A program to generate Gellermann (pseudorandom) series of binary states

RICHARD J. FRAGASZY

*Department of Civil Engineering
University of California, Davis, California 95616*

and

D. MUNKENBECK FRAGASZY

*Department of Psychology
University of California, Davis, California 95616*

A FORTRAN computer program is described for the generation of pseudorandom series of binary states. The program utilizes a generalized set of logical properties derived from those originally developed for series of a specific length. The generalized statement of these properties allows the construction of series of any length.

This paper describes a FORTRAN IV computer program that generates "Gellermann" series (pseudorandom series of binary states; Gellermann, 1933) according to criteria specified by the user. Series of this type are frequently used in experimental designs in which one wishes to control for order of left-right placement or present-absent conditions (Hilgard, 1951, p. 533). Gellermann (1933, p. 207) proposed five criteria for adequately controlled series of length 10:

- "1. Each series must contain five rights and five lefts.
2. No series should have more than three rights or three lefts in succession.
3. At least two rights and two lefts must appear in both the first and last halves of each series.
4. Each series must contain only five reversals from right to left or left to right.
5. The series must offer a chance score of 50% correct from either single or double alternation of response."

We have developed a computer program in which these statements are generalized. The program repeatedly generates a random series of any length desired by the user (up to 40) and then tests it against specific values of the above criteria. The user specifies the acceptable range for each of Gellermann's criteria except the second. For example, the user enters the minimum and maximum numbers of agreements between the generated series and a single-alternation test

series specified in the program. (Note: Gellermann's criteria for a "good" series are specific to series of length 10.) The generalizations of his criteria in this program permit inclusion of series of any length up to 40, and allow relaxation on restriction of criteria to suit the user's needs. The following input variables define the task: (1) LS = length of series desired, (2) ITMAX = maximum number of iterations allowed, (3) NSW = number of unique series desired (a series is not counted if its mirror image has already been found), (4) RAND = the seed for the pseudorandom number generator.

The general test statements follow Gellermann's original statements; our interpretations of Gellermann's criteria, extended to any series of length LS, are noted in parentheses after each general statement cited below. To change criteria values, change entered values of the allowable range of N, H, R, and C.

1. "Each series must contain five rights and five lefts." $NMIN \leq N \leq NMAX$, where N = number of one state ($NMIN = NMAX = LS/2$ for even series; $NMIN = LS/2 - .5$, $NMAX = LS/2 + .5$ for odd series).
2. "No series should have more than three rights or three lefts in succession." (Not generalized.)
3. "At least two rights and two lefts must appear in both the first and last halves of each series." $HMIN \leq H \leq HMAX$, where H = number of one state in either half of the series. For odd series the middle value is not included in this test. ($HMIN = HMAX = LS/4$ for even series divisible by 4; $HMIN = LS/4 - .5$, $HMAX = LS/4 + .5$ for all other series).
4. "Each series must contain only five reversals from right to left or left to right." $RMIN \leq R \leq RMAX$, where R = number of reversals from one state to the other ($RMIN = LS/2 - 1$, $RMAX = LS/2$ for even series; $RMIN = RMAX = LS/2 - .5$ for odd series).
5. "The series must offer a chance score of 50% correct from either single or double alternation of response." ($CMIN \leq C \leq CMAX$, where C = the number of agreements between the series and single- and double-alternation test series, respectively.) $CMIN = CMAX = LS/2$ for even series; $CMIN = LS/2 - .5$, $CMAX = LS/2 + .5$ for odd series).

Using the explicit criteria stated above, it was difficult to find series of length 10 or 18 meeting Criterion 5 (agreements with single- and double-alternation test series). On closer inspection, Gellermann's original (1933) series produce a 40%-60% performance using a single-alternation strategy and a greater variation (up to 10%-90%) using a double-alternation strategy. For example, two-thirds of the 48 series listed by Gellermann produce 30%-70% response accuracy if a double-alternation strategy is used. None met the stated criteria; the double-alternation tests were the sources of failure. For series of length 10, using a sliding series of criteria for agreement with alternation test series,

