Repeated Measures ANOVA and Mixed Model ANOVA

Comparing more than two measurements of the same or matched participants

One-Way Repeated Measures ANOVA

- Used when testing more than 2 experimental conditions.
- In dependent groups ANOVA, all groups are dependent: each score in one group is associated with a score in every other group. This may be because the same subjects served in every group or because subjects have been matched.

Characteristics of Within-Subjects Designs

1. Each participant is exposed to all conditions of the experiment, and therefore, serves as his/her own control.
2. The critical comparison is the difference between the correlated groups on the dependent variable.
3. Susceptible to sequence effects, so the order of the conditions should be "counter-balanced". In complete counter-balancing:
    a. Each participant is exposed to all conditions of the experiment.
    b. Each condition is presented an equal number of times.
    c. Each condition is presented an equal number of times in each position.
    d. Each condition precedes and follows each other condition an equal number of times.

Advantages of Repeated Measures (within-subjects) over Independent Groups (between-subjects) ANOVA

- In repeated measures subjects serve as their own controls.
- Differences in means must be due to:
  - the treatment
  - variations within subjects
  - error (unexplained variation)
- Repeated measures designs are more powerful than independent groups designs.

An example: Fatigue and balance (fatigue.sav)

- Example: Balance errors were measured five times, at five levels of fatigue. Fatigue is a within subjects factor with 5 levels.

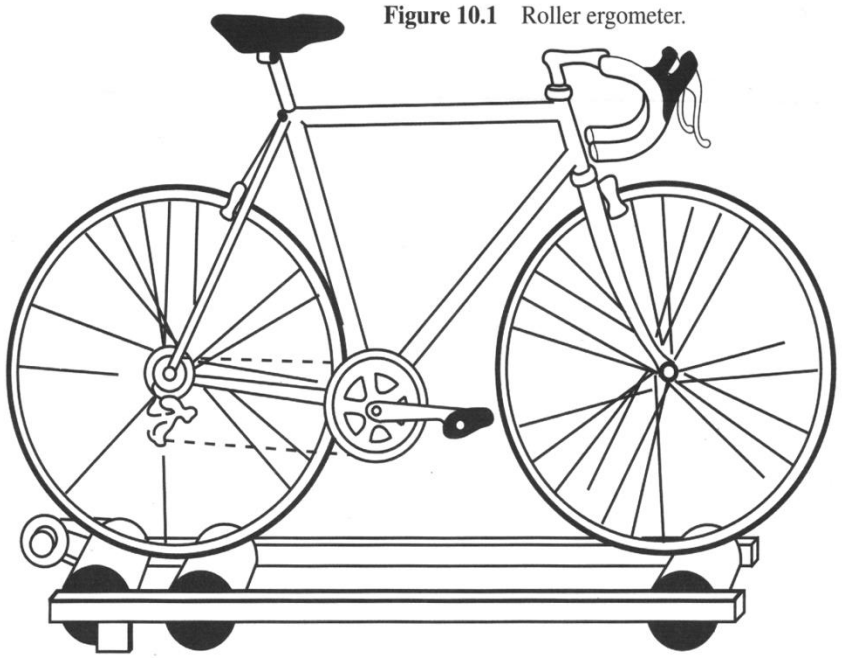


Figure 10.1 Roller ergometer.

