RCMATDIF—A FORTRAN program to calculate the relatedness coefficient matrices on a verbal relatedness task and to compare the mean matrix of one group of subjects to another with Hotelling's T^2

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Description. The trend in research on memory and on instruction is toward experiments on variables causing changes in the structure of memory. Hence, methods are needed for representing memory structure and for comparing the representation of memory structure for one group of subjects with the representation for another group. The program abstracted here in a small way helps meet this need. The purposes of this program are to take data from word association tests—one measure of memory structure (cf. Deese, 1965; Garskof & Houston, 1963; Geeslin & Shavelson, in press; Johnson, 1967; Shavelson, 1972, 1974)—and provide (a) a representation of the way in which a subject interrelates key concepts (words) in his memory (a representation of memory structure), (b) a method for combining the representation of memory structure over subjects, and (c) a method for testing whether a representation of psychological structure for one group of subjects differs significantly from the representation for another group of subjects.

Garskof and Houston (1963) defined associative meaning of a word as an ordered set of associates given by an individual in response to the word. The relatedness of two words was defined as the degree of overlapping meaning (associates) between them. The magnitude of the relatedness of two words depends upon the number of associates shared in common by each word and the congruence of the rank orders of the common associates. The relatedness of two words is indexed by the relatedness coefficient (RC, cf. Garskof & Houston, 1963). A matrix of RC coefficients, then, might be considered a representation of the structure of memory (cf. Shavelson, 1972, 1974).

To obtain the RC, a list of associates must be acquired from a subject for a pair of stimulus words. The words in the associate list are assigned a rank according to the equation: Rank = $(n_1 - j + 1)^p$, where n_1 is the number of associates in the first list, j is the position of the word in the list, and p is a weighting exponent which depends upon the psychological importance of the order in which the associates are retrieved from memory by the subject. In the case where all associates are given equal weight, p is set equal to 1. The ranks for the second list of associates are obtained using the same formula. If Ξ is set equal to one of the sets of ranks, e.g.,

$$\Xi = [n_1^p, (n_1 - 1)^p, \dots, 1^p]$$

and Ω equal to the second set, e.g.,

$$\Omega = [n_2^p, (n_2 - 1)^p, \dots, 1^p],$$

then the *maximum possible overlap* could be calculated by multiplying the corresponding ranks in each set and summing all of the products. Thus, the maximum overlap may be found by:

$$\Xi \cdot \Omega = n_1^p n_2^p + (n_1 - 1)^p (n_2 - 1)^p + \dots + 1^p 1^p.$$

This product represents the case when the two stimuli are the same. Since different stimulus words are used, a correction term,

$$[n^p - (n - 1)^p]^2,$$

where n is the number of words in the longer of the two lists, must be subtracted.

The *observed overlap* between associates of two words is found as follows. The ranks given to the words in Ξ that are also found in Ω are recorded. This set of ranks may be denoted as ξ . Likewise, the ranks given to the words in Ω that are also in Ξ are recorded, denoted as ω . The overlap between the two is calculated by taking the product of the corresponding ranks, $\xi \cdot \omega$.

The value of the RC is equal to the amount of observed overlap divided by the maximum possible overlap:

$$RC = \frac{\xi \cdot \omega}{(\Xi \cdot \Omega) - [n^p - (n - 1)^p]^2}.$$

If $\xi \cdot \omega = 0$, then it follows that Ξ and Ω have no common elements and the RC = 0. If Ξ and Ω share all associates in common, then the maximum value of RC is 1.00.

A matrix of relatedness coefficients is obtained for each subject. The matrix consists of the cross-relatedness of every stimulus word on the list to every other stimulus word. Individual RC matrices may be combined to form a mean RC matrix for each cross-relatedness of stimuli.

The major difference between this program and other relatedness coefficient programs (e.g., Mead, 1972) is this program's ability to examine whether two mean matrices differ significantly from each other. The comparison is performed by a Hotelling's (1931) T^2 test on the difference between each group's respective mean RC matrix.

Computer and language. IBM 360/91, WATFIV, includes a subroutine developed by Veldman (1967) in FORTRAN.