The Computer Center, University of California, Davis, provided funds for the computer work reported here. This work was supported by an NSF predoctoral fellowship to D. M. Fragaszy.


```

C*                                C 002:0014:5
C* READ AND WRITE INPUT DATA    C 002:0014:5
C* N=LENGTH OF THE SERIES        C 002:0014:5
C* NSW=NO. OF DIFFERENT SERIES REQUIRED C 002:0014:5
C* ITMAX=MAXIMUM NO. OF TRIAL SERIES C 002:0014:5
C* NMIN,NMAX=MINIMUM AND MAXIMUM NUMBER OF RIGHTS OR LEFTS PER SERIES C 002:0014:5
C* RMIN,RMAX=MINIMUM AND MAXIMUM NUMBER OF REVERSALS PER SERIES C 002:0014:5
C* CMIN,CMAX=MINIMUM AND MAXIMUM NUMBER OF AGREEMENTS WITH THE SINGLE C 002:0014:5
C* OR DOUBLE ALTERNATION TEST SERIES C 002:0014:5
C* HMIN,HMAX=MINIMUM AND MAXIMUM NO. OF RIGHTS OR LEFTS IN EACH HALF C 002:0014:5
C* OF THE SERIES C 002:0014:5
C* RAND=SEED FOR THE PSEUDO-RANDOM NUMBER GENERATOR (FORMAT F15.10) C 002:0014:5
C*                                C 002:0014:5
5 READ(5,1000,END=9100) N,NSW,ITMAX,NMIN,NMAX,RMIN,RMAX,CMIN,CMAX, C 002:0014:5
*                                C 002:0029:2
*                                C 002:0033:0
*                                C 002:0044:4
*                                C 002:004A:2
*                                C 002:004B:0
*                                C 002:004C:4
*                                C 002:004D:2
*                                C 002:004E:0
*                                C 002:004E:4
*                                C 002:004E:4
*                                C 002:004E:4
*                                C 002:004E:4
*                                C 002:0050:0
*                                C 002:0050:0
*                                C 002:0050:0
*                                C 002:0050:0
*                                C 002:0050:0
*                                C 002:0052:2
*                                C 002:0052:2
*                                C 002:0052:2
*                                C 002:0052:2
*                                C 002:0053:2
*                                C 002:0053:4
*                                C 002:0054:2
*                                C 002:0055:0
*                                C 002:0055:4
*                                C 002:0055:4
*                                C 002:0055:4
*                                C 002:0057:0
*                                C 002:0058:4
*                                C 002:005A:4
*                                C 002:005C:1
*                                C 002:005C:4
*                                C 002:005E:1
*                                C 002:005F:2
*                                C 002:005F:2
*                                C 002:005F:2
*                                C 002:005F:2
*                                C 002:0062:1
*                                C 002:0063:3
*                                C 002:0064:1
*                                C 002:0064:4
*                                C 002:0066:0
*                                C 002:0066:0
*                                C 002:0066:0
*                                C 002:0066:0
*                                C 002:0067:0
*                                C 002:0067:3
*                                C 002:0068:5
*                                C 002:0069:3
*                                C 002:006B:2
*                                C 002:006C:5
*                                C 002:006D:2
*                                C 002:006E:5
*                                C 002:0071:0
*                                C 002:0071:0

