A BASIC program to compute Hotelling's T² and related measures

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In its best-known version, Hotelling's (1931) T² statistic can be computed whenever two independent groups of subjects are tested on two or more dependent variables. T² may be conceptualized variously as a multivariate analog of an independent groups t-test, as a counterpart to multivariate analysis of variance with two groups, or as the equivalent of a two-groups discriminant analysis (Green, 1978). It is integral to profile analysis on test batteries (Groff, 1983).

Unfortunately, computation of T² by hand is cumbersome with two dependent variables and impractical with three or more. While it is entirely practical to perform the computations on microcomputers, appropriate programs apparently are not widely available. The present program, T-SQUARED, computes T² and a number of related statistics on the Apple II family of computers.

Requirements. The program was written in Applesoft BASIC on a 48K Apple II+. Because the program was written with conversion in mind, conversion to computers using other dialects of Microsoft BASIC should be exceptionally easy, and to facilitate this process, the manual contains a discussion of Applesoft-specific code. The program was ported to the Commodore 64 microcomputer with no difficulty, although the conversion required familiarity with the Commodore operating system. Memory requirements are minimal: The program loads in 8K and runs in 24K. It is presently dimensioned to handle up to 30 dependent variables and a virtually unlimited number of subjects (unequal ns are permitted); the number of variables can be increased in a 48K machine. A printer is desirable but not necessary.

Input/Output Options. Data may be entered either from the keyboard as the program executes (the default option), or from a previously created data file in DIF format. Prompts and a record of the data may be directed to any slot number, and an error correction routine is available. Output may also be directed to any slot number; the default sends output to the 40-column screen. The user may elect to have the computer pause periodically, until a keypress is detected, to prevent results from scrolling off the screen.

Methodology and Results Provided. T-SQUARED computes T² indirectly, by creating a dummy variable representing group membership, and by generating a mul-

tiple regression solution predicting that variable from the original dependent variables. T² then is computed from the following formula: $T^2 = R^2(n_1 + n_2 - 2)/(1 - R^2)$ [consult Green (1978, p. 168) for the equations on which this formula is based]. A number of other statistics also are provided: (a) within-group covariance matrices and determinants; (b) within-group means and standard deviations for each dependent variable; (c) Bartlett's chi-square test for equality of covariance matrices (Green, 1978, p. 171), and associated degrees of freedom and probability level; (d) the pooled covariance matrix and determinant; (e) the pooled correlation matrix among dependent variables; (f) means and standard deviations for the combined groups, for each variable; (g) R^2; (h) T^2, and associated F value, degrees of freedom, and probability level; (i) an F-test for equality of profile variances (Plake, Reynolds, & Gutkin, 1981), and associated degrees of freedom and probability level; and (j) a separate independent-groups t-test for each dependent variable (using pooled error variances; Winer, 1971), with associated separate and Bonferroni (Howell, 1982, pp. 289-292) probability values.

T-SQUARED runs on the sample data from Bock (1975) and from Srivastava and Carter (1983) matched the results reported. A run on a dataset consisting of six subjects per group and two dependent variables took 2 min, about two-thirds of which represented data entry.

Availability. A user's manual, including program listing and several sample runs, is available without charge from A. R. Gilpin, Department of Psychology, University of Northern Iowa, Cedar Falls, IA 50614. Copies of the program on diskette (DOS 3.3) may be obtained by sending a blank diskette plus $2 to cover postage and handling costs (make checks payable to the University of Northern Iowa).

REFERENCES

Bock, R. D. (1975). *Multivariate statistical methods in behavioral research.* New York: McGraw-Hill.

Green, P. E. (1978). *Analyzing multivariate data.* Hinsdale, IL: Dryden Press.

Groff, M. G. (1983). A scheme for conducting two-sample profile analysis. *Multivariate Behavioral Research, 18,* 169-181.

Hotelling, H. (1931). The generalization of Student's ratio. *Annals of Mathematical Statistics, 2,* 360-378.

Howell, D. C. (1982). *Statistical methods for psychology.* Boston: Duxbury Press.

Plake, B. S., Reynolds, C. R., & Gutkin, T. B. (1981). A technique for the comparison of profile variability between independent groups. *Journal of Clinical Psychology, 37,* 142-146.

Srivastava, M. S., & Carter, E. M. (1983). *An introduction to applied multivariate statistics.* New York: North-Holland.

Winer, B. J. (1971). *Statistical principles in experimental design* (2nd ed.). New York: McGraw-Hill.

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