CURVAT: A FORTRAN IV subroutine to calculate the index of curvature

JACQUES P. J. MAURISSEN and
GEOFFREY B. INGLIS

*Department of Radiation Biology and Biophysics, School of
Medicine and Dentistry, University of Rochester,
Rochester, New York 14642*

A FORTRAN IV subroutine for the calculation of an index of performance in fixed-interval schedules of reinforcement is shown in Table 1. This index was derived by Fry, Kelleher, and Cook (1960) and describes the changes in rate observed across the duration of the interval.

The first three arguments represent inputs to the subroutine. The first argument (IFIRST) is an integer given the value zero in the main program. It has to be reset to zero in the main program every time a new total index is to be calculated. The second input argument (XIRT) is the array of interresponse times, which is to be dimensioned in the main program to the maximum possible number of interresponse times that can be emitted in a single fixed interval. The third argument (FIVALU) represents the duration of the fixed interval. The interresponse times are expressed in the same unit as the fixed-interval duration; for example, if interresponse times are expressed in milliseconds, a fixed-interval duration of 1 min should be expressed as 60,000 (60 sec $\times$ 1,000 msec).

The first output argument (CRVMAX) returns the maximal value the index can reach with the number of bins chosen. The next argument (CRVIND) gives the value of the index of curvature for the current fixed interval being analyzed, while the last argument (CINDEX) represents the index of curvature calculated from all the interresponse times passed to the subroutine since the last time the argument IFIRST was reset to zero in the main program. Care is taken in the subroutine to discard fixed intervals containing less than a certain number of interresponse times. In the program presented in Table 1, the minimum number of interresponse times required has been arbitrarily set to five. This number can be changed to any value. If there are less than the minimum number of interresponse times required, this interval is skipped during analysis, and stars are printed when writing the value of the current fixed-interval index of curvature. The value of the total index is not affected.

The first part of the program generates a cumulative frequency histogram. All the interresponse times for

Table 1

```

C      THIS SUBROUTINE CALCULATES THE INDEX OF
C      CURVATURE FROM INTERRESPONSE TIMES (IRTS).
C
C      INPUT ARGUMENTS:
C      IFIRST SET TO 0 IN MAIN PROGRAM.
C      XIRT=ARRAY OF IRTS.
C      FIVALU=DURATION OF THE FIXED-INTERVAL.
C
C      OUTPUT ARGUMENTS:
C      CRVMAX=MAXIMUM VALUE THAT THE INDEX CAN REACH.
C      CRVIND=INDEX OF CURVATURE FOR CURRENT FIXED-
C      INTERVAL.
C      CINDEX=TOTAL INDEX OF CURVATURE.
C
C      NUMBIN=NUMBER OF BINS OR TIME INTERVALS INTO WHICH
C      THE FIXED-INTERVAL IS SUBDIVIDED. IT CAN
C      BE GIVEN ANY VALUE IN THIS SUBROUTINE.
C      BIN(K)=TOTAL NUMBER OF RESPONSES IN BINS 1 TO K
C      (FOR CURRENT FIXED-INTERVAL). IT MUST BE
C      DIMENSIONED IN THE SUBROUTINE TO THE VALUE
C      OF NUMBIN.
C      SUMBIN(K)=TOTAL NUMBER OF RESPONSES IN BINS 1 TO K
C      (FOR ALL THE PRECEDING AND CURRENT FIXED-
C      INTERVALS). IT MUST BE DIMENSIONED IN THE
C      SUBROUTINE TO THE VALUE OF NUMBIN.
C      BINDUM=DUMMY ARGUMENT DIMENSIONED IN THE SUBROUTINE
C      TO NUMBIN+1.
C      SUMCUM=TOTAL NUMBER OF RESPONSES IN BINS 1 TO K-1
C      (FOR CURRENT FIXED-INTERVAL).
C      SUMCML=TOTAL NUMBER OF RESPONSES IN BINS 1 TO K-1
C      (FOR ALL THE PRECEDING AND CURRENT FIXED-
C      INTERVALS).
C
C      SUBROUTINE CURVAT (IFIRST, XIRT, FIVALU, CRVMAX,
1  CRVIND, CINDEX)
      DIMENSION XIRT(1)
      INTEGER SUMBIN(10),BIN(10),BINDUM(11)
      EQUIVALENCE(BINDUM(2),BIN(1))
      NUMBIN=10
      IF(IFIRST.NE.0) GO TO 20
      DO 10 K=1,NUMBIN
10      SUMBIN(K)=0
      CRVIND=15E+10
      CINDEX=15E+10
      NRPASS=0
C
C      IFIRST=1
20      NRPASS=NRPASS+1
      CRVMAX=FLOAT(NUMBIN-1)/NUMBIN

```

This project was supported by National Institute of Mental Health Grant MH11752, ES-01248, and in part by a contract with the USDOE. It was assigned report number UR-3490-1360.

