A FORTRAN IV program for the measurement and statistical analysis of higher order units of subjective organization in multitrial free recall learning

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The program described here was written to facilitate the measurement and statistical analysis of higher order subjective organization data obtained from multitrial free recall experiments. There has been increasing interest in the investigation of subjective organization and the structure of recalled words lacking strong or obvious interitem relationships. Much of the research, however, has been hindered by inadequacies associated with the most frequently employed measures of subjective organization, namely, the ratio measure of Tulving (1962) and the intertrial repetition (ITR) deviation index of Bousfield and Bousfield (1966).

A frequent criticism of these measures (Postman, 1972; Shuell, 1969) concerns their reliance on the fixed trial to trial consistency of response orderings in determining subjective organization, such that only pairwise item dependencies are taken into account. Thus, for a recall sequence containing groupings of two or more items to be scored as a single unit, each of the constituents must be recalled in the same sequential order on Trial $t+1$ as on Trial t . As a consequence, many investigations employing these measures are, in practice, ultimately reduced to determining the presence or absence of item pairs connected as a unit solely as simple forward associations. The possibility of higher order subjective units occurring, varying in size and internal ordering sequence, is excluded from analysis.

The serious limitations imposed can be easily illustrated, for example, by considering a stimulus list consisting of 12 items, A-L. Assume that on Trial t , seven of the items are recalled in the sequence BCDEAJK, followed by recall on Trial $t+1$ of CBDELHKJ. Both the Tulving and the Bousfield measures would only score the two-item unit DE as an observed ITR. Note, however, that the item pairs CB and KJ were recalled together on Trial $t+1$ in reverse sequential order. The possibility of bidirectional ordering variation was considered by Gorfein, Blair, and Rowland (1968), who modified the Bousfield formula to accommodate this alternative grouping.

If the Gorfein et al. modification is incorporated, there are three observed ITR units of two items each occurring in the recall of the above trial pair.

The bidirectional fixed sequence consideration does not, however, exhaust the possibility of additional organization being present in the above recall example. If we consider that the first four items common to both trials are identical, then it seems possible that they, too, may represent a single recall unit. The sequence of CBDE represents 1 of the 4! possible permutations of items BCDE. While they do not occur in a fixed pairwise sequence, they are recalled as an intact grouping composed internally of the same elements. Pellegrino (1971) has incorporated this notion, suggesting that an additional criterion, that of unordered consistency, be employed in examining free recall protocols for subjective organization.

The technique suggested by Pellegrino allows determination of the amount of organization present under each criterion: unidirectional, bidirectional, and unordered. Within each criterion, the recall sequence is examined successively for units varying in size from 2 to M , where M = the number of items recalled on Trial t . The general measure provides a separate ARC (adjusted ratio of clustering) score for each unit size and ordering criterion based on the ratio of observed-expected ITRs to the maximum possible-expected ITRs. Further details on the procedure, along with the formulae, can be found in Pellegrino (1971).

Program SOFR

This program calculates and prints the individual ARC (adjusted ratio of clustering) scores for each subject, along with values for the various parameters needed to calculate the expectation of an intertrial repetition by each of the recall unit ordering criteria (unidirectional, bidirectional, unordered). SOFR is a further correction (cf. Walsh & Roach, 1974) and extension of the program presented by Pellegrino (1972), and it contains optional subroutines for a three-way analysis of variance, as well as for analysis of interaction effects (both are discussed later).

The first card of the data deck consists of parameters delineating the architecture of the split-plot analysis of variance (as discussed in the section on subroutine SPLIT). The data on this card are five two-digit numbers, designated IN, IP, IQ, IZ, and IT. IN is the number of subjects per condition cell; IP is the number of plots; IQ is the number of trials per subject; IZ is the number of conditions to be studied in each plot; and IT is the total number of subjects in the experiment. IT is redundant and is used solely as an internal programming consistency check. An example of this card for an experiment involving 72 subjects (IT), divided into two plots (IP), with four condition vari-

ations (IZ), 9 subjects per condition cell (IN), and nine trials per subject (IQ), would be:

0902090472

If the total number of subjects exceeds 99, Card 20 must be modified from:

50 FORMAT(5I2)

to:

50 FORMAT(4I2,I3)

The second card of the data input deck is designated the general parameter card, and contains two values: NS, or number of subjects (identical to IT on the previous card), and MS, the number of items on the recall list. NS occupies the first three digits of the second data input card, and MS is in the fourth and fifth columns. Thus, for the example in the preceding paragraph, with 11 items on the recall list, the second data card in the deck would be:

07211

The actual input data consist of the recall position of the stimulus word, entered as a two-digit numeric for each trial. If the word was not recalled on the trial, then a 00 would be entered. Each pair of columns on the Hollerith card, beginning with Column 1, corresponds to a single trial. Each subject will have a data card for each item in the stimulus list. Thus, for example, for a given list of 11 words, A-K, presented over nine trials, where Item A was recalled six times in the following sequence:

	Trial																	
	1	2	3	4	5	6	7	8	9									
Recall Position	0	0	3	0	1	7	11	10	6									

the data would be entered in the first 18 columns of the card as:

000003000107111006

Preceding each block of individual item data cards will be a subject parameter and identification card. The first two columns of this card contain the number of trials, the third and fourth columns contain the size of the largest subjective organization unit the experimenter wants to analyze (range 2-10), and the fifth, sixth, and seventh columns contain the subject identification number. Thus, for a nine-trial presentation, in which the investigator is interested in examining units no larger than Size 5, the card for Subject 1 would be:

0905001

As written, SOFR has a maximum capacity for analyzing recall of a 40-item list over 20 trials, with 72 subjects. To modify the last capacity upward for larger experiments, the user should change Columns 22 and 23 of the following two cards (Statement 18 SOFR, Appendix A):

COMMON/A/SAVE(72,30,4)

and (Statement 10 in SPLIT, Appendix A):

COMMON/A/SAVE(72,30,4)/B/MATRIX(16,20,20)

to reflect the number of subjects utilized. Thus, for example, if the investigator desired an analysis for a free recall experiment containing 144 subjects, the above statements would be changed in the following manner to reserve more common core:

COMMON/A/SAVE(144,30,4)

and

COMMON/A/SAVE(144,30,4)/B/MATRIX(16,20,20)

Conversely, the statements can similarly be modified downward for smaller experiments and for economy of core when the user's computer has a limited core capacity.

