

Two-Way Independent Samples ANOVA with SAS®

Run the program ANOVA2.sas on my [SAS Programs Page](#). The data, which are within the program, are those that appear on page 415 of Howell's *Statistical methods for psychology* (8th ed., 2010). Although there are three scores for each participant (age group, experimental condition, and number of items recalled), I used a do loop so that I could specify age and condition only once for each cell of the design, followed by a line with the recall scores for all participants in that cell. Had I used "Input Age Condition Items" I would have needed one line of data for each of the 100 participants, from "1 1 9" to "2 5 21." If you wish to see what the data file would look like arranged that way, see [the file on David Howell's web site](#).

```
proc format; value rec 1='Counting' 2='Rhyming' 3='Adjective'  
4='Imagery' 5='Intentional'; value Age 1='Old' 2='Young';
```

%macro Clt;

```
d = t/sqrt(n1*n2/(n1+n2));  
ncp_lower = TNONCT(t,df,.975);  
ncp_upper = TNONCT(t,df,.025);  
d_lower = ncp_lower*sqrt((n1+n2)/(n1*n2));  
d_upper = ncp_upper*sqrt((n1+n2)/(n1*n2));  
output; run; proc print; var d d_lower d_upper; run;  
%mend Clt;
```

```
DATA KLW;
```

```
INPUT Age Condition; DO I=1 TO 10; INPUT Items @@; OUTPUT; END;  
format Condition rec. Age Age.; CARDS;
```

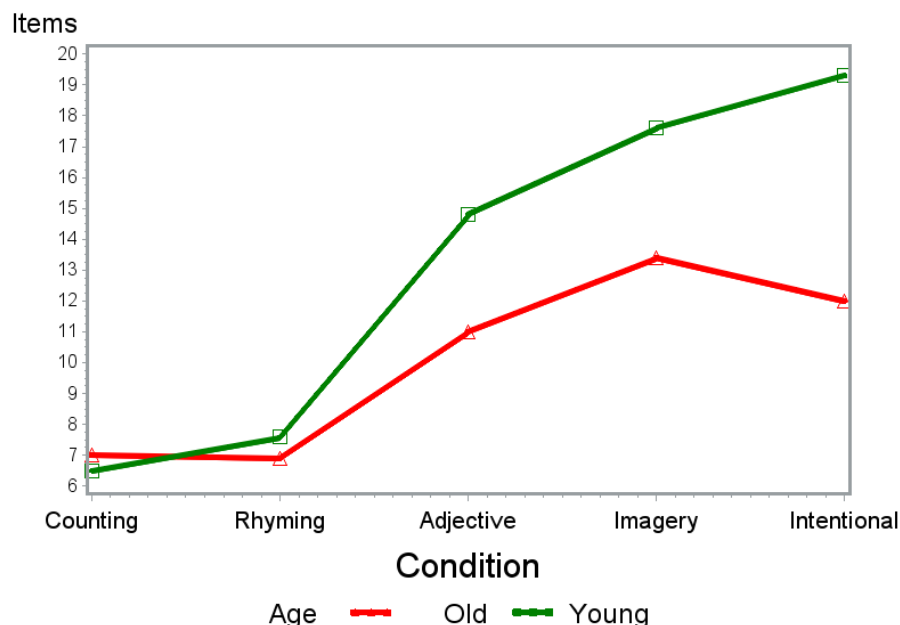
Defining the Macro

Rather than repeatedly enter the code for constructing a confidence intervals for d, I placed the code within a macro that can be easily called later.

Plotting the Means

```
proc means NWAY noprint; class Age Condition; var Items;  
output out=klw2 mean= ;  
*set the default text height to value 2;  
GOPTIONS reset = global;  
goptions htext=2;  
*change text heights and axis widths;  
axis1 value=(h=1.3);  
axis2 label=(h=2.5) value=(h=1.75) width=2;  
proc gplot data=klw2;  
symbol1 interpol=join width=4 value=triangle height=2 color=red;  
symbol2 interpol=join width=4 value=square height=2 color=green;  
plot Items*Condition=Age / vaxis=axis1 haxis=axis2;  
title 'Figure 1. Recall by Age and Condition';  
run; quit;
```

Figure 1. Recall by Age and Condition



You may also want to learn how to use [Microsoft Excel](#) to make an interaction plot.

