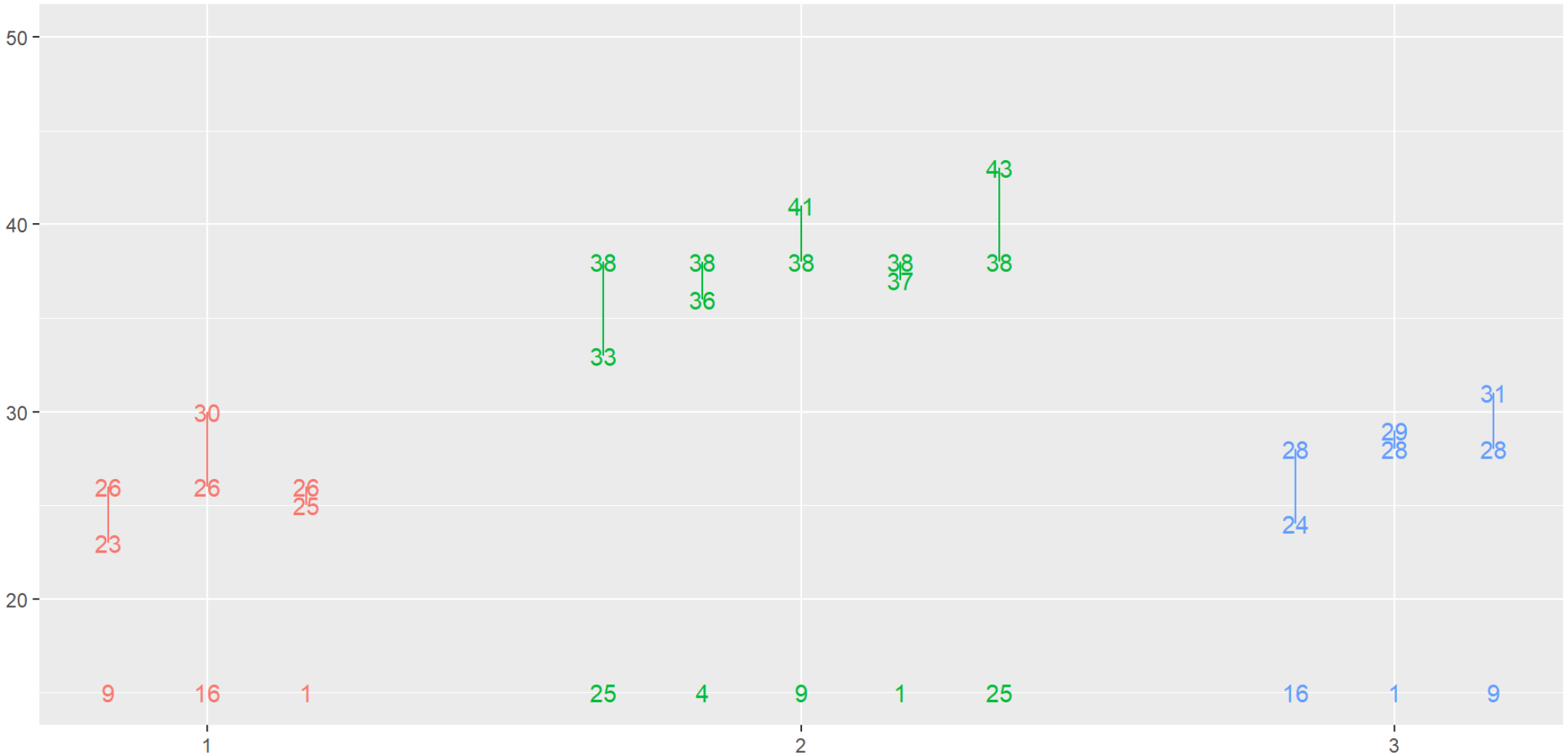
Total SS = 452


50
40
30
20
32
32
32
30
25
23
81
4
49
33
32
32
36
32
16
41
32
81
37
32
25
43
32
121
32
32
24
64
32
29
9
32
31
1
1
2
3

Speaker notes

Total sums of squares is the squared deviation between each individual value and the overall mean.

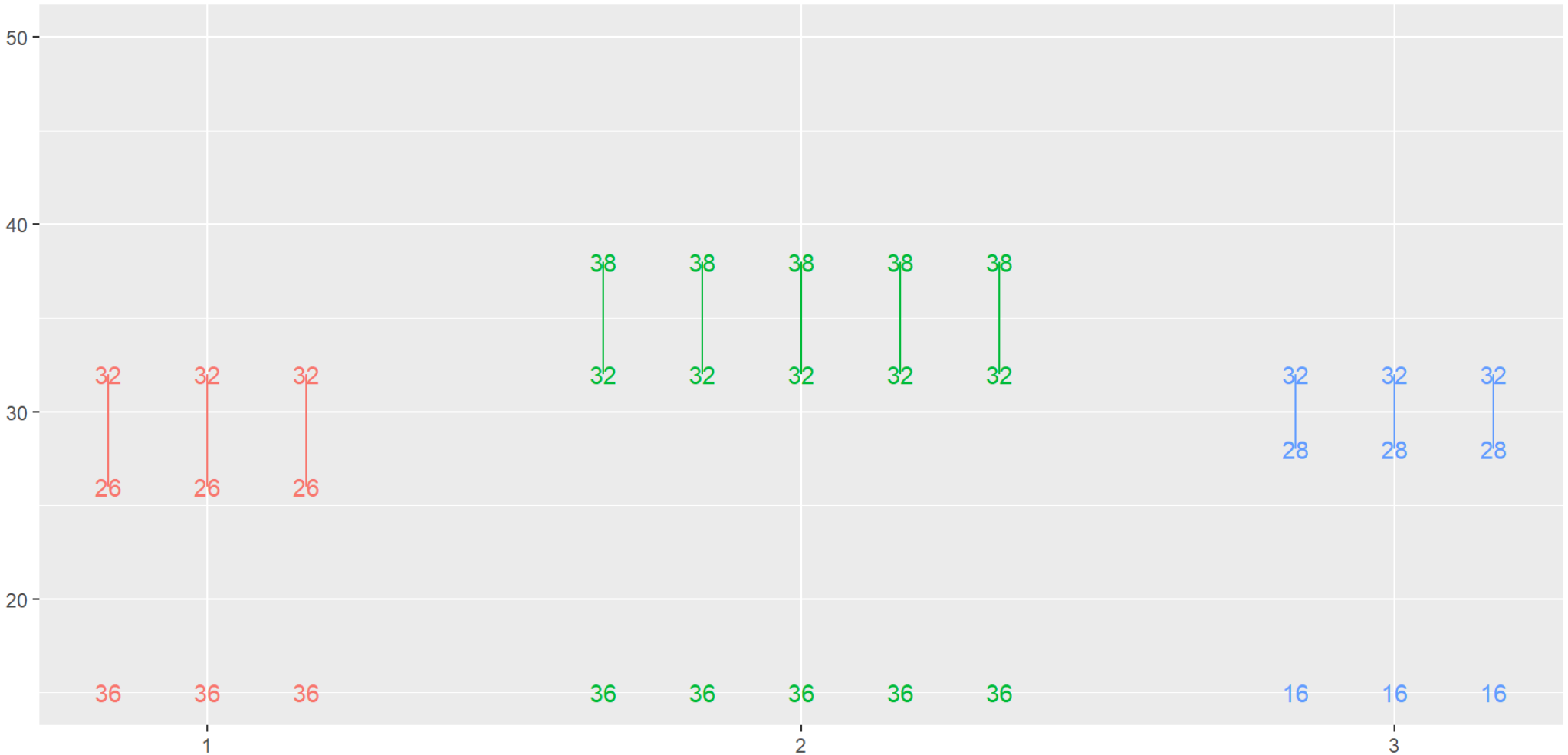
Within SS = 116



Speaker notes

Within sums of squares is the squared deviation between each individual value and the group means.

Between SS = 336



Speaker notes

Between SS is the squared deviation between the group means and the overall mean.

Degrees of freedom

- For Total SS, df = 10
- For Within SS, df = 8
- For Between SS, df = 2
- In general,
  - N = number of observations
  - k = number of groups
    - Total df = N-1
    - Within df = N-k
    - Between df = k-1

Speaker notes

The concept of degrees of freedom is tricky. It is the number of “independent” observations, or the number of observations minus the number of estimated parameters.

