A Computer Program for Regression Analysis of Ordered Categorical Repeated Measurements

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ABSTRACT

RMORD is an easy-to-use FORTRAN program for the analysis of clustered ordinal data using the method of Stram, Wei, and Ware [1]. This method constitutes an extension of the proportional-odds model [2] to the situation in which groups of responses are correlated. At each measurement occasion, a proportional-odds regression model is fit to the data by maximizing the occasion-specific likelihood function. The joint asymptotic distribution of the occasion-specific regression parameter estimators is obtained along with a consistent estimator of their asymptotic covariance matrix. RMORD may be used when ordinal measurements are obtained at a common set of observation times for multiple subjects or clusters. Both missing data and covariates which vary within clusters can be accommodated. The program can be run on microcomputers, workstations, and mainframe computers. Two examples illustrating the usage and features of RMORD are provided.

KEYWORDS

Correlated responses; Ordinal data; Generalized linear models; Longitudinal data; Proportional-odds model

1. Introduction

In biomedical research, studies which collect clustered data are increasingly common. Clustered data may arise from studies which obtain measurements on the same observational units repeatedly through time (i.e., longitudinal data), or repeatedly across different experimental conditions. Alternatively, clustered data may arise when measurements are obtained on different observational units which fall naturally into groups such as families, litters, or neighborhoods. In each case, there is an inherent stochastic dependence among clusters of data which should be taken into account during statistical analysis.

Methods for the analysis of complete, continuous clustered data are well established (see, for example, Ware [3]). However, many techniques for the analysis of non-continuous and/or partially missing data have been introduced only recently. Consequently, software implementations of these new methods are scarce. This paper introduces RMORD (Repeated Measures ORDinal data), a FORTRAN program for the analysis of clustered ordinal responses according to the method of Stram, Wei, and Ware [1]. This approach may be used when measurements are obtained at a common set of occasions. In general, these occasions need not be observation times, but to simplify the description of methods here, it is assumed that the data under consideration are longitudinal in nature.

At each time point, the marginal distribution of the response variable is modelled using the proportional-odds regression model [2] which avoids the assignment of artificial scores to the levels of the ordinal categorical response. The parameters of these models are assumed to be specific to each occasion and are estimated by maximizing the occasion-specific likelihoods. The joint asymptotic distribution of the estimates of these occasion-specific regression coefficients and a consistent estimator of their asymptotic covariance matrix is then obtained without imposing any parametric model of dependence on the repeated observations. This approach allows for both time-dependent covariates and missing data. However, any missing values are assumed to be missing

completely at random (MCAR) as described in Rubin [4]. See Laird [5] for a discussion of missing data in longitudinal studies.

The remainder of this paper is organized as follows: section 2 provides a description of the statistical method implemented in RMORD; section 3 describes the RMORD program and its use; two examples illustrating the usage and features of RMORD are presented in section 4; hardware and software specifications are given in section 5; and program availability is discussed in section 6.

2. Statistical method

To establish notation, suppose that Y_{ti}^*, an ordered categorical response variable with J levels, is observed at time t, $t = 1, \ldots, T_i$, and for subject i, $i = 1, \ldots, N$. In what follows, to simplify notation it will be assumed that $T_i = T$ for all i. Let

$$Y_{jti} = \begin{cases} 1 & \text{if } Y_{ti}^* = j, \\ 0 & \text{otherwise,} \end{cases} \quad j = 1, \ldots, J$$

so that instead of Y_{ti}^*, the $J-$dimensional vector of indicator variables, $\mathbf{Y}_{ti} = (Y_{1ti}, \ldots, Y_{Jti})^T$, may be considered. In addition, at each time t and for each individual i, a $p-$dimensional vector of covariates, $\mathbf{X}_{ti} = (X_{1ti}, \ldots, Xpti)^T$ is observed. When $\mathbf{X}_{ti}$ takes the observed value $\mathbf{x}$, let $\zeta_{jt}(\mathbf{x}) = \Pr(Y_{jti} = 1)$, and $\gamma_{jt}(\mathbf{x}) = \sum_{k=1}^{j} \zeta_{kt}(\mathbf{x})$ for each j, t, and i. That is, $\gamma_{jt}(\mathbf{x})$ is the cumulative probability $\Pr(Y_{ti}^* \leq j)$, for all i. According to the proportional-odds model,

$$\log\left(\frac{\gamma_{jt}(\mathbf{x})}{1-\gamma_{jt}(\mathbf{x})}\right) = \lambda_{jt} - \mathbf{X}_{ti}^T\boldsymbol{\beta}_t, \quad j = 1, \ldots, J, \quad t = 1, \ldots, T, \quad i = 1, \ldots, N, \tag{1}$$

where $\boldsymbol{\beta}_t$ is a $p-$dimensional vector of unknown parameters which may depend on t. Notice that in this model a positive regression parameter implies that the odds of observing a large value of Y_{ti}^* increase as the covariate increases. Since $\boldsymbol{\beta}_t$ does not depend on j, the model makes the strong assumption that the additive effect of a covariate on the log odds that $Y_{ti}^* \leq j$ does not depend on j.

To accommodate missing data, let $\delta_{ti} = 1$ when $\mathbf{X}_{ti}$ and $\mathbf{Y}_{ti}$ are observed, and 0 otherwise. It is assumed that data are MCAR; that is, for each t and i, δ_{ti} may depend on $\mathbf{X}_{ti}$, but is conditionally independent of $\mathbf{Y}_{ti}$ given $\mathbf{X}_{ti}$. In addition, given $\mathbf{X}_{ti}$, δ_{ti} is assumed to be independent of λ_{jt} and $\boldsymbol{\beta}_t$. For each time $t = 1, \ldots, T$, $(\mathbf{Y}_{ti}, \mathbf{X}_{ti}, \delta_{ti})$ are assumed to be independent and identically distributed across individuals $i = 1, \ldots, N$. Under the MCAR assumption the missing data mechanism can be ignored and occasion-specific parameter estimates $\widehat{\boldsymbol{\beta}_t}$ and $\widehat{\lambda_{jt}}$ can be obtained by maximizing the log-likelihood function at time t. This maximization is equivalent to maximizing

$$\sum_{i=1}^{N} \delta_{ti} \sum_{j=1}^{J+1} Y_{jti} \left\{\log\left[\gamma_{jt}(\mathbf{x}) - \gamma_{j-1,t}(\mathbf{x})\right]\right\},$$

where $\gamma_{0t} = 0$, $\gamma_{J+1,t} = 1$, and γ_{jt} satisfies the proportional-odds model given by (1). Stram, Wei, and Ware [1] show that $(\widehat{\boldsymbol{\lambda}_t}^T, \widehat{\boldsymbol{\beta}_t}^T)^T$ is asymptotically normal with mean $(\boldsymbol{\lambda_t}^T, \boldsymbol{\beta_t}^T)^T$ and covariance matrix which can be estimated consistently using expression (A.2) of that paper.

