PsiLab //

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The PsiLab // package of Psychophysical Research Laboratories of Princeton, New Jersey, was developed in the 1980s for the Apple II series of computers. It included this manual, a random number generator (RNG) on a board that fit into an Apple II slot, and a set of programs on 5¼" floppy disks.

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December 2009

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INTRODUCTION

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FOREWARD

PsiLab // is a computer hardware/software system for psi researchers with Apple // series computers. It is a developmental tool designed to foster collaborative research among geographically separated psi researchers by providing a common working environment through which investigators in a variety of settings and representing a range of psi-outcome histories and theoretical orientations can actively collaborate and contribute to the development, testing and evaluation of computer-based psi experiments. A few words may be appropriate regarding the need for such a development.

Standardization

Psi research with electronic random number generators (RNGs) has been ongoing now for some 15 years and continues to yield promising indications of psi by new investigators. We can identify advances in method, technical sophistication, automation of data collection procedures, etc., but we cannot at this juncture point to similar improvements in the effect size or the proportion of investigators who are able to demonstrate any effect at all. We have not yet "learned how to do it." This is perhaps not unusual since we appear to be dealing with relatively weak effects that are influenced by subtle psychological and motivational factors. Due in large part to the fact that most researchers in this area have been working in isolation, there has been little coordination or standardization of effort and this lack of standardization is clearly reflected in our published reports.

While there are dangers to premature standardization in areas where little is known, there are a number of ways in which standardization can expedite comparison of experimental outcomes across laboratories without seriously limiting the individual researcher's options. PsiLab // provides standardization in the following areas:

* A uniform hardware random source that has undergone extensive component and performance checks,

* Standardized software "drivers" and protocols for accessing the RNG,

* Uniform testing protocols to assess and document RNG behavior under control conditions,

* A uniform participant information form (PIF) to facilitate cross-laboratory comparison of participant demographics and methods of recruitment,

* Uniform controlling software (SERIES MANAGER) which explicitly sets, documents, and controls experimental design parameters,

* Ready-to-run psi experiments embedded in intrinsically motivating computer game formats, the first such experiment PSI INVADERS is included in the present package and others will follow.

Collaboration and Assessment of Replicability

It is apparent from discussions at PA meetings and other gatherings of parapsychologists that there is a sense of isolation among researchers and a growing desire for the stimulation and feedback provided by colleagues with similar interests. We hope that PsiLab // will facilitate more effective collaboration at several levels. Through the sharing of uniform instrumentation and testing protocols, we hope to expedite the mutual understanding of one another's work and increase our ability to interpret variable experimental outcomes across investigators. Through the use of intrinsically motivating computer psi games (which are themselves identical across investigators), many common sources of interlaboratory variability can be reduced or at least more clearly identified. These factors should increase our ability to achieve and document interlaboratory replicability. In order to stimulate information exchange and research development among PsiLab // users, PRL plans to sponsor an annual conference and publish a periodic newsletter (Psychophysical Interactions).

PsiLab // Extensions

The package you now have is a "starter kit." Currently under development are additional ready-to-run experiments involving both PK and ESP oriented tasks, additional statistical analysis routines, and a programmers' package for those who want to write their own PsiLab // compatible psi games. These additional software packages will be sent to you as they are released, along with printed documentation which can be inserted in the loose-leaf documentation binder included with the initial package. (The binder includes a section for Psychophysical Interactions which will be sent prepunched for your convenience.) PRL is currently negotiating a group licensing arrangement with Consulting Psychologists Press which will enable you to use our computer-administered and scored version of the Myers Briggs Type Indicator in your PsiLab // experiments.

Acknowledgments

PsiLab // was developed by PRL over a three year period and represents a significant collaborative effort of a number of colleagues. Rick E. Berger of PRL has served as Project Coordinator. Every aspect of PsiLab // bears the Berger touch: programming, debugging, RNG testing, preparation of documentation; without his devotion and skill it is not likely that this project could have been brought to completion. Ephraim Schechter of PRL has contributed in many ways to PsiLab, especially in the preparation of the documentation package. George Hansen, also of PRL, has assisted in testing and debugging PsiLab // software. The hardware RNG board was designed and constructed by Dick Bierman of the Research Institute for Psi Phenomena & Physics in Amsterdam. Robert Chevako of NSW Associates, Syracuse, contributed important design modifications to the RNG and has tested the components of each board prior to shipping. Edwin May of SRI International also contributed useful insights regarding RNG design and testing. The Random Analysis package was prepared by Donald McCarthy of the Dept. of Mathematics & Computer Science of St. John's University. We wish to acknowledge our conceptual indebtedness to James Davis & Charles Akers of the Foundation for Research on the Nature of Man, Durham, whose important paper on RNG randomness testing (Journal of Parapsychology, 1974) provided the basis for the Random Analysis package and to Gary Heseltine of Science Unlimited Research Foundation, San Antonio, who paved the way with his "Apple Computer Psi Tasks," back in 1981. Finally, we gratefully acknowledge the graciousness of William Basham (DSR, Inc.) and Tom Weishaar (Beagle Bros. Software) for allowing us to use Diversa-DOS and Pronto-DOS on PsiLab // disks without the normal licensing fee.

Charles Honorton, Director

Psychophysical Research Laboratories

INSTALLING YOUR RANDOM NUMBER GENERATOR

Your PsiLab // random number generator (RNG) has been hardware tested and subjected to randomness testing to insure that it is an adequately random device. Proper handling will ensure continued reliability over time.

1) Remove the RNG from its plastic bubble packaging.

2) Handle the RNG by its sides. Try not to touch the components.

3) Remove the top cover from your Apple computer.

4) MAKE SURE THE APPLE'S POWER IS OFF BUT THE APPLE IS PLUGGED IN! TOUCH THE APPLE'S POWER SUPPLY TO GROUND YOURSELF.

5) Insert the RNG in a slot, being sure to seat it all the way in. The default slot for the RNG is slot 4 (although any slot 1-7 is okay).

---> APPLE IIe USERS NOTE:
The RNG may be used in any //e slot EXCEPT SLOT 3! IF YOU HAVE AN 80-COLUMN CARD SLOT 3 IS DISABLED!

6) Replace the cover on the computer.

7) NEVER insert the RNG into the Apple with the power on! This will certainly damage the RNG.

MAKING WORKING/BACKUP COPIES

---> IMPORTANT <---
Before using any PsiLab // software (which is write protected), you must make backup copies which are the copies you will use. Master copies should be stored in a safe place and only be used for the creation of working copies.

Working (and backup) disks may be created by booting the "PSILAB // UTILITIES DISK" and running the "Disk Muncher" copy program. This program will duplicate a disk in its entirety, including the DOS tracks (tracks 0-2) that are on the disk (or no DOS, in the case of some PsiLab // data disks).

** TO USE THE "DISK MUNCHER" COPY PROGRAM: **

----

1) Boot PsiLab // Utilities disk

2) Select "Disk Muncher copy program" from the menu

3) Select #3 (Copy Disk) from Disk Muncher menu

4) Press cntl-V to verify the copy. This will cause the flashing "*"'s to move counter-clockwise around the screen.