For Total SS, you have 11 observations, but one estimated parameter, the overall mean of 32. The degrees of freedom is 11-1 = 10.

For Within SS, you also have 11 observations, but there are 3 estimated parameters, the three group means. The degrees of freedom is 11-3 = 8

For Between SS, you only have three observations, the three group means. There is one estimated parameter, the overall mean. The degrees of freedom is 3-1 = 2.

In general, if you let N represent the total number of observations across all groups and let k represent the number of groups, then the degrees of freedom are N-1, N-k, and k-1.

ANOVA table, 1 of 4

	Sum of Squares	df
Between Groups	336.000	2
Within Groups	116.000	8
Total	452.000	10

Speaker notes

You can lay out the sums of squares and the degrees of freedom in a table.

ANOVA table, 2 of 4

	Sum of Squares	df	Mean Square
Between Groups	336.000	2	168.000
Within Groups	116.000	8	14.500
Total	452.000	10	

Speaker notes

Define the mean squares as the sum of squares divided by the degrees of freedom.

ANOVA table, 3 of 4

	Sum of Squares	df	Mean Square	F
Between Groups	336.000	2	168.000	11.586
Within Groups	116.000	8	14.500	
Total	452.000	10		

Speaker notes

Calculate the F ratio as the Between Groups Mean Square divided by the Within Groups Mean Square.

ANOVA table, 4 of 4

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	336.000	2	168.000	11.586	.004
Within Groups	116.000	8	14.500		
Total	452.000	10			

Speaker notes

Calculate the F ratio as the Between Groups Mean Square divided by the Within Groups Mean Square.

ANOVA table from the general linear model

Dependent Variable: y

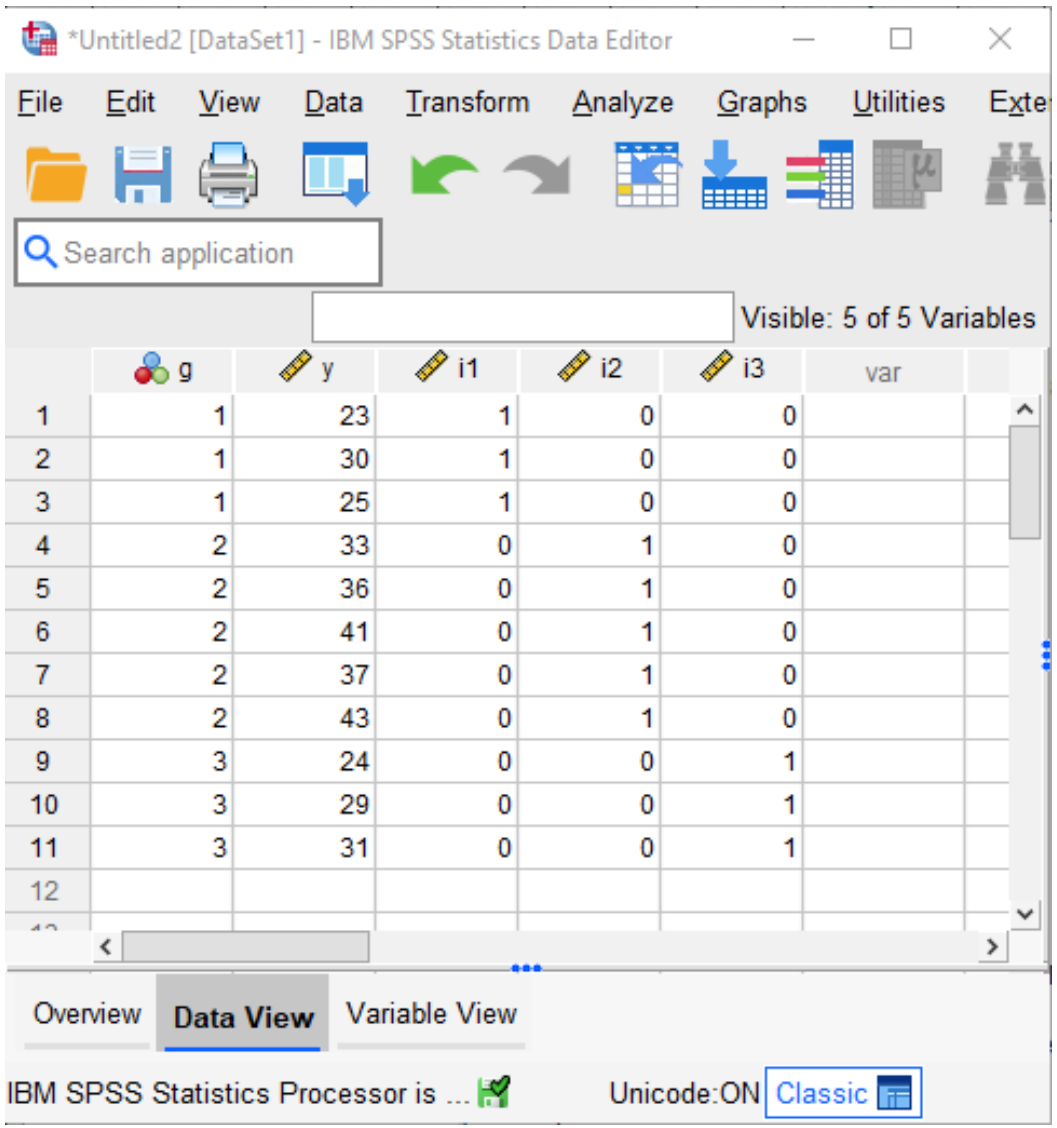
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	336.000[a]	2	168.000	11.586	.004
Intercept	9766.154	1	9766.154	673.528	<.001
g	336.000	2	168.000	11.586	.004
Error	116.000	8	14.500		
Total	11716.000	11			
Corrected Total	452.000	10			

a. R Squared = .743 (Adjusted R Squared = .679)

Speaker notes

You can lay out the sums of squares and the degrees of freedom in a table.