```

```

C*      THEN INCREMENT THE APPROPRIATE COUNTER
C*
      IF(X(I) .EQ. Y(I)) L4=L4+1
      IF(X(I) .EQ. Z(I)) L5=L5+1
      IF(I .NE. (N/2)) GO TO 220
C*
C*      IF THE FIRST HALF OF THE SERIES HAS BEEN GENERATED, CHECK TO SEE IF
C*      IT MEETS THE HMIN, HMAX CRITERIA
C*
      IF(L3 .LT. HMIN .OR. L3 .GT. HMAX)GO TO 200
      L6=L3
220 CONTINUE
C*
C*      TRIAL SERIES HAS BEEN GENERATED, CHECK NMIN, NMAX CRITERIA
C*
      IF(L3 .LT. NMIN .OR. L3 .GT. NMAX)GO TO 200
C*
C*      CHECK RMIN, RMAX CRITERIA
C*
      IF(L2 .LT. RMIN .OR. L2 .GT. RMAX)GO TO 200
C*
C*      CHECK CMIN, CMAX CRITERIA
C*
      IF(L4 .LT. CMIN .OR. L4 .GT. CMAX .OR. L5 .LT. CMIN .OR. L5 .GT.
*      CMAX)GO TO 200
      IF(I1 .EQ. 0)GO TO 230
      L7=L3-L6-X(L/2+1)
      GO TO 231
230 L7=L3-L6
C*
C*      CHECK HMIN, HMAX CRITERIA FOR THE SECOND HALF
C*
231 IF(L7 .LT. HMIN .OR. L7 .GT. HMAX)GO TO 200
C*
C*      A GOOD SERIES HAS BEEN FOUND, CHECK TO SEE IF IT IS A DUPLICATE
C*      OR THE EXACT OPPOSITE OF ONE ALREADY FOUND
C*
      IF(NF .EQ. 0)GO TO 240
      DO 236 K=1,NF
      NA=0
      DO 235 L=1,N
235 IF(X(L) .EQ. XF(K,L)) NA=NA+1
236 IF(NA .EQ. N .OR. NA .EQ. 0)GO TO 200
C*
C*      IF THE SERIES IS A NEW ONE, WRITE IT OUT AND STORE IT IN ARRAY XF
C*
240 NF=NF+1
      WRITE(6,1003) (X(I),I=1,N)
      DO 250 I=1,N
250 XF(NF,I)=X(I)
      GO TO 200
C*
C*      WRITE NO. OF ITERATIONS, NO. OF SERIES FOUND AND LENGTH OF SERIES
C*
9000 WRITE(6,1004) IT, NF, N
C*
C*      GO BACK TO READ DATA FOR THE NEXT SEARCH
C*
      GOTO 5
1000 FORMAT(11I5,F15.10)
1002 FORMAT('1','LENGTH OF THE SERIES=',I2,/, 'NUMBER OF SERIES DESIRED
*=', I2,/, 'MAXIMUM NUMBER OF TRIAL SERIES=',I5,/, 'THE SEED FOR TH
*E PSEUDO-RANDOM NUMBER GENERATOR=',F13.10,/, 'MINIMUM NUMBER OF LE
*FTS OR RIGHTS=',I2,/, 'MAXIMUM NUMBER OF LEFTS OR RIGHTS=',I2,/,
**' MINIMUM NUMBER OF REVERSALS=',I2,/, 'MAXIMUM NUMBER OF REVERSALS
*=',I2,/, 'MINIMUM NUMBER OF AGREEMENTS=',I2,/, 'MAXIMUM NUMBER OF
*AGREEMENTS=',I2,/, 'MINIMUM NUMBER OF RIGHTS OR LEFTS IN EITHER HA
*LF=',I2,/, 'MAXIMUM NUMBER OF RIGHTS OR LEFTS IN EITHER HALF=',I2)
1003 FORMAT(/,40I2)
1004 FORMAT(/,I6,' TRIAL SERIES TESTED',/,I3,2X,' GELLERMANN SERIES OF
*LENGTH',I3,1X,'FOUND')

```

9100 STOP C 002:00C0:5
 END C 002:00C1:4
 002:00C5:4 IS THE LOCATION FOR EXCEPTIONAL ACTION ON THE I/O STATEMENT AT 002:0029
 SEGMENT 002 IS 00DF LONG

#####

FORMAT SEGMENT IS 008D LONG
 START OF SEGMENT 006
 SEGMENT 006 IS 000C LONG

NO ERRORS DETECTED. NUMBER OF CARDS = 170.
 COMPILATION TIME = 23 SECONDS ELAPSED. 2.02 SECONDS PROCESSING (5050 CPM).
 D2 STACK SIZE = 6 WORDS. FILE SIZE = 140 WORDS. ESTIMATED CORE STORAGE REQUIREMENT = 1335 WORDS.
 TOTAL PROGRAM CODE = 262 WORDS. ARRAY STORAGE = 888 WORDS.
 NUMBER OF PROGRAM SEGMENTS = 6. NUMBER OF DISK SEGMENTS = 30.
 PROGRAM CODE FILE = GELLERMANN ON PACK, COMPILER COMPILED ON 09/20/77 (FORTRAN ON PACK)

LENGTH OF THE SERIES=12
 NUMBER OF SERIES DESIRED=10
 MAXIMUM NUMBER OF TRIAL SERIES=5000
 THE SEED FOR THE PSEUDO-RANDOM NUMBER GENERATOR=0.2431245721
 MINIMUM NUMBER OF LEFTS OR RIGHTS=6
 MAXIMUM NUMBER OF LEFTS OR RIGHTS=6
 MINIMUM NUMBER OF REVERSALS=5
 MAXIMUM NUMBER OF REVERSALS=6
 MINIMUM NUMBER OF AGREEMENTS=6
 MAXIMUM NUMBER OF AGREEMENTS=6
 MINIMUM NUMBER OF RIGHTS OR LEFTS IN EITHER HALF=3
 MAXIMUM NUMBER OF RIGHTS OR LEFTS IN EITHER HALF=3