The plot makes it pretty clear that there is an interaction here. The difference between the oldsters and the youngsters is quite small when the experimental condition is one with little depth of cognitive processing (counting or rhyming), but much greater with higher levels of depth of cognitive processing. With the youngsters, recall performance increases with each increase in depth of processing. With the oldsters, there is an interesting dip in performance in the intentional condition. Perhaps that is a matter of motivation, with oldsters just refusing to follow instructions that ask them to memorize a silly list of words.

```
PROC GLM data=klw; CLASS age condition;
MODEL Items=Age|Condition / EFFECTSIZE alpha=0.1
```

I employed **PROC GLM** to do the analysis. PROC ANOVA is appropriate for factorial ANOVA only if you have equal cell sizes, no covariates, no contrast statements, and no LSMEANS statements, and I wanted to use a LSMEANS statement. Note that our two grouping variables (age and condition) are listed in the **CLASS** statement. Our **MODEL** statement indicates that items is the dependent variable and that we wish to test the effects of age (main effect), condition (main effect) and age*condition (interaction). The "bar notation," "age|condition," is expanded by SAS to "age condition age*condition." The EFFECTSIZE option asks SAS to produce estimates and confidence intervals proportion of variance effect sizes.

```
MEANS age|condition; MEANS condition / REGWQ;
```

The bar notation is used again with the **MEANS** statement to get both cell means and marginal means (and standard deviations). The REGWQ option is used to request pairwise comparisons on the marginal means for recall condition.

The Omnibus ANOVA

```
PROC GLM data=klw; CLASS Age Condition;
MODEL Items=Age|Condition / EFFECTSIZE alpha=0.1;
means Age|Condition; MEANS Condition / REGWQ;
LSMEANS Condition / PDIFF CL ALPHA=.05;
LSMEANS Age*Condition / SLICE=Age; LSMEANS Age*Condition / SLICE=Condition;
* Note had to specify DATA=KLW -- otherwise PROC ANOVA would use the last
created data set (KLW2, the cell means);
title 'Omnibus Analysis and Simple Main Effects Using Pooled Error'; run; quit;
```

Look at the output from the omnibus ANOVA. We generally ignore the F for the overall model -- that is the F that would be obtained if we were to do a one-way ANOVA, where the groups are our cells. Here it simply tells us that our cell means differ significantly from one another. The two-way factorial ANOVA is really just an orthogonal partitioning of the treatment variance from such a one-way ANOVA -- that variance is partitioned into three components: The two main effects and the one interaction. If you look at the "R-square" (η^2), you see that the three effects, collectively, account for a whopping 73% of the variance in the number of items recalled. If you divide each effect's SS by the total SS , you see that the condition effect accounts for a whopping 57% of the total variance, with the age effect only accounting for 9% and the interaction only accounting for 7%. Despite the fact that all three of these effects are statistically significant, one really should keep in mind, and point out to the readers of the research report, that the age and interaction effects are much less in magnitude than is the effect of recall condition (depth of processing).

Omnibus Analysis and Simple Main Effects Using Pooled Error

The GLM Procedure

Dependent Variable: Items

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	1945.490000	216.165556	26.93	<.0001
Error	90	722.300000	8.025556		
Corrected Total	99	2667.790000			

R-Square	Coeff Var	Root MSE	Items Mean
0.729252	24.40087	2.832941	11.61000

Proportion of Variation Accounted for	
Eta-Square	0.73
Omega-Square	0.70
90% Confidence Limits	(0.62,0.76)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Age	1	240.250000	240.250000	29.94	<.0001
Condition	4	1514.940000	378.735000	47.19	<.0001
Age*Condition	4	190.300000	47.575000	5.93	0.0003

With equal sample sizes, Type I and Type III sums of squares are identical, so I cut out the Type III sum of squares. Were the sample sizes not equal, it is the Type III sums of squares I would want.