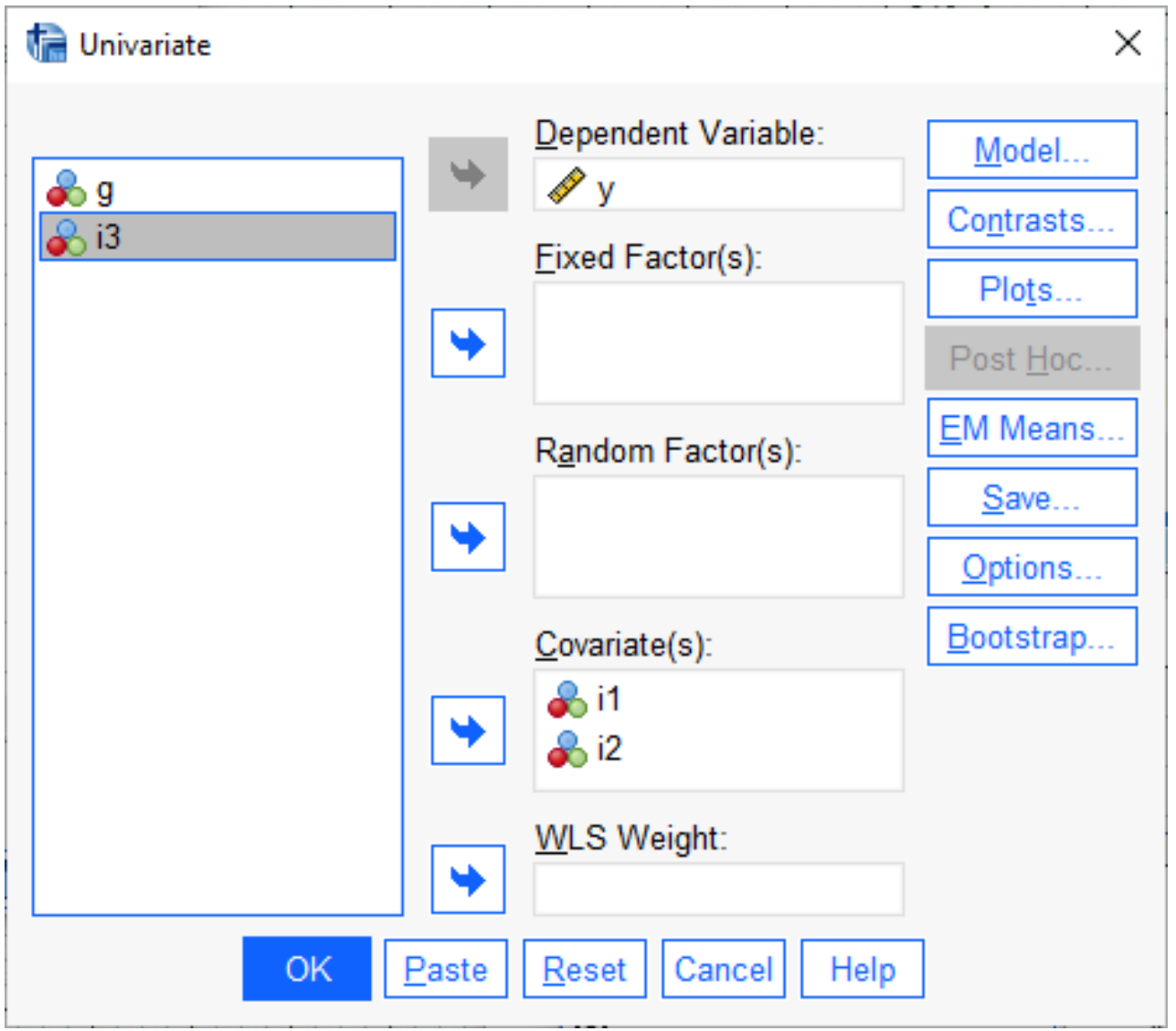
Regression approach to ANOVA, 1 of 4



Speaker notes

Add note.

Regression approach to ANOVA, 2 of 4



Speaker notes

Add note.

Regression approach to ANOVA, 3 of 4

Parameter Estimates

Dependent Variable: y

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	28.000	2.198	12.736	<.001	22.930	33.070
i1	-2.000	3.109	-.643	.538	-9.170	5.170
i2	10.000	2.781	3.596	.007	3.587	16.413

Speaker notes

Add note.

Regression approach to ANOVA, 4 of 4

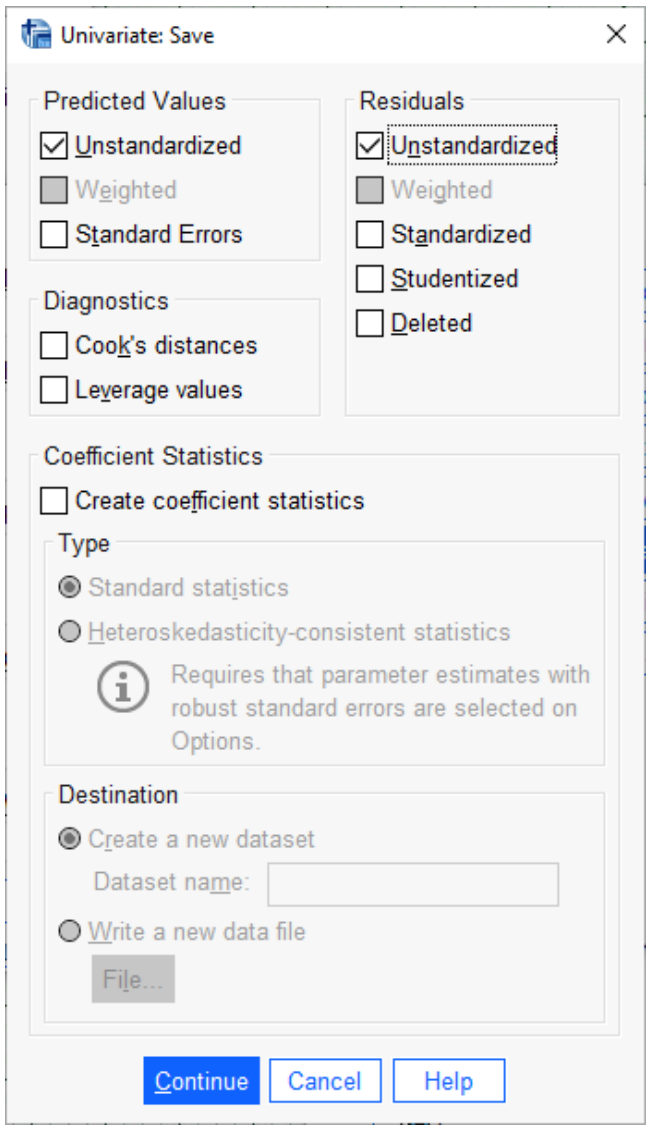
Dependent Variable: y

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	26.000	2.198	11.826	<.001	20.930	31.070
i2	12.000	2.781	4.315	.003	5.587	18.413
i3	2.000	3.109	.643	.538	-5.170	9.170

Speaker notes

Add note.

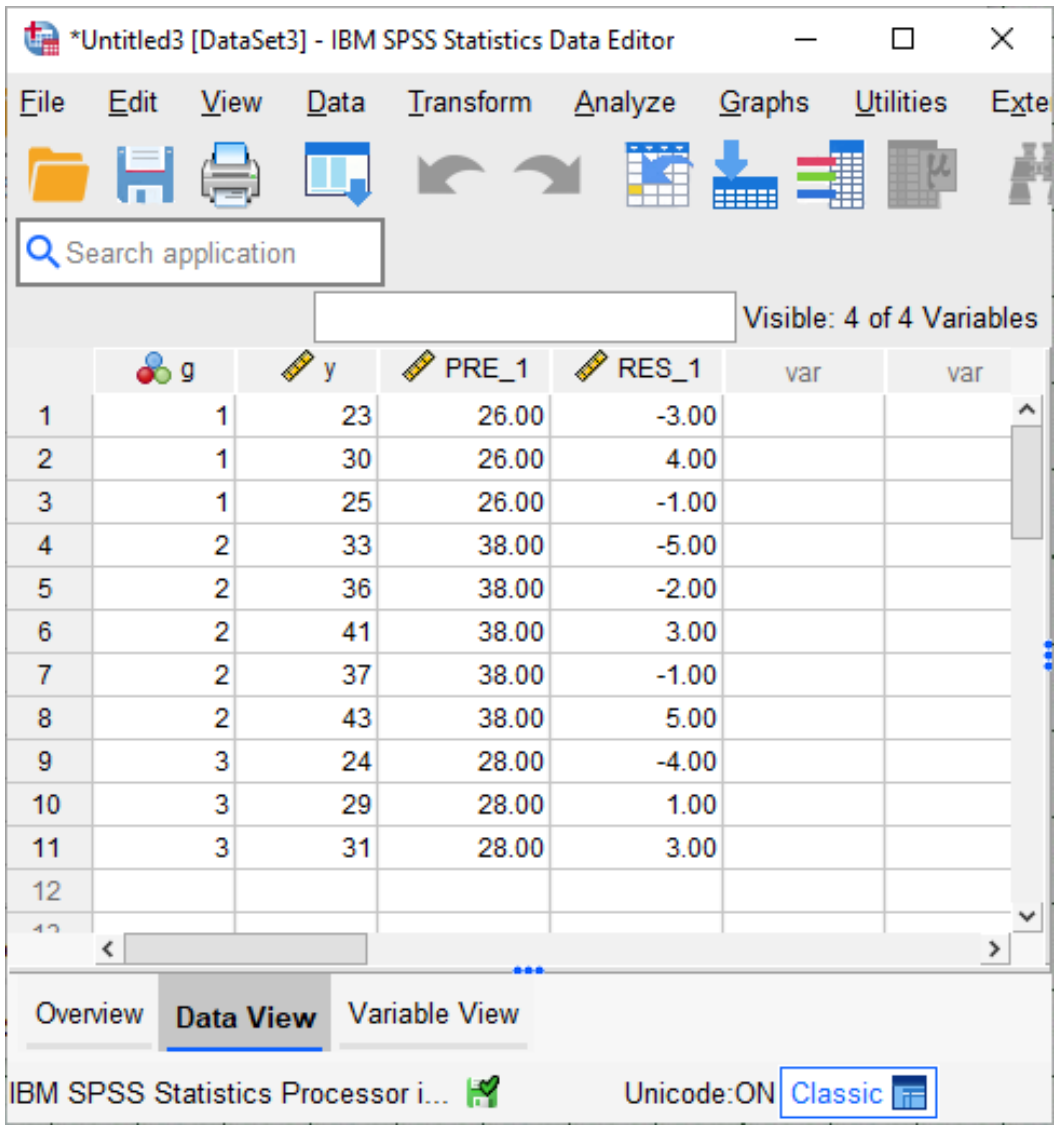
Predicted values and residuals, 1 of 2



Speaker notes

Add note.

