Profile Analysis Example

In the One-Way Repeated Measures ANOVA, two factors represent separate sources of variance. Their interaction presents an independent sources of error variation. Suppose a design in which a Factor A has four levels.

Person	Information (A_1)	Vocabulary (A_2)	Digit Span (A_3)	Digit Symbol (A_4)	$\bar{Y}_{p*}$
P_1	127	103	97	113	110
P_2	123	127	121	89	115
P_3	111	127	97	113	112
P_4	99	95	121	89	101
P_5	99	95	89	81	91
P_6	95	103	89	73	90
P_7	87	87	81	81	84
P_8	83	87	81	73	81
$\bar{Y}_1$	$\bar{Y}_{*1}$= 103	$\bar{Y}_{*2}$ = 103	$\bar{Y}_{*3}$ = 97	$\bar{Y}_{*4}$ = 89	$\bar{Y}_{**}$= 98

ANOVA MODEL: $Y_{ijk} = \mu_{**} + \alpha_j + \pi_i + \pi\alpha_{ij} + \varepsilon_{ij}$

Factor A has four marginal means, $\bar{Y}_1$, $\bar{Y}_2$, $\bar{Y}_3$, and $\bar{Y}_4$, and (A-1=4-1=3) degrees of freedom. The null hypothesis for Factor A is H_0: $\mu_{*1} = \mu_{*2} = \mu_{*3} = \mu_{*4}$ or H_0: $\Sigma\alpha^2_j = 0$.

Factor P is a Between-Subjects factor that estimates the individual differences among the subjects. The Sum of Squares of the subject effect ($\Sigma\pi^2_i$) is a source of variance that is separate from the Within-Subjects Factor A..

Because Factor A is a within-subjects factor, the Sum of Squares for the Repeated Measures by Subjects interaction ($\Sigma\pi\alpha^2_{ij}$) is a source of error.

The computation of the Sums of Squares (SS) for the main effects of Factors A and P are similar to the two-way analysis. Marginal means are subtracted from the grand mean, squared, weighted by the marginal sample size, and summed.

SPSS Output from GLM

Report

	Mean	Std. Deviation	N
Information	103.00	16.00	8
Vocabulary	103.00	16.00	8
Digit Span	97.00	16.00	8
Digit Symbol	89.00	16.00	8

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.
FACTORA	Pillai's Trace	.698	3.859[a]	3.000	5.000	.090
	Wilks' Lambda	.302	3.859[a]	3.000	5.000	.090
	Hotelling's Trace	2.315	3.859[a]	3.000	5.000	.090
	Roy's Largest Root	2.315	3.859[a]	3.000	5.000	.090

a. Exact statistic

SPSS Output from GLM (continued)

Measure: WISC

Mauchly's Test of Sphericity[b]

Within Subject Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse-Geisser	Huynh-Feldt	Lower-Bound
FACTORA	.625	2.689	5	.751	.782	1.00	.333

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 of the averaged tests of significance. Corrected test are displyed in the Tests of Within-Subjects Effects table

b. Design: Intercept+FACTORA Within Subject Design: FACTORB

Residual SSCP Matrix

		Information	Vocabulary	Digit Span	Digit Symbol
Sum-of-Squares and Cross-Products	Information	1792.000	1312.000	1056.000	1376.000
	Vocabulary	1312.000	1792.000	960.000	1024.000
	Digit Span	1056.000	960.000	1792.000	576.000
	Digit Symbol	1376.000	1024.000	576.000	1792.000
Covariance	Information	256.000	187.429	150.857	196.571
	Vocabulary	187.429	256.000	137.143	146.286
	Digit Span	150.857	137.143	256.000	82.286
	Digit Symbol	196.571	146.286	82.286	256.000
Correlations	Information	1.000	.732	.589	.768
	Vocabulary	.732	1.000	.536	.571
	Digit Span	.589	.536	1.000	.321
	Digit Symbol	.768	.571	.321	1.000