	Total Variation Accounted For				Partial Variation Accounted For			
	Semipartial Eta-Square	Semipartial Omega-Square	Conservative 90% Confidence Limits		Partial Eta-Square	Partial Omega-Square	90% Confidence Limits	
Age	0.0901	0.0868	0.0198	0.1867	0.2496	0.2244	0.1194	0.3435
Condition	0.5679	0.5542	0.4407	0.6335	0.6771	0.6488	0.5579	0.7183
A x C	0.0713	0.0591	0.0000	0.1324	0.2085	0.1647	0.0671	0.2867

The sum of the values of eta-squared is .7293, the same as the total model r -square reported earlier. The sum of the values of partial eta-squared = 1.14. Wow, we have explained 114% of the variance. ☺

It is possible for an effect which is significant in the omnibus ANOVA to have zero included in its confidence interval for η^2 – this is most likely to happen when the effect is small relative to another effect in the model. Putting the other (larger) effect into the error term of the adjusted F can make the adjusted F no longer significant. This should not be a problem with partial eta-squared. Notice that the confidence interval for η^2 for the (significant) interaction does include zero, but that for partial η^2

Eta Squared and Partial Eta Squared

The effect of age has an η^2 of 9%. Notice that SAS calls this the “semi-partial eta-squared.” Keep in mind that the denominator of this η^2 contains variance due to the experimental treatment and the interaction of the experimental treatment with age. If we wish to exclude those experimental effects from the denominator of η^2 , we compute partial eta-squared as

$$\eta_p^2 = \frac{SS_{Age}}{SS_{Age} + SS_{Error}} = \frac{240.25}{240.25 + 722.3} = .25, \text{ considerably greater than the } \eta^2.$$

Heterogeneity of Variance

Look at the within-cell standard deviations. In the text book, Howell says "it is important to note that the data themselves are approximately normally distributed with acceptably equal variances." I beg to differ. F_{max} is $4.5^2 / 1.4^2 \sim 10$ -- but I am going to ignore that here. I did ask Dave Howell about this in 2001: "[What guidelines do you use when evaluating ANOVA data with](#)

respect to the homogeneity of variance assumption? The reason I ask is that for the depth of processing data (modeled after Eysenck) in your texts, the ratio of the largest cell variance to the smallest cell variance exceeds 10. Despite that irritation, I like that example, since it is easy for the students to understand the design and intent of the study and it stimulates them to think about depth of cognitive processing, age, and also motivation (the latter possibly being important in explaining the dip in the curve for intentional learning among the older participants)." Dave responded later, during a discussion of Zimmerman's suggestion that the separate variances t always be employed (rather than the pooled variances t) when sample sizes are unequal. "I, too, have used a "4 or more" (F_{\max}) rule, but have generally tempered that with the statement that cell sizes should be at least roughly equal. But I think that a better approach probably is the one Zimmerman advocates. My experience has been that "most of the time" the two tests (separate and pooled variances) agree in terms of their conclusions. I know that there are times when they disagree, but that would cause me to look more closely at the data. A common use of t tests is as multiple comparison tests following anova (usually with some kind of error rate correction). There I am even more in favor of unpooled error terms, because any inequality of variance probably means that the overall pooled error term (i.e. MS_{error}) is probably even less representative of the data in the particular pairwise comparison."

If you look at the marginal standard deviations for age, you will see that they do not differ by much, but the marginal standard deviations do vary considerably across recall conditions, $F_{\max} \sim 9$.

Interpretation of the Main Effect of Age

The interpretation of the effect of **age** is straightforward -- the youngsters recalled significantly more items than did the oldsters, 3.1 items on average. The estimated value of η^2 is **.09**, which is a medium to large effect (.01 is small, .06 medium, and .14 large, by Cohen's standards).

Construct confidence interval for d , main effect of Age.

```
PROC TTEST data=klw; CLASS Age; VAR Items;
title 'Comparing Oldsters with Youngsters'; run;
Data CI; t= 3.11; df = 98; n1 = 50; n2 = 50; %CIt
```

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	98	-3.11	0.0024

Obs	d	d_lower	d_upper
1	0.622	0.21896	1.02201

I prefer d over η^2 as the effect size estimate for the difference between two means. The pooled within-age standard deviation is $s_{\text{pooled}} = \sqrt{.5(4.007^2 + 5.787^2)} = 4.98$, so the standardized difference, estimated d , is $3.1/4.98 = .62$. Do note that **this standardizer does not exclude the variance due to the experimental treatment and the interaction**. Using Cohen's guidelines, that is a medium to large sized effect. The CIt macro was employed to construct a confidence interval for the standardized difference between means, after using Proc Ttest to obtain the value of t . The confidence interval runs from .22 to 1.02.