Predicted values and residuals, 2 of 2



	g	y	PRE_1	RES_1	var	var
1	1	23	26.00	-3.00		
2	1	30	26.00	4.00		
3	1	25	26.00	-1.00		
4	2	33	38.00	-5.00		
5	2	36	38.00	-2.00		
6	2	41	38.00	3.00		
7	2	37	38.00	-1.00		
8	2	43	38.00	5.00		
9	3	24	28.00	-4.00		
10	3	29	28.00	1.00		
11	3	31	28.00	3.00		
12						

Speaker notes

Add note.

What belongs in an interpretation

“Sixty-six women with osteoporosis were alternately assigned to one of three treatment groups: Group 1 (n=22), group 2 (n=22), and controls (n=22). After 6 weeks, the change in bone mineral density from baseline was measured. Analysis with one-way ANOVA indicated a statistically significant difference between the groups ($F_{2,63}=61.07$, $P < 0.001$). Further analysis with Tukey’s pair-wise comparison procedure to control for multiple testing revealed that the mean change (+/- SD) of group 2 (1.6 g/cm^2 +/-0.2) was significantly greater than that of group 1 (1.1 g/cm^2 +/- 0.2) and that of the controls (1.0 g/cm^2 +/- 0.2) with an overall alpha level of 0.05.”

Speaker notes

Add note.

Identify the dependent variable

“Sixty-six women with osteoporosis were alternately assigned to one of three treatment groups: Group 1 (n=22), group 2 (n=22), and controls (n=22). After 6 weeks, **the change in bone mineral density from baseline was measured.** Analysis with one-way ANOVA indicated a statistically significant difference between the groups ($F_{2,63}=61.07$, $P < 0.001$). Further analysis with Tukey’s pair-wise comparison procedure to control for multiple testing revealed that the mean change (+/- SD) of group 2 (1.6 g/cm^2 +/-0.2) was significantly greater than that of group 1 (1.1 g/cm^2 +/- 0.2) and that of the controls (1.0 g/cm^2 +/- 0.2) with an overall alpha level of 0.05.”

Speaker notes

Add note.

Summarize each group

"Sixty-six women with osteoporosis were alternately assigned to one of three treatment groups: **Group 1 (n=22), group 2 (n=22), and controls (n=22).** After 6 weeks, the change in bone mineral density from baseline was measured. Analysis with one-way ANOVA indicated a statistically significant difference between the groups ($F_{2,63}=61.07$, $P < 0.001$). Further analysis with Tukey's pair-wise comparison procedure to control for multiple testing revealed that the **mean change (+/- SD) of group 2 (1.6 g/cm^2 +/-0.2) was significantly greater than that of group 1 (1.1 g/cm^2 +/- 0.2) and that of the controls (1.0 g/cm^2 +/- 0.2)** with an overall alpha level of 0.05."

Speaker notes

Add note.

Explain how subjects were assigned

“Sixty-six women with osteoporosis were **alternately assigned** to one of three treatment groups: Group 1 (n=22), group 2 (n=22), and controls (n=22). After 6 weeks, the change in bone mineral density from baseline was measured. Analysis with one-way ANOVA indicated a statistically significant difference between the groups ($F_{2,63}=61.07$, $P < 0.001$). Further analysis with Tukey’s pair-wise comparison procedure to control for multiple testing revealed that the mean change (+/- SD) of group 2 (1.6 g/cm^2 +/-0.2) was significantly greater than that of group 1 (1.1 g/cm^2 +/- 0.2) and that of the controls (1.0 g/cm^2 +/- 0.2) with an overall alpha level of 0.05.”

Speaker notes

Add note.

Describe the statistical test

“Sixty-six women with osteoporosis were alternately assigned to one of three treatment groups: Group 1 (n=22), group 2 (n=22), and controls (n=22). After 6 weeks, the change in bone mineral density from baseline was measured. **Analysis with one-way ANOVA** indicated a statistically significant difference between the groups ($F_{2,63}=61.07$, $P < 0.001$). Further analysis with Tukey’s pair-wise comparison procedure to control for multiple testing revealed that the mean change (+/- SD) of group 2 (1.6 g/cm^2 +/-0.2) was significantly greater than that of group 1 (1.1 g/cm^2 +/- 0.2) and that of the controls (1.0 g/cm^2 +/- 0.2) with an overall alpha level of 0.05.”

Speaker notes

Add note.

Specify the alpha level

“Sixty-six women with osteoporosis were alternately assigned to one of three treatment groups: Group 1 (n=22), group 2 (n=22), and controls (n=22). After 6 weeks, the change in bone mineral density from baseline was measured. Analysis with one-way ANOVA indicated a statistically significant difference between the groups ($F_{2,63}=61.07$, $P < 0.001$). Further analysis with Tukey’s pair-wise comparison procedure to control for multiple testing revealed that the mean change (+/- SD) of group 2 (1.6 g/cm^2 +/-0.2) was significantly greater than that of group 1 (1.1 g/cm^2 +/- 0.2) and that of the controls (1.0 g/cm^2 +/- 0.2) with an overall **alpha level of 0.05.**”

Speaker notes

Add note.

Specify the F statistic with degrees of freedom

“Sixty-six women with osteoporosis were alternately assigned to one of three treatment groups: Group 1 (n=22), group 2 (n=22), and controls (n=22). After 6 weeks, the change in bone mineral density from baseline was measured. Analysis with one-way ANOVA indicated a statistically significant difference between the groups **(F_2,63=61.07**, P < 0.001). Further analysis with Tukey’s pair-wise comparison procedure to control for multiple testing revealed that the mean change (+/- SD) of group 2 (1.6 g/cm^2 +/-0.2) was significantly greater than that

of group 1 (1.1 g/cm^2 +/- 0.2) and that of the controls (1.0 g/cm^2 +/- 0.2) with an overall alpha level of 0.05.”

- Lang and Secic, How to Report Statistics in Medicine, p110.

Speaker notes

Add note.

State the p-value

“Sixty-six women with osteoporosis were alternately assigned to one of three treatment groups: Group 1 (n=22), group 2 (n=22), and controls (n=22). After 6 weeks, the change in bone mineral density from baseline was measured. Analysis with one-way ANOVA indicated a statistically significant difference between the groups ($F_{2,63}=61.07$, **$P < 0.001$**). Further analysis with Tukey’s pair-wise comparison procedure to control for multiple testing revealed that the mean change (+/- SD) of group 2 (1.6 g/cm^2 +/-0.2) was significantly greater than that of group 1 (1.1 g/cm^2 +/- 0.2) and that of the controls (1.0 g/cm^2 +/- 0.2) with an overall alpha level of 0.05.”

Speaker notes

Add note.

Describe any post hoc analyses

"Sixty-six women with osteoporosis were alternately assigned to one of three treatment groups: Group 1 (n=22), group 2 (n=22), and controls (n=22). After 6 weeks, the change in bone mineral density from baseline was measured. Analysis with one-way ANOVA indicated a statistically significant difference between the groups ($F_{2,63}=61.07$, $P < 0.001$). **Further analysis with Tukey's pair-wise comparison procedure to control for multiple testing** revealed that the mean change (+/- SD) of group 2 (1.6 g/cm^2 +/-0.2) was significantly greater than that of group 1 (1.1 g/cm^2 +/- 0.2) and that of the controls (1.0 g/cm^2 +/- 0.2) with an overall alpha level of 0.05."

Speaker notes

Add note.

Yeast activation experiment

“To shorten the time it takes him tomake his favorite pizza, a student designed an experiment to test the effect of sugar and milk on the activation times for baking yeast. Specifically, he tested four different recipes and measured how many seconds it took for the same amount of dough to rise to the top of a bowl. He randomized the order of the recipes and replicated each treatment 4 times.”

- DASL, Activating baking yeast

Yeast analysis, descriptive statistics

Descriptive Statistics

Dependent Variable: ActivationTimes

Recipe	Mean	Std. Deviation	N
A	486.25	79.622	4
B	196.25	67.004	4
C	656.00	74.099	4
D	183.75	52.182	4
Total	380.56	215.421	16

Speaker notes

Add note.

