A FORTRAN IV program for analyzing higher-order subjective organization units in free recall learning*

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This paper presents a program for the analysis of subjective organization in free recall and the instructions for the organization of data to use this program. The program is capable of handling lists of up to 40 items, as well as 20 trials of data. In addition, the program provides several types of data tables for unit sizes from 2 to 10 items in length and for three types of sequential ordering criteria.

The following is a description and listing of a FORTRAN IV program to compute subjective organization units according to the techniques described by Pellegrino (1971). The program is applicable to any standard multitrial free recall experiment in which the E wishes to determine the amount of subjective organization that a S has demonstrated. In typical multitrial free recall, a S is alternately presented a list of items followed by a test trial in which he is free to reproduce the list members in any sequence desired, with this study-test alternation continuing over several trials in which the same items always constitute the list. Subjective organization refers to the degree to which a S consistently clusters or groups together sets of items from the list over the several test trials required. The measurement of subjective organization is based upon successive pairs of such recall trials (e.g., 1-2, 2-3, 3-4, etc.). Thus, for t trials in a free recall task there are $t-1$ possible trial values that can be obtained. Unlike previous subjective organization programs or techniques, this program [following the procedures described by Pellegrino (1971) for Data Case 1] will examine successive trial pairs for subjective organization units from Size 2 to Size 10 under three increasingly more varied sequential criteria for counting a reproduction of a particular unit.

INDIVIDUAL S DATA CARDS

The data for each S are punched in the form of a matrix, with each card representing performance (recall position) on a different list item across all trials, as in the example in Table 1.¹ The value 00 refers to nonrecall of an item on a particular

trial. The data are stored in matrix MM(40,20), which is capable of handling 40-item lists and 20 trials. If either of these values needs to be increased then the DIMENSION and FORMAT statements can be adjusted.

DECK CONSTRUCTION

The general form of the entire program deck is illustrated in Fig. 1.

Cols. 12345

00907

Individual S Cards

Parameter card. This card provides the parameters for the individual S which are NT, NX, and NSS. NT (Cols. 1-2) refers to the number of trials of data for that S that are to be examined at this time, providing NT - 1 trial

Table 1

Item	Trials						Columns 123456789...
	1	2	3	4	5	6	
A	0	1	5	7	4	1	000105070401
B	1	2	0	1	2	3	010200010203
C	0	4	3	3	1	4	000403030104
D	3	0	2	4	3	6	030002040306
E	2	3	4	2	0	7	020304020007
F	4	5	6	6	5	5	040506060505
G	5	6	1	5	6	2	050601050602

Fig. 1. Arrangement of complete program deck.

