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METHODS & DESIGNS

The BC TRY integrated statistical computer package

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The statistical features and general characteristics of an integrated statistical package, BC TRY, are reported. The BC TRY system of cluster and factor analysis includes many of the same descriptive and multivariate statistical analyses accomplished by the best of the packages reviewed by Berk (1977), as well as some unique routines, and it provides the user with exceptional flexibility.

Berk (1977) recently surveyed seven integrated packages of computer programs for statistical analyses. Selection was made on the basis of "frequency of use in descriptive and experimental research and compatibility with third-generation computers." The purpose of this paper is to document the statistical features and general characteristics of the BC TRY system of cluster and factor analysis (Tryon & Bailey, 1966, 1970) in a manner parallel to that employed by Berk. One of the first such packages to be developed, it continues to be widely used and much in demand. Originally written for the IBM 709 series, the programs are currently running on CDC 6400 (KRONOS operating system) and CYBER (NOS operating system) systems.

The BC TRY system is an example of a higher order of "integration" than that offered by other statistical packages. The integration of most packages is very loose, with frequent points of incompatibility and inconsistency in data manipulation, data flow, and transmission of data to and from elements in the package. Functional aspects of the integrative elements of a package are important in its utility. Many packages, however, include components without the necessary focus on integration between components within the system. In this paper we describe some of the integrative features included in the BC TRY system.

METHOD

The special focus of Berk's (1977) survey was upon the statistical procedures offered by several computer packages. Following Berk, no attempt was made in this paper to present evaluations of the computational accuracy of the individual routines in the BC TRY system, although such evaluations have been made using cross-checks and parallel hand calculation (see Bailey, 1973, p. 20).

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The BC TRY system is a specialized rather than a generalized package, since it does not include data-maintenance capabilities in the sense of a permanent file system for data under direct control of the package. However, the system does have the capability to store files of data for use in different analyses in a single run. For example, using the same data, correlations between variables can be followed by analysis of subjects into homogeneous subtypes, and the latter followed by analysis of the predictive efficiency of these typological assignments upon an outside variable (included in the input but not used in the correlational analysis). These capabilities are called "data sharing" in the BC TRY system (Tyron & Bailey, 1966, p. 106). Data are stored in a system component called DST. Intermediate results, such as a correlation matrix, are stored on a component called IST in appropriately labeled files. Of course, the computer operating system may be used with the BC TRY to access permanent file data also.

From available documentation for each package, Berk identified all statistics designated as mandatory or optional program output. Procedures not so identified were not listed in his survey descriptions. The same method was used here. However, statistical analyses on BC TRY are documented in three different ways: The first requires a minimum knowledge of multivariate statistics (see the EC commands below); the second requires more knowledge (see INCITATION, Tryon & Bailey, 1965, pp. 146h-146j). A third level uses a linear algebra interpretive system SMIS, extends the statistical procedures executable to any procedure that has a linear algebraic expression, and requires a knowledge of linear algebra.

Tables appearing in Berk's (1977) article are matched in this paper so that direct comparisons can be made with the BC TRY system. Table 1 matches exactly the statistics considered in Berk's (1977) Table 1. An X marks the availability of that statistical analysis in mandatory or regular optional form. In addition to the three sections included by Berk (Descriptive, Parametric, and Nonparametric Statistics), the present Table 1 includes a fourth selection on statistically relevant utilities available in the BC TRY system. Statistics unique to BC TRY are shown also.

A special feature of BC TRY is the economy provided in user time required to prepare control cards for job input. This economy is accomplished by the use of modular components and executive control (EC) commands. In presenting the statistical features of the system, references are included to the actual EC command (and related modular component) that cause the analysis in question to be performed. Any one component may

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produce numerous statistics, sometimes on a mandatory basis and other times by investigator's option. The relevant EC commands will be given below.

ANALYSES PROVIDED BY THE BC TRY

The statistical procedures in the BC TRY system are presented in Table 1. Only one of the packages surveyed by Berk (1977) had all of the listed Items A-L available and two had none available. Items M-O are additional descriptive statistics available on the BC TRY system.

In parametric statistics none of the packages reviewed by Berk offered all four correlation analyses listed (Section II-A of the table). Offerings ranged from none to three. Two packages had two correlation offerings, the same two shown for the BC TRY. Use of two coefficients not available (biserial and tetrachoric) in multivariate procedures is questionable in any case.

Section II-B, Univariate Analysis, had at least two items offered by each of the packages Berk surveyed. The SMIS component of BC TRY allows a user to program these analyses in linear alegebra form.

