ANOVA/TT: Analysis of variance teaching template for Lotus 1-2-3

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Inferential statistics courses often require students to conduct multifactor analysis of variance (ANOVA) problems by hand and then employ a computer to check results. Many microcomputer programs perform two-factor ANOVAs (e.g., Anderson, 1984; Brown, 1984; Butler & Eamon, 1985; Coder, 1985, 1985; Collani & Waloszek, 1983; Corrigan, Bonelli, & Borys, 1980a, 1980b; Coulombe, 1983, 1984, 1985; Galla, 1981, 1984; Hacker & Angiolillo-Bent, 1981; Lane, 1981; Strang, 1980), and each has its unique strengths. However, most programs either (1) do not handle repeated measures (within-subjects) or mixed designs, (2) require too high a level of statistical knowledge for first-time users, (3) have cumbersome input procedures, (4) fail to reveal intermediate steps in calculations, (5) give no cues for the interpretation of the results, or (6) are not user friendly. We are aware of none that conduct two-factor ANOVAs, show intermediate steps, produce summary tables, indicate significant contrasts, conduct post hoc tests, and illustrate main and simple effects on a polygon, all on a spreadsheet with instant updates. Some of the recent micro- and mainframe computer packages (e.g., ANOVR, SAS, SPSSX, Minitab, and BMDP) have overcome many of these shortcomings, but there still remains a need for instructional tools to teach two-factor ANOVAs. The program herein described was developed to assist students in learning to analyze and interpret experimental data from entry to illustration.

ANOVA/TT is a teaching template—a set of predesigned worksheet files—to be used in conjunction with Lotus 1-2-3 (Lotus Development Corporation, 1985). It is user friendly and requires no previous computer experience to operate. It begins with a menu-driven interactive query session that directs the user to the proper ANOVA design. Once in the proper file, program flow is nearly identical to performing an ANOVA by hand. After data are entered into the cells of a matrix, a simple keypress initiates a macro that results in an ANOVA summary table, table of means and variances, post hoc analyses, and plots of main effects and interactions.

ANOVA/TT is capable of conducting ANOVAs according to the following designs: (1) *repeated*

measures—completely within-subjects designs in which each subject receives each level of all treatments; (2) *between-groups*—random-groups or independent-groups designs whereby each subject receives only one level of a single treatment; (3) *mixed designs*—combinations of the repeated measures and between-groups designs. Mixed designs, in this system, have the repeated measures on the second factor.

Each of the three types of two-factor ANOVA designs has three configuration levels: 2×2 , 2×3 , and 2×4 . The data may be inverted, however, to make 3×2 and 4×2 designs, for a total of 15 designs. The data matrix accommodates up to 16 observations per cell, but presently requires an equal sample size for each cell.

ANOVA/TT is based on procedures for hand computations (Hendrick & Vercruyssen, in press; Myers, 1979; Winer, 1971). Also, each template's intermediate and final values have been verified using a double precision mainframe package, ANOVR (analysis of variance for repeated measures; Games, 1981; Games, Gray, Herron, & Pitz, 1980).

User Input. Once a design has been chosen, the template file will be loaded into memory automatically and the user will notice a data matrix awaiting input. The user need only to enter data into each cell to see instantaneous recalculations with each input.

Program Output. After the data are entered, scrolling down will show the degrees of freedom, mean squares, sum of squares, the summary table (including each *F* and *p*), and the post hoc analysis. Data exploration or "what if" analyses can be done simply by changing raw data, since the calculations are instantly redone every time data are changed.

Macro functions are utilized to finish the analysis. A macro in Lotus 1-2-3 is a way of batching 1-2-3 menu commands together. For example, depressing the following keys will perform the designated functions:

Alt H	displays a help screen.
Alt F	adds to the summary table <i>F</i> values and Studentized range values (<i>q</i>) per contrast.
Alt G	produces graphs of the means for row, column, and interaction effects.
Alt T	completes the Tukey WSD post hoc tests.
Alt P	prints the entire worksheet.

The paper output is in six pages. (See Appendix A for an example of a 2×4 between-groups input data matrix, Appendix B for the intermediate calculations and ANOVA summary table, Appendix C for the post hoc analyses, Figure 1 for a plot of row main effects, Figure 2 for a plot of column main effects, and Figure 3 for a plot of the interaction.) Output in this form is especially valuable to students trying to determine why hand-calculated

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Figure 1. Sample row main effects for a 2×4 ANOVA between-groups design template, automatically plotted by ANOVA/TT 1.4 via Lotus 1-2-3.

Figure 2. Sample column main effects for a 2×4 ANOVA between-groups design template, automatically plotted by ANOVA/TT 1.4 via Lotus 1-2-3.

Figure 3. Sample interaction from a 2×4 ANOVA between-groups design template, automatically plotted by ANOVA/TT 1.4 via Lotus 1-2-3.

summary tables are incorrect, because it makes intermediate computations available for examination.