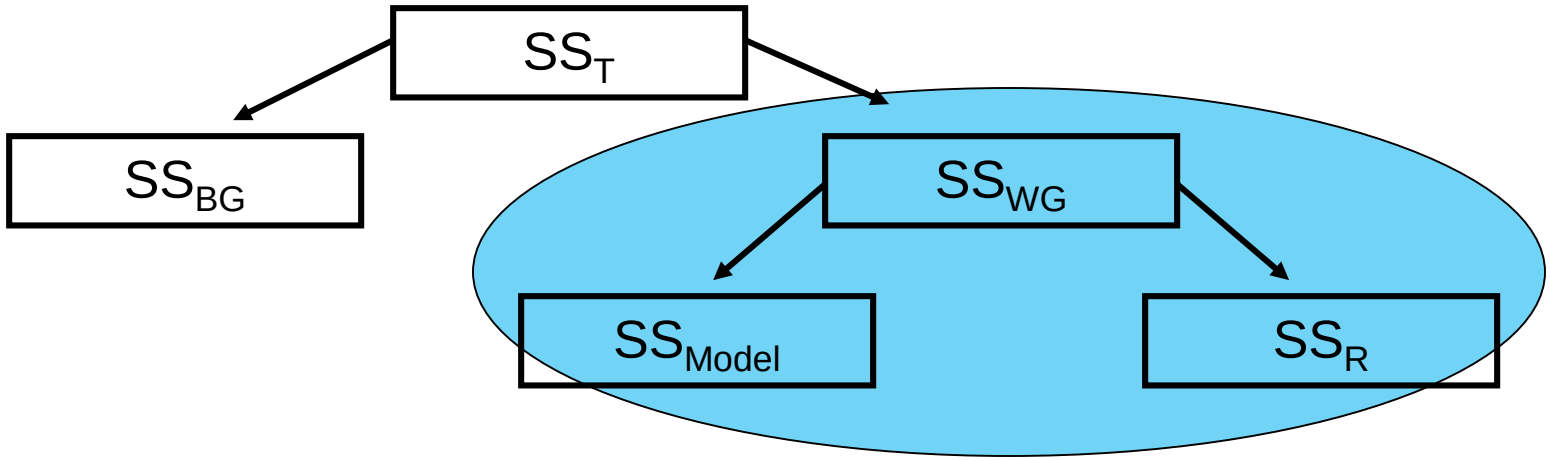
Subjects rode for 15 minutes, divided into five 3-minute periods for the purpose of collecting data. Data were collected on the number of balance errors during the last minute of each 3-minute period, and resistance was increased at the end of each 3-minute period. In this design, the dependent variable is balance errors and the independent variable is increase in resistance (fatigue).

Roller Ergometer Data. Within Subjects Factor with 5 levels (3, 6, 9, 12, 15 min) – Balance errors/minute

Subject	Minute 3	Minute 6	Minute 9	Minute 12	Minute 15
1	7	7	23	36	70
2	12	22	26	26	20
3	11	6	9	31	30
4	10	18	16	40	25
5	6	12	9	28	37
6	13	21	30	55	65
7	5	0	2	10	11
8	15	18	22	37	42
9	0	2	0	16	11
10	6	8	27	32	54

Calculating One-Way Repeated Measures ANOVA

- variance is partitioned into SS_T, SS_M and SS_R
- in repeated-measures ANOVA, the model and residual sums of squares are both part of the within-group variance.



Steps in the Analysis

- SS_T = as before (squared difference between each score and the grand mean)
- $SS_{BG} = SS_T - SS_{WG}$
- SS_{WG} = for each participant, difference between their individual scores and their mean, squared and summed
- SS_M = the squared difference between each condition mean and the grand mean multiplied by the number of subjects, summed
- $SS_R = SS_{WG} – SS_M$ (the amount of within-group variation not explained by the experimental manipulation)

- Divide by the appropriate df:

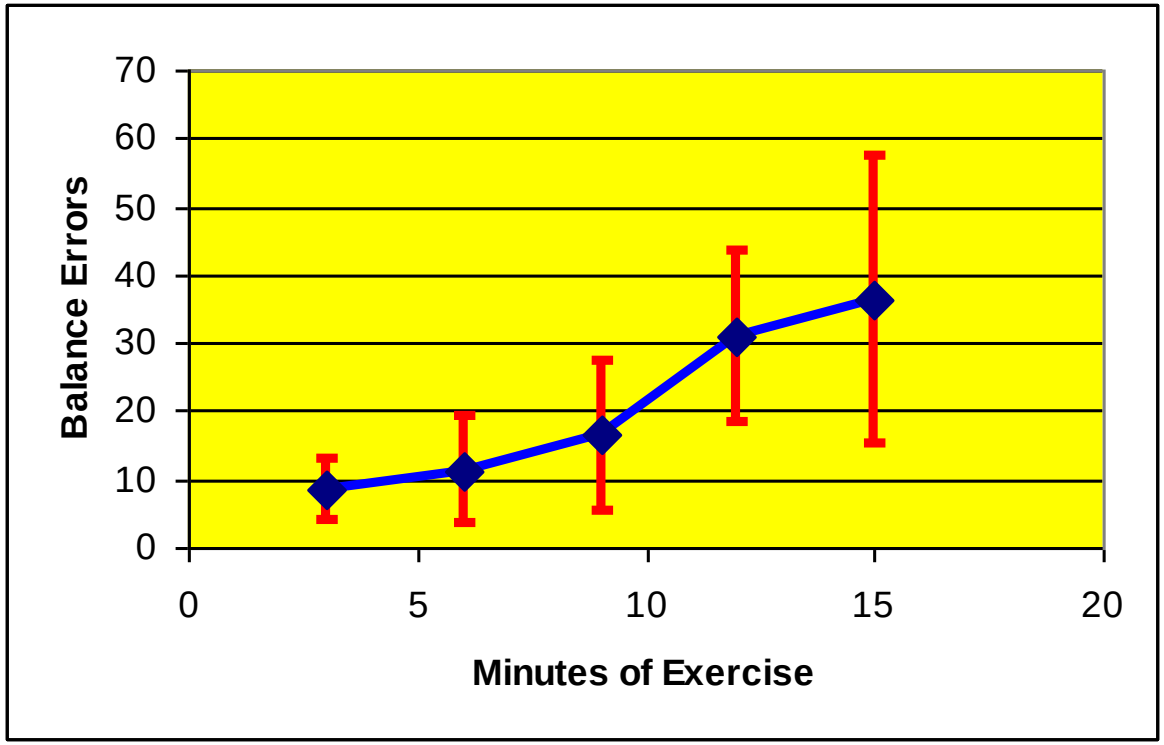
  (1) df for SS_M = levels of the IV minus 1 (= k - 1);