The complete output for SOFR includes the number of observed word repetitions, expected repetitions, maximum possible repetitions, deviation values, and ARC scores for each trial pair by ordering criteria and size of subjective organization unit examined. Also printed are the values of R, M, N, and mean ARC scores averaged over trial pairs. This output is described below.

Observed repetitions. The first item printed following the subject identification number consists of the actual number of observed intertrial repetitions, presented in tabular form. The rows in the table contain each trial pair (e.g., "Trial 2" refers to Trials 1 and 2; "Trial 3" refers to Trials 2 and 3, etc.) with the accompanying ordering criteria. The column heads refer to the size of the unit examined. The numerical entry is the actual number of repetitions occurring in the recall for that trial pair, ordering criterion, and size.

Expected repetitions. This is the second item printed by SOFR, and its tabular layout is the same as in the case of the observed repetitions. The numeric value of the expectation is displayed by unit size, ordering criterion, and trial pair. The value is determined according to the following formula given by Pellegrino (1971):

$$E(ITR) = \frac{(N - X + 1)! (A) (M - X + 1 - R)}{N!},$$

where M = the total number of items recalled on Trial t ; N = total recall on Trial $t + 1$; R = the number of units of Size X recalled on Trial t containing one or more words not recalled on Trial $t + 1$; and, A = a variable parameter whose value is dependent on the ordering criterion under consideration.

Maximum possible repetitions. This is the third table produced by the program and it contains row values corresponding to trial pairs, while the columns contain the unit size. The maximum possible number of observed repetitions is determined by the formula recommended by Pellegrino (1971):

$$\text{MAX(ITR)} = M - X + 1 - R.$$

Deviation score. This is the fourth item printed, and its tabular format is the same in row and column designations as that for the observed repetitions. The deviation score for each ordering criterion by trial pair and unit size is presented. This value is simply the observed minus the expected number of intertrial repetitions.

ARC scores. This is the fifth table printed, and its format is similar to that for the observed repetitions. The ARC value, by ordering criterion, trial pair, and unit size is determined by the ratio of observed minus expected repetitions. Here, total or perfect organization is represented by a value of 1.0, while chance organization is set at 0.

R values for all trials. This is the sixth table printed. The rows identify trial pairs, while the columns refer to the unit size under consideration. The numerical entries are the number of units of that specified size recalled on Trial t that contain one or more items not recalled on Trial $t + 1$.

Mean ARC scores. This is the seventh item printed, and it contains the average subjective organization values taken over trial pairs, listed by ordering criterion (rows) and by unit size (columns).

M and N values. This is the last item printed by SOFR. The rows correspond to individual trials (not trial pairs). The first column (unlabeled) contains the value of M (the number of items recalled on Trial t); the second column contains the N value (the number of items recalled on Trial $t + 1$). This data ends the SOFR output for the indicated subject, and the output for the next subject begins.

Finally, it is possible to completely suppress the printing of SOFR, while continuing to execute the program. To suppress, add the following cards to the source deck at the designated locations:

Add	Between Statements
GO TO 2000	25 and 26
2000 CONTINUE	29 and 30
GO TO 2001	169 and 170

2001 CONTINUE	236 and 237
GO TO 2002	243 and 244
2002 CONTINUE	259 and 260

Inclusion of the above statements in the indicated positions saves, but does not print, the SOFR output for use in the statistical subroutines to be described below.

Subroutine SPLIT

This subroutine performs a three-way univariate analysis of variance on the subjective organization scores calculated by SOFR. It is written for a split-plot factorial experimental design containing two between-blocks treatments and one repeated or within-blocks factor corresponding to trials. The manual computations for this design, designated as a Type SPF—pr.q design, are described in detail by Kirk (1968), whose notation will be utilized below for ease of cross-reference.

For the analysis, the subroutine calculates the error terms in accordance with the mixed effects or Model III analysis of variance where Factors A, B, and C are treated as fixed effects, and subjects are treated as a random effect. Following Kirk, the two between-blocks factors will be designated as consisting of p levels of a_i and r levels of c_k , and the within-factor as q levels of b_j . In its present form, subroutine SPLIT will accommodate values of q up through 20. The capacity of the between-blocks factors together is limited to 16 levels (i.e., $p \times r \leq 16$). For more complex experiments, the latter capacity can easily be increased upward to a maximum combined $p \times r$ value of 99. To modify this capacity, simply change the values in Columns 39 and 40 of Statement 10 in SPLIT, and Columns 23 and 24 of Statement 8 in subroutine SPLITAI to reflect the desired value. For example, if $p = 12$ and $r = 8$, change:

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COMMON/A/SAVE(72,30,4)/B/MATRIX(16,20,20)
```

to read:

```
COMMON/A/SAVE(72,30,4)/B/MATRIX(96,20,20)
```

and change:

```
COMMON/B/MATRIX(16,20,20)
```

to read:

```
COMMON/B/MATRIX(96,20,20).
```

Increasing the size of the matrices in the common blocks may increase the required core capacity to the point that it may exceed the capacity of the computer. If this situation obtains, the user should consult an

experienced programmer for assistance in using auxiliary memory for temporary storage of data and calculational matrices.

This subroutine does not require additional data card preparation, as it utilizes for its input the multiple ARC scores obtained from SOFR. In its present version, SPLIT calls up a second subroutine that performs a simple effects analysis on the main effects and interactions (to be discussed below), and the output consists of identified sums of squares for all sources of variation in the design, in addition to the overall F test values. To obtain only the output of subroutine SPLIT, simply remove the following card (Statement 53 of SPLIT) from the source deck:

CALL SPLITAI (IP, IQ, IR, IN, NX, NT, IT)

Deletion of the above card will limit the statistical output to the following two categories:

ARC score input values. These are the data values used in the analysis of variance arranged in a matrix of Dimension $a_{ijk} \times b_j - 1$, where the rows correspond to N (the total number of subjects) listed sequentially by Treatment Combination a_{ijk} , and columns correspond to $b_j - 1$, the number of levels of the repeated factor (trials) minus one (trial pairs). Each cell entry is that particular subject's ARC score value for the trial pair.

Analysis of variance table. This output is printed in the form of a standard analysis of variance source table, with the row designations identifying the sources of variation, while the column heads label the sums of squares (SS), degrees of freedom (DF), mean squares (MS), and the F ratio value.

The above output is printed sequentially for the ARC score values by ordering criterion and unit size, with each sequence appropriately identified (e.g., "BEGIN UNIDIRECTIONAL SIZE 2").

Subroutine SPLITAI

This subroutine is optional and may be of interest to the investigator employing a three-way analysis of variance design in which there are multiple levels of treatment components and there is significant interaction present. SPLITAI provides a labeled sums of squares calculation for the simple main effects components of all two-way interactions. In addition, the sums of squares for both the simple main effects and simple interactive components of the three-way interaction are provided. As currently written, SPLITAI cannot be used independently of subroutine SPLIT. Output is printed sequentially for each unit of subjective organization examined, by ordering criterion and unit size. Since SPLITAI is dependent upon SPLIT, the SPLIT output will always be printed when SPLITAI is executed. The combined output sequence is described below.

ARC score input values. (Described previously under Subroutine SPLIT.)

Sums of squares for all interaction components. This output is arranged in a single column with each row labeled according to the source of the component. Because of the repeated measures factor, some components will require use of different error terms in determining the appropriate value of F. For components involving only nonrepeated factors (e.g., A at each level c_k), the investigator should use the mean square for subjects within groups. When the repeated factor (either singularly or in interaction) is being considered over levels of a nonrepeated factor (e.g., B x C at each level a_i), then the correct error term would be the mean square for Factor B by subjects within groups. Finally, when a nonrepeated factor (either singularly or in interaction) is being considered over levels that contain a nonrepeated factor (e.g., A at each level b_{jk}), a pooled error term should be utilized. The correct pooled error term for this design, as given by Kirk, is determined by multiplying the mean square for B by subjects within groups times $q - 1$ times the mean square for subjects within groups, divided by q .

The subroutine generates the sums of squares values for the interactive components in the design in the sequence indicated below:

Sums of squares for Factor A at Levels $b_1 - b_j$.

Sums of squares for Factor B at Levels $a_1 - a_i$.

Sums of squares for Factor A at Levels $c_1 - c_k$.

Sums of squares for Factor C at Levels $a_1 - a_i$.

Sums of squares for Factor B at Levels $c_1 - c_k$.

Sums of squares for Factor C at Levels $b_1 - b_j$.

Sums of squares for Factor A at Levels $b_1 c_1 - b_j c_k$.

Sums of squares for Factor B at Levels $a_1 c_1 - a_i c_k$.

Sums of squares for Factor C at Levels $a_1 b_1 - a_i b_j$.

Sums of squares for Factor A x B at Levels $c_1 - c_k$.

Sums of squares for Factor A x C at Levels $b_1 - b_j$.

Sums of squares for Factor B x C at Levels $a_1 - a_i$.

Analysis of variance table. (Described previously under Subroutine SPLIT.)

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 Instrumentation*, 1974, 6, 565.

Appendix A: Program Listings for SOFR, SPLIT and SPLITAI

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1      PROGRAM SOFR(INPUT,OUTPUT,TAPE5=INPUT)
      C
      C      TEST RUN DATE 13/05/74, DATA FOR SUBJECTS 1 - 8 (2ND LIST. ONLY.)
      C
      C      NS=NUMBER OF SUBJECTS
      C      NT=NUMBER OF TRIALS FOR THE SUBJECT TO BE EXAMINED
      C      MS=NUMBER OF ITEMS ON LIST
      C      NX=SIZE OF THE LARGEST ORGANIZATIONAL UNIT TO BE EXAMINED
      C      NSS=SUBJECT IDENTIFICATION NUMBER
10     C      MM(I,J) CONTAINS THE DATA ARRANGED IN MATRIX FORM. I RUNS FROM
      C          1 TO MS. J RUNS FROM 1 TO NT.
      C
      C      DIMENSION EXP(3,20,9),DEV(3,20,9),ARC(3,20,9),E(3)
      C      DIMENSION NN(40),MM(40,20),JTR(3),ITR(3,20,9),MAX(20,9),IX(10),ARC
15     C      /1(3),MATRIX(8,9,9)
      C      DIMENSION IR(20,10)
      C      REAL MEAN (3,10)
      C      COMMON/A/SAVE(72,30,4)
      C      READ 50,IN,IP,IQ,IZ,IT
20     C      FORMAT(5I2)
      C
      C      READ GENERAL PARAMETER CARD
      C
      C      READ 1, NS,MS
25     C      FORMAT(I3,I2)
      C      PRINT 51,IN,IP,IQ,IZ,IT
      C      51     FORMAT(1H ,5I2)
      C      PRINT 52,NS,MS
      C      52     FORMAT(1H ,I3,I2)
30     C      DO 115 N=1,NS
      C      PRINT 15
      C      PRINT 15
      C      15     FORMAT(1H1)
      C
      C      IBUG IS FLAG FOR DETECTING ERROR IN DATA INPUT
35     C
      C      IBUG=0
      C
      C      READ PARAMETER CARD FOR SUBJECT NSS
40     C
      C      READ 2, NT,NX,NSS
      C      2      FORMAT(2I2,I3)
      C
      C      INITIALIZATION OF NN(I), NUMBER OF WORDS RECALLED BY THE SUBJECT
45     C      ON EACH TRIAL, AND MM(I,J) WHICH IS MATRIX FOR EACH SUBJECT
      C
      C      DO 100 I=1,40
      C      NN(I)=0
      C      DO 100 J=1,20
50     C      100  MM(I,J)=0
      C      DO 151 I=1,MS
      C
      C      READ DATA MATRIX FOR SUBJECT NSS
      C
      C      READ 3, (MM(I,J),J=1,NT)
55     C      3      FORMAT(20I2)
      C      151  CONTINUE
      C      DO 99 ITOT=1,NT
    
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        DO 99 ITOT1=1,MS
60      IF(MM(ITOT1,ITOT) .EQ. 0) GO TO 99
        NN(ITOT)=NN(ITOT)+1
99      CONTINUE
C
C      INITIALIZE MATRICES CONTAINING FINAL RESULTS
65 C
        DO 101 I=1,NT
        DO 101 J=1,NX
        IR(I,J)=0
        MAX(I,J)=0
70      DO 101 K=1,3
        ITR(K,I,J)=0
        EXP(K,I,J)=0
        DEV(K,I,J)=0
101     ARC(K,I,J)=0
75      NT1=NT-1
        DO 114 M=1,NT1
        DO 113 L=2,NX
        ICTR1=0
C
C      TRAPS AGAINST NUMBER OF TIMES EACH WORD RECALLED BEING LESS THAN
C      ORGANIZATIONAL UNIT SIZE BEING CALCULATED
C
        IF(NN(M) .LT. L) GO TO 114
        IF(NN(M+1) .LT. L) GO TO 114
85      DO 102 I=1,3
102     JTR(I)=0
        INDEX=NN(M)+1-L
        DO 109 K=1,INDEX
        ICTR2=0
90      KK=K
103     DO 108 J=1,MS
        IF(MM(J,M) .NE. KK) GO TO 108
        IF(MM(J,M+1) .EQ. 0) GO TO 107
        ICTR2=ICTR2+1
95      IX(ICTR2)=MM(J,M+1)
        IF(ICTR2 .NE. L) GO TO 106
        ISUM1=0
        ISUM2=0
        IND=ICTR2-1
100     DO 104 NO=1,IND
        NP=NO+1
        DO 104 NI=NP,ICTR2
        NUM1=IX(NI)-IX(NO)
        NUM2=IABS(NUM1)
105     ISUM1=ISUM1+NUM1
        ISUM2=ISUM2+NUM2
        IF(NUM2 .GE. L) GO TO 109
104     CONTINUE
        ICON=0
110     DO 105 II=1, ICTR2
105     ICON=ICON+(ICTR2-II)*II
        NY=0
        IF(ICON .EQ. ISUM1) NY=1
        IF(NY .EQ. 1) GO TO 666
115     IF(ICON+ISUM1 .EQ. 0) NY=2
        IF(NY .EQ. 2) GO TO 666
        IF(ICON .EQ. ISUM2) NY=3
        IF(NY .EQ. 0) GO TO 109
666     DO 667 I=NY,3
120     667 JTR(I)=JTR(I)+1
        GO TO 109
106     KK=KK+1
        GO TO 103
107     ICTR1=ICTR1+1

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125     GO TO 109
108     CONTINUE
      IBUG=1
      PRINT 9, NSS,M
9       FORMAT(/,5X,20HERROR IN SUBJECT NO.,I4,8H   TRIAL,I4)
130 109     CONTINUE
      IR(M,L)=ICTR1
      IF(IBUG .EQ. 1) GO TO 114
      A=1.
      B=NN(M)-L+1-ICTR1
135     C=L
      LIM=L-1
      DO 110 ILL=1,LIM
      ABC=L-ILL
      C=C*ABC
140     D=NN(M+1)-ILL+1
      A=A*D
110     CONTINUE
      E(1)=B/A
      E(2)=E(1)*2.
145     DO 111 I=1,3
      E(3)=E(1)*C
      IF(B .EQ. E(1)) ARC1(I)=0.
      IF(B .NE. E(1)) ARC1(I)=(FLOAT(JTR(I))-E(I))/(B-E(I))
111     CONTINUE
150     DO 112 I=1,3
      ITR(I,M,L-1)=JTR(I)
      EXP(I,M,L-1)=E(I)
      DEV(I,M,L-1)=FLOAT(JTR(I))-EXP(I,M,L-1)
112     ARC(I,M,L-1)=ARC1(I)
155     MAX(M,L-1)=NN(M)-L+1-ICTR1
113     CONTINUE
114     CONTINUE
      LINCX=NX-1
      LL=3*NT1
160     DO 180 I=1,LL
      DO 180 J=1,LINCX
180     SAVE(NSS,I,J)=0.
      DO 181 JJ=1,NT1
      DO 181 II=1,3
165     J=3*(JJ-1)+II
      DO 181 K=1,LINCX
      SAVE(NSS,J,K)=ARC(II,JJ,K)
181     CONTINUE
      IF(IBUG .EQ. 1) GO TO 115
170     PRINT 529, NSS
529     FORMAT(1H0,13HBEGIN SUBJECT,2X,I3)
      PRINT 510
510     FORMAT(1H0,52HOBSERVED REPITITIONS FOR ALL THREE ORDERING CRITERIA
      /)
175     PRINT 511
511     FORMAT(1H ,25X,6HSIZE 2,2X,6HSIZE 3,2X,6HSIZE 4,2X,6HSIZE 5,2X,6HS
      /IZE 6,2X,6HSIZE 7,2X,6HSIZE 8,2X,6HSIZE 9,2X,7HSIZE 10)
      DO 512 J=1,NT1
      LINCX=NX-1
180     JJ=J+1
      PRINT 513, (ITR(1,J,K),K=1,LINCX)
513     FORMAT(1H ,10X,14HUNIDIRECTIONAL,3X,10(I2,6X))
      PRINT 514, JJ, (ITR(2,J,K),K=1,LINCX)
514     FORMAT(1H ,5HTRIAL,1X,I2,2X,13HBIDIRECTIONAL,4X,10(I2,6X))
185     PRINT 515, (ITR(3,J,K),K=1,LINCX)
515     FORMAT(1H ,10X,9HUNORDERED,8X,10(I2,6X))
512     CONTINUE
      PRINT 516
516     FORMAT(1H0,52HEXPECTED REPETITIONS FOR ALL THREE ORDERING CRITERIA

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190  /)
      PRINT 511
      DO 517 J=1,NT1
      LINCX=NX-1
      PRINT 518, (EXP(1,J,K),K=1,LINCX)
195 518 FORMAT(1H , 10X,14HUNIDIRECTIONAL,1X,10(F6.3,2X))
      JJ=J+1
      PRINT 519, JJ, (EXP(2,J,K),K=1,LINCX)
519 519 FORMAT(1H ,5HTRIAL,1X,I2,2X,13HBIDIRECTIONAL,2X,10(F6.3,2X))
      PRINT 520, (EXP(3,J,K),K=1,LINCX)
200 520 FORMAT(1H ,10X,9HUNORDERED,6X,10(F6.3,2X))
517 CONTINUE
      PRINT 521
      PRINT 511
521 521 FORMAT(1H0,37HMAXIMUM POSSIBLE OBSERVED REPETITIONS)
205 LINCX=NX-1
      DO 522 J=1,NT1
      JJ=J+1
      PRINT 523, JJ, (MAX(J,K),K=1,LINCX)
522 CONTINUE
210 523 FORMAT(1H ,5HTRIAL,1X,I2,19X,10(I2,6X))
      PRINT 524
524 524 FORMAT(1H0,48HDEVIATION SCORES FOR ALL THREE ORDERING CRITERIA)
      PRINT 511
      DO 525 J=1,NT1
215 LINCX=NX-1
      PRINT 518, (DEV(1,J,K),K=1,LINCX)
      JJ=J+1
      PRINT 519, JJ, (DEV(2,J,K),K=1,LINCX)
525 525 PRINT 520, (DEV(3,J,K),K=1,LINCX)
220 PRINT 526
526 526 FORMAT(1H0,42HARC SCORES FOR ALL THREE ORDERING CRITERIA)
      DO 527 J=1,NT1
      PRINT 511
      LINCX=NX-1
225 JJ=J+1
      PRINT 518, (ARC(1,J,K),K=1,LINCX)
      PRINT 519, JJ, (ARC(2,J,K),K=1,LINCX)
527 527 PRINT 520, (ARC(3,J,K),K=1,LINCX)
      PRINT 511
230 PRINT 855
      DO 860 J=1,NT1
      L=J+1
860 860 PRINT 854, J, (IR(J,K),K=2,NX)
854 854 FORMAT(1H ,6HTRIAL ,I2,19X,10(I2,6X))
235 855 FORMAT(1H0,23HR VALUES FOR ALL TRIALS)
      LINCX=NX-1
      DO 850 K=1,LINCX
      DO 850 I=1,3
850 850 MEAN(I,K)=0.
240 DO 851 I=1,3
      DO 851 K=1,LINCX
      DO 851 J=1,NT1
851 851 MEAN(I,K)=MEAN(I,K)+(ARC(I,J,K)/FLOAT(NT1))
      PRINT 852
245 PRINT 511
      PRINT 518, (MEAN(1,JK),JK=1,LINCX)
      PRINT 853, (MEAN(2,JK),JK=1,LINCX)
      PRINT 520, (MEAN(3,JK),JK=1,LINCX)
852 852 FORMAT(1H0,47HMEAN ARC SCORES FOR ALL THREE ORDERING CRITERIA)
250 853 FORMAT(1H ,10X,13HBIDIRECTIONAL,2X,10(F6.3,2X))
800 800 FORMAT(1H0,14HM and N VALUES)
      PRINT 800
      DO 870 I=1,NT
      J=I+1
255 PRINT 801, I, NN(I), NN(J)
801 801 FORMAT(1H ,6HTRIAL ,3(I2,5X))