Required Hardware. An IBM PC or compatible microcomputer with at least 384K of memory and a 5.25-in. (13.3-cm) disk drive is required to run ANOVA/TT. Obviously, processing speed is greatly increased by using hardware comparable to that of an XT, AT, or 386 system. Math coprocessors (e.g., the 8087, 80287, or 80387) can even further accelerate the speed of calculations. A graphics board or card is needed to view the graphs on a monochrome monitor.

Required Software. The ANOVA/TT runs on an MS-DOS operating system. Although the template was developed in DOS 3.1 (International Business Machines, 1985), other DOS versions should be compatible. This template is for Lotus 1-2-3 Release 2.0 or higher.

Availability. ANOVA/TT has a copyright by Psy-Med Associates. A copy of the user's guide and all programs (two 360K floppy disks or one 1.2MB floppy disk) can be obtained by sending a check for \$20 to Psy-Med Associates, 2329 Sonoma Street, Honolulu, HI 96822, or to Max Vercruyssen, Human Factors Laboratory, ISSM, University of Southern California, Los Angeles, CA 90089-0021. Disks mailed will be 5.25-in. double-sided double-density unless high-capacity is requested.

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[illegible]

APPENDIX A (Continued)

Subtot	n	6	6	6	6	
	EX	16	49	11	23	99
	EX SQ	56	415	31	99	601
	M	2.67	8.17	1.83	3.83	
	SD(n)	1.49	1.57	1.34	1.34	
	SD(n-1)	1.63	1.72	1.47	1.47	
TOTALS	EX	29	99	56	76	260
	EX SQ	91	845	386	574	1896

APPENDIX B

Sample Intermediate Calculations and Summary Table on a 2×4 ANOVA Between-Groups Design Template

CALCULATIONS

DEFINITIONS:	a	2 levels of factor A
	b	4 levels of factor B
	n	6 number of observations per cell
	N	48 total number of observations
	C	1408.333 correction term
DEGREES OF FREEDOM:	df TOT	47 N-1
	df A	1 a-1
	df B	3 b-1
	df A X B	3 (a-1)(b-1)
	df WTHN	40 (N-ab)
SUM OF SQUARES:	SS TOT	487.67
	SS A	80.08
	SS B	221.17
	SS A X B	92.08
	SS WTHN	94.33 within subjects error term
MEAN SQUARES:	MS A	80.0833
	MS B	73.7222
	MS A X B	30.6944
	MS WTHN	2.3583
F VALUES:	F A	33.9576
	F B	31.2603
	F A X B	13.0153

ANOVA SUMMARY TABLE

SOURCE	SS	df	MS	F	PROB	F .05	F .01
A	80.08	1	80.0833	33.9576	0.0000	4.08	7.31
B	221.17	3	73.7222	31.2603	0.0000	2.84	4.31
A X B	92.08	3	30.6944	13.0153	0.0000	2.84	4.31
WTHN	94.33	40	2.3583				
TOTAL	487.6666	47		***	ALT F for F Values	***	

APPENDIX C
Sample Post Hoc Analyses Output for a 2×4 ANOVA Between-Groups Design Template

CONCLUSION AT 0.05 ALPHA:

A Factor	Yes Significance
B Factor	Yes Significance
AxB Factor	Yes Significance

Proceed on with POST HOC Analyses if any factor has Significance

TABLE OF M, SD, AND SE:

		B1	B2	B3	B4	TOTALS
A1	M	2.17	8.33	7.50	8.83	6.71
	n	6.00	6.00	6.00	6.00	24.00
	SD(n)	1.07	1.49	1.71	1.07	1.33
	SD(n-1)	1.17	1.63	1.87	1.17	1.46
	SE(n)	0.18	0.25	0.28	0.18	0.22
	SE(n-1)	0.19	0.27	0.31	0.19	0.24
A2	M	2.67	8.17	1.83	3.83	4.13
	n	6.00	6.00	6.00	6.00	24.00
	SD(n)	1.49	1.57	1.34	1.34	1.44
	SD(n-1)	1.63	1.72	1.47	1.47	1.57
	SE(n)	0.25	0.26	0.22	0.22	0.24
	SE(n-1)	0.27	0.29	0.25	0.25	0.26
TOTALS	M	2.42	8.25	4.67	6.33	5.42
	n	12.00	12.00	12.00	12.00	48.00
	SD(n)	1.28	1.53	1.53	1.21	1.39
	SD(n-1)	1.40	1.68	1.67	1.32	1.52
	SE(n)	0.21	0.26	0.25	0.20	0.23
	SE(n-1)	0.23	0.28	0.28	0.22	0.25

TUKEY WSD:

	TABLE	*CALC*	TOTAL
WSD rows =	17.97	1.827	0.000
Variables	6.71	4.13	
Sorted	4.13	6.71	
WSD cols =	6.825	2.479	0.000
Variables	2.42	8.25	4.67 6.33
Sorted	2.42	4.67	6.33 8.25
WSD cells =	8.853	2.262	0.000
Variables	2.17	8.33	7.50 8.83 2.67 8.17 1.83 3.83
Sorted	1.83	2.17	2.67 3.83 7.50 8.17 8.33 8.83

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