Calculation of Epsilon

$$\hat{\varepsilon} = \frac{A^2(\bar{s}_{ii} - \bar{s}_{**})^2}{(A - 1)\left(\sum\sum s_{ij}^2 - 2A\sum \bar{s}_i^2 + A^2\bar{s}_{**}^2\right)},$$

where s_{ij} is any element of the covariance matrix,

$\bar{s}_{ii}$=(256+256+256+256)/4 = 256 is the mean of variances,

$\bar{s}_{**}$=(2825.144)/16 = 176.5714 is the mean of all elements, and

$\bar{s}_i$ is the mean of the i^{th} row of the covariance matrix. Thus,

$\bar{s}_1$ = (256.000+187.429+150.857+196.571)/4 = 197.7140,

$\bar{s}_2$ = (187.429+256.000+137.143+146.286)/4 = 181.7145,

$\bar{s}_3$ = (150.857+137.143+256.000+82.286)/4 = 156.5715 , and

$\bar{s}_4$ = (196.571+146.286+82.286+256.000)/4 = 170.2858.

$$\hat{\varepsilon} = \frac{[(16)(256-176.5714)^2]}{[(3)[(549156.81)-((8)(125622.86))+((16)(31177.473))]]} = 0.782$$

SPSS Output from GLM (continued)

Measure: WISC **Tests of Within-Subjects Effects**

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FACTORA	Sphericity Assumed	1056.000	3	352.000	3.324	.039
	Greehouse-Geisser	1056.000	2.347	449.979	3.324	.055
	Huynh-Feldt	1056.000	3.000	352.000	3.324	.039
	Lower-Bound	1056.000	1.000	1056.000	3.324	.111
ERROR(FACTORA)	Sphericity Assumed	2224.000	21	105.905		
	Greehouse-Geisser	2224.000	16.427	135.383		
	Huynh-Feldt	2224.000	21.000	105.905		
	Lower-Bound	2224.000	7.000	317.714		

Measure: WISC **Tests of Within-Subjects Contrasts**

Effect		Type III Sum of Squares	df	Mean Square	F	Sig.
FACTORA	Level 1 vs. Level 2	.000	1	.000	.000	1.000
	Level 2 vs. Level 3	288.000	1	288.000	1.212	.307
	Level 3 vs. Level 4	512.000	1	512.000	1.474	.264
ERROR(FACTORA)	Level 1 vs. Level 2	960.000	7	137.143		
	Level 2 vs. Level 3	1664.000	7	237.714		
	Level 3 vs. Level 4	2432.000	7	347.429		

This was completed by using the Contrast Option (Repeated)

Measure: WISC
Transformed Variable: Average **Tests of Between-Subjects Effects**

Effect	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	76832.000	1	76832.000	435.133	.000
ERROR	1236.000	7	176.571		

Measure: WISC **Pairwise Comparisons**

(I) FACTORA	(J) FACTORA	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	.000	4.140	1.000	-14.987	14.987
	3	6.000	5.127	.861	-12.559	24.559
	4	14.000 *	3.854	.049	.0475	27.953
2	2	.000	4.140	1.000	-14.987	14.987
	3	6.000	5.451	.890	-13.732	25.732
	4	14.000	5.237	.177	-4.958	32.958
3	1	-6.000	5.127	.861	-24.559	12.559
	2	-6.000	5.451	.890	-25.732	13.732
	4	8.000	6.590	.841	-15.855	31.855
4	1	-14.000 *	3.854	.049	-27.953	-0.0475
	2	14.000	5.237	.177	-32.958	4.958
	3	-8.000	4.140	.841	-31.855	15.855

Based on estimated marginal means

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

a. Adjustment for multiple comparions: Sidak.