```



```

870  CONTINUE
528  FORMAT(1H0,14HEND OF SUBJECT,2X,I3)
      PRINT 528,NSS
260 115 CONTINUE
      CALL SPLIT(IP,IQ,IZ,IN,NX,NT,IT)
      END

1  C
   C
   C
      SUBROUTINE SPLIT(IP,IQ,IR,IN,IX,NT,IT)
5    REAL MS2,MS3,MS4,MS5,MS7,MS8,MS9,MS10,MS11
      INTEGER DF1,DF2,DF3,DF4,DF5,DF6,DF7,DF8,DF9,DF10,DF11,DF12
      DIMENSION SSAATB(10),SSBATA(2),SSCATA(10),SSAATC(10),SSBATC(10),SS
      /CATB(10)
      REAL MATRIX
10   COMMON/A/SAVE(72,30,4)/B/MATRIX(16,20,20)
      PRINT 70,IP,IQ,IR,IN,NX,NT,IT
70   FORMAT(1H ,7I2)
      NIXON=NX-1
      IRP=IR*IP
15   NT1=NT-1
      DO 200 IJK=1,3
      DO 200 IJL=1,NIXON
      N=IJL+1
      IF(IJK-2) 199,198,197
20 199 PRINT 11,N
      11  FORMAT (1H1,34HANOVA FOR UNIDIRECTIONAL ARC SIZE ,1I1)
      GO TO 196
      198 PRINT 12,N
      12  FORMAT (1H1,33HANOVA FOR BIDIRECTIONAL ARC SIZE ,1I1)
25  GO TO 196
      197 PRINT 13,N
      13  FORMAT (1H1,29HANOVA FOR UNORDERED ARC SIZE , 1I1)
196 CONTINUE
      L=0
30   DO 201 I=1,IRP
      DO 201 IJN=1,IN
      L=L+1
      DO 201 K=1,NT1
      M=(K-1)*3+IJK
35   MATRIX(I,IJN,K)=SAVE(L,M,IJL)
201 CONTINUE
      PRINT 10
10   FORMAT(1H0)
      PRINT 799
40 799 FORMAT(1H ,16HARC INPUT VALUES)
      DO 210 I=1,IRP
      DO 210 J=1,IN
      PRINT 9,(MATRIX(I,J,K),K=1,IQ)
9    FORMAT(1H ,10F10.6)
45 210 CONTINUE
      IX=IP*IR*IN
      IY=MOD(IX,IT)
      IF(IY) 100,101
100 PRINT 99
50 99  FORMAT(1H ,47H THE PRODUCT OF IP IN AND IR DOES NOT EQUAL IT)
      GO TO 999
101 CONTINUE
      CALL SPLITAI(IP,IQ,IR,IN,NX,NT,IT)
      SUM=0.
55   SUMSQ=0.
      ABCT=0.
      ACT=0.
      IRP=0
      DO 103 I=1,IP