Yeast analysis, ANOVA table

Dependent Variable: ActivationTimes

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	638967.688[a]	3	212989.229	44.739	<.001
Intercept	2317245.063	1	2317245.063	486.746	<.001
Recipe	638967.687	3	212989.229	44.739	<.001
Error	57128.250	12	4760.688		
Total	3013341.000	16			
Corrected Total	696095.938	15			

a. R Squared = .918 (Adjusted R Squared = .897)

Speaker notes

Add note.

Yeast analysis, parameter estimates

Dependent Variable: ActivationTimes

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	183.750	34.499	5.326	<.001	108.583	258.917
[Recipe=A]	302.500	48.789	6.200	<.001	196.198	408.802
[Recipe=B]	12.500	48.789	.256	.802	-93.802	118.802
[Recipe=C]	472.250	48.789	9.679	<.001	365.948	578.552
[Recipe=D]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Speaker notes

Add note.

Yeast analysis, Tukey post hoc, 1 of 2

Dependent Variable: ActivationTimes

Tukey HSD

(I) Recipe	(J) Recipe	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A	B	290.00*	48.789	<.001	145.15	434.85
	C	-169.75*	48.789	.021	-314.60	-24.90
	D	302.50*	48.789	<.001	157.65	447.35
B	A	-290.00*	48.789	<.001	-434.85	-145.15
	C	-459.75*	48.789	<.001	-604.60	-314.90
	D	12.50	48.789	.994	-132.35	157.35
C	A	169.75*	48.789	.021	24.90	314.60
	B	459.75*	48.789	<.001	314.90	604.60
	D	472.25*	48.789	<.001	327.40	617.10
D	A	-302.50*	48.789	<.001	-447.35	-157.65
	B	-12.50	48.789	.994	-157.35	132.35
	C	-472.25*	48.789	<.001	-617.10	-327.40

Based on observed means.

The error term is Mean Square(Error) = 4760.688.

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

Speaker notes

Add note.

Yeast analysis, Tukey post hoc, 2 of 2

ActivationTimes

Tukey HSD[a,b]

Recipe	N	Subset 1	2	3
D	4	183.75		
B	4	196.25		
A	4		486.25	
C	4			656.00
Sig.		.994	1.000	1.000

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = 4760.688.

a. Uses Harmonic Mean Sample Size = 4.000.

b. Alpha = .05.

Speaker notes

Add note.

Yeast analysis, interpretation, 1 of 3

- The average activation times were compared using oneway ANOVA with a Tukey post hoc follow-up test.
- All tests used a two-sided alpha level of 0.05.

Speaker notes

Add note.

Yeast analysis, interpretation, 2 of 3

- There were statistically significant differences ($p < 0.001$) in the activation times of the four recipes. Recipes D and B had similar average activation times which were significantly faster than Recipe A, which itself was significantly faster than recipe C.

Speaker notes

Add note.

Yeast analysis, interpretation, 3 of 3

- Recipes D and B were similar and had the fastest activation times. These differences were more than four minutes faster than the next best recipe which represents a practical as well as statistically significant result.

Speaker notes

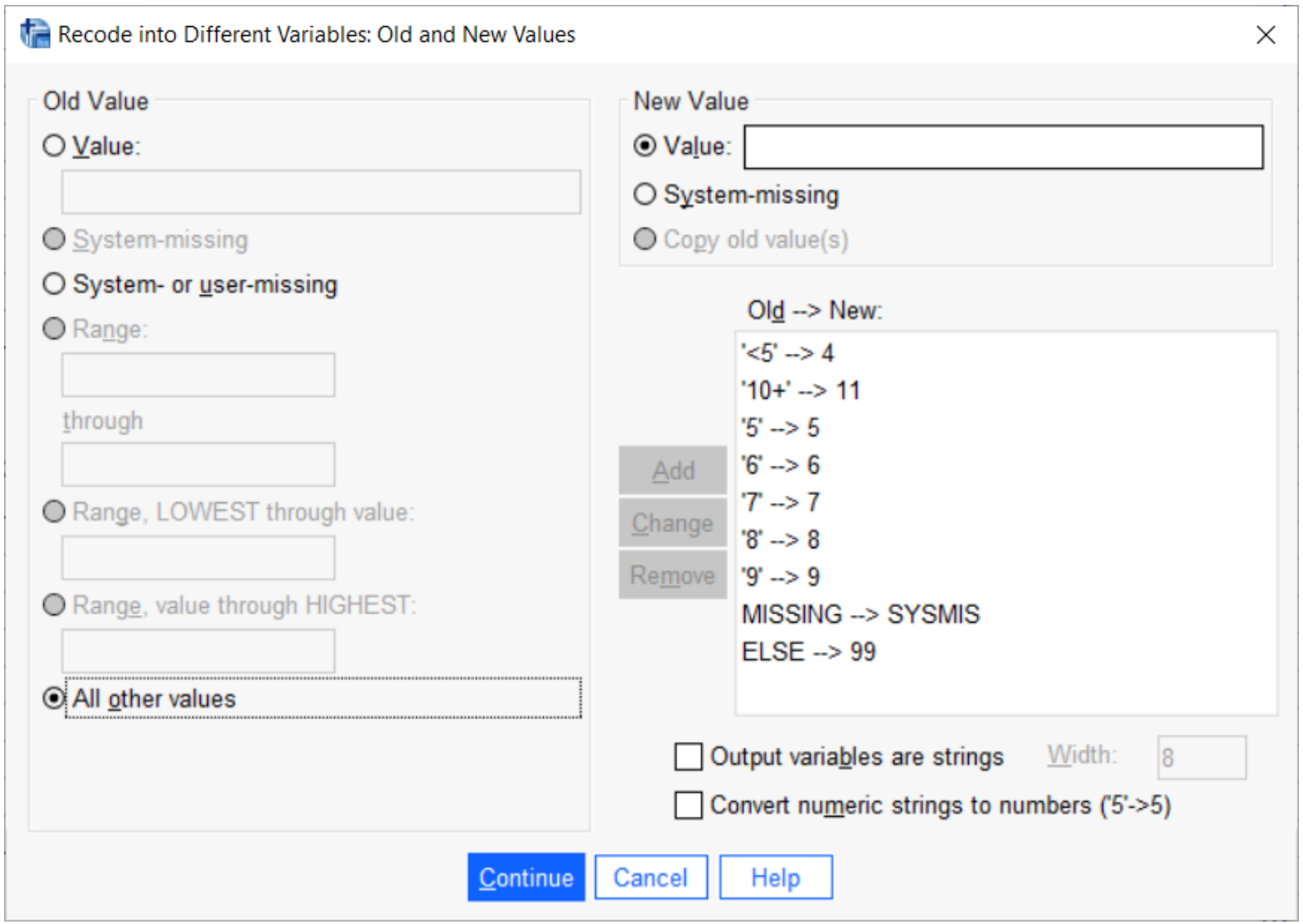
Add note.

Recode into different variables dialog box

Speaker notes

Add note.