Table 1 (Continued)

```

NUMMAX=NUMBIN+1
      DO 30 K=1, NUMMAX
30      BINDUM(K)=0
      BINSIZ=FIVALU/NUMBIN
      NIRT=0
      K=1
      SUMIRT=0.0
      SUMCUM=0.0
      SUMCML=0.0
40      NIRT=NIRT+1
      SUMIRT=SUMIRT+XIRT(NIRT)
50      IF(SUMIRT.GT.K*BINSIZ.AND.K.NE.NUMBIN+1) GO TO 60
      IF(SUMIRT.GT.FIVALU.AND.K.EQ.NUMBIN+1) GO TO 80
      IF(XIRT(NIRT).EQ.0.0) GO TO 70
      BIN(K)=BIN(K)+1
      GO TO 40
60      BIN(K)=BIN(K-1)+BIN(K)
      K=K+1
      GO TO 50
C
70      BIN(K)=BIN(K-1)+BIN(K)
C      NIRT=TOTAL NUMBER OF IRTS INCLUDING THE REINFORCED
IRT.
80      IF(NIRT.LT.5) GO TO 120
      NUMMIN=NUMBIN-1
      DO 90 K=1, NUMMIN
90      SUMCUM=SUMCUM+BIN(K)
      CRVIND=((NUMBIN-1)*BIN(NUMBIN)-2*SUMCUM)/
1      (NUMBIN*BIN(NUMBIN))
      DO 100 K=1, NUMBIN
100      SUMBIN(K)=SUMBIN(K)+BIN(K)
      DO 110 K=1, NUMMIN
110      SUMCML=SUMCML+SUMBIN(K)
      CINDEX=((NUMBIN-1)*SUMBIN(NUMBIN)-2*SUMCML)/
1      (NUMBIN*SUMBIN(NUMBIN))
      RETURN
120      CRVIND=15E+10
      IF(NRPASS.EQ.1) IFIRST=0
      NRPASS=NRPASS+1
      RETURN
END

```

each fixed interval are summed and the cumulative frequency of responses is recorded in the appropriate bin. The reinforced interresponse time must be included at the end of the array containing interresponse times, so that their sum for each interval exceeds the fixed-interval duration. Zero the array before inserting the interresponse times in it, so the unused locations of the array contain zeros.

In the subroutine, the variables BIN and SUMBIN have to be locally dimensioned to the total number of bins. The dummy array BINDUM must be dimensioned to the total number of bins plus one.

Table 2 shows the listing of a program that runs the subroutine CURVAT.

Requirements. This program has been developed on a Digital Equipment Corporation (DEC) PDP-12 computer. It also runs on a PDP-8/e, DEC-10 system, and IBM 360 without modifications. It is written in ANSI standard FORTRAN IV and should work on any other computer that supports FORTRAN IV.

The time required to run the program depends on the type of computer used and on the amount of data to analyze. The subroutine occupies about 600 12-bit words of memory after it has been compiled.

Availability. Copies of the source listing may be obtained at no cost from Jacques P. J. Maurissen, Department of Radiation Biology and Biophysics, School of Medicine and Dentistry, University of Rochester, Rochester, New York 14642.

Table 2

```

C      EXAMPLE OF A MAIN PROGRAM TO RUN
C
      THE SUBROUTINE CURVAT.
      DIMENSION XIRT(10), ZIRT(50)
      DATA ZIRT/5.9,2.1,3.4,0.,0.,0.,0.,0.,0.,0.,
1      3.2,2.1,1.9,,8.,5.,5.,4.,4.,4,0.,
2      1.6,8.9,0.,0.,0.,0.,0.,0.,0.,0.,
3      4.2,1.,1.,7.,8.,5,2.1,0.,0.,0.,
4      6.5,1.4,1.,2.,2.,15.,15.,1.,15.,2/
      IFIRST=0
      FIVALU=10.0
      N=1
      NIRT=10
      DO 20 I=1,5
      L=0
      DO 10 K=N,NIRT
      L=L+1
      XIRT(L)=ZIRT(K)
10
      N=N+10
      NIRT=NIRT+10
      CALL CURVAT(IFIRST,XIRT,FIVALU,CRVMAX,
1      CRVIND,CINDEX)
20      WRITE(4,30) CRVIND,CINDEX,CRVMAX
30      FORMAT(1H0,'INDEX OF CURVATURE FOR
1      CURRENT F1 = ',F6.3,'1H','TOTAL INDEX
2      OF CURVATURE = ',F6.3,'1H','MAXIMUM
3      VALUE FOR THE INDEX = ',F6.3)
      STOP
      END

```

REFERENCE

- FRY, W., KELLEHER, R. T., & COOK, L. A mathematical index of performance on fixed-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1960, 3, 193-199.

(Accepted for publication May 16, 1978.)