Computations

Within-Subjects ANOVA Source Table: $Y_{ijk} = \mu^{**} + \alpha_j + \pi_i + \pi\alpha_{ij} + \varepsilon_{ij}$

Source		Sum of Squares	*df*	MeanSquare	*F*
BETWEEN-	SUBJECTS				
Factor P	$(\Sigma\pi^2_i)$ p_1 = 12 p_2 = 17 p_3 = 14 p_4 = 3 p_5 = - 7 p_6 = - 8 p_7 = -14 p_8 = -17	$\Sigma A(\bar{Y}_{p*} - \bar{Y}_{**})^2$ $4(110 - 98)^2$ + $4(115 - 98)^2$ + $4(112 - 98)^2$ + $4(101 - 98)^2$ + $4(91 - 98)^2$ + $4(90 - 98)^2$ + $4(84 - 98)^2$ + $4(81 - 98)^2$ = **1236**	$(N - 1)$ (8-1) = **7**	$SS_P/(N-1)$ 1236/7 = **176.57**	
WITHIN-	SUBJECTS				
FACTOR A	$(\Sigma\alpha^2_k)$ a_1 = 5 a_2 = 5 a_3 = -1 a_4 = -9	$\Sigma n(\bar{Y}_{*A} - \bar{Y}_{**})^2$ $8(103 - 98)^2$ + $8(103 - 98)^2$ + $8(97 - 98)^2$ + $8(89 - 98)^2$ = **1056**	$(A - 1)$ (4 - 1) = **3**	$SS_a/(A-1)$ 1056/3= **352**	MS_A/MS_{AxP} 352/105.905 = **3.324**
Within- Subjects (Error)	$(\Sigma\pi\alpha^2_{ij})$ pa_{11} = 12 pa_{21} = 3 . . . pa_{12} = -12 pa_{22} = 7 . . . pa_{14} = 12 . . . pa_{84} = 1	$\Sigma(Y_{ij} - \bar{Y}_{p*} - \bar{Y}_{*A} + \bar{Y}_{**})^2$ $(127-110-103+98)^2$ + $(123-115-103+98)^2$ + $(103-110-103+98)^2$ + $(127-115-103+98)^2$ . . . + $(113-110-89+98)^2$ + $(73-81-89+98)^2$=**2224**	$(A-1)(N-1)$ (4-1)(8-1) **21**	SS_{AxP}/df_{AxP} (2224/21	= **105.905**)
Total Variance		$\Sigma(Y_{ij} - \bar{\ }_{**})^2$ = **4516**	AN - 1 4(8)-1=**31**	($s^2=S_T/(AN-1)$	= **145.68**)

where N = total number of subjects, A= number of groups for Factor A, $\bar{Y}_{**}$ = the grand mean of Y across all measures, Y_{ij} = each individual score on Y, and $\bar{Y}_{p*}$ = the mean for each subject. $\bar{Y}_{*A}$ = the mean for each measure.

General Linear Model Approach

$Y_{ij} = \mu_*$	$+ \alpha_j$	$+ \pi_i$	$+ \alpha\pi_i$
$Y_{ij} = \bar{Y}_*$	$+ a_j$	$+ p_i$	$+ ap_i$
127 = 98	+5	+12	+12
123 = 98	+5	+17	+ 3
111 = 98	+5	+14	- 6
99 = 98	+5	+ 3	- 7
99 = 98	+5	- 7	+ 3
95 = 98	+5	- 8	+ 6
87 = 98	+5	-14	- 2
83 = 98	+5	-17	- 3
103 = 98	+5	+12	-12
127 = 98	+5	+17	+ 7
127 = 98	+5	+14	+10
95 = 98	+5	+ 3	-11
95 = 98	+5	- 7	- 1
103 = 98	+5	- 8	+ 8
87 = 98	+5	-14	- 2
87 = 98	+5	-17	+ 1
97 = 98	-1	+12	-12
121 = 98	-1	+17	+ 7
97 = 98	-1	+14	-14
121 = 98	-1	+ 3	+21
89 = 98	-1	- 7	- 1
89 = 98	-1	- 8	+ 0
81 = 98	-1	-14	- 2
81 = 98	-1	-17	+ 1
113 = 98	-10	+12	+13
89 = 98	-10	+17	-16
113 = 98	-10	+14	+11
89 = 98	-10	+ 3	- 2
81 = 98	-10	- 7	+ 0
73 = 98	-10	- 8	- 7
81 = 98	-10	-14	+ 7
73 = 98	-10	-17	+ 2
$SS_Y =$ $\sum (Y_{ij} - \mu_{**})^2$	$\Sigma\alpha^2 \quad +$ $= \sum (\mu_{*j} - \mu_{**})^2$	$\Sigma\pi^2 \quad +$ $= \sum (\mu_{p*} - \mu_{**})^2$	$\Sigma\pi\alpha^2$ $+ \sum (Y_{ij} - \mu_{p*} - \mu_{*j} - \mu_{**})^2$
$\sum (Y_{ij} - \bar{Y}_{**})^2$	$= \sum (\bar{Y}_{*j} - \bar{Y}_{**})^2$	$= \sum (\bar{Y}_{p*} - \bar{Y}_{**})^2$	$+ \sum (Y_{ij} - \bar{Y}_{p*} - \bar{Y}_{*j} - \bar{Y}_{**})^2$
SS_Y **= 4516**	= (SS_A = **1056**)	= (SS_P = **1236**)	= (SS_{AxP} = = **2224**)