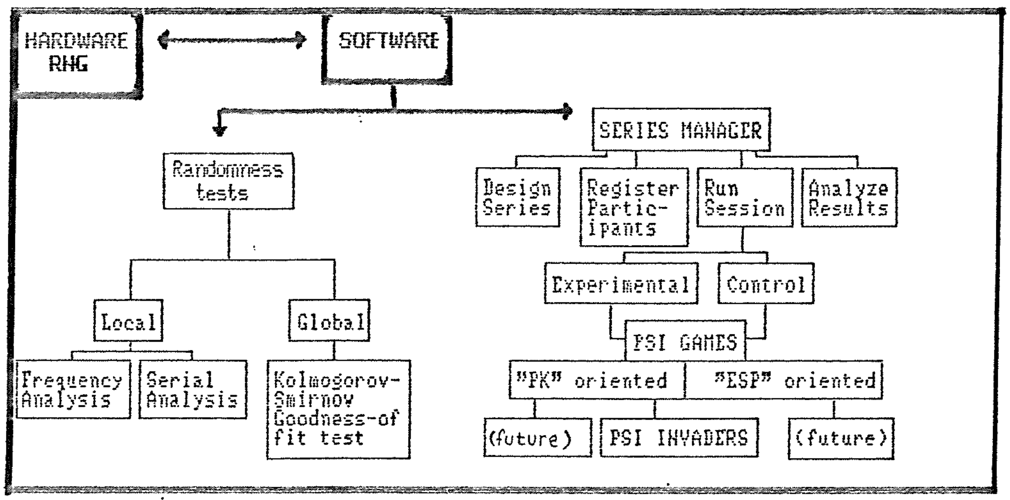
5) Make sure you have a disk in drive #2- Make sure the disk to be copied is in drive #1

6) Press the "return" key

7) WATCH THE SCREEN. Any notation on the screen other than a period indicates a read or write error. If the whole screen fills with periods, you have a good copy. If not, make the copy again. If it still fails, you probably have a bad disk in drive 2.

8) After copy is made, press "ESC" to return to main menu, or "RETURN" to make another copy.

FLOWCHART OF PSILAB // SOFTWARE



PSILAB //

RANDOM ANALYSIS

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TESTS OF RANDOMNESS

There are two aspects to PsiLab // data evaluation. One involves comparing the results of experimental sessions with data from <u>simulated</u> sessions that mimic the experimental sessions but do not involve participants. (Simulation programs and procedures are described in the manuals for the individual experiments.) The second aspect involves comparing the results of experimental or simulated sessions with those expected under the assumption that the "normal" (or "control", or "uninfluenced") output of the hardware random number generator (RNG) is random. For this kind of comparison to be appropriate, it is important to periodically check the RNG's output to make sure that it <u>does</u> approximate the randomness that is assumed. PsiLab // includes a disk of <u>Random Analysis</u> software to gather and analyze such <u>RNG</u> <u>verification</u> data. The PROGRAMS section of this manual contains a discussion of protocols for verification testing.

-> IMPORTANT <--

PRL HAS EXPENDED CONSIDERABLE EFFORT TO INSURE THAT THE HARDWARE RANDOM NUMBER GENERATOR SUPPLIED WITH PSILAB // IS A HIGH-QUALITY DEVICE CAPABLE OF PROVIDING AN ADEQUATE SOURCE OF RANDOM NUMBERS FOR SERIOUS RESEARCH APPLICATIONS. AS WITH OTHER ELECTRONIC INSTRUMENTS, HOWEVER, THE DEVICE'S ADEQUACY MUST BE PERIODICALLY VERIFIED TO INSURE CONTINUED PROPER OPERATION. THE PSILAB // <u>RANDOM</u> <u>ANALYSIS</u> DISK DESCRIBED IN THIS MANUAL PROVIDES STANDARD PROTOCOLS AND TESTS FOR SUCH VERIFICATION. IT IS THE USER'S RESPONSIBILITY TO CONDUCT THESE TESTS.

The PROGRAMS section of this manual describes the random analysis programs in "cookbook" style -- a short statement of what a set of programs does is followed by a detailed description of how to use the program. The THEORY section provides the background -- general information on randomness testing and the specific analyses we are using, with suggested readings for those who wish to pursue the topics further. It also includes detailed discussions of the Kolmogorov-Smirnov (K-S) test and graphs, which may be less familiar to PsiLab // users than the other analyses are.

You may wish to familiarize yourself with the PsiLab // random analysis software by running the programs as described in the PROGRAMS section, referring to the THEORY section when necessary in order to understand more fully just what is happening.

-> IMPORTANT <--
BEFORE YOU RUN THE PSILAB // RANDOM ANALYSIS PROGRAMS, BE SURE TO READ AND FOLLOW THE INSTRUCTIONS FOR MAKING BACKUP COPIES OF THE DISKS (SEE THE PSILAB // INTRODUCTION).

-> IMPORTANT <--
BE SURE THAT YOUR RNG IS PROPERLY INSTALLED (SEE THE PSILAB // INTRODUCTION). The PSILAB // RANDOM ANALYSIS PROGRAMS BEGIN BY TESTING THE DESIGNATED APPLE II EXPANSION SLOT TO MAKE SURE THAT A PSILAB // RNG IS IN PLACE. THE PROGRAMS WILL NOT RUN IF A PSILAB // RNG IS NOT IN THE SPECIFIED SLOT.

PROGRAMS

FREQUENCY ANALYZER

General Description

The Frequency Analyzer on the "PsiLab // Random Analysis" disk will perform a frequency analysis on the output of a PsiLab // random number generator (RNG). The main program ("ANALYZER.FREQ") automatically generates and analyzes a specified number of data sets, each comprised of a specified number of trials. A trial consists of sampling one random number (0-255) from the RNG and incrementing the appropriate counter. Separate counters are used to keep track of the number of times each of the 256 different byte values is obtained. Once the assigned number of trials has been completed, the frequency distribution of the random numbers obtained in that data set is then examined, and a standard chi-square statistic is calculated. This measures how well the observed frequency distribution matches the expected distribution in which each value (0-255) is equally likely to occur. The examination of the frequency distribution is done with respect to four different cell breakdowns: in addition to the full breakdown using all 256 values individually, we also examine the effect of grouping adjacent values - into 2, 4 or 16 cells. For example, when using 4 cells the values are grouped as follows: 0 to 63, 64 to 127, 128 to 191, 192 to 255.

Thus for each data set the program calculates four different chi-square values: one for each of the four cell breakdowns. These chi-square values are saved on disk for subsequent examination by the Kolmogorov-Smirnov program ("K-S.FREQ"). Similarly, the actual frequency counts using the full 256 cell breakdown may be saved on a (separate) data disk for future examination using the Frequency Cumulator program (to be available in 1985).

These supplementary analyses employing the Kolmogorov-Smirnov and Frequency Cumulator programs will ordinarily be performed only after a large volume of data has been collected during many individual uses of the Frequency Analyzer program, thus enabling an overall evaluation of the behavior of the random number generator over a period of time.

The Frequency Analyzer package automatically carries out the same types of overall analyses on a small scale, based on the different sets of data generated in a single use of the program (see Sample Frequency Analysis printouts following this section). After each of the individual data sets has been generated, the four chi-square values calculated for each data set, and (optionally) printed out, the program will printout the results of a cumulative frequency analysis obtained by adding together the frequency counts over all the data sets. It will also construct for each of the four cell breakdowns an empirical distribution based on the chi-square values obtained from the individual data sets, and a Kolmogorov-Smirnov analysis will be done to examine the goodness-of fit of this empirical distribution to the theoretical chi-square distribution having the appropriate degrees of freedom.

The results of these analyses are then presented in a hardcopy printout. For each of the four cell breakdowns, the Kolmogorov-Smirnov analysis is accompanied by a graph displaying the empirical cumulative distribution superimposed on the theoretical cumulative distribution. A discussion of how to interpret this graphic information is presented in a separate section at the end of the discussion of the Kolmogorov-Smirnov Analysis.