Hypotheses concerning occasion-specific parameters of the form $H_0\colon \mathbf{C}_t\boldsymbol{\beta}_t$ can be tested using the Wald statistic

$$W_t = \widehat{\boldsymbol{\beta}_t}^T \mathbf{C}_t^T \left[\mathbf{C}_t \left(\widehat{\operatorname{cov}(\boldsymbol{\beta}_t)}\right)^{-1} \mathbf{C}_t^T\right]^{-1} \mathbf{C}_t\widehat{\boldsymbol{\beta}_t},$$

where $\mathbf{C}_t$ is a $c \times p$ matrix of constants. Under H_0, W_t has an asymptotic chi-square distribution with c degrees of freedom (df). Hypotheses concerning covariate-specific parameters of the form H_0: $\mathbf{C}_k\boldsymbol{\beta}_k$, where $\boldsymbol{\beta}_k = \beta_{k1}, \ldots, \beta_{kT}$, $k = 1, \ldots, p$, can be tested similarly.

Parameters specific to the k^{th} covariate, $\boldsymbol{\beta}_k$, can be combined to obtain a pooled estimate, $\widehat{\beta}_k = \sum_{t=1}^{T} w_t \widehat{\beta_{kt}}$, of the covariate's effect across time. In general, $\mathbf{w} = (w_1, \ldots, w_T)^T$ is any vector of weights summing to one. However, the estimator $\widehat{\beta_k^*}$ which uses

$$\mathbf{w}^* = \left[\mathbf{e}^T \widehat{\text{cov}\left(\widehat{\boldsymbol{\beta}_k}\right)}^{-1} \mathbf{e}\right]^{-1} \widehat{\text{cov}(\boldsymbol{\beta}_k)}^{-1} \mathbf{e},$$

where $\mathbf{e}$ is a $T \times 1$ vector of ones, has the smallest asymptotic variance among all linear estimators $\widehat{\beta_k}$.

3. Usage of RMORD

In terms of structure and usage, RMORD is similar to the previously published programs RMGEE [6] and RMNP2 [7]. The use of RMORD involves three components: the structure of the input data file, the specification of analysis options, and the structure of optional contrast files.

3.1 Structure of the input data file

The input data file must be a standard text (ASCII) file with no hidden characters or word-processing format codes. The general structure of the data file is shown in Table 1. Each line of the input file contains the data (time identifier, ordered categorical response, and covariate values) from a single time point for one subject. Note that the ordering of the variables is arbitrary (for example, the time variable is not required to appear first) and that the data file may contain additional variables which will not be used in the analysis.

The maximum number of time points (repeated measurements) is eight. It is required that the time variable be coded as $1, \ldots, T^*$, where $T^* = \max(T_i)$, that the repeated observations from each subject be in consecutive order from time 1 to time T^*, and that each subject has exactly T^* observations. Thus, if a subject's data from a particular time point are missing, the corresponding line in the data file will contain the time variable and missing values for the response and covariates.

The response variable can have at most eight possible outcomes; these must be coded using consecutive integers $\ell, \ell+1, \ldots, \ell+J-1$, where ℓ is the smallest nonmissing response code. Often, $\ell = 0$ and the outcome variable is coded as $0, 1, \ldots, J-1$. However, since ordinal categorical responses are sometimes coded from $1, \ldots, J$ (i.e., $\ell = 1$), the value of ℓ is specified by the user.

Although a maximum of 30 variables can be read in, a model can include at most eleven covariates. Note that the set of covariates to be included in a model may be a subset of the total number of variables read in from the data file.

All data items are read in as double-precision, floating point numbers. By default, free format input is used. In this case, data fields must be separated by one or more blanks or commas. However, the program allows the user to specify a FORTRAN format statement for inputting more complex data files. All data values less than a user-specified missing data code are interpreted as missing values.

3.2 Specification of analysis options

Analysis options may be specified in one of three ways. Options may be entered interactively in response to program prompts, included at the beginning of the input data file, or included in a separate data file. Examples of all three types of option specifications are given in the next section. The RMORD options are described in Table 2.

3.3 Structure of optional contrast files

Options **M**, **N**, and **O** pertain to two optional contrast files which may be specified. The first file (option **N**) contains one or more occasion-specific coefficient matrices for testing hypotheses of the form $\mathbf{C}_t\boldsymbol{\beta}_t = \mathbf{0}$, where $\boldsymbol{\beta}_t$ denotes the vector of estimated parameters at the t^{th} time point. Note that the hypotheses specified in this file are tested at each time point. This file should be structured as in Table 3.

Multiple contrast matrices, $\mathbf{C}_t^{(1)}, \mathbf{C}_t^{(2)}, \ldots$, may be specified. For single degree of freedom contrasts, the program will output the estimate and standard deviation of the contrast $\mathbf{C}_t\boldsymbol{\beta}_t$. For all specified coefficient matrices $\mathbf{C}_t\boldsymbol{\beta}_t$, the hypothesis $H_0\colon \mathbf{C}_t\boldsymbol{\beta}_t = \mathbf{0}$ will be tested using a Wald statistic as described in section 2. If H_0 is true, the test statistic has an asymptotic chi-square distribution with degrees of freedom equal to the number of rows in the matrix $\mathbf{C}_t$.

The second file (option **O**) contains one or more parameter-specific coefficient matrices for testing hypotheses of the form $\mathbf{C}_k\boldsymbol{\beta}_k = \mathbf{0}$, where $\boldsymbol{\beta}_k$ now denotes the $T \times 1$ vector of estimated parameters for the k^{th} covariate across the T time points. Note that the hypotheses specified in this file are tested for each covariate, $k = 1, \ldots, p$. These contrasts are specified and tested in the same manner as was described for occasion-specific linear combinations. For eack k, the number of columns in $\mathbf{C}_k$ must equal the value specified for option **J** and the number of rows in $\mathbf{C}_k$ must be less than or equal to the value of **J**.

4. Examples

Two examples will be considered. Example 1 uses RMORD to analyze data arising from a clinical trial which compared two treatments for a respiratory disorder [8]. Example 2 concerns a study comparing post-surgical recovery among children receiving different dosages of anesthesia [9]. In each example both an initial and a reduced model will be fit using RMORD.

4.1 Respiratory Disorder Study

A clinical trial comparing two treatments for a respiratory disorder was conducted in 111 patients at two centers (A and B). In each center, eligible patients were randomly assigned to active treatment ($N = 54$) or placebo ($N = 57$). During treatment, respiratory status (0=terrible, 1=poor, 2=fair, 3=good, 4=excellent) was determined at four visits. Potential covariates were center, treatment group, gender, age, and baseline respiratory status. All covariates are time-independent and there were no missing data for responses or covariates. The data from this study are contained in the file RESP1.DAT. The data from the first six active-treated patients from center A are listed in Table 4.

These data will be analyzed using interactive specification of the analysis options. Since all data values are positive and there are no missing values, a missing value indicator of -1 will be used. The regression model at each time point will include all five covariates. At each visit, the occasion-specific contrast option will be used to test the hypothesis that the simultaneous effects of center, gender, and age are not significantly different from zero. The necessary contrast file (RESP1A.CON) is listed in Table 5. Results will be written to the file RESP1.OUT.

The program is invoked by typing RMORD. The session log is listed in Table 6. Note that statements in capital letters denote prompts which appear on the screen; these are followed by user responses. The output file from this example (RESP1.OUT) contains 286 lines. A partial listing of this file is given in Table 7. Comments following $***$ describe omitted sections of the output.