1	0	0	0	1	1	0	1	0	0	1	1
1	1	1	0	0	0	1	0	0	1	0	1
0	0	1	1	1	0	0	0	1	1	0	1
1	1	0	1	0	0	1	1	1	0	0	0
1	0	1	1	0	0	0	1	1	1	0	0
1	0	1	0	0	1	0	0	0	1	1	1
1	1	1	0	0	0	1	1	0	1	0	0
1	0	0	1	1	0	0	1	1	0	0	1
0	0	1	1	0	1	1	0	1	1	0	0
1	1	0	0	1	0	1	1	0	0	0	1

1494 TRIAL SERIES TESTED
 10 GELLERMANN SERIES OF LENGTH 12 FOUND

LENGTH OF THE SERIES=12
 NUMBER OF SERIES DESIRED=10
 MAXIMUM NUMBER OF TRIAL SERIES=5000
 THE SEED FOR THE PSEUDO-RANDOM NUMBER GENERATOR=0.3520784129
 MINIMUM NUMBER OF LEFTS OR RIGHTS=6
 MAXIMUM NUMBER OF LEFTS OR RIGHTS=6
 MINIMUM NUMBER OF REVERSALS=5
 MAXIMUM NUMBER OF REVERSALS=6
 MINIMUM NUMBER OF AGREEMENTS=6
 MAXIMUM NUMBER OF AGREEMENTS=6
 MINIMUM NUMBER OF RIGHTS OR LEFTS IN EITHER HALF=3
 MAXIMUM NUMBER OF RIGHTS OR LEFTS IN EITHER HALF=3

0	1	1	1	0	0	1	0	1	1	0	0
1	1	1	0	0	0	1	1	0	1	0	0
1	1	1	0	0	0	1	0	0	1	0	1
1	1	0	0	1	0	1	1	0	0	0	1
1	0	1	0	0	1	0	0	0	1	1	1
0	0	1	1	1	0	0	0	1	1	0	1
1	0	0	1	1	0	0	1	1	0	0	1
0	0	1	0	1	1	0	0	0	1	1	1
1	0	1	1	0	0	0	1	1	1	0	0
1	1	0	0	1	0	0	1	0	0	1	1

4669 TRIAL SERIES TESTED
 10 GELLERMANN SERIES OF LENGTH 12 FOUND

LENGTH OF THE SERIES=12
 NUMBER OF SERIES DESIRED=10
 MAXIMUM NUMBER OF TRIAL SERIES=5000
 THE SEED FOR THE PSEUDO-RANDOM NUMBER GENERATOR=0.9502147427
 MINIMUM NUMBER OF LEFTS OR RIGHTS=6
 MAXIMUM NUMBER OF LEFTS OR RIGHTS=6
 MINIMUM NUMBER OF REVERSALS=6
 MAXIMUM NUMBER OF REVERSALS=6
 MINIMUM NUMBER OF AGREEMENTS=6
 MAXIMUM NUMBER OF AGREEMENTS=6
 MINIMUM NUMBER OF RIGHTS OR LEFTS IN EITHER HALF=3
 MAXIMUM NUMBER OF RIGHTS OR LEFTS IN EITHER HALF=3

1	0	1	1	0	0	0	1	1	1	0	0
1	1	1	0	0	0	1	0	0	1	0	1
0	0	0	1	1	1	0	0	1	0	1	1
0	1	1	0	0	1	1	0	0	1	1	0
0	1	0	1	1	0	1	1	1	0	0	0
1	0	0	0	1	1	0	1	0	0	1	1
1	1	0	0	0	1	1	1	0	0	1	0
0	0	1	0	1	1	0	0	0	1	1	1
1	1	0	0	1	0	1	1	0	0	0	1

5001 TRIAL SERIES TESTED
 9 GELLERMANN SERIES OF LENGTH 12 FOUND

REFERENCES

GELLERMANN, L. W. Chance orders of alternating stimuli in visual discrimination experiments. *Journal of Genetic Psychology*, 1933, **42**, 206-208.

HILGARD, E. R. Methods and procedures in the study of learning. In S. S. Stevens (Ed.), *Handbook of experimental psychology*. New York: Wiley, 1951. Pp. 517-567.

(Accepted for publication December 16, 1977.)