Section II-C of Table 1 refers to seven multivariate procedures, five of which (at most) were offered by the packages Berk (1977) surveyed. Four offered factor analysis and only one offered cluster analysis. Note that "multivariate analysis" includes a number of quite different types of analyses. Some seek to reduce a number of dependent variables to a single linear weighted composite measure such that a certain criterion is maximized. Here the "groups" of subjects are assumed known. For example, they might be experimental and control groups or groups composed of persons having different ages or diagnostic labels. Multivariate analysis of variance and multiple discriminant analysis accomplish such goals. For such analyses, it is assumed that group membership is determined and the measures taken on the groups have acceptable psychometric properties such as reliability and validity. What remains is the determination of weights to be used in making one or more weighted composite measures to achieve selected objectives. By contrast, when the measures to be used are still under investigation, or when the groups to be studied are yet hidden in an undifferentiated pool of subjects, then a different task faces the investigator. Factor analysis, cluster analysis of measures, analysis of the pool of subjects in homogeneous subgroups or types must be carried out. The BC TRY system contains a large number of options specializing in the latter tasks, hence the offerings shown in Table 1, Section II-C. These specializations lead to a very large number of procedures available in the BC TRY that are not available in other packages. Additional procedures may be designed and executed by the user with the linear algebra interpretive system, SMIS.

Section III of Table 1 refers to nonparametric statistics, of which the BC TRY system has no offerings, except the Monte Carlo estimation of sampling distributions. Berk (1977, p. 280) noted that this category was generally neglected in the packages he surveyed, although one package contained nearly 24 such statistics. As Berk noted, there are several special-purpose programs available. In addition, the Guttman-Lingoes series of nonmetric programs offers a package of analyses based upon 24 different models of data structures (Lingoes, 1973).

Section IV of Table 1 provides a partial list of the utilities available in the BC TRY system. Some are sufficiently described in the table; some (like GIVE) are more fully explained below.

The components of the BC TRY system shown in Table 1 refer to modular component programs callable by the user through an EC command. The system is modular. The basic building blocks of multivariate analysis are incorporated into the system in independently callable segments. The independence of the segments is limited only to the data input requirements of the various types of analyses. However, there are numerous paths for the input of data for each segment of the system, matching the configuration of almost any desired data analysis. Indeed, the data-sharing capability is one of the unique elements of the system among computer program packages. Input and output of data between stages of an analysis are accomplished easily, providing the user with a way of introducing new data at intermediate stages and a way of outputting (on punch cards or magnetic files) results of intermediate calculations of an analysis.

The modularity of the system is reflected in the manner in which the various stages of analysis are initiated and controlled. The basic building blocks of the system consist of primary components that are executed by use of an EC command, or "verb" of the system. The verbs play the role of identifying the primary type of operation to be performed. The modifiers of the verbs are component control (CC) commands, in the form of punched cards containing option control parameters. The EC commands are of two sorts, data-sharing commands and commands that control statistical, analytical, and logical problems.

A run of the BC TRY system consists of a sequence of the EC commands (each on a separate punch card), CC command cards, and data cards. There are 31 standard EC commands in the system, most of which have a large number of modifiers in the form of CC commands. For example, in V analysis there are eight primary EC commands: CC5 for key-cluster analysis, DVP for determination of initial diagonal values in the correlation matrix, FALS for least-squares methods of factor analysis, GYRO for rotational methods, etc. In the FALS EC command, there are three primary modifiers for the three methods of least-squares factoring available: principal axes, augmented factoring, and canonical factor analysis. Each of the primary modifiers in FALS has two separate sets of parameters that determine such things as how the dimensionality of the