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PROGRAM SUBORG(INPUT,OUTPUT,PUNCH)
DIMENSION NN(40),MM(40,20),JTR(3),
DIMENSION MAX(20,9),ITR(3,20,9),
READ 1, NS,MS
1  FORMAT(13,I2) IX(10),E(3),ARC1(3)
DO 115 N=1,NS EXP(3,20,9)
IBUG=0
2  READ 2, NT,NX,NSS
FORMAT(212,I3)
DO 100 I=1,40
NN(I)=0
DO 100 J=1,20
100 MM(I,J)=0
DO 151 I=1,MS
3  READ 3, (MM(I,J),J=1,NT)
FORMAT(2012)
151 CONTINUE
DO 99, ITOT=1,NT
DO 99, ITOT1=1,MS
IF(MM(ITOT1,ITOT) .EQ. 0) GO TO 99
NN(ITOT)=NN(ITOT)+1
99 CONTINUE
DO 101 I=1,NT
DO 101 J=1,NX
MAX(I,J)=0
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.
NT1=NT-1
DO 114 M=1,NT1
DO 113 L=2,NX
ICTR1=0
IF(NN(M) .LT. L) GO TO 114
IF(NN(M+1) .LT. L) GO TO 114
DO 102 I=1,3
102 JTR(I)=0
IN=NN(M)+1-L
DO 109 K=1,IN
ICTR2=0
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
IX(ICTR2)=MM(J,M+1)
IF(ICTR2 .NE. L) GO TO 106
ISUM1=0
ISUM2=0
IND=ICTR2-1
DO 104 NO=1,IND
NP=NO+1
DO 104 NI=NP,ICTR2
NUM1=IX(NI)-IX(NO)
NUM2=IABS(NUM1)
ISUM1=ISUM1+NUM1
ISUM2=ISUM2+NUM2
IF(NUM2 .GE. L) GO TO 109
104 CONTINUE
ICON=0
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
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
667 JTR(I)=JTR(I)+1
GO TO 109
106 KK=KK+1
GO TO 103
107 ICTR1=ICTR1+1
GO TO 109
108 CONTINUE
IBUG=1
PRINT 9, NSS,M
9  FORMAT(/,5X,20HERROR IN SUBJECT NO.,I4,8H TRIAL,I4)
109 CONTINUE
IF(IBUG .EQ. 1) GO TO 114
A=1.
B=NN(M)-L+1-ICTR1
C=L
LIM=L-1
DO 110 ILL=1,LIM
ABC=L-ILL
C=C*ABC
D=NN(M+1)-ILL+1
A=A*D
110 CONTINUE
E(1)=B/A
E(2)=E(1)*2.
E(3)=E(1)*C
DO 111 I=1,3
IF(B .EQ. E(I)) ARC1(I)=0.
IF(B .NE. E(I)) ARC1(I)=(FLOAT(JTR(I))-E(I))/(B-E(I))
111 CONTINUE
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)
MAX(M,L-1)=NN(M)-L+1-ICTR1
113 CONTINUE
114 CONTINUE
IF(IBUG .EQ. 1) GO TO 115
PRINT 510
510 FORMAT(1H1,52HOBSERVED REPETITIONS FOR ALL THREE ORDERING CRITERIA
/)
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
NIXON=NX-1
JJ=J+1
PRINT 513, (ITR(1,J,K),K=1,NIXON)
513 FORMAT(1H ,10X,14HUNIDIRECTIONAL,3X,10(I2,6X))
PRINT 514, JJ,(ITR(2,J,K),K=1,NIXON)
514 FORMAT(1H ,5HTRIAL,1X,I2,2X,13HBIDIRECTIONAL,4X,10(I2,6X))
PRINT 515, (ITR(3,J,K),K=1,NIXON)
515 FORMAT(1H ,10X,9HUNORDERED,8X,10(I2,6X))
512 CONTINUE
PRINT 516
516 FORMAT(1H0,52HEXPECTED REPETITIONS FOR ALL THREE ORDERING CRITERIA
/)
PRINT 511
DO 517 J=1,NT1
NIXON=NX-1
PRINT 518, (EXP(1,J,K),K=1,NIXON)
518 FORMAT(1H , 10X,14HUNIDIRECTIONAL,1X,10(F6.3,2X))
JJ=J+1
PRINT 519, JJ,(EXP(2,J,K),K=1,NIXON)
519 FORMAT(1H ,5HTRIAL,1X,I2,2X,13HBIDIRECTIONAL,2X,10(F6.3,2X))
PRINT 520, (EXP(3,J,K),K=1,NIXON)
520 FORMAT(1H ,10X,9HUNORDERED,6X,10(F6.3,2X))
517 CONTINUE
PRINT 521
521 FORMAT(1H0,37HMAXIMUM POSSIBLE OBSERVED REPETITIONS)
PRINT 511
DO 522 J=1,NT1
NIXON=NX-1
JJ=J+1
PRINT 523, JJ,(MAX(J,K),K=1,NIXON)

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523 FORMAT(1H ,5HTRIAL,1X,I2,19X,10(I2,6X))
522 CONTINUE
PRINT 524
524 FORMAT(1H0,48HDEVIATION SCORES FOR ALL THREE ORDERING CRITERIA)
PRINT 511
DO 525 J=1,NT1
NIXON=NX-1
JJ=J+1
PRINT 518, (DEV(1,J,K),K=1,NIXON)
PRINT 519, JJ,(DEV(2,J,K),K=1,NIXON)
525 PRINT 520, (DEV(3,J,K),K=1,NIXON)
PRINT 526
526 FORMAT(1H0,42HARC SCORES FOR ALL THREE ORDERING CRITERIA)
PRINT 511
DO 527 J=1,NT1
NIXON=NX-1
JJ=J+1
PRINT 518, (ARC(1,J,K),K=1,NIXON)
PRINT 519, JJ,(ARC(2,J,K),K=1,NIXON)
527 PRINT 520, (ARC(3,J,K),K=1,NIXON)
PRINT 528, NSS
528 FORMAT(1H ,14HEND OF SUBJECT,2X,I3)
115 CONTINUE
CALL EXIT
END

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If a S's data is in error, the program will print out the trial numbers on which the errors occurred. Each error on a trial means that a number is missing from the recall sequence on that trial, e.g., use of the number 12 twice, with 13 missing. The number of error messages for a particular trial indicates how many such errors have occurred.

The program has an internal protection against the possibility of searching for a unit of size X when either or both trials in the trial pair under examination have a total item recall of less than X.