Reliability Example

In the One-Way Repeated Measures ANOVA, two factors represent separate sources of variance. Their interaction presents an independent sources of error variation. Suppose a questionnaire with five Likert-type items with a 5-point scale.

Person	Item 1 (A_1)	Item 2 (A_2)	Item 3 (A_3)	Item 4 (A_4)	Item 5 (A_5)	$\bar{Y}_{p*}$
P_1	4	4	5	3	4	4
P_2	4	3	5	3	5	4
P_3	2	5	1	2	5	3
P_4	2	3	5	1	4	3
P_5	4	5	5	1	5	4
P_6	2	2	3	1	2	2
P_7	4	5	5	3	3	4
P_8	4	2	1	1	2	2
P_9	3	3	5	1	3	3
P_{10}	2	3	1	1	3	2
P_{11}	4	4	5	3	3	3.8
P_{12}	4	1	1	3	1	2
P_{13}	2	1	1	1	1	1.2
P_{14}	2	1	1	3	3	2
P_{15}	2	3	1	3	1	2
$\bar{Y}_1$	$\bar{Y}_{*1}= 3$	$\bar{Y}_{*2}=3$	$\bar{Y}_{*3}=3$	$\bar{Y}_{*4}=2$	$\bar{Y}_{*5}=3$	$\bar{Y}_{**}= 2.8$

ANOVA MODEL: $Y_{ijk} = \mu^{**} + \alpha_j + \pi_i + \pi\alpha_{ij} + \varepsilon_{ij}$

SPSS Output from GLM

Report

	Mean	Std. Deviation	N
A1	3.00	1.00	15
A2	3.00	1.41	15
A3	3.00	2.00	15
A4	2.00	1.00	15
A5	3.00	1.41	15

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.
FACTORA	Pillai's Trace	.485	2.593[a]	4.000	11.000	.095
	Wilks' Lambda	.515	2.593[a]	4.000	11.000	.095
	Hotelling's Trace	.943	2.593[a]	4.000	11.000	.095
	Roy's Largest Root	.943	2.593[a]	4.000	11.000	.095

a. Exact statistic

SPSS Output from GLM

Measure: MEASURE_1 **Mauchly's Test of Sphericity**[b]

Within Subject Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a] Greenhouse -Geisser	Huynh -Feldt	Lower-Bound
FACTORA	.429	10.514	9	.315	.717	.922	.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 of the averaged tests of significance. Corrected test are displyed in the Tests of Within-Subjects Effects table

b. Design: Intercept+FACTORA Within Subject Design: FACTORB

Residual SSCP Matrix

		A1	A2	A3	A4	A5
Sum-of-Squares and Cross-Products	A1	14.000	6.000	14.000	5.000	4.000
	A2	6.000	28.000	22.000	2.000	19.000
	A3	14.000	22.000	56.000	2.000	22.000
	A4	5.000	2.000	2.000	14.000	.000
	A5	4.000	19.000	22.000	.000	28.000
Covariance	A1	1.000	.429	1.000	.357	.286
	A2	.429	2.000	1.571	.143	1.357
	A3	1.000	1.571	4.000	.143	1.571
	A4	.357	.143	.143	1.000	.000
	A5	.286	1.357	1.571	.000	2.000
Correlations	A1	1.000	.303	.500	.357	.202
	A2	.303	1.000	.556	.101	.679
	A3	.500	.556	1.000	.071	.556
	A4	.357	.101	.071	1.000	.000
	A5	.202	.679	.556	.000	1.000