The contrast testing the significance of center, gender, and age at time point 1 was not significant (chi-square = 2.91, df = 3, $p = 0.41$). Similar results (not shown here) were obtained at times 2, 3, and 4 (the chi-square statistics were equal to 1.56, 3.26, and 2.96, respectively). In addition, the test of the hypothesis that the center effects (BETA 1) at all four time points are equal to zero was also not significant (chi-square = 6.20, df = 4, $p = 0.18$). Similar tests for gender (BETA 3)

and age (BETA 4) were also non-significant; the respective chi-square statistics were 1.24 and 3.25, each with 4 df. On the other hand, the results for BETA 2 (treatment) and BETA 5 (baseline respiratory status) indicate that the effects of these covariates are significantly different from zero at all four time points. Based on these results, we will now fit a reduced model including only two covariates: treatment group and baseline respiratory status. In addition, two parameter-specific contrasts will be tested. Since the estimated effects of baseline respiratory status in the previous model were equal to 1.29, 0.89, 0.76, and 0.81, at visits 1–4, respectively, we will test the hypotheses that:

a. the effect at visit 1 is not significantly different from the effects at the other three visits;
b. there is no significant difference between the effects at visits 2, 3, and 4.

Although we are only interested in testing these hypotheses for the baseline respiratory status covariate, the same contrasts will also be tested for treatment group.

In order to demonstrate the use of RMORD when input options are included at the beginning of the data file, the input file RESP1.DAT is modified by adding the following five lines before the data from the first subject (comments in parentheses are not part of the file):

```
-1 8 1          (analysis options B, C, and D)
3 5 0 2 4 2 1   (analysis options F–K and M)
5 8             (analysis option L)
*               (analysis option N)
resp2b.con      (analysis option O)
```

The resulting modified file is named RESP2.DAT. The first line of RESP2.DAT contains the missing value indicator, the total number of variables to be read in, and the data input mode (options **B**, **C**, and **D**). If the data input mode had been equal to 2, the second line would have contained the FORTRAN format statement for reading in the data (option **E**). The next line (line 2) contains the index of the response variable, the number of response levels, the smallest nonmissing response code, the index of the time variable, the number of time periods, the number of covariates in the model, and the indicator for tests of linear combinations (options **F**–**K** and **M**). Line 3 contains the indices of the covariates to be included in the model (option **L**). Since linear contrasts are to be tested (option **M** is equal to 1), the final two lines contain the names of the contrast files. These would have been omitted if no contrasts were to be tested. The contrast file (RESP2B.CON) is listed in Table 8. The session log and partial results from this example are listed in Tables 9 and 10, respectively.

These results indicate that the active treatment is positively related to improvement in respiratory status at all visits. Although the estimated treatment effect varies across time points, the hypothesis of equality of parameter estimates is not rejected (chi-square = 5.48, df = 3, $p = 0.14$). Baseline respiratory status is also positively associated with improvement in respiratory status at all four visits. There is some evidence that the estimated effects are not homogeneous over time (chi-square = 7.77, df = 3, $p = 0.05$). The estimated effect at visit 1 is significantly different from the average effect at visits 2, 3, and 4 ($p = 0.02$) and there is no evidence of differences among the effects at the last three visits ($p = 0.42$).

4.2 Anesthesia Study

In a comparison of the effects of varying dosages of an anesthetic on post-surgical recovery, sixty young children undergoing outpatient surgery were randomized to one of four dosages (15, 20, 25 and 30 mg/kg), with 15 children per group. Recovery scores were assigned upon admission to the recovery room and at minutes 5, 15 and 30 following admission. The response at each of the four time points was an ordinal categorical variable ranging from 0 (least favorable) to 6 (most favorable). In addition to the dosage, potential covariates were age of the patient (in months) and duration of the surgery (in minutes). Again, all covariates are time-independent.

The data from this study are contained in the file ANESTH.DAT. In addition to the actual dosage (mg/kg), three indicator variables for dosage are included. The observations from the first five subjects in the 15 mg/kg dosage group are presented in Table 11.

The first model for these data will include the three dosage indicator variables, age, and surgery duration as covariates. Two hypotheses will be tested using time-specific contrasts :

a. the overall dosage effect is not significantly different from zero;
b. the nonlinear components of the dosage effect are not significantly different from zero.

The analysis options are contained in the file ANESTH1.CTL, which is listed in Table 12. (Note that the line numbers and descriptions are not part of the file ANESTH1.CTL.) The contrast file ANESTH1A.CON is listed in Table 13. The contrast testing nonlinearity of the dosage effect was derived as follows. For each t, $t = 1, \ldots, T$, let $\beta_{t,D20}$, $\beta_{t,D25}$, and $\beta_{t,D30}$ denote the parameters associated with the indicator variables for the 20, 25, and 30 mg/kg dosages. Thus, $\beta_{t,D20}$ is the difference in effect between dosages 15 and 20, $\beta_{t,D25}$ is the difference in effect between dosages 15 and 25, etc. If the effect of dosages is linear then $\beta_{t,D20} = \beta_{t,D25} - \beta_{t,D20}$, and $\beta_{t,D20} = \beta_{t,D30} - \beta_{t,D25}$; that is, both $2\beta_{t,D20} - \beta_{t,D25} = 0$, and $\beta_{t,D20} + \beta_{t,D25} - \beta_{t,D30} = 0$ must hold.

In this example, the statement "RMORD <ANESTH1.CTL" invokes the program. In general, the use of "RMORD <filename" instructs the program to read the input parameters from the file called "filename". Partial results from this model are given in Table 14.

At each of the four time points, the hypothesis that all covariates are simultaneously equal to zero is not rejected (the $p-$values at times 1, 2, 3, and 4 are 0.44, 0.91, 0.46, and 0.31, respectively). Thus, there is little evidence that any of the covariates are associated with the recovery score. The three degree of freedom tests that the dosage effects are equal to zero are non-significant at each of the four time points.

Since the nonlinear dosage effects are also nonsignificant at all four time points, the final model uses dosage as a quantitative covariate. The effects of age and surgery duration are also included. These analysis options are contained in the file ANESTH2.CTL, which is listed in Table 15. The statement "RMORD <ANESTH2.CTL" invokes the program. Partial results are given in Table 16.

There is some evidence of an effect due to duration of surgery; the test of the hypothesis that the regression coefficients at all four time points are equal to zero was significant at the 10% level of significance (chi-square = 7.95, df = 4, $p = 0.09$). However, there is little reason to conclude that recovery scores were affected by dosage or age.

5. Hardware and software specifications

RMORD is written in standard FORTRAN-77. It was originally developed for MS-DOS personal computers and compiled using the MICROSOFT (R) FORTRAN Optimizing Compiler Version 5.0. The program has also been compiled and executed on HP APOLLO Series 700 workstations using the HP-UX FORTRAN 77 compiler. Calculations are performed using double-precision arithmetic. When run on IBM PC or compatible machines, a math coprocessor is not required, but is used if available. However, without a coprocessor, program execution may be quite slow for large data files.

While executing, the program creates two temporary files on the default disk drive. As a rule of thumb, the default directory should have about twice as much space available as is required by the input data file. These temporary files will automatically be deleted when the program is finished. If execution is halted due to a power failure or other interruption, any files with unusual names on the default directory may be deleted.