  (2) df for SS_R = (k - 1) x (n - 1) *[n = number of participants]*

- *F* = MS_M/MS_R = the probability of getting a value like this by chance alone.

Descriptives

Minutes of Exercise	Balance Errors	sd
3	8.5	4.5
6	11.4	7.96
9	16.4	10.8
12	31.1	12.56
15	36.5	21.13



Sphericity condition

- **Sphericity**: refers to the equality of variances of the differences between treatment levels.
  - If we were to take each pair of treatment levels and calculate the differences between each pair of scores, then it is necessary that these differences have equal variances.
- **Mauchly's** test statistic
  - If significant, the variances are significantly different from equal, and a correction must be applied to produce a valid F-ratio:

Corrections applied to degrees of freedom to produce a valid F-ratio:

- when G-G Sphericity Epsilon estimates < .75, use Greenhouse-Geisser estimate
- When G-G sphericity Epsilon esimates > .75, use Huynh-Feldt estimate

SPSS Output

Within-Subjects Factors

Measure: MEASURE_1

treatmnt	Dependent Variable
1	Minute_3
2	Minute_6
3	Minute_9
4	Minute_12
5	Minute_15

General Linear Model

Descriptive Statistics

	Mean	Std. Deviation	N
Minute_3	8.5000	4.50309	10
Minute_6	11.4000	7.96102	10
Minute_9	16.4000	10.80329	10
Minute_12	31.1000	12.55610	10
Minute_15	36.5000	21.13055	10

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
treatmnt	Pillai's Trace	.866	9.694[b]	4.000	6.000	.009	.866	38.777	.934
	Wilks' Lambda	.134	9.694[b]	4.000	6.000	.009	.866	38.777	.934
	Hotelling's Trace	6.463	9.694[b]	4.000	6.000	.009	.866	38.777	.934
	Roy's Largest Root	6.463	9.694[b]	4.000	6.000	.009	.866	38.777	.934

a. Computed using alpha = .05

b. Exact statistic

c.
Design: Intercept
Within Subjects Design: treatmnt

Repeated Measure ANOVA Assumptions: Sphericity?

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

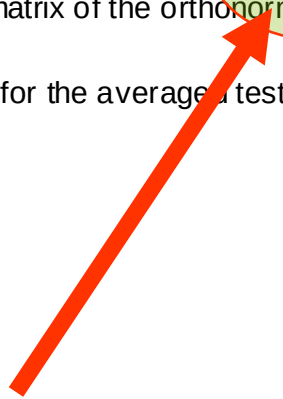
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
treatmnt	.024	27.594	9	.001	.371	.428	.250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.

Design: Intercept
Within Subjects Design: treatmnt



You don't want this to be significant.

Mauchly's Test of Sphericity indicated that sphericity was violated [W(9) =27.59, p = .001

Since Sphericity is violated, we must use either the G-G or H-F adjusted ANOVAs

SPSS Output: Within Subjects Factors

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
treatmnt	Sphericity Assumed	6115.880	4	1528.970	18.359	.000	.671	73.437	1.000
	Greenhouse-Geisser	6115.880	1.485	4117.754	18.359	.000	.671	27.268	.995
	Huynh-Feldt	6115.880	1.710	3575.916	18.359	.000	.671	31.400	.998
	Lower-bound	6115.880	1.000	6115.880	18.359	.002	.671	18.359	.967
Error(treatmnt)	Sphericity Assumed	2998.120	36	83.281					
	Greenhouse-Geisser	2998.120	13.367	224.289					
	Huynh-Feldt	2998.120	15.393	194.776					
	Lower-bound	2998.120	9.000	333.124					

a. Computed using alpha = .05

If Sphericity was okay then the statistics would be F(4,36) = 18.36, p = .000, power = 1.000