Interpretation of the Main Effect of Recall Condition

Ryan-Einot-Gabriel-Welsch Multiple Range Test for Items

Note: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	90
Error Mean Square	8.025556

Number of Means	2	3	4	5
Critical Range	2.1164209	2.3146876	2.3450673	2.4939286

Means with the same letter are not significantly different.			
REGWQ Grouping	Mean	N	Condition
A	15.6500	20	Intentional
A			
A	15.5000	20	Imagery
B	12.9000	20	Adjective
C	7.2500	20	Rhyming
C			
C	6.7500	20	Counting

The interpretation of the recall condition means is also pretty simple. With greater depth of processing, recall is better, but the difference between the intentional condition and the imagery condition is too small to be significant, as is the difference between the rhyming condition and the counting condition. The η^2 is a very large .57, with a 90% CI running from .44 to .63.

LSMEANS – Adjusted Means

The **LSMEANS** command is used to obtain adjusted means – these are estimates of what the means would be if the classification variables (the grouping variables) were independent of one another. Since we have equal sample sizes, our classification variables are independent, and the adjusted means will be identical to the unadjusted means. There are many options available with LSMEANS, and I want to illustrate a few of them here. Do use SAS Help to get a better idea of the various options available with LSMEANS.

“LSMEANS condition / PDIFF CL ALPHA=.05” produces an adjusted mean for each level of the condition variable, a probability value for comparing each adjusted mean with each other adjusted mean (pdiff – tdiff would give you the same but also give you a value of t for each difference), and 95% confidence limits (cl) for each adjusted mean and each difference in adjusted means. The default alpha is .05, so I did not really need the alpha statement.

Simple Main Effects: Pooled or Individual Error Terms ?

Although the significant interaction effect is small compared to the main effect of recall condition, we shall investigate it by examining simple main effects. For pedagogical purposes, I show you the simple main effects of recall condition for each age as well as the simple main effects of age at each level of recall condition. “LSMEANS age*condition / SLICE=age” produces tests of the simple main effects of condition at each level of age using a pooled error term. “LSMEANS age*condition / SLICE=condition” does the same for the simple main effects of age within each condition. The F statistics produced are identical to those reported in Howell, except that Howell’s has a little rounding error. Since the denominator of these F ratios is the MSE from the overall analysis (pooled across all ten cells), the df are 4, 90.

Age	DF	Sum of Squares	Mean Square	F Value	Pr > F	Total Variation Accounted For		
						Semipartial Eta-Square	Semipartial Omega-Square	Conservative 90% Confidence Limits
Old	4	351.520000	87.880000	10.95	<.0001	0.1318	0.1194	0.0203 0.2101
Young	4	1353.720000	338.430000	42.17	<.0001	0.5074	0.4939	0.3703 0.5804

CAUTION: Do not use the eta-squared statistics provided by the simple effects analysis here. For both groups (Old and Young) it includes in the denominator the total variance in both groups, that is, $SS_{Total} = 2667.79$. I recommend getting the eta-squared statistics from the individual error terms approach below.

Some statisticians (like G. Keppel) prefer to use “individual” or “separate” rather than “pooled” error terms when testing simple effects, especially when there is some evidence of heterogeneity of variance, and we certainly have some evidence of heterogeneity of variance in these data. I have illustrated how to obtain tests of simple effects with individual error terms. First I sorted by age and then used PROC ANOVA to test the effect of recall condition for each age group. Please notice that for each of these two tests SAS bases the error on only scores within the tested age group, rather than using the pooled error term from the omnibus analysis. Accordingly, the df are 4, 45. The loss of error df will generally result in a loss of power

```
PROC SORT data=klw; BY Age;
PROC GLM data=klw; CLASS Condition; MODEL Items=Condition / EFFECTSIZE alpha=0.1; BY Age;
title 'Simple Main Effects of Recall Condition Using Individual Error Terms'; run;
```

Simple Main Effects of Recall Condition Using Individual Error Terms

The GLM Procedure

Age=Old

Class Level Information		
Class	Levels	Values
Condition	5	Adjective Counting Imagery Intentional Rhyming

Number of Observations Read 50

Number of Observations Used 50

Dependent Variable: Items

Age=Old

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	351.5200000	87.8800000	9.08	<.0001
Error	45	435.3000000	9.6733333		
Corrected Total	49	786.8200000			