RMORD makes use of two algorithms from Press et al. [10]. Subroutine GAUSSJ (pp. 24–29) inverts a matrix and subroutine SORT (pp. 229–232) sorts a vector in ascending order. Chi-square probabilities were calculated using the algorithm of Shea [11] for computing the incomplete gamma

integral. This subroutine uses algorithms of MacLeod [12] and Hill [13] for computing the natural logarithm of the gamma function and tail areas of the standard normal distribution, respectively.

6. Availability

A UNIX SHell ARchive (SHAR) file containing FORTRAN code; executables; data, input, and output files for the two examples; and documentation is available through STATLIB. This SHAR file (RMORD.shar) can be obtained through anonymous ftp (lib.stat.cmu.edu) or electronic mail (statlib@lib.stat.cmu.edu). RMORD.shar is a self-extracting archive containing files appropriate for UNIX and DOS-based systems.

References

[1] D. O. Stram, L. J. Wei, and J. H. Ware, Analysis of repeated ordered categorical outcomes with possibly missing observations and time-dependent covariates, Journal of the American Statistical Association 83 (1988) 631–637.

[2] P. McCullagh, Regression methods for ordinal data, J. Roy. Statist. Soc. B 42 (1980) 109–142.

[3] J. H. Ware, Linear models for the analysis of longitudinal studies, The American Statistician 39 (1985) 95–101.

[4] D.B. Rubin, Inference and missing data, Biometrika 63 (1976) 81–92.

[5] N. M. Laird, Missing data in longitudinal studies, Statistics in Medicine 7 (1988) 305–315.

[6] C.S. Davis, A computer program for regression analysis of repeated measures using generalized estimating equations, Computer Methods and Programs in Biomedicine 40 (1993) 15–31.

[7] C.S. Davis, A computer program for non-parametric analysis of incomplete repeated measures from two samples, Computer Methods and Programs in Biomedicine 42 (1994) 39–52.

[8] G. G. Koch, G. J. Carr, I. A. Amara, M. E. Stokes, and T. J. Uryniak, Categorical data analysis, in Statistical Methodology in the Pharmaceutical Sciences. ed. D. A. Berry (1990) 389–473 New York: Marcel Dekker.

[9] C. S. Davis, Semi-parametric and non-parametric methods for the analysis of repeated measurements with applications to clinical trials, Statistics in Medicine 10 (1991) 1959–1980.

[10] W. H. Press, B. P. Flannery, S. A. Teukolsky, and W. T. Vetterling, Numerical Recipes: The Art of Scientific Computing (Cambridge University Press, Cambridge UK, 1986).

[11] B.L. Shea, B.L, Algorithm AS 239: chi-squared and incomplete gamma integral, Applied Statistics 37 (1988) 466–473.

[12] A.J. MacLeod, Algorithm AS 245: a robust and reliable algorithm for the logarithm of the gamma function, Applied Statistics 38 (1989) 397–402.

[13] I. D. Hill, Algorithm AS 66: the normal integral, Applied Statistics 22 (1973) 424–427.

Table 1
Structure of the input data file

Line Number	Time Identifier	Variables (Response and Potential Covariates)
1	1	Data from first time point for subject 1
2	2	Data from second time point for subject 1
⋮	⋮	⋮
T_1	T_1	Data from last (T_1th) time point for subject 1
$T_1 + 1$	1	Data from first time point for subject 2
⋮	⋮	⋮

Table 2
Analysis options

Option	Description
A	Method of specifying input options: 1=included at the beginning of the input file, 2=specified interactively or included in a separate file
B	Missing value indicator (data items less than this value are interpreted as missing values).
C	Total number of variables to be read in. Permissible values are $3, \ldots, 30$.
D	Data input mode: 1=free format (data items separated by commas, spaces, or tabs), 2=data input specified using a FORTRAN format statement.
E	FORTRAN format statement for data input, e.g., (F5.0,3F6.0). This option is skipped if **D** is equal to 1.
F	Index of the response variable. Permissible values are $1, \ldots, \mathbf{C}$.
G	Number of response levels for the ordinal categorical response. Permissible values are $2, \ldots, 9$.
H	Smallest nonmissing response code (usually equal to 0 or 1).
I	Index of the time variable. Permissible values are $1, \ldots, \mathbf{C}$.
J	Number of time periods. Permissible values are $1, \ldots, 12$.
K	Number of covariates to be used in the model. Permissible values are $1, \ldots, 12$.
L	Indices of covariates to be used in the model. Each of the **K** values specified must be in the range $1, \ldots, \mathbf{C}$ and must not be equal to **F** or **I**.
M	Indicator for tests of hypotheses concerning linear combinations of parameters: 1=hypotheses concerning linear combinations are to be tested 2=hypotheses concerning linear combinations will not be tested
N	Name of the data file containing occasion-specific contrasts (may include a path name). Enter $*$ if these contrasts are not specified. This option is skipped if **M** is equal to 2.
O	Name of the data file containing parameter-specific contrasts (may include a path name). Enter $*$ if these contrasts are not specified. This option is skipped if **M** is equal to 2.
P	Name of the input data file (may include a path name).
Q	Name of the output data file (may include a path name) Enter $*$ if results are to be written to the screen instead of to a file.

Table 3
Structure of the occasion-specific contrast file

Line Number	Description
1	A comma or space-separated pair, $a^{(1)}, b^{(1)}$, where $a^{(1)}$ =number of rows in the first contrast matrix $\mathbf{C}_t^{(1)}$ and $b^{(1)}$ =number of columns in $\mathbf{C}_t^{(1)}$. For $\mathbf{C}_t^{(1)}$ to be a valid contrast matrix, $a^{(1)} = \mathbf{G} - 1 + \mathbf{K}$ and $b^{(1)} \leq \mathbf{G} - 1 + \mathbf{K}$ must be satisfied.
2	First row of $\mathbf{C}_t^{(1)}$.
3	Second row of $\mathbf{C}_t^{(1)}$.
$\vdots$	$\vdots$
$a^{(1)} + 2$	A comma-separated pair, $a^{(2)}, b^{(2)}$, where $a^{(2)}$ =number of rows in the second contrast matrix $\mathbf{C}_t^{(2)}$ and $b^{(2)}$ =number of columns in $\mathbf{C}_t^{(2)}$.
$a^{(1)} + 3$	First row of $\mathbf{C}_t^{(2)}$.
$a^{(1)} + 4$	Second row of $\mathbf{C}_t^{(2)}$.
$\vdots$	$\vdots$

Table 4
Data from example 4.1 (first 24 lines)

Data	Description	
1 1 2 0 1 1 32 1	Field 1:	patient identifier
1 2 2 0 1 1 32 1		
1 3 4 0 1 1 32 1	Field 2:	time variable (1, 2, 3, or 4)
1 4 2 0 1 1 32 1		
2 1 2 0 1 1 47 2	Field 3:	respiratory status
2 2 3 0 1 1 47 2		(0=terrible, 1=poor, 2=fair,
2 3 4 0 1 1 47 2		3=good, 4=excellent)
2 4 4 0 1 1 47 2		
3 1 4 0 1 0 11 4	Field 4:	center (0=center A, 1=center B)
3 2 4 0 1 0 11 4		
3 3 4 0 1 0 11 4	Field 5:	treatment (0=placebo, 1=active)
3 4 2 0 1 0 11 4		
4 1 3 0 1 0 14 2	Field 6:	gender (0=male, 1=female)
4 2 3 0 1 0 14 2		
4 3 3 0 1 0 14 2	Field 7:	patient's age (years)
4 4 2 0 1 0 14 2		
5 1 2 0 1 0 15 0	Field 8:	baseline respiratory status
5 2 3 0 1 0 15 0		(0=terrible, 1=poor, 2=fair,
5 3 3 0 1 0 15 0		3=good, 4=excellent)
5 4 3 0 1 0 15 0		
6 1 3 0 1 0 20 3		
6 2 2 0 1 0 20 3		
6 3 3 0 1 0 20 3		
6 4 1 0 1 0 20 3		

