The ANOVA for Dependent Groups — Analysis of k-Within-Group Data with a Quantitative DV

Application: To compare the means of two or more quantitative variables obtained from dependent samples (repeated measures or matched groups). The two or more scores might be the same variable measured at different times or under different conditions, comparable variables measured at the same time, or some combination.

Research Hypothesis: The data come from the Pet shop database. The researcher hypothesized that stores would tend to display more fish than other types of animals, fewer reptiles, and an intermediate number of mammals.

H0: for this analysis: Pet stores display the same mean number of reptiles, fish and mammals.

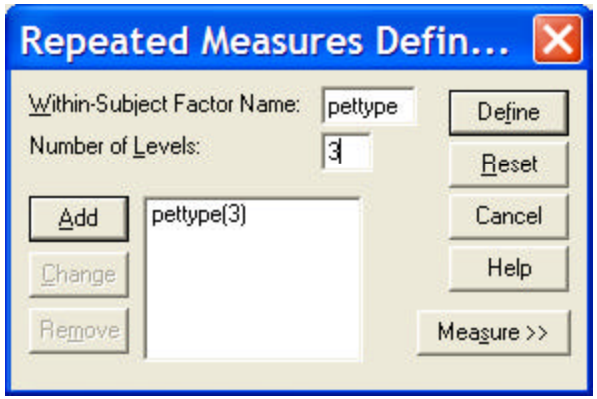
Research Design: The IV is Pet Type, with the conditions Reptiles, Fish & Mammals
The DV is the number animals of each type.
(fishnum,

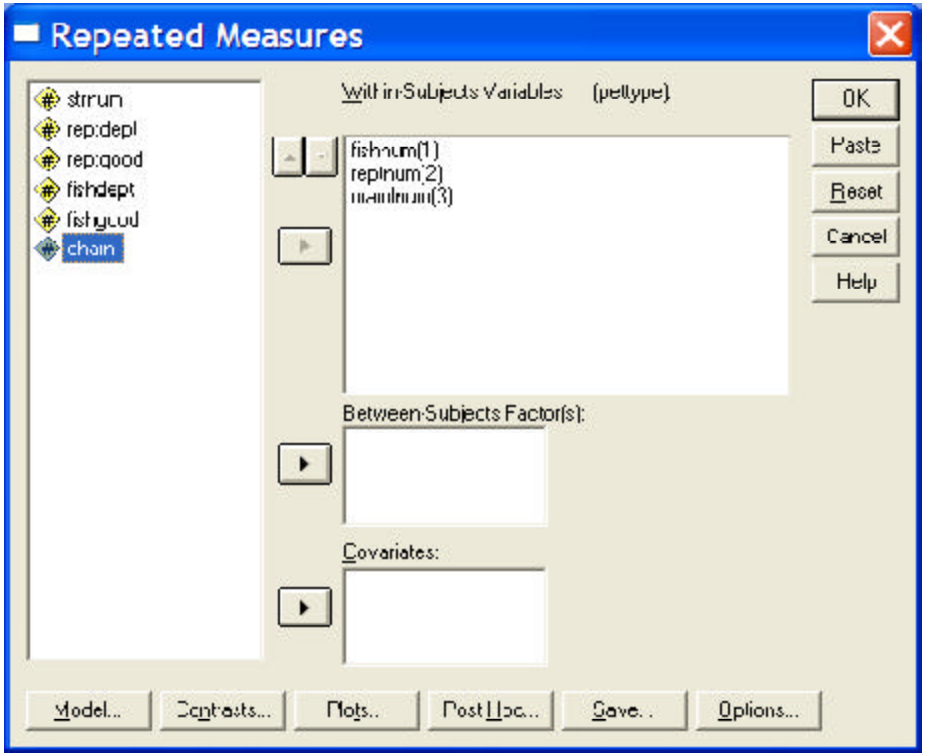
Variables in the Analysis: In a WG design the variables in the analysis are the variables holding the DV scores for each IV condition
reptnum & mamlnum)