Fig. 1
Sample Printout (with raw data)

FREQUENCY ANALYSIS

CURRENT PROGRAM: ANALYZER.FREQ VERSION 6

BOARD NO. 3 DATE: 1/7/85 TIME: 3 PM
NO. SAMPLES: 100 NO. TRIALS/SAMPLE: 20000
DELAY: 1 SLOT: 4

SAMPLE NO. 1

DATA FILE : RNG3.0.15.1.FREQ

NO. CELLS	CHI-SQ VALUE	PROBABILITY
2	.304	.581
4	1.768	.622
16	6.078	.978
256	268.698	.266

SAMPLE NO. 2

DATA FILE : RNG3.0.15.2.FREQ

NO. CELLS	CHI-SQ VALUE	PROBABILITY
2	0	.989
4	.277	.964
16	9.587	.845
256	245.35	.657

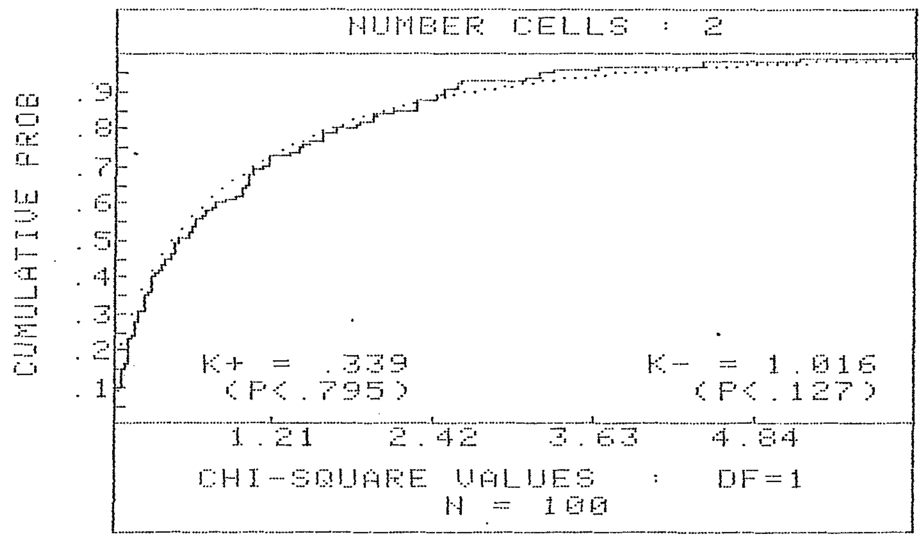
SAMPLE NO. 3

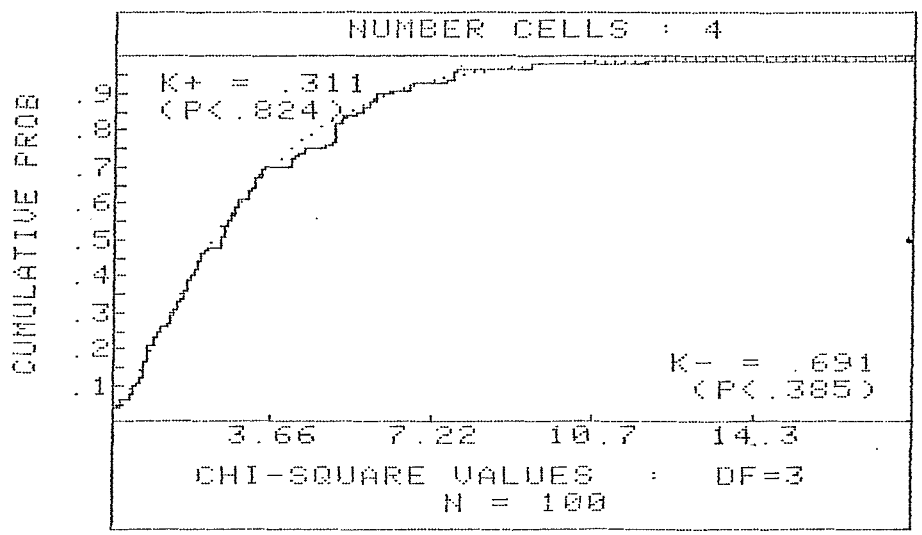
DATA FILE : RNG3.0.15.3.FREQ

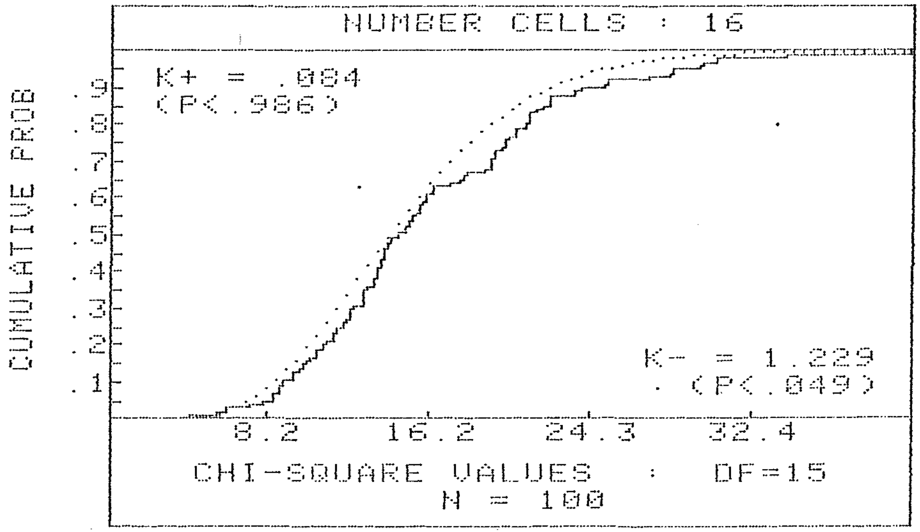
NO. CELLS	CHI-SQ VALUE	PROBABILITY
2	1.037	.309
4	1.94	.585
16	19.114	.209
256	263.219	.348

TOTALS

NO. CELLS	CHI-SQ VALUE	PROBABILITY
2	.233	.63
4	6.518	.089
16	17.852	.271
256	266.528	.297






NUMBER CELLS : 16
K+ = .084
(P<.986)
K- = 1.229
(P<.049)
CUMULATIVE PROB
.9
.8
.7
.6
.5
.4
.3
.2
.1
8.2
16.2
24.3
32.4
CHI-SQUARE VALUES : DF=15
N = 100

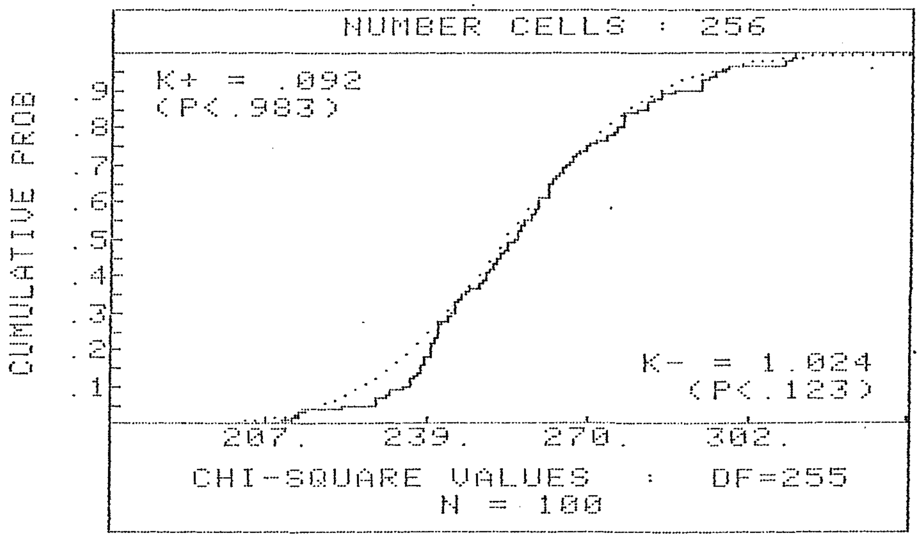

NUMBER CELLS : 256
K+ = .092
(P<.983)
K- = 1.024
(P<.123)
CUMULATIVE PROB
.9
.8
.7
.6
.5
.4
.3
.2
.1
207.
239.
270.
302.
CHI-SQUARE VALUES : DF=255
N = 100