R-Square	Coeff Var	Root MSE	Items Mean
0.446760	30.91648	3.110198	10.06000

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Total Variation Accounted For			
						Semipartial Eta-Square	Semipartial Omega-Square	Conservative 90% Confidence Limits	
Condition	4	351.5200000	87.8800000	9.08	<.0001	0.4468	0.3928	0.2166	0.5448

Simple Main Effects of Recall Condition Using Individual Error Terms

The GLM Procedure

Age=Young

Class Level Information		
Class	Levels	Values
Condition	5	Adjective Counting Imagery Intentional Rhyming

Number of Observations Read 50

Number of Observations Used 50

Dependent Variable: Items

Age=Young

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1353.720000	338.430000	53.06	<.0001
Error	45	287.000000	6.377778		
Corrected Total	49	1640.720000			

R-Square	Coeff Var	Root MSE	Items Mean
0.825077	19.19017	2.525426	13.16000

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Total Variation Accounted For			
						Semipartial Eta-Square	Semipartial Omega-Square	Conservative 90% Confidence Limits	
Condition	4	1353.720000	338.430000	53.06	<.0001	0.8251	0.8064	0.7217	0.8588

Note that the effect of condition is significant for both age groups, but is larger in magnitude for the youngsters ($\eta^2 = .83$) than for the oldsters ($\eta^2 = .45$). Typically one would make pairwise comparisons among the cell means for a significant simple main effect with $df > 1$. That would be easy to do here, just add a MEANS statement with the keyword for the desired type of pairwise contrasts (such as REGWQ, TUKEY, BON, or LSD) -- but I don't think that would really add much to our understanding of the interaction. I think that the interaction plot, along with the simple main effects of recall condition at each level of age (below), is all we need to interpret the interaction.

*****.

```
PROC SORT data=klw; BY Condition;
PROC GLM data=klw; CLASS Age; MODEL Items=Age / EFFECTSIZE alpha=0.1; BY Condition;
title 'Simple Main Effects of Age Using Individual Error Terms'; run;
```

Simple Main Effects of Age Using Individual Error Terms

The GLM Procedure
Condition=Counting

Class Level Information

Class Levels Values

Age 2 Old Young

Number of Observations Read 20

Number of Observations Used 20

The GLM Procedure

Dependent Variable: Items

Condition=Counting

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.25000000	1.25000000	0.46	0.5045
Error	18	48.50000000	2.69444444		
Corrected Total	19	49.75000000			

R-Square	Coeff Var	Root MSE	Items Mean
0.025126	24.31817	1.641476	6.750000

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Total Variation Accounted For			
						Semipartial Eta-Square	Semipartial Omega-Square	Conservative 90% Confidence Limits	
Age	1	1.2500000	1.2500000	0.46	0.5045	0.0251	-0.0275	0.0000	0.2110

The GLM Procedure
Condition=Rhyming

Class Level Information	
Class Levels Values	
Age	2 Old Young

Number of Observations Read	20
Number of Observations Used	20

Dependent Variable: Items

Condition=Rhyming

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	2.4500000	2.4500000	0.59	0.4540
Error	18	75.3000000	4.1833333		
Corrected Total	19	77.7500000			

R-Square	Coeff Var	Root MSE	Items Mean
0.031511	28.21131	2.045320	7.250000

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Total Variation Accounted For			
						Semipartial Eta-Square	Semipartial Omega-Square	Conservative 90% Confidence Limits	
Age	1	2.4500000	2.4500000	0.59	0.4540	0.0315	-0.0212	0.0000	0.2242

Simple Main Effects of Age Using Individual Error Terms

The GLM Procedure
Condition=Adjective

Class Level Information	
Class Levels Values	

Class Level Information
Class Levels Values
 Age 2 Old Young

Number of Observations Read 20
Number of Observations Used 20

Dependent Variable: Items

Condition=Adjective

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	72.2000000	72.2000000	7.85	0.0118
Error	18	165.6000000	9.2000000		
Corrected Total	19	237.8000000			

R-Square 0.303616 **Coeff Var** 23.51279 **Root MSE** 3.033150 **Items Mean** 12.90000

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Total Variation Accounted For			
						Semipartial Eta-Square	Semipartial Omega-Square	Conservative 90% Confidence Limits	
Age	1	72.20000000	72.20000000	7.85	0.0118	0.3036	0.2551	0.0432	0.5119