Table 5
Contents of file RESP1A.CON

```
3 9
0 0 0 0 1 0 0 0 0
0 0 0 0 0 0 1 0 0
0 0 0 0 0 0 0 1 0
```

Table 6
Session log from example 1a

```
ARE INPUT PARAMETERS INCLUDED AT THE BEGINNING OF YOUR DATA FILE?
(1=YES, 2=NO)
2

ENTER MISSING VALUE INDICATOR
(VALUES LESS THAN THIS VALUE ARE MISSING)
-1

ENTER TOTAL NUMBER OF VARIABLES TO BE READ IN
8

ARE INPUT DATA IN FREE FORMAT, WITH DATA ITEMS SEPARATED BY COMMAS,
SPACES, OR TABS? (1=YES, 2=NO)
1

ENTER THE INDEX OF THE RESPONSE VARIABLE
3

ENTER NUMBER OF RESPONSE LEVELS FOR THE ORDERED CATEGORICAL RESPONSE
5

THE ORDERED CATEGORICAL RESPONSE MUST BE CODED USING CONSECUTIVE INTEGERS
ENTER THE SMALLEST NON-MISSING RESPONSE CODE
0

ENTER THE INDEX OF THE TIME VARIABLE
2

ENTER THE NUMBER OF TIME PERIODS
4

ENTER NUMBER OF COVARIATES TO BE INCLUDED IN THE MODEL
5

ENTER INDICES OF COVARIATES TO BE INCLUDED IN THE MODEL
4 5 6 7 8
ARE LINEAR CONTRASTS TO BE TESTED? (1=YES, 2=NO)
1

ENTER THE NAME OF THE FILE CONTAINING THE OCCASION SPECIFIC CONTRASTS
(* IF THESE CONTRASTS ARE NOT SPECIFIED)
resp1a.con

ENTER THE NAME OF THE FILE CONTAINING THE PARAMETER SPECIFIC CONTRASTS
(* IF THESE CONTRASTS ARE NOT SPECIFIED)
*

ENTER THE NAME OF THE INPUT DATA FILE
resp1.dat

ENTER THE NAME OF THE OUTPUT DATA FILE
(* IF RESULTS ARE TO BE WRITTEN TO THE SCREEN)
resp1.out
```

Table 7
Output from example 1a

```
 MISSING VALUE CODE:   -1.0
 NUMBER OF VARIABLES TO BE READ IN:   8
 INDEX OF THE RESPONSE VARIABLE:      3
 NUMBER OF CATEGORIES IN RESPONSE:    5
 SMALLEST NON-MISSING RESPONSE CODE:  0
 INDEX OF TIME VARIABLE:  2
 NUMBER OF TIME POINTS:   4
 NUMBER OF COVARIATES:    5
 INDICES OF COVARIATES:   4  5  6  7  8
 NUMBER OF RECORDS IN DATA FILE:   444

 TIME  1 RESULTS:

  VARIABLE           ESTIMATE     STD. ERROR        Z      P-VALUE
  1  LAMBDA  1       -.228501        .779724      -.29       .7695
  2  LAMBDA  2       1.079806        .712657      1.52       .1297
  3  LAMBDA  3       3.266499        .838493      3.90       .0001
  4  LAMBDA  4       4.930299        .888513      5.55       .0000
  5  BETA    1        .599444        .394609      1.52       .1287
  6  BETA    2        .984731        .404757      2.43       .0150
  7  BETA    3        .330587        .528756       .63       .5318
  8  BETA    4       -.006080        .016854      -.36       .7183
  9  BETA    5       1.286244        .222106      5.79       .0000

 TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
 CHI-SQUARE=  38.29   DF= 5   P-VALUE= .0000

 CONTRAST:
   .00   .00   .00   .00  1.00   .00   .00   .00   .00
   .00   .00   .00   .00   .00   .00  1.00   .00   .00
   .00   .00   .00   .00   .00   .00   .00  1.00   .00

 CHI-SQUARE=   2.91   DF= 3   P-VALUE= .4050

***  corresponding results from times 2, 3, and 4 are omitted

***  parameter-specific results (across the four time-points for the
intercept parameters (labelled LAMBDA 1 -- LAMBDA 4 in this output) are
omitted

 BETA  1 RESULTS:

 TIME     ESTIMATE     STD. ERROR        Z    P-VALUE
  1        .599444        .394609      1.52     .1287
  2        .324476        .392335       .83     .4082
  3        .015117        .392662       .04     .9693
  4        .612176        .408594      1.50     .1341

 TEST OF HYPOTHESIS THAT ALL COEFFICIENTS EQUAL ZERO:
 CHI-SQUARE=   6.20   DF= 4   P-VALUE= .1848

 TEST OF HYPOTHESIS OF EQUALITY OF COEFFICIENTS:
 CHI-SQUARE=   3.78   DF= 3   P-VALUE= .2857

 VECTOR OF OPTIMAL WEIGHTS FOR COMBINING COEFFICIENTS:
    .4010    .1319    .1759    .2912

 POOLED ESTIMATOR=     .464102      S.E.=     .317455
 CHI-SQUARE=   2.14   DF= 1   P-VALUE= .1438
```

Table 7 (continued)
Output from example 1a

```
 BETA  2 RESULTS:

 TIME     ESTIMATE     STD. ERROR        Z    P-VALUE
  1        .984731        .404757      2.43     .0150
  2       1.752241        .420224      4.17     .0000
  3       1.299445        .388287      3.35     .0008
  4        .981851        .415253      2.36     .0181

 TEST OF HYPOTHESIS THAT ALL COEFFICIENTS EQUAL ZERO:
 CHI-SQUARE=  19.33   DF= 4   P-VALUE= .0007

 TEST OF HYPOTHESIS OF EQUALITY OF COEFFICIENTS:
 CHI-SQUARE=   4.78   DF= 3   P-VALUE= .1882

***  optimal weights and pooled estimators for BETA 2--BETA 5 are
omitted

 BETA  3 RESULTS:

 TIME     ESTIMATE     STD. ERROR        Z    P-VALUE
  1        .330587        .528756       .63     .5318
  2        .126992        .489084       .26     .7951
  3        .454423        .474907       .96     .3386
  4        .325166        .492843       .66     .5094

 TEST OF HYPOTHESIS THAT ALL COEFFICIENTS EQUAL ZERO:
 CHI-SQUARE=   1.24   DF= 4   P-VALUE= .8708

 TEST OF HYPOTHESIS OF EQUALITY OF COEFFICIENTS:
 CHI-SQUARE=    .64   DF= 3   P-VALUE= .8865

 BETA  4 RESULTS:

 TIME     ESTIMATE     STD. ERROR        Z    P-VALUE
  1       -.006080        .016854      -.36     .7183
  2       -.018602        .016568     -1.12     .2615
  3       -.026908        .015451     -1.74     .0816
  4       -.010905        .014505      -.75     .4522

 TEST OF HYPOTHESIS THAT ALL COEFFICIENTS EQUAL ZERO:
 CHI-SQUARE=   3.25   DF= 4   P-VALUE= .5166

 TEST OF HYPOTHESIS OF EQUALITY OF COEFFICIENTS:
 CHI-SQUARE=   2.01   DF= 3   P-VALUE= .5697

 BETA  5 RESULTS:

 TIME     ESTIMATE     STD. ERROR        Z    P-VALUE
  1       1.286244        .222106      5.79     .0000
  2        .885982        .189105      4.69     .0000
  3        .764630        .211976      3.61     .0003
  4        .805639        .193274      4.17     .0000

 TEST OF HYPOTHESIS THAT ALL COEFFICIENTS EQUAL ZERO:
 CHI-SQUARE=  43.08   DF= 4   P-VALUE= .0000

 TEST OF HYPOTHESIS OF EQUALITY OF COEFFICIENTS:
 CHI-SQUARE=   6.45   DF= 3   P-VALUE= .0916
```