Fig. 2

Sample Printout (no raw data)

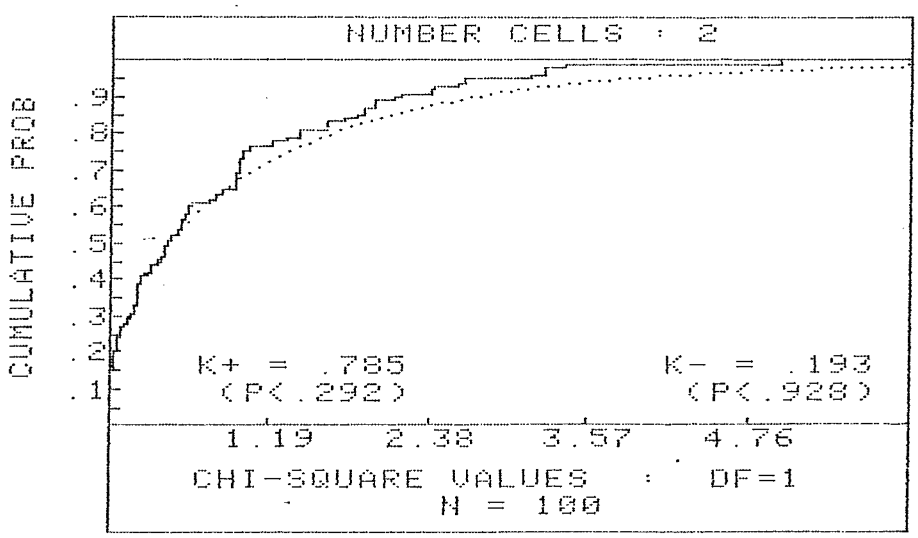
FREQUENCY ANALYSIS

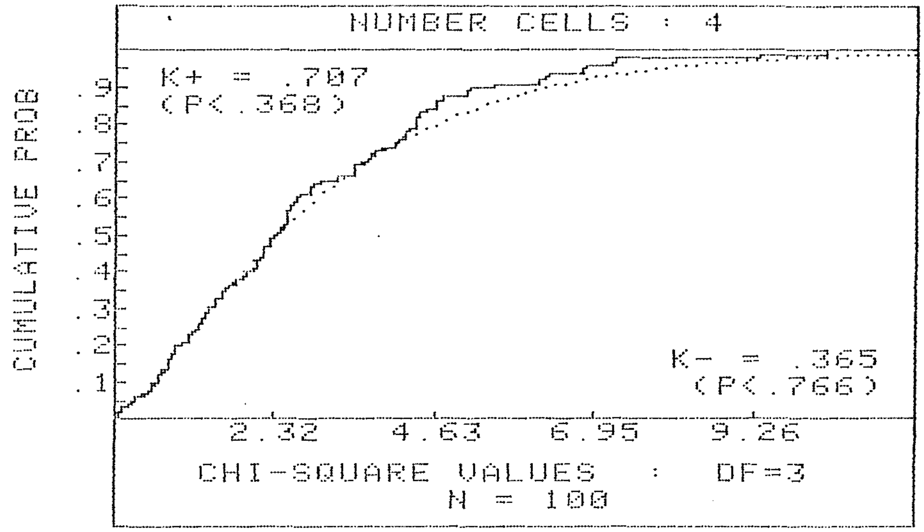
CURRENT PROGRAM: ANALYZER.FREQ VERSION 6

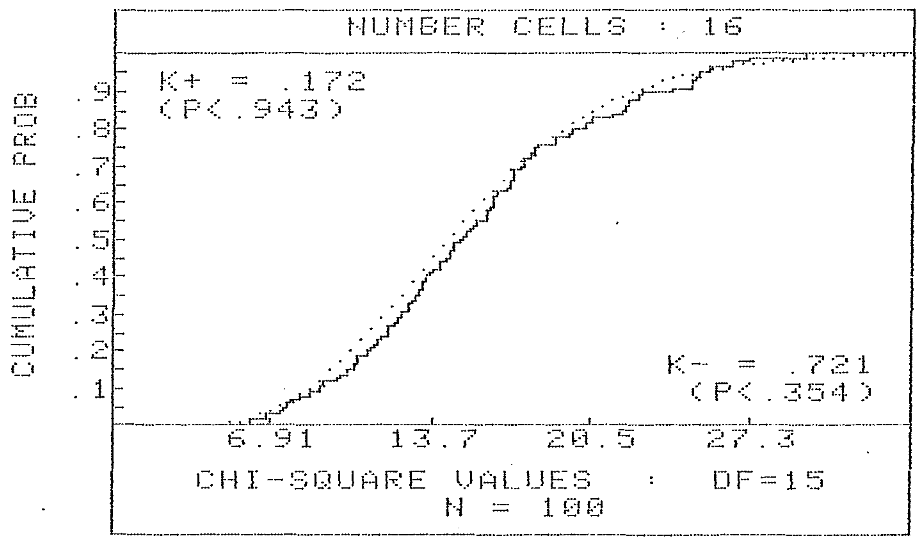
BOARD NO. 3 DATE: 1/4/85 TIME: 3 PM
NO. SAMPLES: 100 NO. TRIALS/SAMPLE: 20000
DELAY: 1 SLOT: 4

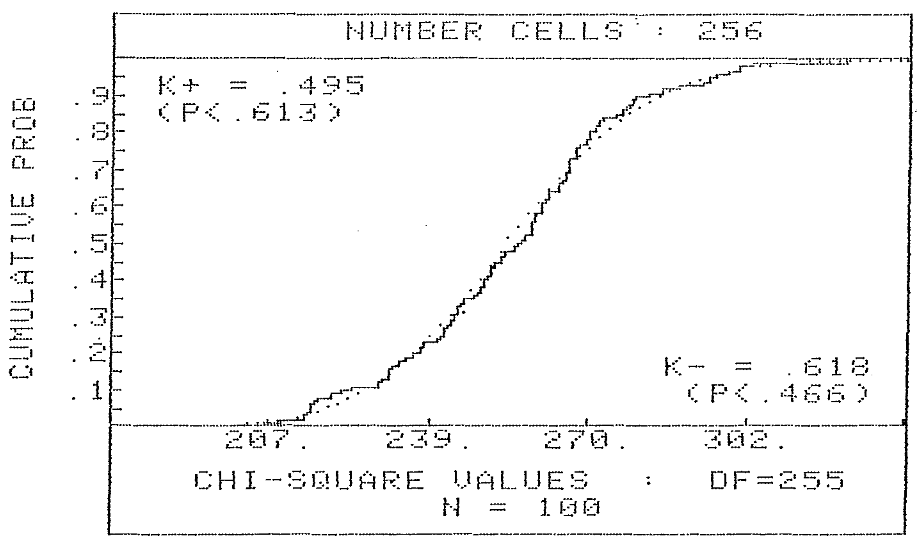
TOTALS

NO. CELLS	CHI-SQ VALUE	PROBABILITY
2	.167	.683
4	.323	.956
16	9.052	.875
256	270.554	.241




NUMBER CELLS : 4
K+ = .707
(P< .368)
K- = .365
(P< .766)
CUMULATIVE PROB
.9
.8
.7
.6
.5
.4
.3
.2
.1
2.32
4.63
6.95
9.26
CHI-SQUARE VALUES : DF=3
N = 100


NUMBER CELLS : 16
K+ = .172
(P< .943)
K- = .721
(P< .354)
CUMULATIVE PROB
.9
.8
.7
.6
.5
.4
.3
.2
.1
6.91
13.7
20.5
27.3
CHI-SQUARE VALUES : DF=15
N = 100


NUMBER CELLS : 256
K+ = .495
(P< .613)
K- = .618
(P< .466)
CUMULATIVE PROB
.9
.8
.7
.6
.5
.4
.3
.2
.1
207.
239.
270.
302.
CHI-SQUARE VALUES : DF=255
N = 100

SERIAL ANALYZER

General Description

The Serial Analyzer on the "PsiLab // Random Analysis" disk will perform a serial analysis on the output of a PsiLab // random number generator (RNG). The program ("SERIALYZER.II") automatically generates and analyzes a specified number of data sets, each comprised of a specified number of trials. A trial consists of obtaining one random bit (0 or 1) from the RNG. The RNG is sampled at a specified rate (frequency) and the resulting "bitstream" is saved in memory. Once the assigned number of trials has been completed, the distribution of the random bits obtained in that data set is then examined for serial dependence at depths of 1, 2, 4, and 8.

