observations are mutually independent Normally distributed and have equal variances. In the repeated measures model situation, measures made on the same subject are usually correlated. As a consequence, F tests are made in a way that allows some relaxation of the assumption of complete independence. The independence assumption is replaced by the symmetry assumption based on **sphericity** test. The sphericity test examines the hypothesis that all the orthogonal contrasts of any within-subject factor are independent and have equal variances. A related concept is that of compound symmetry.

Compound Symmetry: when we have constant variance in the diagonal and constant covariances off the diagonal.

The sphericity test is more restrictive than the compound symmetry. SPSS produces the **Mauchly's Test for Sphericity**.

For our example, the value of the test statistic is 0.909. This test has an equivalent approximate Chi-Square test value of 0.76 which can be compared to a Chi-Square random variable with 2 degrees of freedom. The Chi-square value is not significant (P=0.684) indicating that the sphericity assumption can be accepted and the usual ANOVA F test can be used.

The sphericity test should be viewed with the following reservations: It has low power for small sample sizes. For large sample sizes the test is likely to show significance although the effect on the analysis of variance may be negligible. The sphericity test can be very sensitive to outliers.

6.3.5 Univariate Test of within-subject effect

Test of implement effect
From the Within-Subjects Effects ANOVA table, the F test indicates a significant implement effect, F = 4.859 with 2 and 18 degrees of freedom, P = 0.021. Thus the type of implement used does affect the ratings that a picture receive.

6.4 Experiments with Within-Subjects and Between-Subjects Factors

It is possible to have between-subjects factors in repeated measures design. **Between-subjects factors** subdivide the subjects into discrete subgroups. Each subject has only one value for a between-subject factor.

Example 2

The data are from table 14.4 of Howell (1997)

The experiment investigates motor activity in rats following injection of the drug midazolam. 'The first time that the drug is injected it typically leads to a distinct decrease in motor activity, however a tolerance for midazolam develops rapidly'.
Three groups were used. Two groups of animals were repeatedly injected with midazolam

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

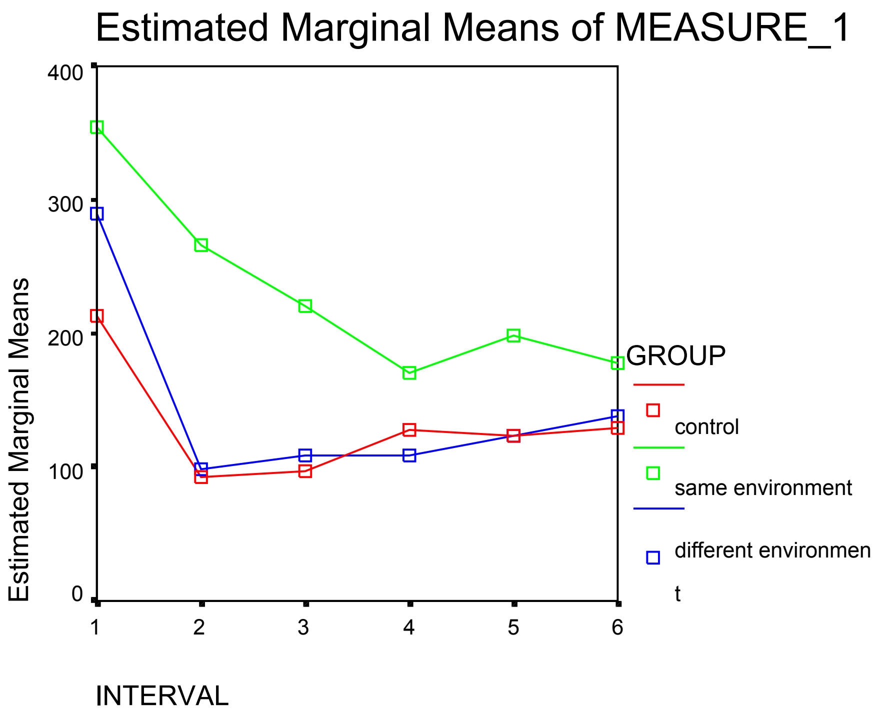
Source	INTERVAL	Type III Sum of Squares	df	Mean Square	F	Sig.
INTERVAL	Linear	170066	1	170066	42.84	.000
	Quadratic	166879	1	166879	60.84	.000
	Cubic	53116.	1	53116.	16.89	.000
	Order 4	6688.0	1	6688.0	2.90	.103
	Order 5	2986.5	1	2986.5	2.43	.134
INTERVAL * GROUP	Linear	40039.	2	20019.	5.04	.016
	Quadratic	11883.	2	5941.8	2.16	.140
	Cubic	12976.	2	6488.1	2.06	.152
	Order 4	12449.	2	6224.8	2.70	.090
	Order 5	3470.5	2	1735.2	1.41	.266
Error(INTERVAL)	Linear	83359.	21	3969.5		
	Quadratic	57596.	21	2742.7		
	Cubic	66040.	21	3144.7		
	Order 4	48399.	21	2304.7		
	Order 5	25802.	21	1228.6		

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	[illegible]	1	41137	224.5	.000
GROUP	285815	2	142907	7.80	.003
Error	384722	21	18320.		

Profile Plots



6.5 Interpretation of the Multivariate and Univariate results

6.5.1 Between-Subjects Factors

In repeated measures analysis we can test hypotheses about within subjects and about between subjects. For tests that involve only between-subjects effects both the multivariate and the univariate approaches give rise to the same tests.

We can see from the Tests of Between-Subjects Effects table that the factor *group* is highly significant. (F statistic 7.801 with 2 and 21 degrees of freedom and with a p-value=0.003). So we conclude that there is difference among the three groups.

6.5.2 Within Subjects Multivariate

For within subjects effects and for within subject by between subject interaction effects, the univariate and multivariate approaches yield different tests.

All the multivariate tests show that *INTERVAL* is a highly significant factor. The interaction between *INTERVAL* and *group* is marginally significant.