Table 1
Statistical Features of BC TRY Package

Statistics	X = Mandatory or Optional in BC TRY	Component
I. Descriptive Statistics		
A. Mean	X	DAP2
B. Median	X	RSCAT
C. Mode		
D. Range		
E. Variance	X	DAP2
F. Standard deviation	X	DAP2
G. Standard error (mean)	X	DAP2
H. Skewness		
I. Kurtosis		
J. Frequency distribution	X	RSCAT
K. Cross tabulation	X	RSCAT
L. Scattergram/plot	X	RSCAT
(M.) Means of O types*	X	OSTAT
(N.) Standard deviations of O types	X	OSTAT
(O.) Homogeneities of O types	X	OSTAT
(P.) Percentiles	X	RSCAT
II. Parametric Statistics		
A. Correlation		
1. Pearson	X	COR2
2. Biserial		
3. Tetrachoric		
4. Partial	X	FAST
B. Univariate analysis		
1-4. t test, ANOVA	X	SMIS
C. Multivariate analysis		
1. MANOVA/MANCOVA	X	SMIS
2. Multiple correlation/regression	X	SMIS
3. Simple/multiple discriminant analysis	X	SMIS
4. Canonical correlation	X	SMIS
5. Factor analysis	X	FALS, GYRO**
6. Cluster analysis	X	CC5
7. Multidimensional scaling		
(8.) Communality estimation	X	DVP
(9.) Linear and curvilinear regression	X	RSCAT
(10.) Predicted Y values from regressions	X	RSCAT
(11.) Principal components analysis	X	FALS
(12.) Cluster structure analysis	X	CSA2
(13.) Cluster reliabilities (alpha-)	X	CSA2
(14.) Cluster domain validities	X	CSA2
(15.) Expanded cluster reliabilities	X	CSA2
(16.) Preset cluster analysis	X	CC5
(17.) Factor estimation	X	FACS
(18.) Factor matching	X	COMP1, COMP2
(19.) Proximity analysis of object clusters	X	OTYPE
(20.) Typological prediction	X	4CAST
(21.) Spherical analysis (three-dimensional plots)	X	SPAN
III. Nonparametric Statistics		
A. Nominal data 1-8		
B. Ordinal data 1-15		
C. Monte Carlo estimation of sampling distributions	X	4CAST
(IV. Statistically Relevant Utilities)		
(1.) Missing data adjustments	X	DAP2
(2.) Correlations with missing data	X	COR3
(3.) Compile and list missing data statistics	X	RLIST
(4.) Reorder and delete specified variates	X	REDE
(5.) Suppress certain variates at Stage Sp	X	SLEP1
(6.) Reinstate suppressed variates at Sp + q	X	SLEP2
(7.) Compute and print residual and reproduced matrices	X	FAST
(8.) Sampling and merging variates	X	BIGNV

Table 1 Continued

Statistics	X = Mandatory or Optional in BC TRY	Component
(9.) Call special matrix operations	X	SMIS
(10.) Punch latest state of analysis	X	GIVE
(11.) Reinstate previous state of analysis	X	TAKE
(12.) Create intermediate state of analysis	X	GIST

Note–Items in parentheses are found in the BC TRY system; no comparable statistic was mentioned in the table given by Beck (1977, p. 278). Items not in parentheses match the items appearing in Beck's table.
**An O type is a homogeneous subgroup of subjects produced by the component OTYPE.*
***The BC TRY component FALS may be set for principal axes, canonical, augmented, centroid, bifactor, or square-root factoring. The GYRO component carries out orthogonal rotation of axes to simple structure, either quartimax or varimax. Oblique rotation is accomplished by the CSA2 component. Other procedures, such as maximum likelihood methods may be implemented using SMIS.*

solution is to be determined and how convergence in factor iteration is to be determined.

The range of possible analyses involving FALS is extensive when used in concert with other EC commands that provide a manipulation of the basic data that FALS addresses in its calculation. For example, different forms of factor analyses are given when the diagonal values program (DVP), executed before FALS, is used with different modifiers providing various types of values.

Repeated use of an EC command, preceded by various other EC commands can provide methodological studies in data analysis. A string of BC TRY EC and CC commands represents completely and accurately a complex and highly individualized multivariate procedure. Because of the richness of the EC and the CC command structure, and because of the data-sharing aspects of the system, the user virtually interacts with his data analysis, exercising control over the detail and broad strategy of the analysis.

The flexibility of analysis using the BC TRY system is illustrated in the following example. Imagine data in which a general factor influences the intercorrelation of all of the observed variables (say, an instrument factor or a factor representing systematic context variation across the observational procedures). We wish to extract this variation as a general factor and then perform a cluster analysis on the resulting corrected correlation matrix. The corrected correlation matrix is of interest in itself and we want a card deck containing the matrix. The sequence of EC commands is presented in Table 2.

A simple cluster analysis of the correlation matrix, without the removal of the first principal axis, is performed by the following sequence of EC commands: START, DAP2, DPRINT, COR2, GIVE, DVP, CC5. The GIVE command serves to punch the status of the data in the analysis at the point the command is used. The punch cards provided by GIVE are read by using the command TAKE, reestablishing the status of the analysis as it was when the GIVE was used. Consequently, the following analysis picks up where the previous analysis had just completed calculating the correlation matrix: START, TAKE, DVP, CC5. Now, imagine that we want the first analysis described above, we also want a cluster analysis of the matrix before the first principal axis is extracted, and we do not want the correlation matrix punched out: START, TAKE, DVP, CC5, FALS, FAST, DVP, CC5, GIVE. To perform a varimax rotated principal axis analysis and a key-cluster analysis, using the communality estimates provided by the full principal axis analysis, the following sequence of EC commands is used: START, TAKE, DVP, FALS, GYRO, CC5. The printouts of the procedures appear in the order of the use of the executive commands.