In a stream of binary digits, the frequency of the binary digits may be exactly MCE while the pattern of the stream may be nonrandom. For example, the following bitstreams have "perfect" frequency counts but are not random sequences: (10101010101010...) (11001100110011 00...) (111000111000111000...).

For a binary sequence to be adequately random, it should contain an appropriate number of occurrences of doublets, triplets, quadruplets, etc. This means that certain "patterns" of bits are expected and should by chance appear in a truly random sequence. For example, at the doublet (depth of two) level, there are 4 possible "patterns" of bits: 00, 01, 10, and 11. At the triplet (depth of three) level there are 8 possible "patterns" of bits: 000, 001, 010, 011, 100, 101, 110, and 111. At the quadruplet (depth of four) level there are 16 combinations, and at a depth of 8 (the deepest that the PsiLab // Serial analysis goes) there are 256 possible bit combinations.

The serial analysis counts the number of occurrences of each "pattern" at each depths 1, 2, 4, and 8. The serial analysis does this by first gathering the number of trials for one data set specified by the experimenter. For example, if the experimenter set the parameters as 100 data sets of 20000 trials at a delay of 5, the program would first collect the 20000 trials at the sampling frequency specified by delay=5. This bitstream is then analyzed in the following manner: Starting with the first bit, a "window" which is 8 bits long is examined. Suppose the first 20 bits of the random sequence were 10001101101101111001. The first pass of the analyzer would examine the first 8 bits--10001101--and count all doublets (occurrences of 00, 01, 10, and 11) then quadruplets and octuplets (depth of 8).

At the doublet level we have this distribution:

pattern	frequency of occurrence
00	2
01	2
10	2
11	1

At the quadruplet level we would have this distribution:

pattern	frequency of occurrence
0000	0
0001	1
0010	0
0011	1
0100	0
0101	0
0110	1
0111	0
1000	1
1001	0
1010	0
1011	0
1100	0
1101	1
1110	0
1111	0

This tallying process is carried out up to strings which are 8 bits long. After this has been completed the "window" is slid over one to the right-- The next sequence examined is 00011011. This process is repeated until the entire bitstream of 20000 trials has been examined.

A generalized Serial test (Good, 1953, 1957), which corrects for the overlapping counts (that the same bits are counted more than once) is conducted on the obtained data, and chi-squares indicate whether the obtained bitstream was within the expected distribution.

After collecting the number of data sets specified in the setup program, a Kolmogorov-Smirnov test is conducted on all the samples collected to observe their "goodness of fit" to the expected distribution.

Fig. 3

Sample Printout (with raw data)

SERIAL ANALYSIS

CURRENT PROGRAM: SERIALYZER VERSION 5.4

BOARD NO. 8 DATE: 12/12/84 TIME: 7 PM
NO. SAMPLES: 100 NO. TRIALS/SAMPLE: 20000
BIT MASKED: 7 DELAY RATE: 1 SLOT: 4

SAMPLE NO. 1

SERIAL RESULTS

DEPTH	D.F.	CHI-SQ VALUE	PROBABILITY
1	1	0	1
2	2	1.497	.473
4	4	3.345	.502
8	64	47.298	.942

TOTAL NO. RUNS : 9914 (Z = -1.216)

SAMPLE NO. 2

SERIAL RESULTS

DEPTH	D.F.	CHI-SQ VALUE	PROBABILITY
1	1	.125	.724
2	2	.326	.85
4	4	6.671	.154
8	64	77.182	.125

TOTAL NO. RUNS : 10033 (Z = .467)

SAMPLE NO. 3

SAMPLE NO. 99

SERIAL RESULTS

DEPTH	D.F.	CHI-SQ VALUE	PROBABILITY
1	1	2.247	.134
2	2	2.227	.328
4	4	2.025	.731
8	64	60.813	.59

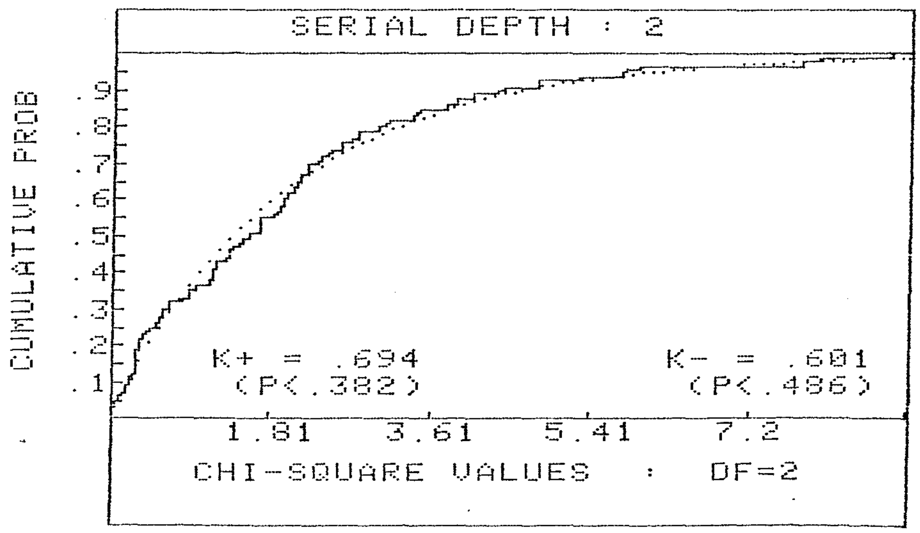
TOTAL NO. RUNS : 10011 (Z = .156)