OBSERVED REPETITIONS FOR ALL THREE ORDERING CRITERIA						DEVIATION SCORES FOR ALL THREE ORDERING CRITERIA					
		SIZE 2	SIZE 3	SIZE 4	SIZE 5			SIZE 2	SIZE 3	SIZE 4	SIZE 5
TRIAL 2	UNIDIRECTIONAL	3	0	0	0	TRIAL 2	UNIDIRECTIONAL	2.474	-.023	-.001	-.000
	BIDIRECTIONAL	4	0	0	0		BIDIRECTIONAL	2.947	-.047	-.002	-.000
	UNORDERED	4	1	0	0		UNORDERED	2.947	.860	-.029	-.008
TRIAL 3	UNIDIRECTIONAL	6	1	0	0	TRIAL 3	UNIDIRECTIONAL	5.227	.965	-.002	-.000
	BIDIRECTIONAL	6	1	0	0		BIDIRECTIONAL	4.455	.931	-.003	-.000
	UNORDERED	6	1	0	0		UNORDERED	4.455	.792	-.039	-.010
TRIAL 4	UNIDIRECTIONAL	9	6	4	3	TRIAL 4	UNIDIRECTIONAL	8.125	5.964	3.998	3.000
	BIDIRECTIONAL	12	6	4	3		BIDIRECTIONAL	10.250	5.928	3.997	3.000
	UNORDERED	12	8	6	6		UNORDERED	10.250	7.783	5.962	5.992

EXPECTED REPETITIONS FOR ALL THREE ORDERING CRITERIA						ARC SCORES FOR ALL THREE ORDERING CRITERIA					
		SIZE 2	SIZE 3	SIZE 4	SIZE 5			SIZE 2	SIZE 3	SIZE 4	SIZE 5
TRIAL 2	UNIDIRECTIONAL	.526	.023	.001	.000	TRIAL 2	UNIDIRECTIONAL	.261	-.003	-.000	-.000
	BIDIRECTIONAL	1.053	.047	.002	.000		BIDIRECTIONAL	.329	-.006	-.000	-.000
	UNORDERED	1.053	.140	.029	.008		UNORDERED	.329	.109	-.004	-.001
TRIAL 3	UNIDIRECTIONAL	.773	.035	.002	.000	TRIAL 3	UNIDIRECTIONAL	.322	.060	-.000	-.000
	BIDIRECTIONAL	1.545	.069	.003	.000		BIDIRECTIONAL	.288	.058	-.000	-.000
	UNORDERED	1.545	.208	.039	.010		UNORDERED	.288	.050	-.003	-.001
TRIAL 4	UNIDIRECTIONAL	.875	.036	.002	.000	TRIAL 4	UNIDIRECTIONAL	.404	.299	.210	.167
	BIDIRECTIONAL	1.750	.072	.003	.000		BIDIRECTIONAL	.532	.297	.210	.167
	UNORDERED	1.750	.217	.038	.008		UNORDERED	.532	.393	.314	.333

MAXIMUM POSSIBLE OBSERVED REPETITIONS				
	SIZE 2	SIZE 3	SIZE 4	SIZE 5
TRIAL 2	10	8	7	6
TRIAL 3	17	16	15	14
TRIAL 4	21	20	19	18

values. NX (Cols. 3-4) is the size of the largest subjective organization unit that is to be examined, with a maximum of 10. Thus, the program will compute for unit sizes 2 through NX. NSS (Cols. 5-7) is the S identification number. In the above example, if the maximum size unit to be examined is 5, then for a hypothetical S number 82 the card would be:

Cols. 1234567
0605082

Individual S data cards. These are the previously described cards which

represent the performance on each individual list item across all trials.

The data for each new S immediately follows that of the preceding S. The program processes one S at a time, reading in the MS + 1 data cards for that S and printing out several data tables, as shown in the tables following the program listing. These data include all three ordering criteria, as well as Unit Sizes 2-10. The tables are in the following order: (1) observed number of units, (2) expected values, (3) maximum possible observed units, (4) observed-expected (deviation score), (5) observed-expected/maximum-expected ($ARC_{\alpha/X}$ score).

REFERENCES

PELLEGRINO, J. W. A general measure of organization in free recall for variable unit size and internal sequential consistency. *Behavior Research Methods & Instrumentation*, 1971, 3, 241-246.

NOTE

1. The data are punched in this type of matrix to facilitate transfer to several other organizational programs developed by the author. These programs, as well as a deck for the present program, are available upon request (the cost is \$1 to cover duplication and postage). The additional programs concern input-output organizational analyses, primacy and recency effects, and priority analyses.