Simple Main Effects of Age Using Individual Error Terms

The GLM Procedure
 Condition=Imagery

Class Level Information
Class Levels Values
 Age 2 Old Young

Number of Observations Read 20
Number of Observations Used 20

Dependent Variable: Items

Condition=Imagery

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	88.2000000	88.2000000	6.54	0.0198
Error	18	242.8000000	13.4888889		
Corrected Total	19	331.0000000			

R-Square	Coeff Var	Root MSE	Items Mean
0.266465	23.69498	3.672722	15.50000

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Total Variation Accounted For			
						Semipartial Eta-Square	Semipartial Omega-Square	Conservative 90% Confidence Limits	
Age	1	88.20000000	88.20000000	6.54	0.0198	0.2665	0.2169	0.0256	0.4817

Simple Main Effects of Age Using Individual Error Terms

The GLM Procedure
Condition=Intentional

Class Level Information

Class Levels Values

Age 2 Old Young

Number of Observations Read 20

Number of Observations Used 20

Simple Main Effects of Age Using Individual Error Terms

Dependent Variable: Items

Condition=Intentional

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	266.4500000	266.4500000	25.23	<.0001
Error	18	190.1000000	10.5611111		
Corrected Total	19	456.5500000			

R-Square	Coeff Var	Root MSE	Items Mean
0.583616	20.76541	3.249786	15.65000

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Total Variation Accounted For			
						Semipartial Eta-Square	Semipartial Omega-Square	Conservative 90% Confidence Limits	
Age	1	266.4500000	266.4500000	25.23	<.0001	0.5836	0.5478	0.2862	0.7165

Since Age has only two levels, I prefer to use Cohen's d as the effect size estimate.

```

title2 'Counting'; run;
Data CI; t= .678; df = 18; n1 = 10; n2 = 10; %Clt
title2 'Rhyming'; run;
Data CI; t= .768; df = 18; n1 = 10; n2 = 10; %Clt
title2 'Adjective'; run;
Data CI; t= 2.80; df = 18; n1 = 10; n2 = 10; %Clt
title2 'Imagery'; run;
Data CI; t= 2.56; df = 18; n1 = 10; n2 = 10; %Clt
title2 'Intentional'; run;
Data CI; t= 5.02; df = 18; n1 = 10; n2 = 10; %Clt

```

Simple Main Effects of Age Using Individual Error Terms
Counting

Obs	d	d_lower	d_upper
1	0.30321	-0.58294	1.18110

Simple Main Effects of Age Using Individual Error Terms
Rhyming

Obs	d	d_lower	d_upper
1	0.34346	-0.54477	1.22237

Simple Main Effects of Age Using Individual Error Terms
Adjective

Obs	d	d_lower	d_upper
1	1.25220	0.27190	2.20396

Simple Main Effects of Age Using Individual Error Terms
Imagery

Obs	d	d_lower	d_upper
1	1.14487	0.17952	2.08336

Simple Main Effects of Age Using Individual Error Terms
Intentional

Obs	d	d_lower	d_upper
1	2.24501	1.08716	3.36582

The simple main effects of age at each level of recall condition. These fall short of significance with the conditions that involve little depth of cognitive processing, but increase in magnitude (and

become significant) with the three conditions involving greater depth of processing. For each condition, the square root of the obtained F is the value of t necessary as input to the Clt macro for computing confidence intervals for the standardized difference between means. I have included these confidence intervals in the summary of results, below.

Writing up the Results – Here is an Example

A 2 x 5 factorial ANOVA was employed to determine the effects of age group and recall condition on participants' recall of the items. A .05 criterion of statistical significance was employed for all tests. The main effects of age, $F(1, 90) = 29.94, p < .001, \eta^2 = .090, 90\% \text{ CI } [.020, .187]$, and recall condition, $F(4, 90) = 47.19, p < .001, \eta^2 = .568, 90\% \text{ CI } [.441, .633]$ were statistically significant, as was their interaction, $F(4, 90) = 5.93, p < .001, \eta^2 = .071, 90\% \text{ CI } [.000, .132]$, $MSE = 8.03$ for each effect. Overall, younger participants recalled more items ($M = 13.16$) than did older participants ($M = 10.06$), $d = .622, 95\% \text{ CI } [.219, 1.022]$. The REGWQ procedure was employed to conduct pairwise comparisons on the marginal means for recall condition, holding familywise error rate at a maximum of .05. As shown in the table below, recall was better for the conditions which involved greater depth of processing than for the conditions that involved less cognitive processing.