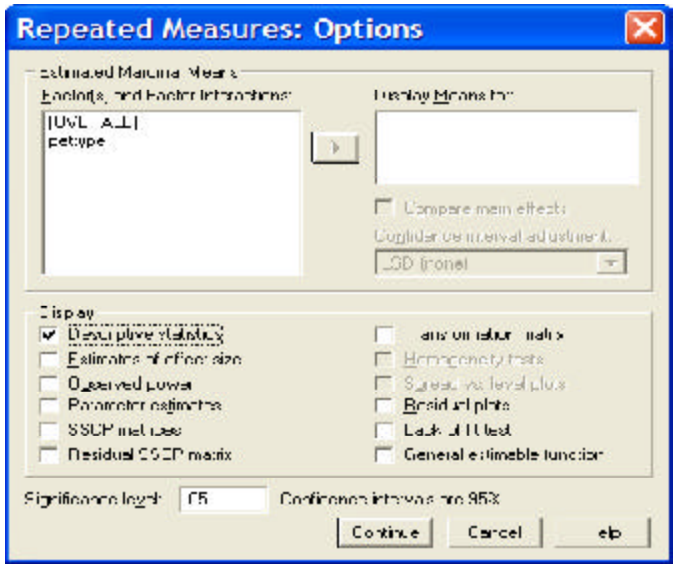
Type of Pet		
Reptiles	**Fish**	**Mammals**

Analyze ➔ General Linear Model ➔ Repeated Measures

- In the **Repeated Measures Definition Window** enter your name for the IV in the "Within-subject Factor Name" box (pettype)
- enter the number of conditions of the IV in the "Number of levels" window (2)
- click the "Add" button
- click the "Define" button
- In the **Repeated Measures** window highlight the variables that are the DV score for each condition and click the arrow
- click the "Options" button -- in the **Repeated Measures: Options** window check the "Descriptives" box







Descriptive Statistics

	Mean	Std. Deviation	N
number of fish at store	23.92	9.605	12
number of mammals	21.50	12.866	12
number of reptiles at store	9.25	4.267	12

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
PETTYPE	Sphericity Assumed	1484.056	2	742.028	22.222	.000
	Greenhouse-Geisser	1484.056	1.672	887.492	22.222	.000
	Huynh-Feldt	1484.056	1.937	766.233	22.222	.000
	Lower-bound	1484.056	1.000	1484.056	22.222	.001
Error(PETTYPE)	Sphericity Assumed	734.611	22	33.391		
	Greenhouse-Geisser	734.611	18.394	39.937		
	Huynh-Feldt	734.611	21.305	34.481		
	Lower-bound	734.611	11.000	66.783		

SPSS provides different "versions" of the ANOVA output. We will focus on the "traditional" analysis, which SPSS labels as "Sphericity Assumed"

df, F & p-value to use

There is a significant difference among the means of the three different munbers of animals displayed in the stores.

df(error) & Mean Square Error term for this analysis

Steps for computing and interpreting LSD minimum mean difference

1. Dermine df(error) for the analysis **df(error) = 22**
2. Use the t-table to determine the critical value of t (at p = .05) for this df(error) with df=22 **t-critical = 2.07**
3. Determine the MSerror for the analysis **MSerror = 33.39**
4. Determine the number of participants in the analysis **n = 12**
5. Apply the LSD formula to obtain the minimum mean difference

$$d_{LSD} = \frac{t * \sqrt{(2 * MS_{Error})}}{\sqrt{n}} = \frac{2.07 * \sqrt{(2 * 33.39)}}{\sqrt{12}} = \mathbf{4.89}$$

6. Compare the minimum mean difference (4.89) with each pairwise mean difference
   -- if the pairwise mean difference is larger than the minimum mean difference, then those two conditions have means that are "significantly different"
   -- if the pairwise mean difference is smaller than the minimum mean difference, then those two conditions have means that are "statistically equivalent"

For this analysis -- compare the minimum mean difference of 4.89 with each of the pairwise differences. There were about the same mean number of mammals (M=21.50) and fish (M=23.92) in these stores (the mean difference between these two conditions is less than 4.89). There were significantly more fish than reptiles (M=9.25), and significantly more mammals than reptiles (both mean differences were larger than 4.89).

Reporting the Results

Table 1 summarizes the data for the numbers of animals displayed at the stores. There was a significant difference among the distributions of the three types of animals ($F(2,22) = 22.22$, $p < .05$, Mse = 33.39). Pairwise comparisons using LSD (with a minimum mean difference = 4.98) revealed that, consistent with the research hypothesis, more fish than reptiles were displayed on average and also more mammals than reptiles were displayed on average. However, contrary to the research hypothesis, there was not a significant difference between the average number of fish and mammals displayed.