```

```

60      DO 104 J=1,IR
        IRP=IRP+1
        TEMP=0.
        DO 105 K=1,IQ
          SUMT=0.
65      DO 106 L=1,IN
        SUM=SUM+MATRIX(IRP,L,K)
        SUMSQ=SUMSQ+MATRIX(IRP,L,K)**2
        SUMT=MATRIX(IRP,L,K)+SUMT
106     TEMP=MATRIX(IRP,L,K)+TEMP
70 105     ABCT=ABCT+(SUMT**2)
104     ACT=ACT+(TEMP**2)
103     CONTINUE
        XX=(SUM**2)/(IR*IP*IQ*IN)
        XAC=ACT/(IN*IQ)
75     XABC=ABCT/IN
        IRP=IR*IP
        ACS=0.
        DO 107 I=1,IRP
          DO 107 J=1,IN
80         TEMP=0.
          DO 108 K=1,IQ
108        TEMP=TEMP+MATRIX(I,J,K)
107        ACS=ACS+TEMP**2
        XACS=ACS/IQ
85        B=0.
        AB=0.
        DO 109 I=1,IQ
          IRP=0
          TEMPL=0.
90        DO 110 J=1,IP
          TEMPI=0.
          DO 111 K=1,IR
            IRP=IRP+1
            DO 111 L=1,IN
95            TEMPI=MATRIX(IRP,L,I)+TEMPI
111          TEMPL=MATRIX(IRP,L,I)+TEMPL
110          AB=AB+TEMPL**2
109          B=B+TEMPL**2
          XB=B/(IN*IP*IR)
100         XAB=AB/(IN*IR)
          A=0.
          IRP=0
          DO 112 I=1,IP
            TEMPI=0.
105          DO 113 J=1,IR
            IRP=IRP+1
            DO 113 K=1,IN
              DO 113 L=1,IQ
113              TEMPI=TEMPI+MATRIX(IRP,K,L)
110 112          A=A+TEMPI**2
          XA=A/(IN*IQ*IR)
          C=0.
          BC=0.
          DO 114 I=1,IR
115          IRP=0
          TEMPL=0.
          DO 115 J=1,IQ
            TEMPI=0.
            DO 116 K=1,IP
              IRP=(K-1)*IR+I
              DO 116 L=1,IN
                TEMPI=TEMPI+MATRIX(IRP,L,J)
                TEMPL=MATRIX(IRP,L,J)+TEMPL
116              BC=BC+TEMPL**2
115              C=C+TEMPL**2
125 114              XC=C/(IN*IP*IQ)
              XBC=BC/(IN*IP)
              SS1=XACS-XX
              SS2=XA-XX
130              SS3=XC-XX
              SS4=XAC-XA-XC+XX
              SS5=XACS-XAC
              SS6=SUMSQ-XACS
              SS7=XB-XX
135              SS8=XAB-XA-XB+XX
              SS9=XBC-XB-XC+XX
              SS10=XABC-XAB-XAC-XBC+XA+XB+XC-XX
              SS11=SUMSQ-XABC-XACS+XAC
              SS12=SUMSQ-XX
140              DF1=IN*IP*IR-1
              DF2=IP-1
              DF3=IR-1
              DF4=(IP-1)*(IR-1)
              DF5=IP*IR*(IN-1)
145              DF6=IN*IR*IP*(IQ-1)
              DF7=IQ-1
              DF8=(IP-1)*(IQ-1)
              DF9=(IQ-1)*(IR-1)
              DF10=(IP-1)*(IQ-1)*(IR-1)
150              DF11=IP*IR*(IN-1)*(IQ-1)
              DF12=(IN*IP*IQ*IR)-1
              MS2=SS2/FLOAT(DF2)
              MS3=SS3/FLOAT(DF3)
              MS4=SS4/FLOAT(DF4)
155              MS5=SS5/FLOAT(DF5)
              MS7=SS7/FLOAT(DF7)
              MS8=SS8/FLOAT(DF8)
              MS9=SS9/FLOAT(DF9)
              MS10=SS10/FLOAT(DF10)
160              MS11=SS11/FLOAT(DF11)
              F2=MS2/MS5
              F3=MS3/MS5
              F4=MS4/MS5
              F7=MS7/MS11
              F8=MS8/MS11
              F9=MS9/MS11
              F10=MS10/MS11
              PRINT 796
796      FORMAT(1H1,26HANALYSIS OF VARIANCE TABLE)

170      PRINT 67
67      FORMAT (1H0,7X,6HSOURCE,12X,2HSS,13X,2HDF,13X,2HMS,13X,1HF)
      PRINT 55,SS1,DF1
55      FORMAT(1H0,1H1,5X,7HBETWEEN,7X,F10.4,9X,I2)
      PRINT 56,SS2,DF2,MS2,F2
175 56      FORMAT (1H ,1H2,8X,1HA,10X,F10.4,9X,I2,9X,2(F10.4,5X))
      PRINT 57,SS3,DF3,MS3,F3
57      FORMAT(1H ,1H3,8X,1HC,10X,F10.4,9X,I2,9X,2(F10.4,5X))
      PRINT 58,SS4,DF4,MS4,F4
58      FORMAT(1H ,1H4,8X,2HAC,9X,F10.4,9X,I2,9X,2(F10.4,5X))