Table 8
Contents of file RESP2B.CON

1 4
3 -1 -1 -1
2 4
0 1 -1 0
0 1 0 -1

Table 9
Session log from example 1b

```
LONGITUDINAL DATA ANALYSIS FOR ORDINAL CATEGORICAL RESPONSES USING
THE METHOD OF STRAM, WEI, AND WARE (1988)

ARE INPUT PARAMETERS INCLUDED AT THE BEGINNING OF YOUR DATA FILE?
(1=YES, 2=NO)
1

ENTER THE NAME OF THE INPUT DATA FILE
resp2.dat

ENTER THE NAME OF THE OUTPUT DATA FILE
(* IF RESULTS ARE TO BE WRITTEN TO THE SCREEN)
resp2.out
```

Table 10
Output from example 1b

```
MISSING VALUE CODE:   -1.0
NUMBER OF VARIABLES TO BE READ IN:   8
INDEX OF THE RESPONSE VARIABLE:      3
NUMBER OF CATEGORIES IN RESPONSE:    5
SMALLEST NON-MISSING RESPONSE CODE:  0
INDEX OF TIME VARIABLE:  2
NUMBER OF TIME POINTS:   4
NUMBER OF COVARIATES:    2
INDICES OF COVARIATES:   5  8
NUMBER OF RECORDS IN DATA FILE:   444

TIME  1 RESULTS:

 VARIABLE           ESTIMATE     STD. ERROR        Z      P-VALUE
 1  LAMBDA  1       -.196967        .577825      -.34       .7332
 2  LAMBDA  2       1.080382        .490157      2.20       .0275
 3  LAMBDA  3       3.217925        .578546      5.56       .0000
 4  LAMBDA  4       4.862386        .647244      7.51       .0000
 5  BETA    1        .908425        .382394      2.38       .0175
 6  BETA    2       1.342210        .218475      6.14       .0000

TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
CHI-SQUARE=  39.65   DF= 2   P-VALUE= .0000

TIME  2 RESULTS:

 VARIABLE           ESTIMATE     STD. ERROR        Z      P-VALUE
 1  LAMBDA  1        .021816        .558625       .04       .9688
 2  LAMBDA  2       1.087939        .494356      2.20       .0278
 3  LAMBDA  3       2.788221        .538814      5.17       .0000
 4  LAMBDA  4       3.870235        .594635      6.51       .0000
 5  BETA    1       1.729951        .407127      4.25       .0000
 6  BETA    2        .928410        .180725      5.14       .0000

TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
CHI-SQUARE=  36.52   DF= 2   P-VALUE= .0000

TIME  3 RESULTS:

 VARIABLE           ESTIMATE     STD. ERROR        Z      P-VALUE
 1  LAMBDA  1       -.016999        .549630      -.03       .9753
 2  LAMBDA  2        .664461        .513368      1.29       .1956
 3  LAMBDA  3       1.928326        .534149      3.61       .0003
 4  LAMBDA  4       3.067686        .595833      5.15       .0000
 5  BETA    1       1.178688        .386828      3.05       .0023
 6  BETA    2        .747214        .188520      3.96       .0001

TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
CHI-SQUARE=  20.39   DF= 2   P-VALUE= .0000

TIME  4 RESULTS:

 VARIABLE           ESTIMATE     STD. ERROR        Z      P-VALUE
 1  LAMBDA  1        .147121        .532117       .28       .7822
 2  LAMBDA  2        .952031        .510265      1.87       .0621
 3  LAMBDA  3       2.376372        .543761      4.37       .0000
 4  LAMBDA  4       3.205453        .569839      5.63       .0000
 5  BETA    1        .909854        .399906      2.28       .0229
 6  BETA    2        .875985        .188049      4.66       .0000
```

Table 10 (continued)
Output from example 1b

```
 TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
 CHI-SQUARE=  24.71   DF= 2   P-VALUE= .0000

***  parameter-specific results (across the four time-points for the
intercept parameters (labelled LAMBDA 1 -- LAMBDA 4 in this output) are
omitted

 BETA  1 RESULTS:

 TIME     ESTIMATE     STD. ERROR        Z    P-VALUE
  1        .908425        .382394      2.38     .0175
  2       1.729951        .407127      4.25     .0000
  3       1.178688        .386828      3.05     .0023
  4        .909854        .399906      2.28     .0229

 TEST OF HYPOTHESIS THAT ALL COEFFICIENTS EQUAL ZERO:
 CHI-SQUARE=  19.05   DF= 4   P-VALUE= .0008

 TEST OF HYPOTHESIS OF EQUALITY OF COEFFICIENTS:
 CHI-SQUARE=   5.48   DF= 3   P-VALUE= .1398

***  optimal weights and pooled estimators for BETA 1 and BETA 2 are omitted

 CONTRAST:
  3.00 -1.00 -1.00 -1.00

 CHI-SQUARE=    .94   DF= 1   P-VALUE= .3332   ESTIMATE= -1.093   S.D.=  1.130

 CONTRAST:
   .00  1.00 -1.00   .00
   .00  1.00   .00 -1.00

 CHI-SQUARE=   4.20   DF= 2   P-VALUE= .1224

 BETA  2 RESULTS:

 TIME     ESTIMATE     STD. ERROR        Z    P-VALUE
  1       1.342210        .218475      6.14     .0000
  2        .928410        .180725      5.14     .0000
  3        .747214        .188520      3.96     .0001
  4        .875985        .188049      4.66     .0000

 TEST OF HYPOTHESIS THAT ALL COEFFICIENTS EQUAL ZERO:
 CHI-SQUARE=  50.61   DF= 4   P-VALUE= .0000

 TEST OF HYPOTHESIS OF EQUALITY OF COEFFICIENTS:
 CHI-SQUARE=   7.77   DF= 3   P-VALUE= .0511

 CONTRAST:
  3.00 -1.00 -1.00 -1.00

 CHI-SQUARE=   5.74   DF= 1   P-VALUE= .0166   ESTIMATE=  1.475   S.D.=   .615

 CONTRAST:
   .00  1.00 -1.00   .00
   .00  1.00   .00 -1.00

 CHI-SQUARE=   1.76   DF= 2   P-VALUE= .4149
```