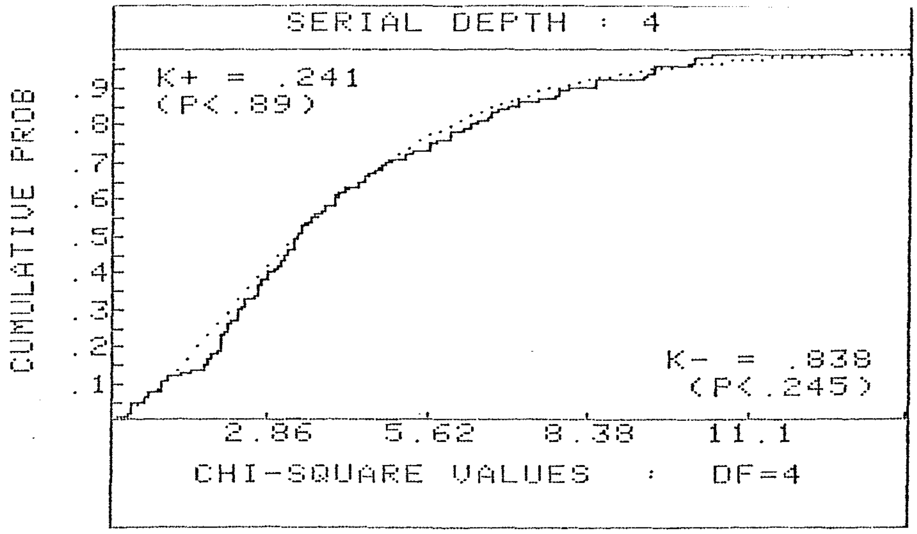
SAMPLE NO. 100

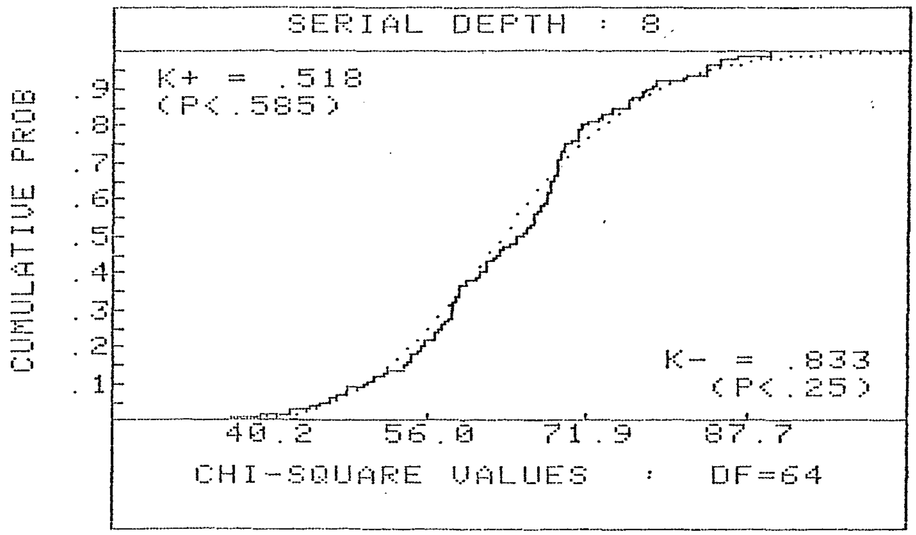
SERIAL RESULTS

DEPTH	D.F.	CHI-SQ VALUE	PROBABILITY
1	1	4.682	.03
2	2	8.801	.012
4	4	4.185	.382
8	64	58.898	.657

TOTAL NO. RUNS : 10144 (Z = 2.036)




SERIAL DEPTH : 4
K+ = .241
(P<.89)
K- = .838
(P<.245)
CUMULATIVE PROB
.9 .8 .7 .6 .5 .4 .3 .2 .1
2.86 5.62 8.38 11.1
CHI-SQUARE VALUES : DF=4


SERIAL DEPTH : 8
K+ = .518
(P<.585)
K- = .833
(P<.25)
CUMULATIVE PROB
.9 .8 .7 .6 .5 .4 .3 .2 .1
40.2 56.0 71.9 87.7
CHI-SQUARE VALUES : DF=64

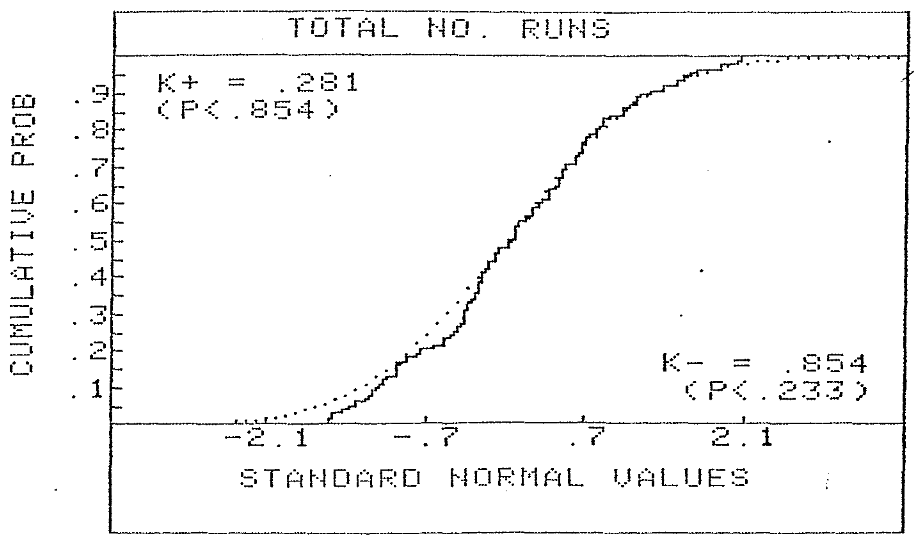

TOTAL NO. RUNS
K+ = .281
(P<.854)
K- = .854
(P<.233)
CUMULATIVE PROB
.9 .8 .7 .6 .5 .4 .3 .2 .1
-2.1 -.7 .7 2.1
STANDARD NORMAL VALUES

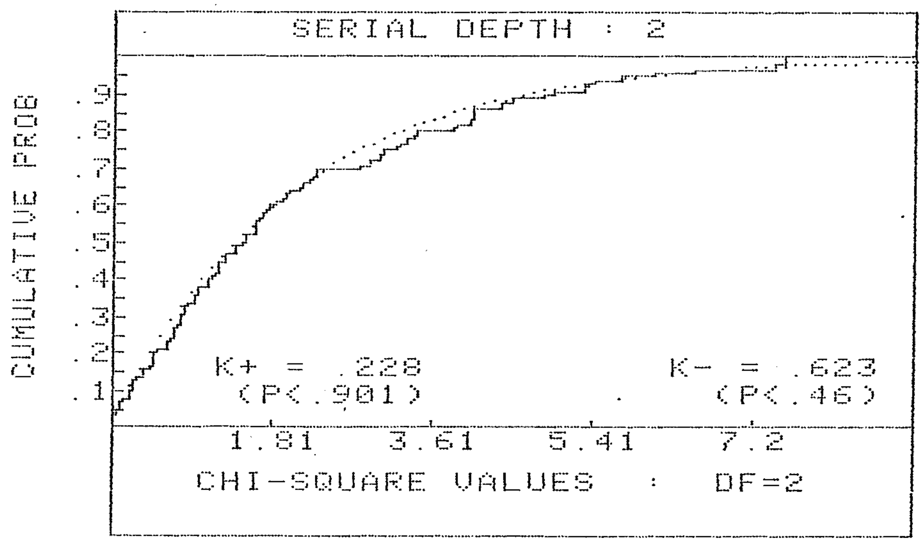
Fig. 4

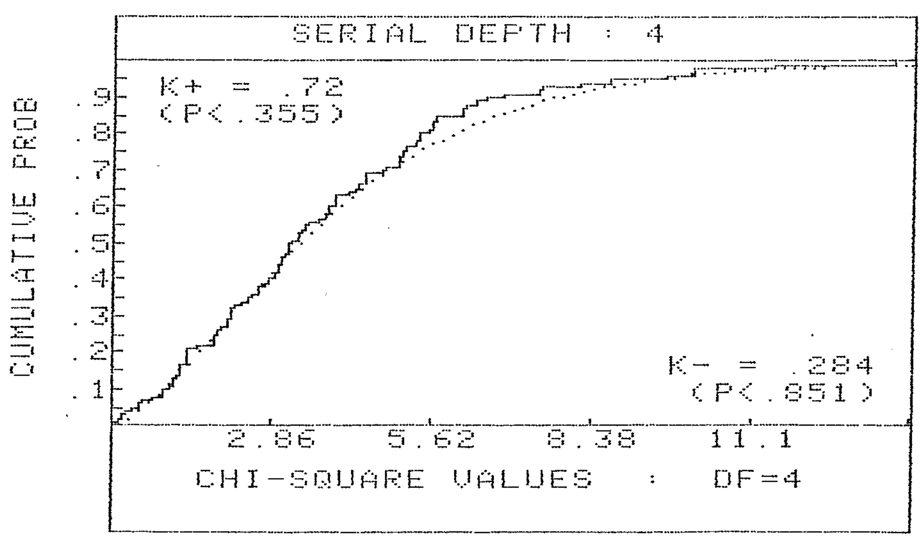
Sample Printout (no raw data)