```

```

180 PRINT 59,SS5,DF5,MS5
59  FORMAT (1H ,1H5,3X,12HSUBJ. WITHIN,4X,F10.4,9X,I2,9X,F10.4)
    PRINT 60,SS6,DF6
60  FORMAT (1H ,1H6,3X,12HWITHIN SUBJ.,4X,F10.4,7X,I4)
    PRINT 61,SS7,DF7,MS7,F7
185 61  FORMAT (1H ,1H7,8X,1HB,10X,F10.4,9X,I2,9X,2(F10.4,5X))
    PRINT 62,SS8,DF8,MS8,F8
62  FORMAT (1H ,1H8,8X,2HAB,9X,F10.4,9X,I2,9X,2(F10.4,5X))
    PRINT 63,SS9,DF9,MS9,F9
63  FORMAT (1H ,1H9,8X,2HBC,9X,F10.4,9X,I2,9X,2(F10.4,5X))
190 64  PRINT 64,SS10,DF10,MS10,F10
64  FORMAT(1H ,2H10,6X,3HABC,9X,F10.4,9X,I2,9X,2(F10.4,5X))
    PRINT 65,SS11,DF11,MS11
65  FORMAT (1H ,2H11,1X,16HB X SUBJ. WITHIN,1X,F10.4,7X,I4,9X,F10.4)
    PRINT 66,SS12,DF12
195 66  FORMAT (1H ,2H12,5X,5HTOTAL,8X,F10.4,7X,I4)
200 CONTINUE
999 CONTINUE
    RETURN
    END

1  C
   C
   C
5  SUBROUTINE SPLITAI(IP,IQ,IR,IN,NX,NT,IT)
    REAL MATRIX
    DIMENSION SSAATB(10),SSBATA(2),SSCATA(10),SSAATC(10),SSBATC(10),SS
    CATB(10)
    COMMON/B/MATRIX(16,20,20)
    PRINT 12
10 12  FORMAT(6(/))
    PRINT 797
    DO 1000 K=1,IQ
    ABSQ1=0.
    ABSQ2=0.
15    DO 1001 I=1,IP
    ABSQ=0.
    DO 1002 J=1,IR
    DO 1002 L=1,IN
    IG=(I-1)*IR+J
20    ABSQ=ABSQ+MATRIX(IG,L,K)
    1002 CONTINUE
    ABSQ1=ABSQ**2+ABSQ1
    ABSQ2=ABSQ+ABSQ2
    1001 CONTINUE
25 797  FORMAT(1H ,42HSUMS OF SQUARES OF ALL INTERACTION EFFECTS)
    SSAATB(K)=(ABSQ1-((ABSQ2**2)/FLOAT(IP)))/FLOAT(IN*IR)
    PRINT 1009, K,SSAATB(K)
    1009 FORMAT (1H ,18HSUM/SQUARES A AT B,1I2,3H = ,1F12.6)
    PRINT 11
30 11  FORMAT (/)
    1000 CONTINUE
    PRINT 13
    C
    DO 2000 I=1,IP
35    ABSQ1=0.
    ABSQ2=0.
    DO 2001 K=1,IQ
    ABSQ=0.
    DO 2002 J=1,IR
40    DO 2002 L=1,IN
    IG=(I-1)*IR+J
    ABSQ=ABSQ+MATRIX(IG,L,K)
2002 CONTINUE
    ABSQ1=ABSQ**2+ABSQ1