Table 11
Data from example 4.2 (first 20 lines)

Data	Description	
1 1 3 15 0 0 0 36 128	Field 1:	patient identifier
1 2 5 15 0 0 0 36 128		
1 3 6 15 0 0 0 36 128	Field 2:	time variable
1 4 6 15 0 0 0 36 128		(1=baseline, 2=minute 5,
2 1 3 15 0 0 0 35 70		3=minute 15, 4=minute 30)
2 2 4 15 0 0 0 35 70		
2 3 6 15 0 0 0 35 70	Field 3:	recovery score
2 4 6 15 0 0 0 35 70		
3 1 1 15 0 0 0 54 138	Field 4:	dosage (mg/kg)
3 2 1 15 0 0 0 54 138		
3 3 1 15 0 0 0 54 138	Field 5:	1 if dosage=20 mg/kg, 0 otherwise
3 4 4 15 0 0 0 54 138		
4 1 1 15 0 0 0 47 67	Field 6:	1 if dosage=25 mg/kg, 0 otherwise
4 2 3 15 0 0 0 47 67		
4 3 3 15 0 0 0 47 67	Field 7:	1 if dosage=30 mg/kg, 0 otherwise
4 4 5 15 0 0 0 47 67		
5 1 5 15 0 0 0 42 55	Field 8:	patient's age (months)
5 2 6 15 0 0 0 42 55		
5 3 6 15 0 0 0 42 55	Field 9:	duration of surgery (minutes)
5 4 6 15 0 0 0 42 55		

Table 12
Contents of file ANESTH1.CTL

Line Number	Contents	Description
1	2	analysis options are not part of the data file
2	-1	missing value indicator
3	9	number of variables to be read in
4	1	specified free-format input
5	3	index of the response variable
6	7	number of response levels
7	0	smallest nonmissing response code
8	2	index of the time variable
9	4	number of time periods
10	5	number of covariates to be included in the model
11	5 6 7 8 9	indices of covariates in the model
12	1	linear contrasts are to be tested
13	ANESTH1A.CON	name of file containing time-specific contrasts
14	*	parameter-specific contrasts will not be tested
15	ANESTH.DAT	name of input data file
16	ANESTH1.OUT	name of output data file

Table 13
Contents of file ANESTH1A.CON

```
3 11
0 0 0 0 0 0 1 0 0 0 0
0 0 0 0 0 0 0 1 0 0 0
0 0 0 0 0 0 0 0 1 0 0
2 11
0 0 0 0 0 0 2 -1 0 0 0
0 0 0 0 0 0 1 1 -1 0 0
```

Table 14
Output from example 2a

```
 MISSING VALUE CODE:   -1.0
 NUMBER OF VARIABLES TO BE READ IN:   9
 INDEX OF THE RESPONSE VARIABLE:      3
 NUMBER OF CATEGORIES IN RESPONSE:    7
 SMALLEST NON-MISSING RESPONSE CODE:  0
 INDEX OF TIME VARIABLE:  2
 NUMBER OF TIME POINTS:   4
 NUMBER OF COVARIATES:    5
 INDICES OF COVARIATES:   5  6  7  8  9
 NUMBER OF RECORDS IN DATA FILE:   240

 TIME  1 RESULTS:

***  parameter estimates for times 1, 2, 3, and 4 are omitted

 TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
 CHI-SQUARE=   4.78   DF= 5   P-VALUE= .4431

 CONTRAST:
   .00   .00   .00   .00   .00   .00  1.00   .00   .00   .00   .00
   .00   .00   .00   .00   .00   .00   .00  1.00   .00   .00   .00
   .00   .00   .00   .00   .00   .00   .00   .00  1.00   .00   .00

 CHI-SQUARE=   2.09   DF= 3   P-VALUE= .5542

 CONTRAST:
   .00   .00   .00   .00   .00   .00  2.00 -1.00   .00   .00   .00
   .00   .00   .00   .00   .00   .00  1.00  1.00 -1.00   .00   .00

 CHI-SQUARE=    .10   DF= 2   P-VALUE= .9504

 TIME  2 RESULTS:

 TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
 CHI-SQUARE=   1.51   DF= 5   P-VALUE= .9121
```

Table 14 (continued)
Output from example 2a

```
 CONTRAST:
   .00   .00   .00   .00   .00   .00  1.00   .00   .00   .00   .00
   .00   .00   .00   .00   .00   .00   .00  1.00   .00   .00   .00
   .00   .00   .00   .00   .00   .00   .00   .00  1.00   .00   .00

 CHI-SQUARE=    .91   DF= 3   P-VALUE= .8239

 CONTRAST:
   .00   .00   .00   .00   .00   .00  2.00 -1.00   .00   .00   .00
   .00   .00   .00   .00   .00   .00  1.00  1.00 -1.00   .00   .00

 CHI-SQUARE=    .00   DF= 2   P-VALUE= .9990

 TIME  3 RESULTS:

 TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
 CHI-SQUARE=   4.64   DF= 5   P-VALUE= .4620

 CONTRAST:
   .00   .00   .00   .00   .00   .00  1.00   .00   .00   .00   .00
   .00   .00   .00   .00   .00   .00   .00  1.00   .00   .00   .00
   .00   .00   .00   .00   .00   .00   .00   .00  1.00   .00   .00

 CHI-SQUARE=   1.52   DF= 3   P-VALUE= .6783

 CONTRAST:
   .00   .00   .00   .00   .00   .00  2.00 -1.00   .00   .00   .00
   .00   .00   .00   .00   .00   .00  1.00  1.00 -1.00   .00   .00

 CHI-SQUARE=    .93   DF= 2   P-VALUE= .6267

 TIME  4 RESULTS:

 TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
 CHI-SQUARE=   5.95   DF= 5   P-VALUE= .3114

 CONTRAST:
   .00   .00   .00   .00   .00   .00  1.00   .00   .00   .00   .00
   .00   .00   .00   .00   .00   .00   .00  1.00   .00   .00   .00
   .00   .00   .00   .00   .00   .00   .00   .00  1.00   .00   .00

 CHI-SQUARE=    .75   DF= 3   P-VALUE= .8617

 CONTRAST:
   .00   .00   .00   .00   .00   .00  2.00 -1.00   .00   .00   .00
   .00   .00   .00   .00   .00   .00  1.00  1.00 -1.00   .00   .00

 CHI-SQUARE=    .25   DF= 2   P-VALUE= .8837

***  parameter-specific results are omitted
```

Table 15
Contents of file ANESTH2.CTL

Line Number	Contents	Description
1	2	analysis options are not part of the data file
2	-1	missing value indicator
3	9	number of variables to be read in
4	1	specified free-format input
5	3	index of the response variable
6	7	number of response levels
7	0	smallest nonmissing response code
8	2	index of the time variable
9	4	number of time periods
10	3	number of covariates to be included in the model
11	4 8 9	indices of covariates in the model
12	2	linear contrasts will not be tested
13	ANESTH.DAT	name of input data file
14	*	output will be written to the screen