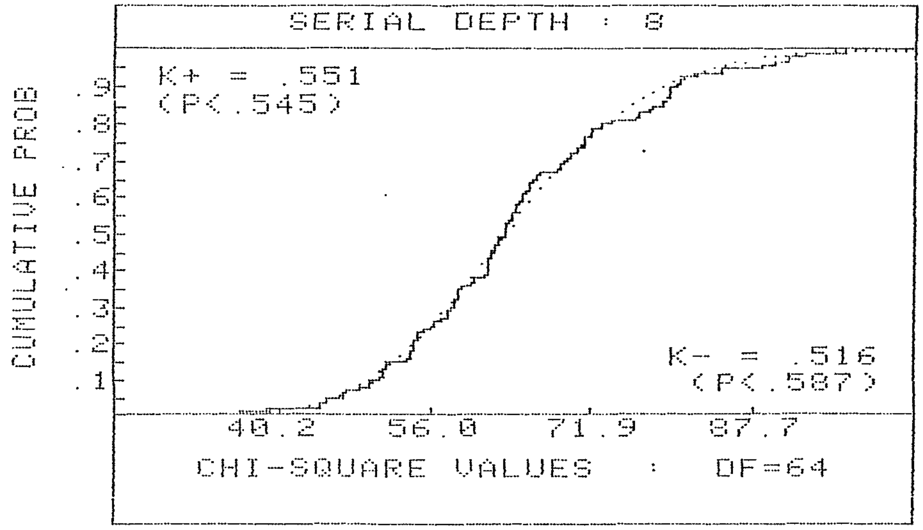
SERIAL ANALYSIS
==============

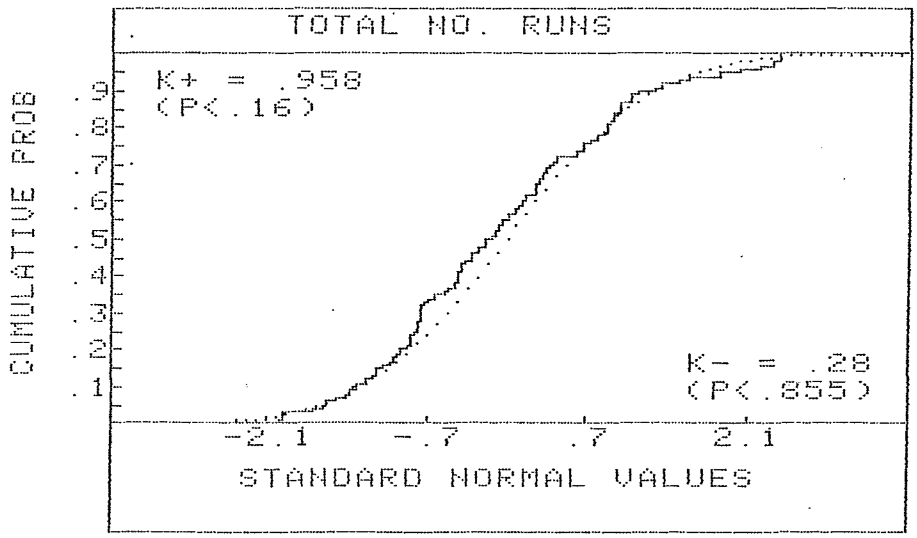
CURRENT PROGRAM: SERIALYZER VERSION 6

BOARD NO. 3 DATE: Ø1/Ø8/85 TIME: 11 AM
NO. SAMPLES: 1ØØ NO. TRIALS/SAMPLE: 2ØØØØ
BIT MASKED: 7 DELAY RATE: 1 SLOT: 4






SERIAL DEPTH : 8
CUMULATIVE PROB
K+ = .551
(P<.545)
K- = .516
(P<.587)
.9
.8
.7
.6
.5
.4
.3
.2
.1
40.2
56.0
71.9
87.7
CHI-SQUARE VALUES : DF=64


TOTAL NO. RUNS
CUMULATIVE PROB
K+ = .958
(P<.16)
K- = .28
(P<.855)
.9
.8
.7
.6
.5
.4
.3
.2
.1
-2.1
-.7
.7
2.1
STANDARD NORMAL VALUES

FREQUENCY/SERIAL ANALYZER TUTORIAL

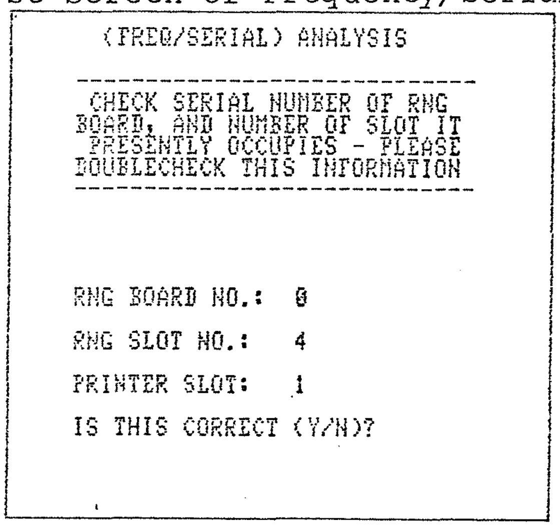
--> IMPORTANT <--
BEFORE DOING ANYTHING WITH THE PSILAB // RANDOM ANALYSIS DISK, MAKE SEVERAL "WORKING" COPIES USING THE "DISK MUNCHER COPY PROGRAM" ON THE PSILAB // UTILITIES DISK. DO <u>NOT</u> USE THE MASTER COPY FOR ANYTHING EXCEPT MAKING WORKING COPIES. STORE THE MASTER IN A SAFE PLACE!"

--> IMPORTANT <--
APPLE //e USERS SHOULD <u>NOT</u> USE APPLE SLOT 3 FOR THEIR RNG's. IF YOU ARE USING AN 80 COLUMN TEXT CARD, THE RNG WILL NOT WORK!

<u>GETTING STARTED</u>

When you boot your PsiLab // Random Analysis disk you will see the logo and then a menu which allows you to select Frequency or Serial Analysis. After selecting the appropriate analysis, you will be presented with the screen shown in Fig. 1.

Fig. 1. First Screen of Frequency/Serial Analyzer



Your disk is already configured with your RNG board number (as they are assigned by PRL). The number on your screen should agree with the number found on your RNG. Press "return" to accept this default value and the cursor will move down to RNG slot number. The default value is 4, but you may use any slot from 1-7 (with the exception of slot 3 in Apple //e's). If you are going to use slot 4, press "return." If you are going to use another slot, type in that number and press "return." The cursor will then move to the printer interface slot. If your printer interface is in slot 1 (the default), then press "return" to accept the default.

If your interface is in another slot, enter that number in response to the prompt "PRINTER SLOT:" and then press "return".

When you answer "Y" to the question "IS THIS CORRECT?" the values that you have specified (if you have made any changes) will be saved to the disk and will be the default values <u>for this disk until you change them.</u>

<u>SETTING THE DATE AND TIME</u>

You will now be prompted to input today's date. Input the month (a number from 1 to 12), the day (a number from 1 to 31) and then the last two digits of the current year. You will then be prompted to input the current hour (a number from 1 to 12) and specify whether that is "AM" or "PM" (or if 12 o'clock to specify noon or midnight).

<u>SETTING THE AMOUNT OF DATA TO BE COLLECTED</u>

The next screen (Fig. 2) will allow you to specify the amount of data to be collected in this Frequency/Serial analysis.