But since Sphericity was violated we use the adjusted values: F(1.48,13.37) = 18.36, p = .000, effect size or partial η^2 = .67
(remember: $\eta^2 = (SS_M/SS_M + SS_R)$ .02 small, .13 medium, .26 large)

SPSS Output: Between Subjects Effects

Tests of Between-Subjects Effects

Measure: MEASURE_1

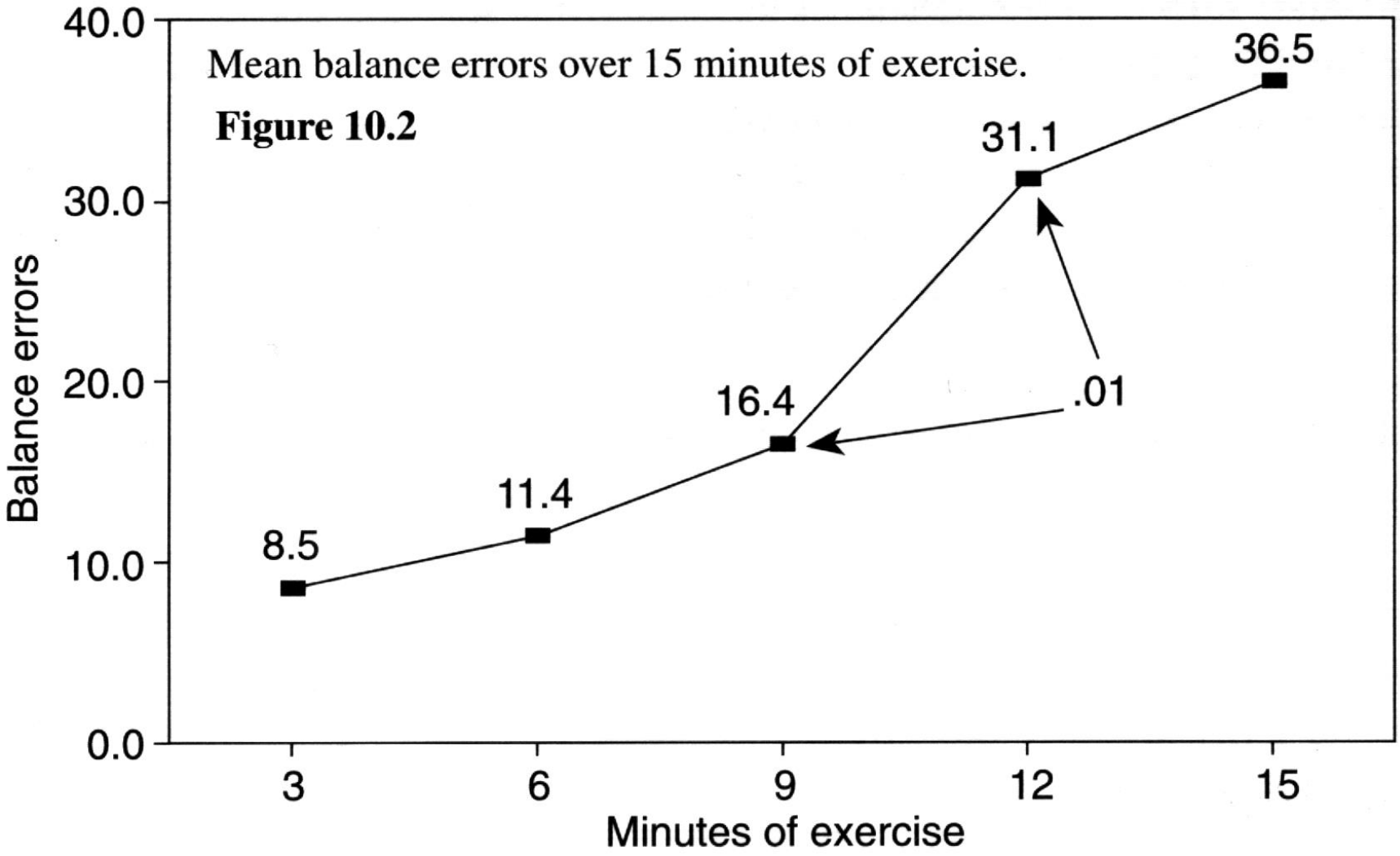
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	21590.420	1	21590.420	45.801	.000	.836	45.801	1.000
Error	4242.580	9	471.398					

a. Computed using alpha = .05

If we had a between subjects factor like Gender, the ANOVA results would be printed here.