From Cronbach (1951), the Coefficeint Alpha = $A/(A\text{-}1)[1 - (\Sigma s_{ii}/\Sigma\Sigma s_{ij})]$.
where $\Sigma\Sigma s_{ij}$ = [(1+2+4+1+2)+(2(.429+1.00+.357+.286+1.571+.143+1.357+.143+1.571+.000)]=23.714 is the sum of all elements,
Σs_{ii} = (1+2+4+1+2) =10 is the sum of the variances (the diagonal of the covariance matirx), and A = the number of items. Thus Alpha = (5/4)[1-(10/23.714)] = 1.2(.5783) = .7229.

From Cronbach (1951), the Standardized Coefficeint Alpha = $A(\bar{r})/[1+((A\text{-}1)\bar{r})]$, where $\bar{r}$ = [(.303+.500+.357+.202+.556+.101+.679+.556+.000)/10] = .3325 is the average of the 10 correlations and A = the number of items. Thus Alpha = (5(.3325)/[1+(4(.3325))] = .7135

Calculation of Epsilon

$$\hat{\varepsilon} = \frac{A^2(\bar{s}_{ii} - \bar{s}_{**})^2}{(A - 1)\,(\sum\sum s_{ij}^2 - 2A\sum \bar{s}_i^2 + A^2\bar{s}_{**}^2)}$$

where s_{ij} is any element of the covariance matrix,
$\bar{s}_{ii}$=(1+2+4+1+2)/5=2 is the mean of variances,
$\bar{s}_{**}$=(23.714)/25=0.94856 is the mean of all elements,
and $\bar{s}_i$ is the mean of the i^{th} row of the covariance matrix. Thus,
$\bar{s}_1$ = (1.0+.429+1.0+.357+.286)/5 = 0.6144, $\bar{s}_2$ = (.429+2.0+1.571+.143+1.357)/5 = 1.10,
$\bar{s}_3$ = (1.0+1.571+4.0+.143+1.571)/5 = 1.657, $\bar{s}_4$ = (.357+.143+.143+1.0+0.0)/5 = 0.3286, and
$\bar{s}_5$ = (.286+1.357+1.571+0.0+2.0)/5 = 1.0428.

$$\hat{\varepsilon} = \frac{[(25)(2-0.94856)^2]}{[(4)[(42.42343)-((10)(5.52855))+((25)(0.89977))]]} = 0.717$$

SPSS Output from GLM (continued)

Measure: WISC **Tests of Within-Subjects Effects**

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
FACTORA	Sphericity Assumed	12.000	4	3.000	2.283	.072
	Greehouse-Geisser	12.000	2.869	4.183	2.283	.096
	Huynh-Feldt	12.000	3.686	3.255	2.283	.078
	Lower-Bound	12.000	1.000	12.000	2.283	.153
ERROR(FACTORA)	Sphericity Assumed	73.600	56	1.314		
	Greehouse-Geisser	73.600	40.165	1.832		
	Huynh-Feldt	73.600	51.610	1.426		
	Lower-Bound	73.600	14.000	5.257		

Measure: WISC
Transformed Variable: Average **Tests of Between-Subjects Effects**

Efect	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	588.000	1	588.000	123.976	.000
ERROR	66.400	14	4.743		

The use of ANOVA to estimate internal consistency reliability was first proposed by Hoyt (1941). The Hoyt reliability is identical to the Cronbach's (1951) Alpha.