The system is truly eclectic in its selection of procedures implemented as standard procedures and options within the EC commands. In addition, the system contains a subsystem of 35 matrix and vector operators and

Table 2
Sequence of Executive Control Commands

START	Initializes computer resources and data storage facilities
DAP2	Inputs the raw data, variable names, and object names and provides simple descriptive statistics for the raw data
DPRINT	Lists the data as they actually appear to the programs
COR2	Calculates the correlation matrix from the raw data
GIVE	Produces a card deck containing the status of the analysis at this point
DVP	Provides diagonal values for the correlation matrix (communalities)
FALS	Under modifiers used for this analysis, this program calculates a single principal axis factor (the first Eigenvector)
FAST	Calculates the correlation matrix orthogonal to the first Eigenvector and replaces the original correlation matrix with the reduced matrix
GIST	Punches specified information; the corrected correlation matrix in this example
DVP	Calculates new estimates of communality to be used in the cluster analysis
CC5	Performs a full key-cluster analysis
GIVE	Produces a card deck containing the status of the analysis at this point, including data necessary to restart at a later time

Table 3
General Characteristics, Availability, and User's Manuals of BC TRY

	BC TRY Specifications
Date of Release	1965
Languages	FORTRAN II, IV, and Assembly
Machines	CDC 6400, 6500, 6600; CYBER
Operating Systems	Kronos, Scope, NOS
Core Required	75K Bytes
Cost: Nonprofit Cost: Profit Availability	Current system availability and cost information may be obtained by writing to D. Cartwright, CLIPR, Box 346, University of Colorado, Boulder, Colorado 80309. Also available is a list of installations in the U.S. and Canada where BC TRY is operational and arrangements can be made to use it.
User's Manual	Tryon and Bailey, 1965, 1967, 1970 (see References section). Tryon and Bailey (1970, Chapter 13) contains complete descriptions of statistical procedures and theory as well as much of the computing science theory employed in the BC TRY system.

special control commands in the SMIS interpreter to manipulate the data-sharing facilities of the BC TRY system. With this special subsystem, any calculation that can be expressed in terms of vector, matrix, scalar, and elemental algebraic operations can be incorporated into the BC TRY system without additional programming or modification of the system.

Table 3 shows the general characteristics of the BC TRY system comparable to those listed by Berk (1977, p. 279). For economy of space, the elements of his Tables 2 and 3 have been combined in the present Table 3.

From Tables 1 and 3, it appears that the BC TRY system compares very favorably with other packages in those respects for which it was designed, the factor and cluster analysis and typology group of multivariate analyses, and in descriptive statistics.

INTEGRATIVE FEATURES OF THE BC TRY

Certain integrative features in the BC TRY system enhance its utility and increase the range of statistical procedures that can be executed by the system. One such feature has been mentioned before: the general linear algebraic interpreter component, SMIS. Like other standard components, SMIS has access to the file structure of the system. SMIS may operate on files output by other components, and in turn may output files that are used by other components. Consequently, virtually any linear algebraic operation may be performed within the EC sequence, using data produced by other components..

The primary integrative vehicle of the BC TRY system is its file structure. Each component program calls certain files as input and defines certain files as output. A component program is not sensitive to the source of a file, as long as it is available when needed. For example, COR2 outputs the file CORRM1 containing a correlation matrix; CORRM1 is then required as input to DVP, CC5, CSA2, and FACS. CSA2 outputs a file BASIS1 containing a matrix of correlations between factors. BASIS1 is required by FACS if the user chooses to obtain regression estimates of factor scores rather than simple sum scores.

These and other integrative features of the BC TRY system give it many of the aspects of a specialized programming language or an information management system with powerful operators.

Several specialized file management components are available in the system. The file-save component GIVE permits the user to specify anywhere in the control sequence (EC) that the entire file structure is to be punched in a binary card deck (or, alternatively, output to a magnetic tape or disk file). This binary image of the files can later be reinstated on IST by execution of a TAKE command together with the binary deck. When several different analyses are to be performed, all starting with a common sequence of computations, that sequence needs to be done only once and its results preserved in the binary file image. A GIVE is executed in the first run, and subsequent runs begin with a TAKE. In addition, when a fatal control card error (either in a CC or an EC card) or a machine fault is detected by the system, a GIVE is automatically executed to preserve the file contents existing. The binary file image can easily be restored before continuing with the analysis, avoiding repetition of completed calculations of the aborted run.