Table 1. The Main Effect of Recall Condition

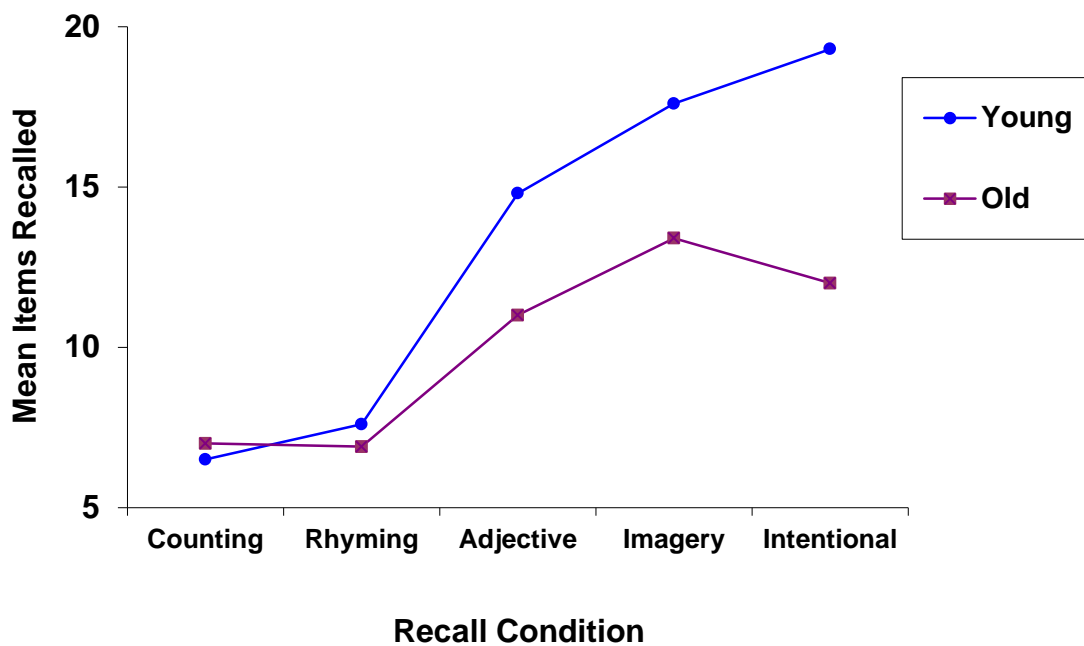
	Recall Condition				
	Counting	Rhyming	Adjective	Imagery	Intentional
Mean	6.75 ^A	7.25 ^A	12.90 ^B	15.50 ^C	15.65 ^C

Note. Means sharing a letter in their superscript are not significantly different from one another according to REGWQ tests.

The interaction is displayed in Figure 1. Recall condition had a significant simple main effect in both the younger participants, $F(4, 45) = 53.06, MSE = 6.38, p < .001, \eta^2 = .825, 90\% \text{ CI } [.722, .859]$, and the older participants, $F(4, 45) = 9.08, MSE = 9.68, p < .001, \eta^2 = .447, 90\% \text{ CI } [.216, .545]$, but the effect was clearly stronger in the younger participants than in the older participants. The younger participants recalled significantly more items than did the older participants in the adjective condition, $F(1, 18) = 7.85, MSE = 9.2, p = .012, d = 1.252, 95\% \text{ CI } [.272, 2.204]$, the imagery condition, $F(1, 18) = 6.54, MSE = 13.49, p = .020, d = 1.145, 95\% \text{ CI } [.180, 2.083]$, and the intentional condition, $F(1, 18) = 25.23, MSE = 10.56, p < .001, d = 2.245, 95\% \text{ CI } [1.087, 3.366]$, but the effect of age fell well short of significance in the counting condition, $F(1, 18) = 0.46, MSE = 2.69, p = .50, d = .303, 95\% \text{ CI } [-.583, 1.181]$ and in the rhyming condition, $F(1, 18) = 0.59, MSE = 4.18, p = .45, d = .343, 95\% \text{ CI } [-.545, 1.222]$.

Interaction Plot Made With Microsoft Graph or Excel

Recall in Young and Old Participants



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