```

```

45     ABSQ2=ABSQ+ABSQ2
2001  CONTINUE
      SSBATA(I)=(ABSQ1-((ABSQ2**2)/FLOAT(IQ)))/FLOAT(IN*IR)
      PRINT 1010,I,SSBATA(I)
1010  FORMAT (1H ,18HSUM/SQUARES B AT A,1I2,3H = ,1F12.6)
50    PRINT 11
2000  CONTINUE
      PRINT 13

C
      DO 3000 L=1,IR
55    A2=0.
      A3=0.
      DO 3001 I=1,IP
        A1=0.
        DO 3002 J=1,IN
60    DO 3002 K=1,IQ
          IG=L+(I-1)*IR
          A1=A1+MATRIX(IG,J,K)
3002  CONTINUE
        A2=(A1**2)+A2
65    A3=A1+A3
3001  CONTINUE
      SSAATC(L)=(A2-((A3**2)/FLOAT(IP)))/FLOAT(IN*IQ)
      PRINT 1011,L,SSAATC(L)
1011  FORMAT (1H ,18HSUM/SQUARES A AT C, 1I2,3H = ,1F12.6)
70    PRINT 11
3000  CONTINUE
      PRINT 13

C
      DO 4000 L=1,IP
75    A2=0.
      A3=0.
      DO 4001 I=1,IR
        A1=0.
        DO 4002 J=1,IN
80    DO 4002 K=1,IQ
          IG=I+(L-1)*IR
          A1=A1+MATRIX(IG,J,K)
4002  CONTINUE
        A2=(A1**2)+A2
85    A3=A1+A3
4001  CONTINUE
      SSCATA(L)=(A2-((A3**2)/FLOAT(IR)))/FLOAT(IN*IQ)
      PRINT 1012,L,SSCATA(L)
1012  FORMAT (1H ,18HSUM/SQUARES C AT A,1I2,3H = ,1F12.6)
90    PRINT 11
4000  CONTINUE
      PRINT 13

C
13    FORMAT(2(/))
95    DO 5000 L=1,IR
      A2=0.
      A3=0.
      DO 5001 K=1,IQ
        A1=0.
100   DO 5002 I=1,IP
          IG=L+(I-1)*IR
          DO 5002 J=1,IN
            A1=A1+MATRIX(IG,J,K)
5002  CONTINUE
105   A2=(A1**2)+A2
        A3=A1+A3
5001  CONTINUE
      SSBATC(L)=(A2-((A3**2)/FLOAT(IQ)))/FLOAT(IN*IP)
      PRINT 1013,L,SSBATC(L)