Hoyt reliability = 1 - (MS_{AxP}/MS_P) = Alpha = 1 - (1.314/4.743) = .7229

This formulation is based on the perspective that MS_{AxP} is measurement error or error due to inconsistency. In the calculation of SS_{AxP}, note that for each individual score the Person effect [$\bar{Y}_{*j}-\bar{Y}_{**}$] and the Item effect [$\bar{Y}_{p*}-\bar{Y}_{**}$] are subtracted, yielding [$Y_{ij}-\bar{Y}_{p*}-\bar{Y}_{*j}+\bar{Y}_{**}$]). If an individual's score on any item (Y_{ij}) can be perfectly predicted from the combination of how well they did on the test in total (i.e. the person's mean, $\bar{Y}_{p*}$) and how "difficult" the item was (i.e., the item mean, $\bar{Y}_{*j}$), then the residual (i.e., [Y_{ij} - $\bar{Y}_{p*}$ -$\bar{Y}_{*j}$ -$\bar{Y}_{**}$]) is 0 and that response is consistent. If an individual's scores on any item can not be perfectly predicted from the combination of how well they did on the test in total (i.e. the person's mean,) and item "difficulty," then there is inconsistency. Squaring these residuals provides an estimate variance due to inconsistency or measurement error.

It should also be noted that the Person variance in the denominator is based on MS_P. There is no guarantee that this will be larger than MS_{AxP}. Just as the expected value of an *F*-ratio is 1 but can be less than 1 in any sample, the ratio of (MS_{AxP}/MS_P) is expected to be 1 under conditions of inconsistency. However, imagine that some students take an exam and respond very differently to the items, however, they all end up with almost identical total scores. This means the items did not contribute to separating these students on their ability (i.e., item discrimination). In this scenario the person variance would be small, but the error variance would be relatively large. Cronbach's Alpha would be negative. The concept of negative reliability is a oxymoron, you cannot have negative variance. However, there is nothing in any of the formulas to keep the reliability estimate from being slightly negative. A negative Cronbach's Alpha usually comes about because (1) the sample of test takers had homogeneous test scores or (2) because a few items had negative correlations (i.e., negative discrimination coefficients) with the other items. The second scenario often occurs when a Likert-type item is a "reversal" item (i.e., stated with negative framing), but the data analysts forgets to recode the variable.

Output from SPSS Scale - Reliability Analysis (Alpha Model)

****** Method 2 (covariance matrix) will be used for this analysis ******

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

N of Cases = 15.0

Statistics for	Mean	Variance	Std Dev	N of Variables
Scale	14.0000	23.7143	4.8697	5

	Mean	Minimum	Maximum	Range	Max/Min	Variance
Item Means	2.8000	2.0000	3.0000	1.0000	1.5000	.2000
Item Variances	2.0000	1.0000	4.0000	3.0000	4.0000	1.5000
Inter-item Covariances	.6857	.0000	1.5714	1.5714	1.000E+20	.3697
Inter-item Correlations	.3324	.0000	.6786	.6786	1.000E+20	.0524

Item-total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Alpha if Item Deleted
A1	11.0000	18.5714	.4807	.3628	.6872
A2	11.0000	14.7143	.6452	.5159	.6084
A3	11.0000	11.1429	.6419	.4974	.6154
A4	12.0000	21.4286	.1389	.1490	.7733
A5	11.0000	15.2857	.5813	.5186	.6355

Analysis of Variance

Source of Variation	Sum of Sq.	DF	Mean Square	F	Prob.
Between People	66.4000	14	4.7429		
Within People	85.6000	60	1.4267		
Between Measures	12.0000	4	3.0000	2.2826	.0717
Residual	73.6000	56	1.3143		
Total	152.0000	74	2.0541		
Grand Mean	2.8000				

Intraclass Correlation Coefficient

Two-Way Mixed Effect Model (Consistency Definition):
People Effect Random, Measure Effect Fixed
Single Measure Intraclass Correlation = .3429*
95.00% C.I.: Lower = .1244 Upper = .6287
F = 3.6087 DF = (14, 56.0) Sig. = .0003 (Test Value = .0000)
Average Measure Intraclass Correlation = .7229**
95.00% C.I.: Lower = .4154 Upper = .8943
F = 3.6087 DF = (14, 56.0) Sig. = .0003 (Test Value = .0000)
*: Notice that the same estimator is used whether the interaction effect is present or not.
**: This estimate is computed if the interaction effect is absent, otherwise ICC is not estimable.