The component GIVE outputs all files generated so far. Selective input and output of files from the BC TRY system file structure is provided by the GIST component. Particular statistics, lists, etc., produced by component programs can be output selectively by calling GIST. The file is punched (or output to a magnetic tape or disk) in Hollerith format, with headings and parameters required to input it (using GIST) in a subsequent run. Files prepared by keypunch may also be input by GIST.

SOME STUDIES USING BC TRY

Studies using the BC TRY can be found in Tryon and Bailey (1970). These include clinical descriptions of patients, ecology analyses of the city of San Francisco, prediction of 1954 voting behavior in different types of precincts from data gathered in 1940, analysis of 301 grade-school children into 15 subtypes on 24 psychological tests, comparative cluster analyses in two samples, and others.

Cartwright and Howard (1973) and Cartwright, Howard, and Reuterman (1970) studied structural properties (differentiation, etc.) of small groups using behavior profiles and intraclass correlation coefficients between members. Hindelang and Weis (1972) reported an impressive study testing Eysenck's hypothesis that criminality is associated with a personality type characterized by both high extraversion and high neuroticism. Components DAP2-4CAST were used.

The sequence DAP2, COR2, CC5, CSA2, SPAN, FACS, OTYPE is often used in behavioral and social sciences. Bloom and Parad (1976, 1977) reported a series of studies on community mental health staff, using the sequence through CSA2. Braucht and his associates used the entire sequence in a series of studies on drugs and alcohol use (Braucht, 1974), drinking behavior (Braucht, Kirby, and Berry, 1978), suicide attempts (Braucht, in press), and others in progress that include the use of COMP1 and COMP2 to interrelate pairs of analyses. Jessor and his associates used the sequence in continuing studies of personality and perceived environments in relation to adolescent problem behavior (see Donovan, 1977; Finney, 1974). Donovan's (1977) study is of special interest in that OTYPE was employed on two random national samples (Ns approximately 5,000 and 4,000). Of 14 types found in each sample, 12 pairs had a small enough Euclidean distance to have been condensed into one type had the samples been pooled for a single run; the other two were only slightly beyond the distance criterion for condensation. Oetting and Goldstein (1978) used the sequence in a continuing series of studies of native American children and youth. They have developed a particularly striking method for studying and presenting the output from SPAN, which projects all vectors in three-space to the surface of a sphere. As many plots are produced as there are three-spaces in the cluster solution from CC5. Thomas (1975) studied patterns of national instability and war using lead-lag data over a 20-year period.

Studies currently in progress which use the same sequence include those of Harvey, Coates, Gore, and Prather (Note 1), who are examining types of cognitive systems in teachers and students. Rusmore and Dean (Note 2) are investigating types of business executives. Dean and Hogan (Note 3) are studying empathy and have found no less than 12 different types of persons in this regard.

Methodological work includes that of Nelson (1976), who studied the problems of clustering categorical and continuous variables simultaneously and devised new methods. Huizinga (1977) studied the identifiability of clusters, comparing a number of different clustering algorithms applied to a variety of data structures. Gore (1979) developed routines for CC5 clustering of large numbers of variables (500) without sampling and merging (which are the essential procedures of BIGNV).

In a recent study of semantic word norms, Toglia, Battig, Barrow, Cartwright, Posnansky, Pellegrino, Moore, and Camilli (1978) asked: Are there subgroups in a sample of nearly 3,000 English words with respect to the words' rated mean values on semantic variables including concreteness, imagery, categorizability, and others?

The answer was sought using OTYPE. Beginning with arbitrary subgroupings of the full sample (of words, in this case), OTYPE calculates within-group centroids, Euclidean distances between centroids, and distances between each individual (word) and each centroid. Each object is then reassigned to the subgroup having the closest centroid to itself. Centroids are recalculated and the procedure iterated until no improved assignments are possible. Each final centroid is then assumed to characterize a type of object (an O type), and each member of the relevant subgroup is assumed to be properly classified as an instance of this type. OTYPE then studies hierarchic relations between types and provides data for a dendrogram. Toglia et al. (1978) found eight O types which included all but two of the words studied, each word having a unique membership in one group. The tightness (homogeneity) of the groups was very high, as were rating reliabilities.

Thus, it appears that eight, and only eight, types of words are available for experimental material in studies such as paired-associate learning of English words. This rather stark result contrasts with what might otherwise be expected, namely, that any combination of values on semantic variables can be found and any variable of this kind can be systematically controlled over all levels of other such variables. Use of the BC TRY system shows that that is simply not the case, at least as thus far determined on one large sample of words.

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