Table 1.
Summary of the number of animals of each type displayed in the pet stores.

	Type of Animal		
	Fish	Mammals	Reptiles
Mean	23.92	21.50	9.25
Standard Deviation	9.61	12.87	4.27

t-table Critical values of t for $\alpha = .05$ & $\alpha = .01$

df	$\alpha = .05$	$\alpha = .01$
1	12.71	63.66
2	4.30	9.92
3	3.18	5.84
4	2.78	4.60
5	2.57	4.03
6	2.45	3.71
7	2.36	3.50
8	2.31	3.36
9	2.26	3.25
10	2.23	3 17
11	2.20	3.11
12	2.18	3.06
13	2.16	3.01
14	2.14	2.98
15	2.13	2.95
16	2.12	2.92
17	2.11	2.90
18	2.10	2.88
19	2.09	2.86
20	2.09	2.84
21	2.08	2.83
22	2.07	2.82
23	2.07	2.81
24	2.06	2.80
25	2.06	2.79
26	2.06	2.78
27	2.05	2.77
28	2.05	2.76
29	2.04	2.76
30	2.04	2.75
40	2.02	2.70
60	2.00	2.66
120	1.98	2.62
∞	1.96	2.58

Steps for computing and interpreting HSD minimum mean difference

1. Determine the MSerror for the analysis **MSerror = 33.39**
2. Determine the number of participants in the analysis **n = 12**
3. Determine the number of conditions or means involved in the design **k = 3**
4. Dermine df(error) for the analysis **df(error) = 22**
5. Use the table of Q values to determine the value of Q with df=22 and k=3 (with no df = 22, we drop to the row with df = 20) **Q = 3.58**
5. Apply the HSD formula to obtain the minimum mean difference

$$d_{HSD} = \frac{Q * \sqrt{MS_{Error}}}{\sqrt{n}} = \frac{3.58 * \sqrt{33.39}}{\sqrt{12}} = \mathbf{5.98}$$

6. Compare the minimum mean difference (5.98) with each pairwise mean difference
   -- if the pairwise mean difference is larger than the minimum mean difference, then those two conditions have means that are "significantly different"
   -- if the pairwise mean difference is smaller than the minimum mean difference, then those two conditions have means that are "statistically equivalent"

By the Way: Sometimes LSD and HSD analyses will produce different results for one or more of the pairwise comparisons. If so, the difference will always be that you have rejected H0: based on the LSD test (the more sensitive test) and retained H0: based on the HSD test (the more conservative test). When this happens you should consider the general trend among statisticians (and journal editors) towards "statistical conservatism". More importantly, you should remember that rejecting the null for a particular analysis is not a guarantee that the effect is "really there" . Replication (finding the effect in several different studies) is a much better indicator of the "reality" of an effect.

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Studentized Range Statistic Table
Values of Q for α = .05

Denominator df	k = number of means 2	3	4	5	6
5	3.64	4.60	5.22	5.67	6.03
6	3.46	4.34	4.90	5.30	5.63
7	3.34	4.16	4.68	5.06	5.36
8	3.26	4.04	4.53	4.89	5.17
9	3.20	3.95	4.41	4.76	5.02
10	3.15	3.88	4.33	4.65	4.91
11	3.11	3.82	4.26	4.57	4.82
12	3.08	3.77	4.20	4.51	4.75
13	3.06	3.73	4.15	4.45	4.69
14	3.03	3.70	4.11	4.41	4.64
15	3.01	3.67	4.08	4.37	4.59
16	3.00	3.65	4.05	4.33	4.56
17	2.98	3.63	4.02	4.30	4.52
18	2.97	3.61	4.00	4.28	4.49
19	2.96	3.59	3.98	4.25	4.47
20	2.95	3.58	3.96~	4.23	4.45
24	2.92	3.53	3.90	4.17	4-37
30	2.89	3.49	3.85	4.10	4.30
40	2.86	3.44	3.79	4.04	4.23
60	2.83	3.40	3.74	3.98	4.16
120	2.80	3.36	3.68	3.92	4.10
∞	2.77	3.31	3.63	3.86	4.03