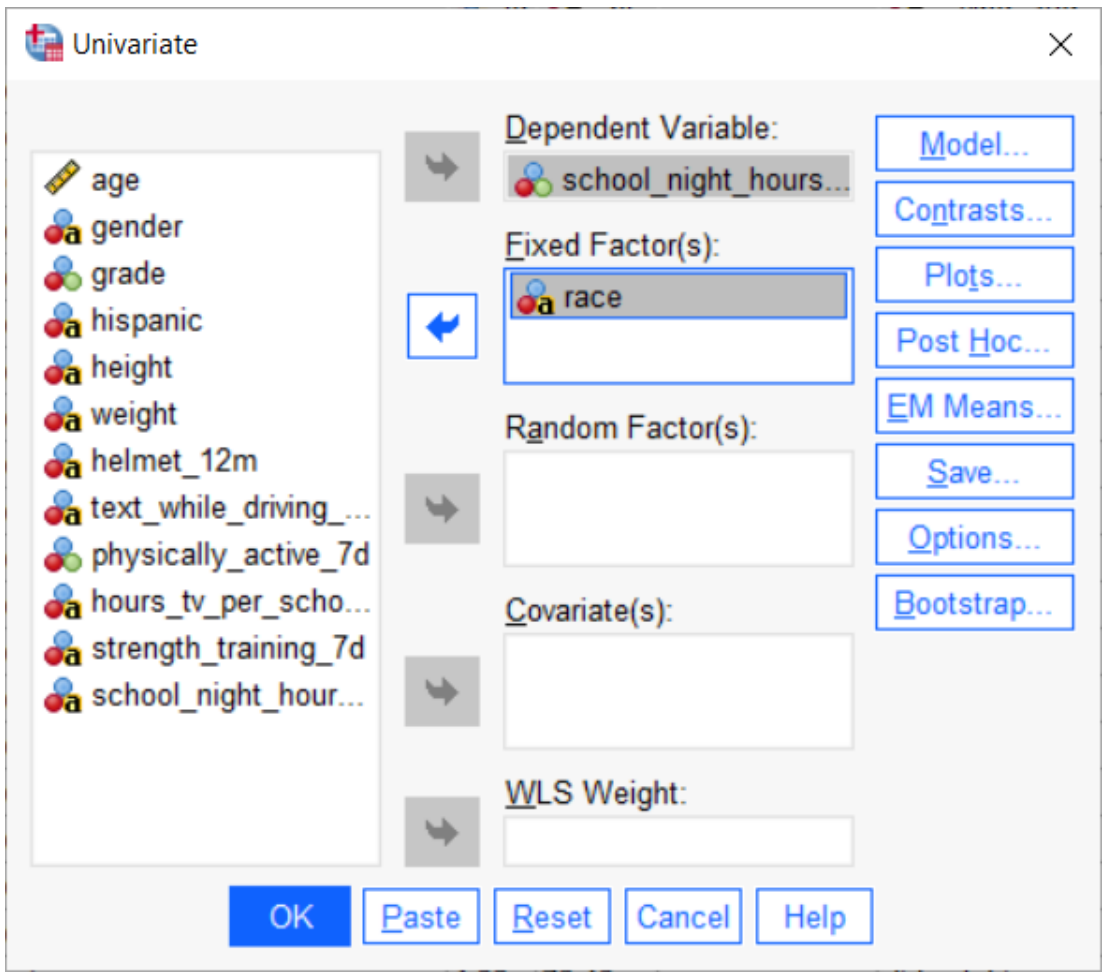
Old and new Values dialog box



Speaker notes

Add note.

General Linear Model | Univariate dialog box



Speaker notes

Add note.

Descriptives output

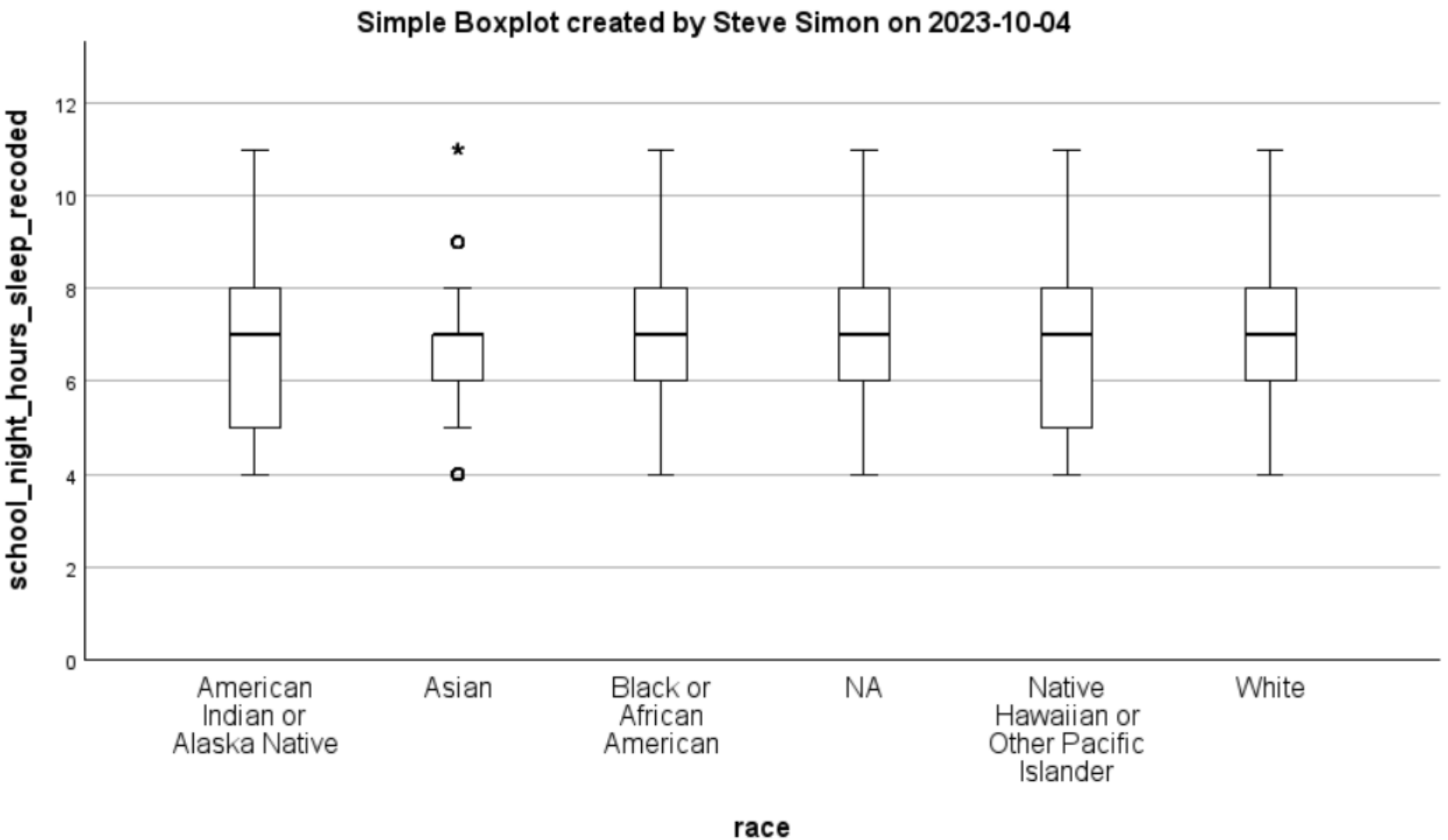
school_night_hours_sleep_recoded

race	Mean	N	Std. Deviation
American Indian or Alaska Native	6.6207	290	1.65990
Asian	6.5326	522	1.41689
Black or African American	6.6353	2830	1.63252
NA	6.8004	2575	1.48907
Native Hawaiian or Other Pacific Islander	6.6500	200	1.66172
White	6.8207	5918	1.39864
Total	6.7543	12335	1.48824

Speaker notes

Add note.

Boxplot


Simple Boxplot created by Steve Simon on 2023-10-04
school_night_hours_sleep_recoded
12
10
8
6
4
2
0
American Indian or Alaska Native
Asian
Black or African American
NA
Native Hawaiian or Other Pacific Islander
White
race

Speaker notes

Add note.

Analysis of variance table

Dependent Variable: school_night_hours_sleep_recoded

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	104.643[a]	5	20.929	9.482	<.001
Intercept	142334.965	1	142334.965	64484.295	<.001
race	104.643	5	20.929	9.482	<.001
Error	27213.568	12329	2.207		
Total	590044.000	12335			
Corrected Total	27318.212	12334			

a. R Squared = .004 (Adjusted R Squared = .003)

Speaker notes

Add note.

Analysis of variance table with irrelevant rows removed

Dependent Variable: school_night_hours_sleep_recoded

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
race (Between)	104.643	5	20.929	9.482	<.001
Error (Within)	27213.568	12329	2.207		
Corrected Total	27318.212	12334			

a. R Squared = .004 (Adjusted R Squared = .003)

Speaker notes

Add note.

Parameter estimates

Dependent Variable: school_night_hours_sleep_recoded

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	6.821	.019	353.174	<.001	6.783	6.859
[race=American Indian or Alaska Native]	-.200	.089	-2.239	.025	-.375	-.025
[race=Asian]	-.288	.068	-4.248	<.001	-.421	-.155
[race=Black or African American]	-.185	.034	-5.460	<.001	-.252	-.119
[race=NA]	-.020	.035	-.580	.562	-.089	.048
[race=Native Hawaiian or Other Pacific Islander]	-.171	.107	-1.598	.110	-.380	.039
[race=White]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Speaker notes

Add note.