```

```

110 1013 FORMAT (1H ,18HSUM/SQUARES B AT C,1I2,3H = ,1F12.6)
      PRINT 11
5000 CONTINUE
      PRINT 13
      C
115      DO 6000 L=1,IQ
          A2=0.
          A3=0.
          DO 6001 K=1,IR
              A1=0.
120              DO 6002 I=1,IP
                  DO 6002 J=1,IN
                      IG=(I-1)*IR+K
                      A1=A1+MATRIX(IG,J,L)
125              CONTINUE
                  A2=(A1**2)+A2
                  A3=A1+A3
130              CONTINUE
                  SSCATB(L)=(A2-((A3**2)/FLOAT(IR)))/FLOAT(IN*IP)
                  PRINT 1014,L,SSCATB(L)
1014 FORMAT (1H ,18HSUM/SQUARES C AT B,1I2,3H = ,1F12.6)
      PRINT 11
6000 CONTINUE
      PRINT 12
      C
135 C   THIS SEGMENT CALCULATES THE SUMS OF SQUARES FOR BC AT ALL LEVELS OF A
      DO 1502 II=1,IQ
          DO 1502 JJ=1,IR
              A1=0.
              A2=0.
140              DO 1501 L=1,IP
                  IG=JJ+(L-1)*IR
                  A=0.
                  DO 1500 J=1,IN
                      A=A+MATRIX(IG,J,II)
145 1500 CONTINUE
                  A1=A**2+A1
                  A2=A+A2
1501 CONTINUE
                  SSABC1=(A1/FLOAT(IN))-((A2**2)/FLOAT(IN*IP))
150          PRINT 1503,II,JJ,SSABC1
1503 FORMAT (1H0,20HSUMS/SQUARES A AT BC,1I2,1H,,1I2,3H = ,1F12.6)
1502 CONTINUE
      PRINT 11
      C
155 C   THIS SEGMENT CALCULATES THE SUMS OF SQUARES FOR AC AT ALL LEVELS OF B
      DO 2502 II=1,IP
          DO 2502 JJ=1,IR
              IG=JJ+IR*(II-1)
              A1=0.
              A2=0.
160              DO 2501 K=1,IQ
                  A=0.
                  DO 2500 J=1,IN
                      A=A+MATRIX(IG,J,K)
165 2500 CONTINUE
                  A1=A**2+A1
                  A2=A2+A
2501 CONTINUE
                  SSBAC1=(A1/FLOAT(IN))-((A2**2)/FLOAT(IN*IQ))
170          PRINT 2503,II,JJ,SSBAC1
2503 FORMAT (1H0,20HSUMS/SQUARES B AT AC,1I2,1H,,1I2,3H = ,1F12.6)
2502 CONTINUE
      PRINT 11
    
```

```

      C
175 C   THIS SEGMENT CALCULATES THE SUMS OF SQUARES FOR AB AT ALL LEVELS OF C
      DO 3502 II=1,IP
      DO 3502 JJ=1,IQ
      A1=0.
      A2=0.
180     DO 3501 I=1,IR
      A=0.
      DO 3500 J=1,IN
      IG=1+(II-1)*IR
      A=A+MATRIX(IG,J,JJ)
185 3500 CONTINUE
      A1=A**2+A1
      A2=A+A2
      3501 CONTINUE
      SSCAB1=(A1/FLOAT(IN))-((A2**2)/FLOAT(IN*IR))
190     PRINT 3503,II,JJ,SSCAB1
      3503 FORMAT (1H0,20HSUMS/SQUARES C AT AB,1I2,1H,,1I2,3H = ,1F12.6)
      3502 CONTINUE
      PRINT 11

      C
195 C   THIS SEGMENT CALCULATES THE SUMS OF SQUARES FOR C AT ALL LEVELS OF AB
      DO 4505 II=1,IR
      A1=0.
      A2=0.
      DO 4502 I=1,IP
      IG=II+(I-1)*IR
200     DO 4501 K=1,IQ
      A=0.
      DO 4500 J=1,IN
      A=A+MATRIX(IG,J,K)
205 4500 CONTINUE
      A1=(A**2)+A1
      A2=A+A2
      4501 CONTINUE
      4502 CONTINUE
210     SABAC1=(A1/FLOAT(IN))-((A2**2)/FLOAT(IN*IP*IQ))-SSAATC(II)-SSBATC(
      /II)
      PRINT 4503,II,SABAC1
      4503 FORMAT (1H0,20HSUMS/SQUARES AB AT C,1I2,3H = ,3X,1F12.6)
      4504 CONTINUE
      PRINT 11

      C
      C   THIS SEGMENT CALCULATES THE SUMS OF SQUARES FOR B AT ALL LEVELS OF AC
      DO 5504 II=1,IQ
      A1=0.
      A2=0.
220     DO 5502 I=1,IP
      DO 5501 L=1,IR
      IG=L+(I-1)*IR
      A=0.
225     DO 5500 J=1,IN
      A=A+MATRIX(IG,J,II)
      5500 CONTINUE
      A1=A1+(A**2)
      A2=A+A
230 5501 CONTINUE
      5502 CONTINUE
      SACAB1=(A1/FLOAT(IN))-((A2**2)/FLOAT(IN*IP*IR))-SSAATB(II)-SSCATB(
      /II)
      PRINT 5503,II,SACAB1
235 5503 FORMAT (1H0,20HSUMS/SQUARES AC AT B,1I2,3H = ,3X,1F12.6)
      5504 CONTINUE
      PRINT 11

```

```
C
C   THIS SEGMENT CALCULATES THE SUMS OF SQUARES FOR A AT ALL LEVELS OF BC
240  DO 6504 II=1,IP
      A1=0.
      A2=0.
      DO 6502 I=1,IR
      DO 6501 K=1,IQ
245    IG=(II-1)*IR+I
      A=0.
      DO 6500 J=1,IN
      A=A+MATRIX(IG,J,K)
6500  CONTINUE
250    A1=A1+(A**2)
      A2=A2+A
6501  CONTINUE
6502  CONTINUE
      SBCAA1=(A1/FLOAT(IN))-((A2**2)/FLOAT(IN*IQ*IR))-SSBATA(II)-SSCATA(
255    / II)
6503  FORMAT (1H0,20HSUMS/SQUARES BC AT A,1I2,3H = ,3X,1F12.6)
      PRINT 6503,II,SBCAA1
6504  CONTINUE
      RETURN
260  END
```