Core requirements. 350K when dimensioned for 15 stimuli words and 180K when dimensioned for 10 stimuli words or less.

Execution time. Less than 5 min.

Input. Two parameter cards. The first is the problem card. It defines the number of subjects in each of the two groups, the option of printing or suppressing every subject's RC matrix, and the value of p . The second card is the label card. It identifies the stimuli. For each data card, Columns 1-3 are reserved for the subject's identification number, Column 4 is for the number of cards needed to enter the subject's data, and finally, in fields of eight columns, the respective stimulus word and responses are entered.

Output. Optional output of each individual RC matrix with ID number. The mean RC matrix for each of the two groups is printed, followed by the T^2 statistic. The T^2 statistic will tell the user whether or not a difference was found between the two mean RC matrices.

Limitations. Two to 15 stimuli words only. Core size depends on the number of stimuli words.

Availability. The source listing of the program, its documentation, and a sample application may be obtained from Richard J. Shavelson, UCLA Graduate School of Education, Los Angeles, California 90024, at no cost.

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Program to determine growth and decline functions from semi-longitudinal data

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Description. The semi-longitudinal method is appropriate for computing growth functions of subject characteristics when two or more measures are available for each of a large number of subjects over any part of the life span. It is not necessary that the measures be taken at the same chronological ages (CA) for all individuals. The rationale for the semi-longitudinal method is presented in Fisher and Zeaman (1970). The program computes an average slope of the function for each CA interval using data from all subjects whose measures either fall within that interval or span it. These slopes determine the shape of the semi-longitudinal function. The absolute level of the curve is determined by a least-squares fit of the curve to the mean cross-sectional values for each interval. Regression coefficients, m and b , are computed for the equation $\hat{x} = m(1/CA) + b$, where x is the slope of the semi-longitudinal function corresponding to each CA interval. The correlation coefficient for the regression is also computed. This linear regression function should fit well when the growth function is logarithmic.

Input. A set of input cards containing the information from the Pinneau (1961) tables for an optional MA-to-IQ conversion is unchanging and comes with the program. The user specifies the abscissa interval size in months of CA and the increment size for successive least-squares approximations. Average slopes are computed for each of the abscissa intervals. For each subject, the user prepares one punched card record containing a list of successive measures on that subject and the CAs for each measure.

Output. Each input data card is printed followed by the values of the dependent variable after optional conversion and by the first and last CA intervals into which measures for this subject fall. The

initial deviations and sums of squared deviations for successive least-squares approximations fixing the level of the curve are printed out. A table is printed containing for each CA interval: the initial CA in months, the ordinal number of the interval, the weighted mean slope of all line segments in that interval, the number of measures on which the mean is based, mean cross-sectional value of y , the dependent variable, the mean semi-longitudinal value of y , and the standard deviation of the cross-sectional measures. This table is also punched into cards. A final table is printed with the regression coefficients, the correlation coefficient, and the observed and estimated values of x at each interval.

User options. The user may specify interval size and least-square increment size. The program may be used with any dependent variable. If the variable is MA, there are optional transformations available in the program to use instead: (1) the IQ as computed from the input MA and CA by means of the Pinneau tables and functions, or (2) K , the constant of mental growth developed by Fisher and Zeaman. The program will easily accept other transformations of the raw data supplied by the user as subroutines.

Limitations. Current restrictions are arbitrary in that these were established in accordance with expected use rather than in deference to machine limitations. There are up to 100 intervals of CA, up to 11 measures per subject, up to 4,000 measures altogether. Intermediate storage on a scratch tape is required. The total execution time for the IBM 360 to do five separate analyses, reading a total of 1,500 subject cards averaging four measures each, printing 5,000 lines, and punching 600 cards, was 2.73 min.

Computer and language. The program is written in FORTRAN IV and has been run on both the IBM 7040 and the IBM 360. Since there are no machine-bound parts of the program, it should run on any system having a fully implemented FORTRAN IV capability.

Availability. The documented program is available from the author at: Department of Psychology, University of Maryland Baltimore County, 5401 Wilkens Avenue, Baltimore, Maryland 21228.

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