Tukey post hoc test, 1 of 7

(I) race	(J) race	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
American Indian or Alaska Native	Asian	.0881	.10881	.966	-.2220	.3983
	Black or African American	-.0146	.09160	1.000	-.2757	.2464
	NA	-.1797	.09202	.370	-.4420	.0826
	Native Hawaiian or Other Pacific Islander	-.0293	.13656	1.000	-.4185	.3599
	White	-.2000	.08935	.220	-.4547	.0546

Speaker notes

Add note.

Tukey post hoc test, 2 of 7

Asian	American Indian or Alaska Native	-.0881	.10881	.966	-.3983	.2220
	Black or African American	-.1028	.07077	.695	-.3045	.0989
	NA	-.2678*	.07131	.002	-.4711	-.0646
	Native Hawaiian or Other Pacific Islander	-.1174	.12355	.933	-.4696	.2347
	White	-.2881*	.06783	<.001	-.4815	-.0948

Speaker notes

Add note.

Tukey post hoc test, 3 of 7

Black or African American	American Indian or Alaska Native	.0146	.09160	1.000	-.2464	.2757
	Asian	.1028	.07077	.695	-.0989	.3045
	NA	-.1651*	.04046	<.001	-.2804	-.0497
	Native Hawaiian or Other Pacific Islander	-.0147	.10870	1.000	-.3245	.2952
	White	-.1854*	.03395	<.001	-.2822	-.0886

Speaker notes

Add note.

Tukey post hoc test, 4 of 7

NA	American Indian or Alaska Native	.1797	.09202	.370	-.0826	.4420
	Asian	.2678*	.07131	.002	.0646	.4711
	Black or African American	.1651*	.04046	<.001	.0497	.2804
	Native Hawaiian or Other Pacific Islander	.1504	.10906	.740	-.1604	.4612
	White	-.0203	.03507	.992	-.1203	.0796

Speaker notes

Add note.

Tukey post hoc test, 5 of 7

Native Hawaiian or Other Pacific Islander	American Indian or Alaska Native	.0293	.13656	1.000	-.3599	.4185
	Asian	.1174	.12355	.933	-.2347	.4696
	Black or African American	.0147	.10870	1.000	-.2952	.3245
	NA	-.1504	.10906	.740	-.4612	.1604
	White	-.1707	.10681	.600	-.4752	.1337

Speaker notes

Add note.

Tukey post hoc test, 6 of 7

White	American Indian or Alaska Native	.2000	.08935	.220	-.0546	.4547
	Asian	.2881*	.06783	<.001	.0948	.4815
	Black or African American	.1854*	.03395	<.001	.0886	.2822
	NA	.0203	.03507	.992	-.0796	.1203
	Native Hawaiian or Other Pacific Islander	.1707	.10681	.600	-.1337	.4752

Based on observed means.
The error term is Mean Square(Error) = 2.207.

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

Speaker notes

Add note.

Tukey post hoc test, 7 of 7

school_night_hours_sleep_recoded

Tukey HSD[a,b,c]

race	N	Subset 1	Subset 2
Asian	522	6.5326	
American Indian or Alaska Native	290	6.6207	6.6207
Black or African American	2830	6.6353	6.6353
Native Hawaiian or Other Pacific Islander	200	6.6500	6.6500
NA	2575		6.8004
White	5918		6.8207
Sig.		.791	.239

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 2.207.

a. Uses Harmonic Mean Sample Size = 532.166.

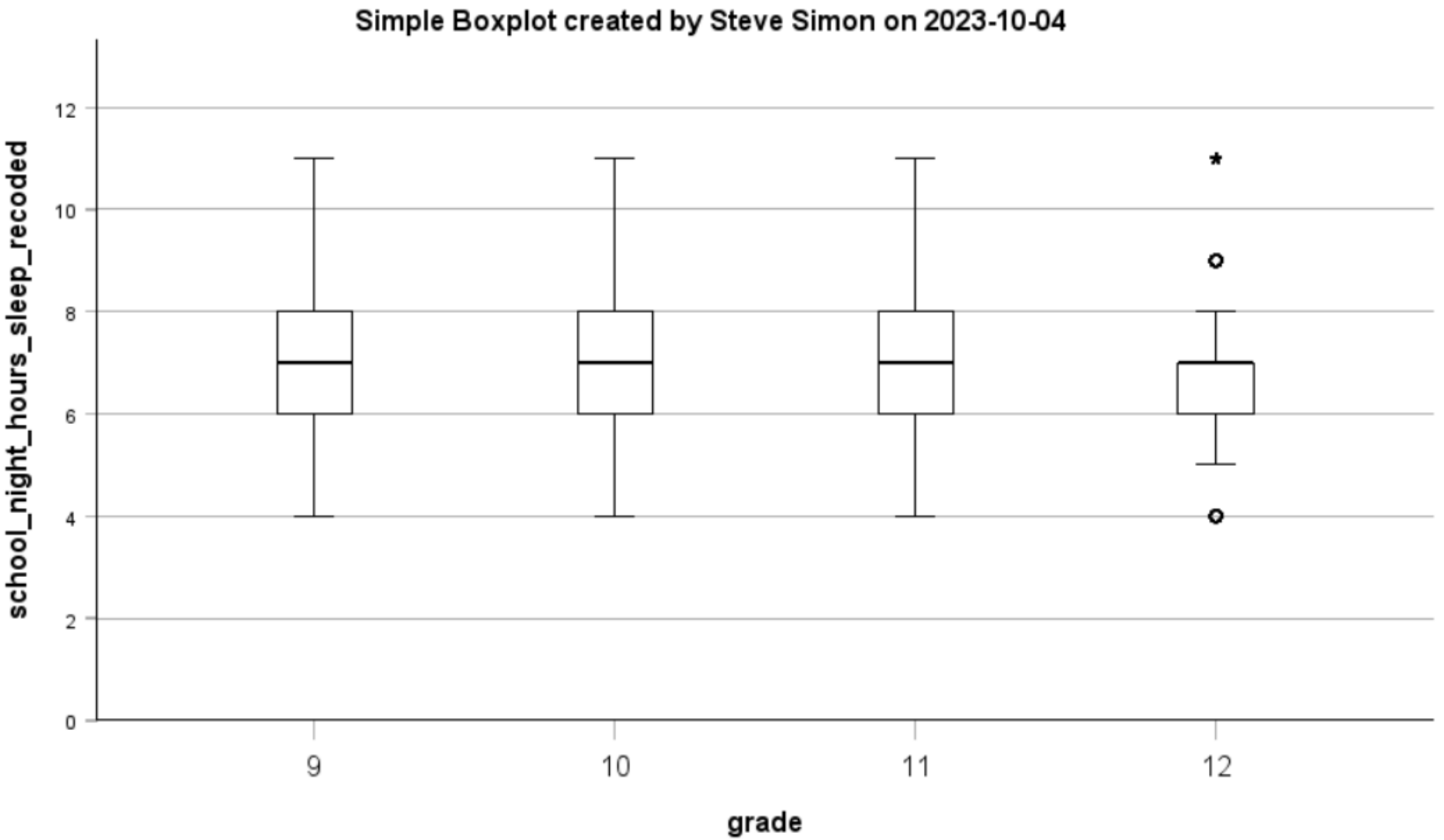
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Speaker notes

Add note.

Checking assumptions, boxplots



Speaker notes

Add note.