“Repeated” contrast because we expect linear increase, or Bonferroni post-hoc tests



Reporting the Results

Participants's balance errors were measured after 3, 6, 9, 12 and 15 minutes of exercise on an ergometer.

The results of a One-Way Repeated Measures ANOVA show that the number of balance errors was significantly affected by fatigue, $F(1.48, 13.36) = 18.36$, $p<.001$. Since Mauchley's test of sphericity was violated, the Greenhouse-Geisser correction was used. Eta^2 effect size ($\eta^2 = .67$) indicated that the effect of fatigue on balance errors was substantial. Bonferroni post-hoc tests comparing adjacent fatigue conditions revealed a significant difference in the number of balance errors between 9 and 12 minutes of exercise $p = .001$, $\eta^2 = .78$. No other comparisons were significant.

Two-way repeated measures

- Two (or more) independent variables
- All are within-group variables – repeated measures
- Effects:
  - Main effect of Factor A
  - Main effect of Factor B
  - Interaction A x B
- In SPSS: define all independent variables in General Lineral Model

MIXED MODEL ANOVA

Mixed Model ANOVA

- Two (or more) independent variables
  - Some within-subjects
  - Some between-subjects
- Effects:
  - Main effect of within-subject variable
  - Between-subject effect
  - Interaction

Sample Problem: Stress and partner

The researcher conducts a study to determine whether the presence of a person's spouse while sleeping reduces the presence of sleep disturbances (reduction in deep (delta) sleep) in individuals who are stressed.

attachSleep.sav

Method

Participants. 30 women who had recently moved to a new area to begin new jobs with their spouses. Among the women, 10 are secure, 10 are anxious, and 10 are avoidant in their attachment styles.

Procedure. The sleep patterns of the 30 women are monitored while they sleep alone and while they sleep with their spouses. The DV is the overall percentage of time spent in deep delta sleep.

Design. Two-way mixed ANOVA with one within-subjects factor and one between-groups factor. Partner-proximity (sleep with spouse vs. sleep alone) is the within-subjects factor; Attachment style is the between-subjects factor.

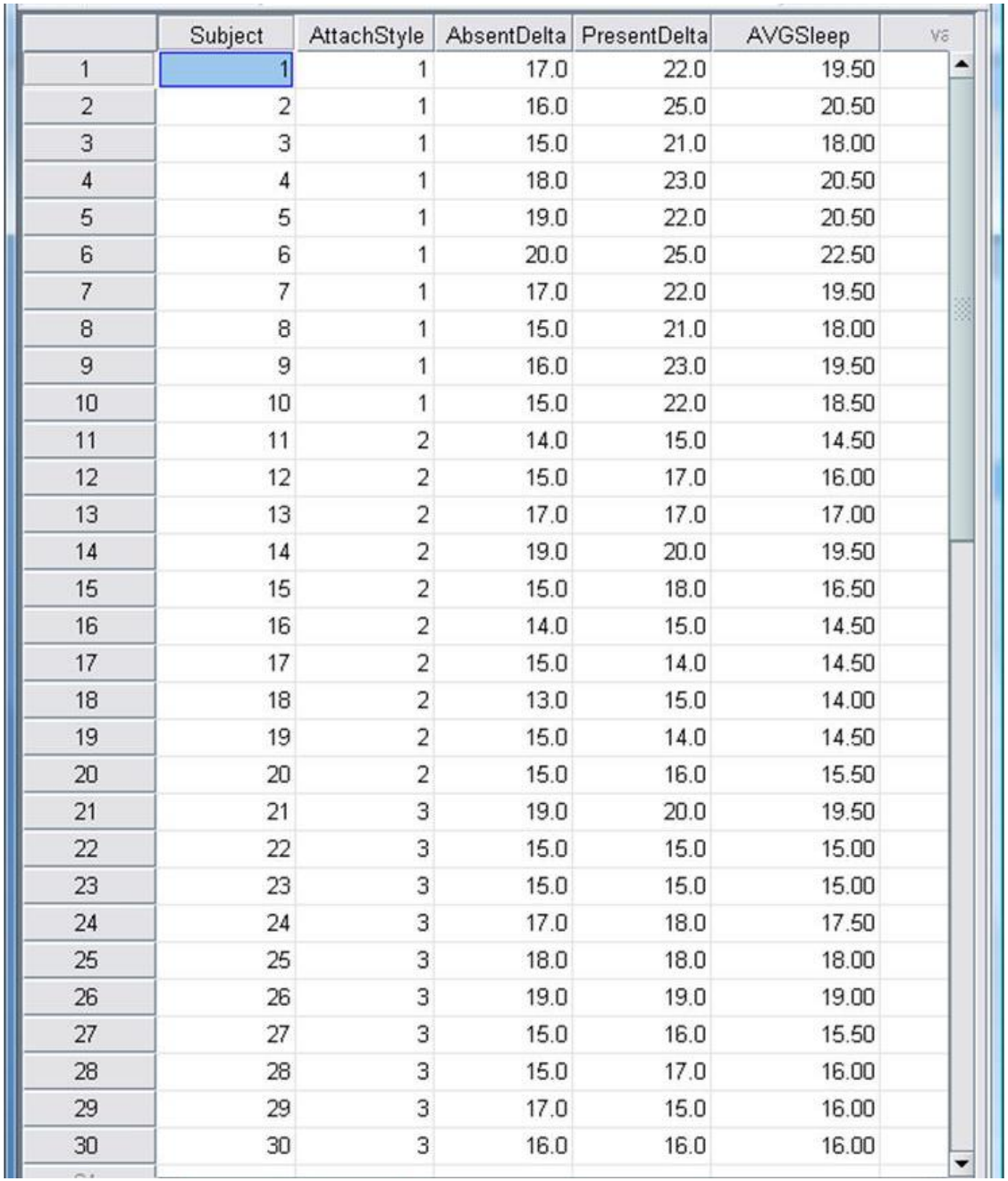
H1: Subjects will experience significantly greater sleep disturbances in the absence of their spouses due to the stressful nature of their present circumstances.