Table 16
Output from example 2b

```
MISSING VALUE CODE:  -99.9
NUMBER OF VARIABLES TO BE READ IN:   9
INDEX OF THE RESPONSE VARIABLE:      3
NUMBER OF CATEGORIES IN RESPONSE:    7
SMALLEST NON-MISSING RESPONSE CODE:  0
INDEX OF TIME VARIABLE:  2
NUMBER OF TIME POINTS:   4
NUMBER OF COVARIATES:    3
INDICES OF COVARIATES:   4  8  9
NUMBER OF RECORDS IN DATA FILE:   240

TIME  1 RESULTS:

 VARIABLE           ESTIMATE     STD. ERROR        Z      P-VALUE
 1  LAMBDA  1      -4.712660       1.670461     -2.82       .0048
 2  LAMBDA  2      -2.700893       1.462130     -1.85       .0647
 3  LAMBDA  3      -2.096924       1.430160     -1.47       .1426
 4  LAMBDA  4      -1.172609       1.437648      -.82       .4147
 5  LAMBDA  5       -.690163       1.368986      -.50       .6142
 6  LAMBDA  6       -.233374       1.455473      -.16       .8726
 7  BETA    1       -.070048        .049154     -1.43       .1541
 8  BETA    2       -.013206        .016220      -.81       .4155
 9  BETA    3       -.011700        .007468     -1.57       .1172

TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
CHI-SQUARE=   5.16   DF= 3   P-VALUE= .1607
```

Table 16 (continued)
Output from example 2b

```
 TIME  2 RESULTS:

  VARIABLE           ESTIMATE     STD. ERROR        Z      P-VALUE
  1  LAMBDA  1      -4.078925       1.578726     -2.58       .0098
  2  LAMBDA  2      -2.051323       1.409167     -1.46       .1455
  3  LAMBDA  3      -1.636750       1.404431     -1.17       .2438
  4  LAMBDA  4       -.856809       1.396244      -.61       .5394
  5  LAMBDA  5       -.435062       1.389186      -.31       .7541
  6  LAMBDA  6        .116316       1.341706       .09       .9309
  7  BETA    1       -.044414        .046559      -.95       .3401
  8  BETA    2       -.010534        .017029      -.62       .5362
  9  BETA    3       -.003041        .006797      -.45       .6546

 TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
 CHI-SQUARE=   1.50   DF= 3   P-VALUE= .6822

 TIME  3 RESULTS:

  VARIABLE           ESTIMATE     STD. ERROR        Z      P-VALUE
  1  LAMBDA  1      -4.866368       1.624798     -3.00       .0027
  2  LAMBDA  2      -3.428512       1.512050     -2.27       .0234
  3  LAMBDA  3      -3.007284       1.479633     -2.03       .0421
  4  LAMBDA  4      -2.558393       1.439580     -1.78       .0755
  5  LAMBDA  5      -2.136072       1.426865     -1.50       .1344
  6  LAMBDA  6      -1.449869       1.396153     -1.04       .2990
  7  BETA    1       -.033369        .046214      -.72       .4703
  8  BETA    2       -.024785        .018712     -1.32       .1853
  9  BETA    3       -.007803        .006937     -1.12       .2606

 TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
 CHI-SQUARE=   3.52   DF= 3   P-VALUE= .3177

 TIME  4 RESULTS:

  VARIABLE           ESTIMATE     STD. ERROR        Z      P-VALUE
  1  LAMBDA  1      -6.592996       1.895656     -3.48       .0005
  2  LAMBDA  2      -5.819715       1.959412     -2.97       .0030
  3  LAMBDA  3      -5.553672       1.787216     -3.11       .0019
  4  LAMBDA  4      -4.689676       1.757453     -2.67       .0076
  5  LAMBDA  5      -3.842532       1.686357     -2.28       .0227
  6  LAMBDA  6      -3.185710       1.633571     -1.95       .0512
  7  BETA    1       -.037029        .056321      -.66       .5109
  8  BETA    2       -.017450        .018733      -.93       .3516
  9  BETA    3       -.017122        .008823     -1.94       .0523

 TEST OF HYPOTHESIS THAT ALL COVARIATES EQUAL ZERO:
 CHI-SQUARE=   5.18   DF= 3   P-VALUE= .1594

***  parameter-specific results (across the four time-points for the
intercept parameters (labelled LAMBDA 1 -- LAMBDA 4) are omitted

 BETA  1 RESULTS:

 TIME     ESTIMATE     STD. ERROR        Z    P-VALUE
  1       -.070048        .049154     -1.43     .1541
  2       -.044414        .046559      -.95     .3401
  3       -.033369        .046214      -.72     .4703
  4       -.037029        .056321      -.66     .5109
```

Table 16 (continued)
Output from example 2b

```
TEST OF HYPOTHESIS THAT ALL COEFFICIENTS EQUAL ZERO:
CHI-SQUARE=   2.10   DF= 4   P-VALUE= .7176

TEST OF HYPOTHESIS OF EQUALITY OF COEFFICIENTS:
CHI-SQUARE=    .89   DF= 3   P-VALUE= .8283

VECTOR OF OPTIMAL WEIGHTS FOR COMBINING COEFFICIENTS:
   .2296    .3173    .2584    .1946

POOLED ESTIMATOR=    -.046009      S.E.=     .042360
CHI-SQUARE=   1.18   DF= 1   P-VALUE= .2774

BETA  2 RESULTS:

TIME     ESTIMATE     STD. ERROR        Z    P-VALUE
 1       -.013206        .016220      -.81     .4155
 2       -.010534        .017029      -.62     .5362
 3       -.024785        .018712     -1.32     .1853
 4       -.017450        .018733      -.93     .3516

TEST OF HYPOTHESIS THAT ALL COEFFICIENTS EQUAL ZERO:
CHI-SQUARE=   2.84   DF= 4   P-VALUE= .5844

TEST OF HYPOTHESIS OF EQUALITY OF COEFFICIENTS:
CHI-SQUARE=   1.82   DF= 3   P-VALUE= .6103

VECTOR OF OPTIMAL WEIGHTS FOR COMBINING COEFFICIENTS:
   .4576    .2179    .0417    .2828

POOLED ESTIMATOR=    -.014307      S.E.=     .016172
CHI-SQUARE=    .78   DF= 1   P-VALUE= .3763

BETA  3 RESULTS:

TIME     ESTIMATE     STD. ERROR        Z    P-VALUE
 1       -.011700        .007468     -1.57     .1172
 2       -.003041        .006797      -.45     .6546
 3       -.007803        .006937     -1.12     .2606
 4       -.017122        .008823     -1.94     .0523

TEST OF HYPOTHESIS THAT ALL COEFFICIENTS EQUAL ZERO:
CHI-SQUARE=   7.95   DF= 4   P-VALUE= .0935

TEST OF HYPOTHESIS OF EQUALITY OF COEFFICIENTS:
CHI-SQUARE=   5.84   DF= 3   P-VALUE= .1196

VECTOR OF OPTIMAL WEIGHTS FOR COMBINING COEFFICIENTS:
   .3067    .3385    .1658    .1891

POOLED ESTIMATOR=    -.009148      S.E.=     .006540
CHI-SQUARE=   1.96   DF= 1   P-VALUE= .1619
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