Checking assumptions, descriptive statistics

Descriptive Statistics

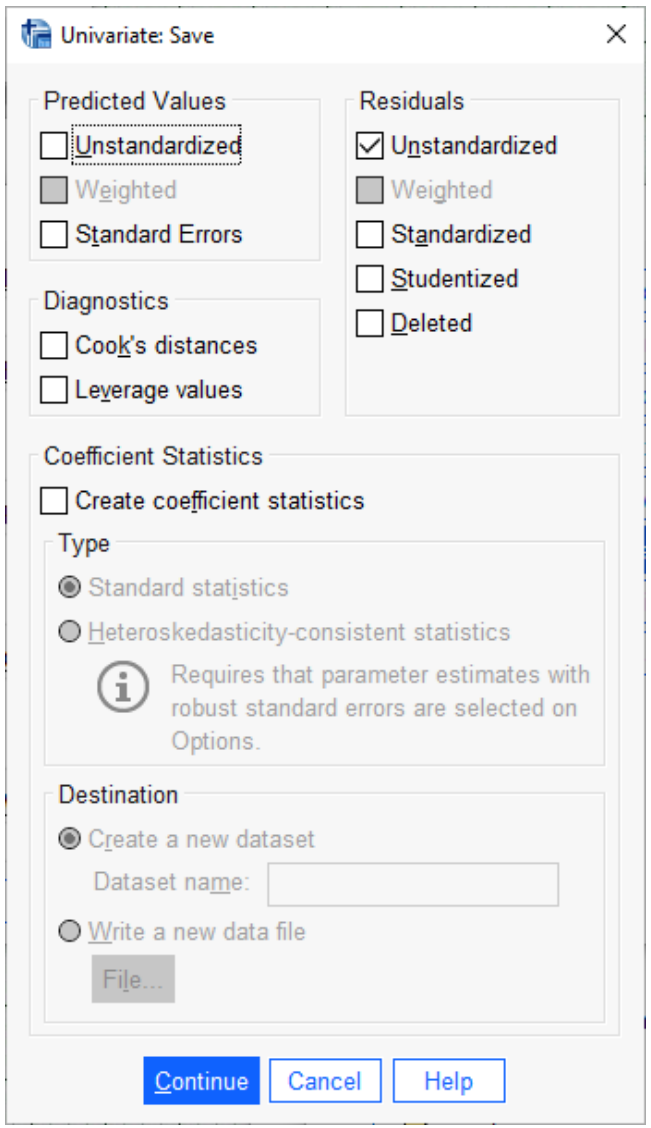
Dependent Variable: school_night_hours_sleep_recoded

grade	Mean	Std. Deviation	N
9	7.0084	1.56499	3204
10	6.8518	1.47786	2840
11	6.6531	1.44953	2917
12	6.5146	1.39146	3278
Total	6.7551	1.48449	12239

Speaker notes

Add note.

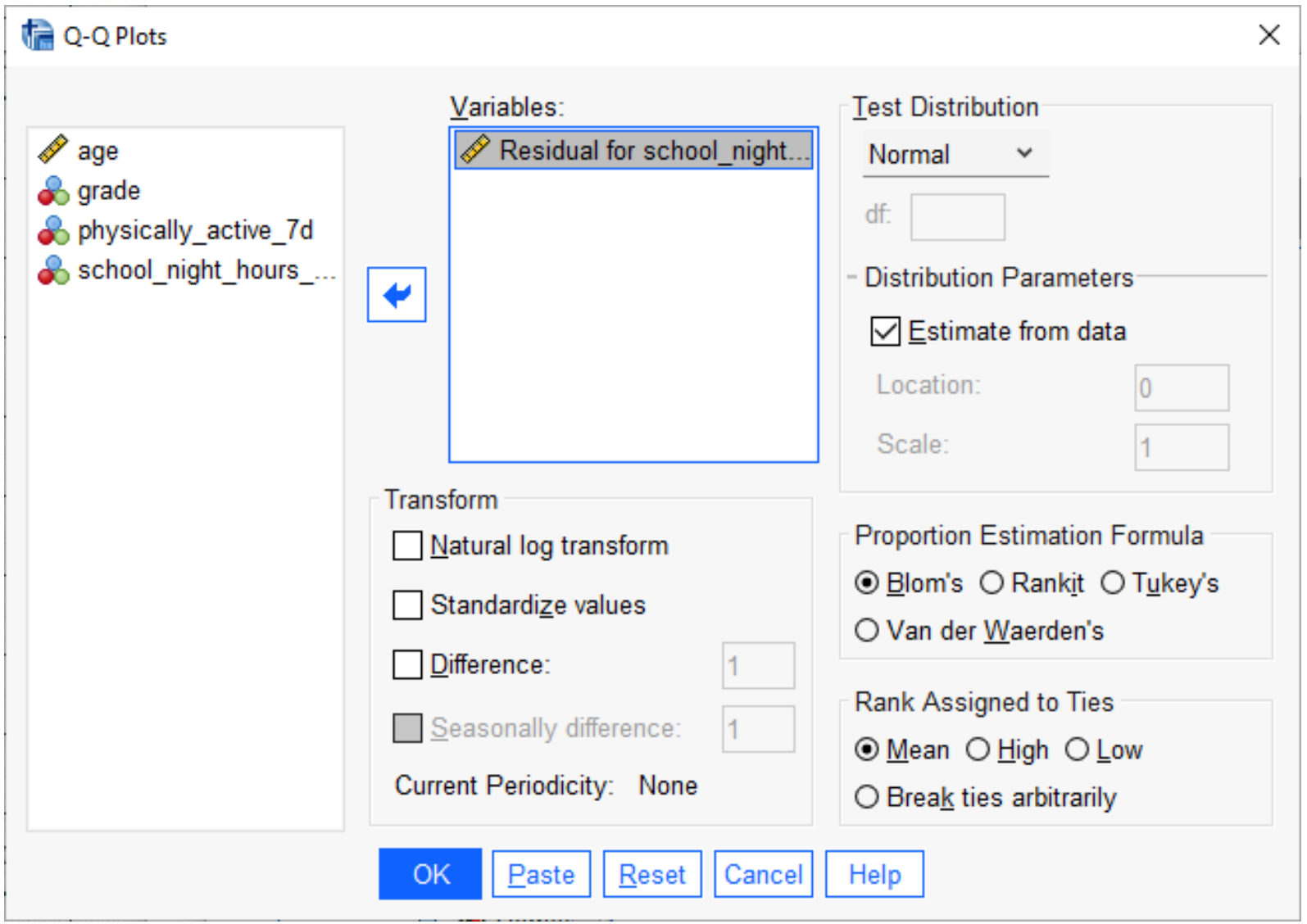
Residual analysis, 1 of 2



Speaker notes

Add note.

Residual analysis, 2 of 2



Speaker notes

Add note.

Analysis of school year, 1 of 4

Dependent Variable: school_night_hours_sleep_recoded

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	452.050[a]	3	150.683	69.525	<.001
Intercept	556744.740	1	556744.740	256882.565	<.001
grade	452.050	3	150.683	69.525	<.001
Error	26517.066	12235	2.167		
Total	585456.000	12239			
Corrected Total	26969.116	12238			

a. R Squared = .017 (Adjusted R Squared = .017)

Speaker notes

Add note.

Analysis of school year, 2 of 4

Parameter Estimates

Dependent Variable: school_night_hours_sleep_recoded

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	6.515	.026	253.358	<.001	6.464	6.565
[grade=9]	.494	.037	13.501	<.001	.422	.565
[grade=10]	.337	.038	8.933	<.001	.263	.411
[grade=11]	.138	.037	3.694	<.001	.065	.212
[grade=12]	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Speaker notes

Add note.

Analysis of school year, 3 of 4

Multiple Comparisons

Dependent Variable: school_night_hours_sleep_recoded

Tukey HSD

(I) grade	(J) grade	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
9	10	.1567*	.03794	<.001	.0592	.2542
	11	.3554*	.03768	<.001	.2586	.4522
	12	.4938*	.03657	<.001	.3998	.5878
10	9	-.1567*	.03794	<.001	-.2542	-.0592
	11	.1987*	.03881	<.001	.0990	.2984
	12	.3371*	.03774	<.001	.2401	.4341
11	9	-.3554*	.03768	<.001	-.4522	-.2586
	10	-.1987*	.03881	<.001	-.2984	-.0990
	12	.1384*	.03747	.001	.0421	.2347
12	9	-.4938*	.03657	<.001	-.5878	-.3998
	10	-.3371*	.03774	<.001	-.4341	-.2401
	11	-.1384*	.03747	.001	-.2347	-.0421

Based on observed means.

The error term is Mean Square(Error) = 2.167.

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

Speaker notes

Add note.

Analysis of school year, 4 of 4

school_night_hours_sleep_recoded

Tukey HSD[a,b,c]

		Subset			
grade	N	1	2	3	4
12	3278	6.5146			
11	2917		6.6531		
10	2840			6.8518	
9	3204				7.0084
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 2.167.

a. Uses Harmonic Mean Sample Size = 3048.538.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Speaker notes

Add note.