H2: Subjects with secure attachment styles will derive more comfort from the presence of their spouses and will experience a greater increase in deep delta sleep than subjects with insecure attachment styles.

Data View

Attachment Style Key

1 = Secure
2 = Anxious
3 = Avoidant



	Subject	AttachStyle	AbsentDelta	PresentDelta	AVGSleep	var
1	1	1	17.0	22.0	19.50	
2	2	1	16.0	25.0	20.50	
3	3	1	15.0	21.0	18.00	
4	4	1	18.0	23.0	20.50	
5	5	1	19.0	22.0	20.50	
6	6	1	20.0	25.0	22.50	
7	7	1	17.0	22.0	19.50	
8	8	1	15.0	21.0	18.00	
9	9	1	16.0	23.0	19.50	
10	10	1	15.0	22.0	18.50	
11	11	2	14.0	15.0	14.50	
12	12	2	15.0	17.0	16.00	
13	13	2	17.0	17.0	17.00	
14	14	2	19.0	20.0	19.50	
15	15	2	15.0	18.0	16.50	
16	16	2	14.0	15.0	14.50	
17	17	2	15.0	14.0	14.50	
18	18	2	13.0	15.0	14.00	
19	19	2	15.0	14.0	14.50	
20	20	2	15.0	16.0	15.50	
21	21	3	19.0	20.0	19.50	
22	22	3	15.0	15.0	15.00	
23	23	3	15.0	15.0	15.00	
24	24	3	17.0	18.0	17.50	
25	25	3	18.0	18.0	18.00	
26	26	3	19.0	19.0	19.00	
27	27	3	15.0	16.0	15.50	
28	28	3	15.0	17.0	16.00	
29	29	3	17.0	15.0	16.00	
30	30	3	16.0	16.0	16.00	

Homogeneity Assessment

Mauchly's Test of Sphericity[b]

Measure:MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Partner	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept + AttachStyle
Within Subjects Design: Partner

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

	F	df1	df2	Sig.
AbsentDelta	.273	2	27	.763
PresentDelta	.622	2	27	.544

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

a. Design: Intercept + AttachStyle
Within Subjects Design: Partner

Main Analyses:
Repeated Measures

Note:
Partner "1" = Sleeping Partner Absent
Partner "2" = Sleeping Partner Present

2. AttachStyle * Partner

Measure:MEASURE_1

Attach Style	Partner	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	16.800	.536	15.700	17.900
	2	22.600	.545	21.482	23.718
2	1	15.200	.536	14.100	16.300
	2	16.100	.545	14.982	17.218
3	1	16.600	.536	15.500	17.700
	2	16.900	.545	15.782	18.018