Reliability Coefficients 5 items

Alpha = .7229 Standardized item alpha = .7135

Computations

Within-Subjects ANOVA Source Table: $Y_{ijk} = \mu^{**} + \alpha_j + \pi_i + \pi\alpha_{ij} + \varepsilon_{ij}$

Source		Sum of Squares	*df*	MeanSquare	*F*
BETWEEN-	SUBJECTS				
Factor P	$(\Sigma\pi^2_i)$ p_1 = 1.2 p_2 = 1.2 p_3 = 0.2 p_4 = 0.2 p_5 = 1.2 p_6 = -0.8 p_7 = 1.2 p_8 = -0.8 p_9 = 0.2 p_{10} = -0.8 p_{11} = 1.0 p_{12} = -0.8 p_{13} = -1.6 p_{14} = -0.8 p_{15} = -0.8	$\Sigma A(\bar{Y}_{p*} - \bar{Y}_{**})^2$ $5(4 - 2.8)^2$ $+ 5(4 - 2.8)^2$ $+ 5(3 - 2.8)^2$ $+ 5(3 - 2.8)^2$ $+ 5(4 - 2.8)^2$ $+ 5(2 - 2.8)^2$ $+ 5(4 - 2.8)^2$ $+ 5(2 - 2.8)^2$ $+ 5(3 - 2.8)^2$ $+ 5(2 - 2.8)^2$ $+ 5(3.8 - 2.8)^2$ $+ 5(2 - 2.8)^2$ $+ 5(1.2 - 2.8)^2$ $+ 5(2 - 2.8)^2$ $+ 5(2 - 2.8)^2$ = **66.40**	$(N - 1)$ (15-1) = **14**	$SS_P/(N-1)$ 66.40/14 = **4.743**	
WITHIN-	SUBJECTS				
FACTOR A	$(\Sigma\alpha^2_k)$ a_1 = 0.2 a_2 = 0.2 a_3 = 0.2 a_4 = -0.8 a_5 = 0.2	$\Sigma n(\bar{Y}_{*A} - \bar{Y}_{**})^2$ $15(3 - 2.8)^2$ $+ 15(3 - 2.8)^2$ $+ 15(3 - 2.8)^2$ $+ 15(2 - 2.8)^2$ $+ 15(3 - 2.8)^2$ = **12**	$(A - 1)$ (5 - 1) = **4**	$SS_a/(A-1)$ 12/4= **3.0**	MS_A/MS_{AxP} 352/105.905 = **3.324**
Within- Subjects (Error)	$(\Sigma\pi\alpha^2_{ij})$ pa_{11} = -0.2 pa_{21} = -0.2 . . . pa_{12} = -0.2 pa_{22} = -1.2 . . . pa_{15} = -0.2 . . . $pa_{15,4}$= -1.2	$\Sigma(Y_{ij} - \bar{Y}_{p*} - \bar{Y}_{*A} + \bar{Y}_{**})^2$ $(4 - 4 - 3 + 2.8)^2$ $+ (4 - 4 - 3 + 2.8)^2$ $+ (4 - 4 - 3 + 2.8)^2$ $+ (3 - 4 - 3 + 2.8)^2$ . . . $+ (4 - 4 - 3 + 2.8)^2$ $+(1 - 2 - 3 + 2.8)^2$=**73.60**	$(A-1)(N-1)$ (5-1)(15-1) **56**	SS_{AxP}/df_{AxP} (73.60/56	= **1.314**)
Total Variance		$\Sigma(Y_{ij} - \bar{\ }_{**})^2$ = **152**	$AN - 1$ 5(15)-1=**74**	$(s^2=S_T/(AN-1)$	= **2.054**)

where N = total number of subjects, A= number of groups for Factor A, $\bar{Y}_{**}$ = the grand mean of Y across all measures, Y_{ij} = each individual score on Y, and $\bar{Y}_{p*}$ = the mean for each subject. $\bar{Y}_{*A}$ = the mean for each measure.