

## MATH 204 - ONE-WAY ANOVA WORKED EXAMPLE

A standard model of memory is that the degree to which the subject remembers verbal material is a function of the degree to which it was processed when it was initially presented.

Reference: Craik, F. I. M. and Lockhart, R. S. (1972). Levels of Processing: a framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, 11, 671-684.

**Experiment:** Fifty subjects aged between 55 and 65 years were randomly assigned to one of five groups which carried out different memory tasks. The five groups included

- The **Counting** group was asked to read through a list of words and simply count the number of letters in each word.
- The **Rhyming** group was asked to read each word and think of a word that rhymed with it.
- The **Adjective** group had to process the words to the extent of giving an adjective that could reasonably be used to modify each word on the list.
- The **Imagery** group was instructed to try to form vivid images of each word.
- The **Intentional** group was told to read through the list and to memorize the words for later recall.

After subjects had gone through the list of 27 items three times, they were given a sheet of paper and asked to write down all the words they could remember. The response data were the number of words recalled by each individual in each group, and are presented below:

Counting	Rhyming	Adjective	Imagery	Intentional
9	7	11	12	10
8	9	13	11	19
6	6	8	16	14
8	6	6	11	5
10	6	14	9	10
4	11	11	23	11
6	6	13	12	14
5	3	13	10	15
7	8	10	19	11
7	7	11	11	11

These data may be downloaded

- in plain text format from

<http://www.math.mcgill.ca/~dstephens/204/Data/MemoryTask.txt>

- in SPSS format from

<http://www.math.mcgill.ca/~dstephens/204/Data/MemoryTask.sav>

**Research question:** Does the level of processing required when material is processed affect how much material is remembered ?

Test a hypothesis to answer this question using an ANOVA F-test. Specifically

- (a) Form the ANOVA table, and report the result of the ANOVA F-test.
- (b) Discuss whether the assumptions of behind the ANOVA F-test hold for this example.

## MATH 204 - One Way ANOVA Worked Example Solution

Memory Task Data Set: Response is Number of Words remembered, Factor is Memory Training method.

### (a) ANOVA TABLE (from SPSS)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	351.520	4	87.880	9.085	.000
Within Groups	435.300	45	9.673		
Total	786.820	49			

Thus the result of the ANOVA F-test implies that we can

**REJECT  $H_0$**

ANOVA F-test statistic  $F=9.085$

ANOVA F-test p-value = 0.000.  
(to three decimal places)

at significance levels  $\alpha = 0.05/0.01$ , and conclude that there is a significant difference between the treatment means.

For completeness: the exact  $p$ -value is 1.815e-05. Critical values are

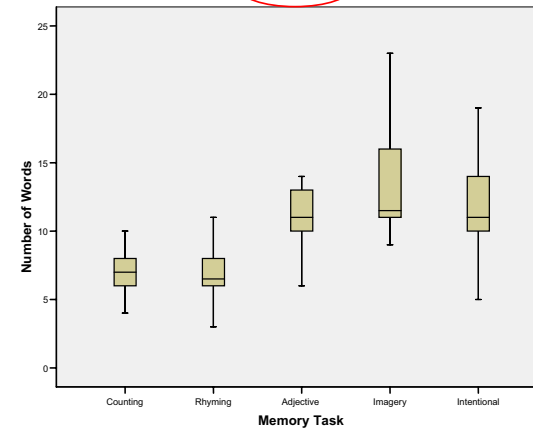
- $\alpha = 0.05$ ,  $C_R = F_{\alpha}(4,45) = 2.579$  (textbook gives  $F_{\alpha}(4,40) = 2.61, F_{\alpha}(4,60) = 2.53$ )
- $\alpha = 0.01$ ,  $C_R = F_{\alpha}(4,45) = 3.767$  (textbook gives  $F_{\alpha}(4,40) = 3.83, F_{\alpha}(4,60) = 3.65$ )

Therefore we reject the hypothesis of equal treatment means at the 5% significance level (and, indeed, at every significance level greater than 0.1%).

### (b) Checking the Assumptions:

- Independent samples: this is apparently a completely randomized design, so this assumption is met.
- Normality of the populations: visual inspection of the boxplot below provides no categorical evidence that the normality assumption is violated. This could be tested more formally.
- Equal Variances: Levene's test (below) implies that the equality of variances is not rejected at the 5% level ( $p=0.054$ )

### SPSS Output



Boxplot

Boxplot indicates that the assumption of normality may be valid, although this is perhaps questionable. A formal test would probably be needed.

### Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Counting	10	7.00	1.826	.577	5.69	8.31	4	10
Rhyming	10	6.90	2.132	.674	5.38	8.42	3	11
Adjective	10	11.00	2.494	.789	9.22	12.78	6	14
Imagery	10	13.40	4.502	1.424	10.18	16.62	9	23
Intentional	10	12.00	3.742	1.183	9.32	14.68	5	19
Total	50	10.06	4.007	.567	8.92	11.20	3	23

### Levene's Test of Homogeneity of Variances

Number of Words			
Levene Statistic	df1	df2	Sig.
2.529	4	45	.054

Levene's Test p-value = 0.054.

Therefore no reason to reject the hypothesis of equal variances at the 5% significance level.