Tests of Within-Subjects Effects

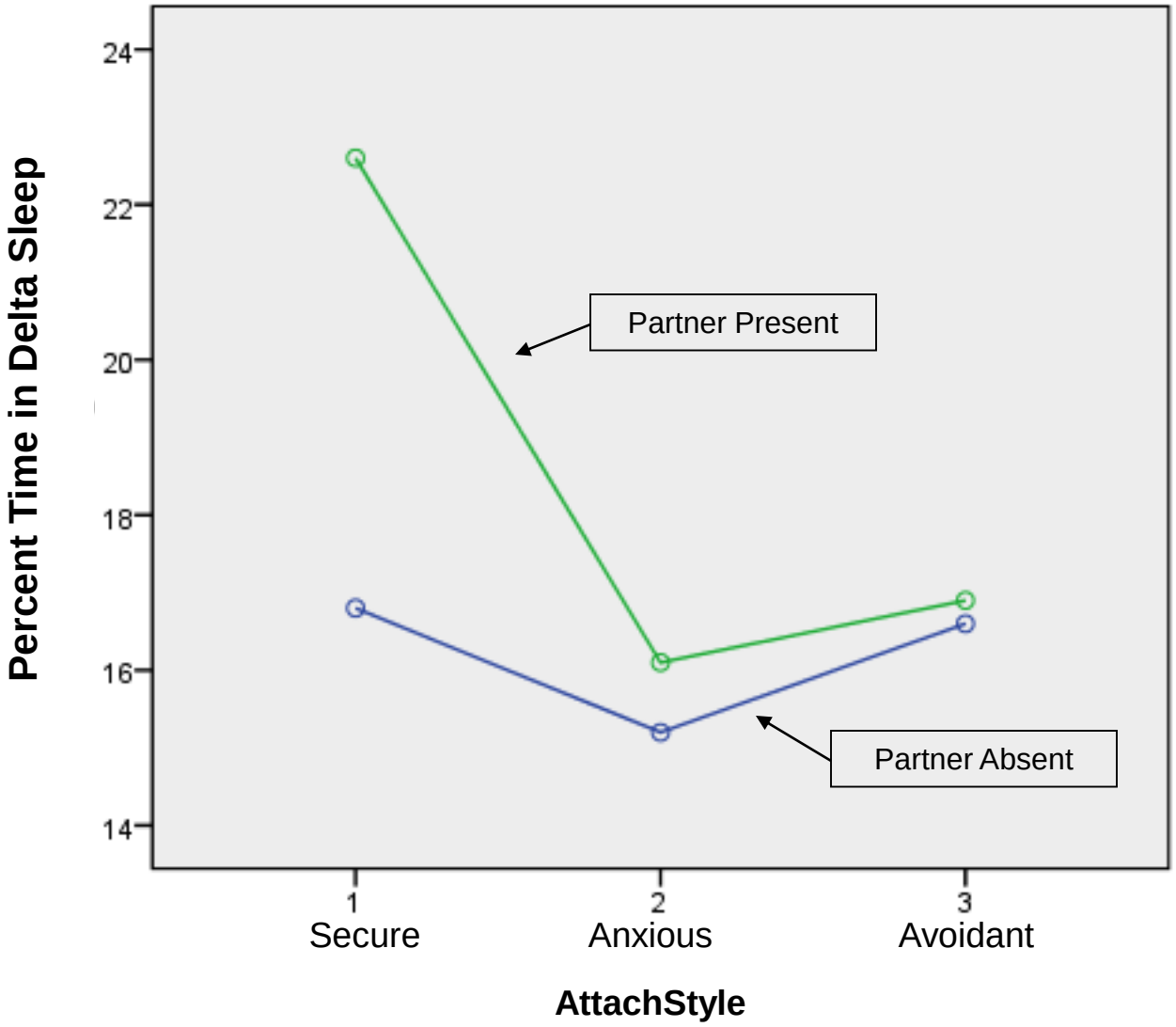
Main effect of Partner

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Partner	Sphericity Assumed	81.667	1	81.667	90.741	.000	.771
	Greenhouse-Geisser	81.667	1.000	81.667	90.741	.000	.771
	Huynh-Feldt	81.667	1.000	81.667	90.741	.000	.771
	Lower-bound	81.667	1.000	81.667	90.741	.000	.771
Partner * AttachStyle	Sphericity Assumed	91.033	2	45.517	50.574	.000	.789
	Greenhouse-Geisser	91.033	2.000	45.517	50.574	.000	.789
	Huynh-Feldt	91.033	2.000	45.517	50.574	.000	.789
	Lower-bound	91.033	2.000	45.517	50.574	.000	.789
Error(Partner)	Sphericity Assumed	24.300	27	.900			
	Greenhouse-Geisser	24.300	27.000	.900			
	Huynh-Feldt	24.300	27.000	.900			
	Lower-bound	24.300	27.000	.900			

Partner x Attachment Style Interaction

Can you find the source of the interaction?



Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	18096.067	1	18096.067	3659.879	.000	.993
AttachStyle	175.433	2	87.717	17.740	.000	.568
Error	133.500	27	4.944			

Estimates

Measure:MEASURE_1

Attach Style	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Secure	19.700	.497	18.680	20.720
Anxious	15.650	.497	14.630	16.670
Avoidant	16.750	.497	15.730	17.770

Pairwise Comparisons

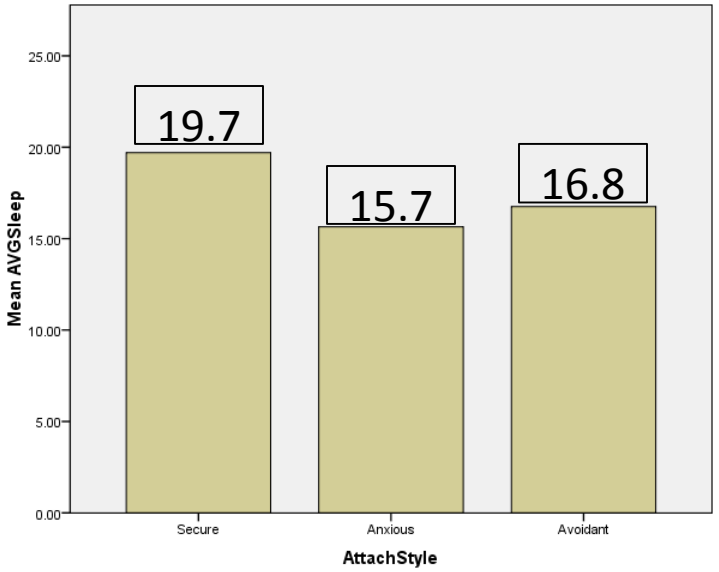
Measure:MEASURE_1

(I) Attach Style	(J) Attach Style	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Secure	Anxious	4.050*	.703	.000	2.255	5.845
	Avoidant	2.950*	.703	.001	1.155	4.745
Anxious	Secure	-4.050*	.703	.000	-5.845	-2.255
	Avoidant	-1.100	.703	.388	-2.895	.695
Avoidant	Secure	-2.950*	.703	.001	-4.745	-1.155
	Anxious	1.100	.703	.388	-.695	2.895

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Bonferroni.



Reporting

The sleep quality (percentage of time spent in delta sleep) of women with secure, anxious or avoidant attachment styles (N = 3 x 10) was measured when sleeping with and without their partners. If a harmonious relationship has a stress reducing effect, we expect sleep quality to improve in the presence of their partner especially for securely attached women. A 3 x 2 ANOVA with Attachment Style as an independent factor and absence or Presence of Partner as a within-subjects factor was run.

The analysis revealed a main effect of Partner Presence ($F(1, 27) = 90.74$, $p < .001$) in the predicted direction, a main effect of Attachment Style ($F(2, 27) = 17.47$, $p < .001$) and an interaction between Partner Presence and Attachment Style ($F(2, 27) = 50.57$, $p > .001$). As predicted, women with secure attachment styles slept better than either of the other two groups ($p = .001$) and they experienced the greatest improvement in sleep quality by the presence of their partners.

Exercise: Two-Way Repeated Measures

- attitude.sav:

  The effects of advertising on various drinks. Full within-subjects design.

  - Independent variable 1: type of drink (beer, wine, water)
  - Independent variable 2: type of imagery associated with drink (negative, positive, neutral)
  - Dependent variable: participants's rating of the drinks
  - Run descriptives and a Two-way Repeated Measures ANOVA

Homework

- Word recall 2:
  Lists of words had to be learnt: just words, words with pictures, words with pictures and sounds – number of items recalled measured
  - Run descriptives and a Repeated Measures ANOVA
  - Write up the results
- perham & sykora 2012: learning 8-item word lists to music
  - Independents:
    - Music (none, liked, disliked)
    - word position in list (1^{st}, 2^{nd} etc)

Optional exercise: Bernard et al 2012

- Three-Way ANOVA
- Are women seen as objects?

  A human face presented upside-down is more difficult to identify than an object presented upside-down. If women are seen as sexual objects, seeing a picture of a woman upright or inverted should make no difference in terms of recognition.

  - Within-subject variables
    - Gender of model in stimulus picture (men, women)
    - Orientation of picture (upright, inverted)
  - Between-subject variable:
    - Gender of participant (male, female)
  - Dependent variable: percentage of pictures correctly identified in a test where participants had to pick from a set the person whose picture they had seen