Fig. 2 Setting the Quantity of Data to be Collected

```
--------------------------------------
THIS PROGRAM IS SET TO OPERATE IN AUTO
MODE. IT WILL SAMPLE THE RNG TO
OBTAIN SEVERAL SETS OF DATA IN SUCCES-
SION. IN EACH SET THE NUMBER OF TRIALS
WILL BE THE SAME.
--------------------------------------

(PRESS RETURN TO ACCEPT DEFAULT VALUE)

 NO. OF DATA SETS:  100

 NO. TRIALS / SET:  20000

 RNG DELAY RATE :   5
```

The Frequency/Serial Analyzers collect data in sets composed of a specified number of trials. The <u>number</u> of data sets collected impacts on the Kolmogorov-Smirnov test which will be conducted at the end of the data collection: the more data sets you collect (up to about 150 sets), the closer the empirical graph should be to the expected curve in the K-S test. (After about 150 points the curve will not change appreciably). The PRL default is 100 data sets. We suggest a minimum of 40 and no more than 200. With 100 data sets the K-S graph will be generally very close to the expected curve at all levels and deviations from randomness are easy to spot by eye.

Both analyses require a minimum of 2 data sets. The Frequency Analyzer requires at least 2500 trials per set (so that each cell in the chi-square has an expected frequency of about 10). The Serial Analyzer requires a minimum of 3000 trials per data set.

SETTING THE DELAY

You will now be asked to input an INTEGER number between 1-255 which will determine the SAMPLING FREQUENCY for the Analyzer (i.e., the number of times that the RNG is sampled per second). Appendix 1 of the Psi Invaders section of the PsiLab // manual presents a table of conversions between the values selected here and the approximate effective sampling frequency.

As the RNG produces random numbers at the rate of 32000 BITS/SECOND (4000 INDEPENDENT BYTES/SECOND), it is not recommended that byte sampling be attempted at frequencies much higher than 4000 Hz., or a delay of 7. The Serial Analyzer may be sampled with a delay of 1, with serial independence between bits sampled.

The PRL default sample size (number of trials/set) is 20000. Using a delay of 5-10 this number only takes a few seconds to be generated. It takes many minutes, however, between samples as the computer does calculations on the obtained data and (optionally) saves the results to disk. It is recommended that large data collections be obtained "overnight" or when the laboratory activity is at a bare minimum.

SAVING RAW DATA TO DISK (FREQUENCY ANALYZER ONLY!!!)

The Frequency Analyzer (optionally) allows raw data (frequency counts for each cell) to be saved to a datadisk in drive 2. (There will be a PsiLab // utility program available in 1985 which will analyze this raw data.) It takes almost one whole disk to save the raw data from a collection of 100 datasets. TO SUPPRESS THIS FUNCTION, SPECIFY "N" TO THE PROMPT "SAVE RAW DATA?" AND THE SYSTEM WILL NOT REQUIRE DISK DRIVE 2.

SELECTING THE SAMPLE BIT (SERIAL ANALYSIS ONLY!!!)

The Serial Analysis works by sampling the RNG (which produces an 8-bit value) and saving only one bit from each byte for analysis. The program allows the user to specify which bit (from 0-7) will be sampled.

PRINTING OUT RAW DATA

Whether or not you choose to "save raw data", you may obtain a hardcopy printout of it by answering "Y" to the prompt "DO YOU WANT TO PRINT RAW DATA?" A data collection of 100 datasets uses approximately 26 pages of paper. If you choose to not print raw data you will end up with just 2 pages giving the K-S summaries of the entire data set.

ENTERING COMMENT LINE

Oftentimes you may run randomness tests under special conditions which you might want to record. You can do this by entering the information as a comment which will be printed out with the data on the header. You may enter up to 40 characters of information. If you choose not to enter a comment, nothing will be printed on the printout.

PRINTING THE PRINTOUT HEADER

The program will now print the header on the printout. The header contains all of the information you specified in the setup. If the header is printed correctly, answer "Y" to the prompt "IS THE HEADER OK?" and the analyzer will begin data collection. If you answer "N" then the setting of parameters will begin anew. A typical data collection using 20,000 trials/set takes approximately 1.8 minutes/set using a delay of "5" for the Frequency Analyzer.

SUGGESTED RANDOMNESS TESTING PROTOCOL

We have adopted the approach to randomness testing outlined by Davis and Akers (1974). They discuss three types of testing which we have given specific names to stress their differing purposes. The first two types fall into the category of "verification" and the third type is "simulation." "RNG VERIFICATION" is your insurance that your RNG is indeed approximating the randomness that is assumed. "SIMULATIONS" act as randomness tests which are matched to the experimental conditions to show that differences obtained in experimental conditions were due to the systematic interaction between the program and an experimental subject (and not simply a highly variable, or nonrandom, RNG).

RNG VERIFICATION

Preliminary RNG verification.

We refer to the first type of testing as "Preliminary RNG verification." Davis and Akers state, "When a generator is first constructed and before it is placed into service for serious research, as well as at regular intervals afterwards, it should be checked by generating a sufficiently long sequence of targets and analyzing them by the best methods available. In general, 'sufficiently long' entails four times and preferably ten times the longest test series anticipated for the generator. When a generator is used in a major line of research, more extensive tests of a million digits or more are appropriate." (p. 401)

All PsiLab // RNGs are subjected to a two-part series of RNG Verification testing before they are shipped to PsiLab // researchers. Each unmodified RIPP RNG is tested with the Frequency Analyzer (100 data sets of 20000 trials each), the Serial Analyzer (100 data sets of 20000 trials each), and 100 simulated games of Psi Invaders (10000 trials/game). Any Kolmogorov-Smirnov or chi-square test that reveals potential non-randomness in the empirical distributions leads to further testing. Following these "pre-tests," each RNG is modified by Robert Chevako (NWS Associates, Inc., New Woodstock, N.Y. Details on the modification may be found in the section on "Hardware.") Following modification, each RNG is again subjected to the battery of tests. Any RNG showing a consistent pattern of nonrandomness is returned to Chevako for further diagnosis. The number of trials per data set (20000) was derived from the number of trials obtained in one game of Psi Invaders (as well as other PRL PK games) counting both contingent and noncontingent data trials.

Ongoing RNG verification.

Davis and Akers suggest a second testing procedure which we call "Ongoing RNG Verification" testing. They state, "A second procedure, to check for temporary malfunctions of a generator, should be carried out on a routine basis. These routine tests should be several times the length of a typical experimental series (a good minimum would be four times as long), so that small deviations from randomness could be detected. (A single control series the same length as an experimental series would not be sufficiently sensitive)." (p. 401)

--> IMPORTANT <--

We consider the recommendation to routinely check your RNG for temporary malfunctions extremely important. Though the PsiLab // RNG has been thoroughly pretested, electronic devices DO fail. Failures can be very subtle. Periodic "overnight" testing of RNGs is good insurance that your RNG is fully operational.

Our procedure differs from that suggested by Davis and Akers in an important way: Instead of collecting longer samples of data as a verification, we choose to collect lots of "experiment-sized" chunks of data and use the Kolmogorov-Smirnov test on the outcomes to verify that they indeed conform to the theoretical distribution. Any one (or several) samples is still a sample from a population. Even long tests of randomness (e.g., 1,000,000 digits) are still one sample. Ten such tests, however, may reveal that the tiny positive deviation present in the first sample was also present in all subsequent nine samples, indicating that the RNG has a small, but persistent, bias. The Kolmogorov-Smirnov test is ideal for detecting small, but consistent, deviations from the expected distribution of terminal (end-of-experiment) chi-square or z-scores.

SIMULATIONS

The third type of randomness testing suggested by Davis and Akers are "tests done in the actual test environment (but without subjects).... Control sequences should be analyzed in blocks of about the same length as experimental series and should be performed at the beginning, end, and, when feasible, at a convenient breaking point in a series (determined in advance). In PK experiments, at least four control blocks should be generated, with each the same size as the experimental series." (p. 402)

All PsiLab // experiments (e.g., Psi Invaders) will have a built-in option to run "matched" simulations. In Psi Invaders, for example, the simulation program is the same as the experimental program except that no feedback of any sort is provided on the screen, and all decisions which are made by the participant in an experimental game (i.e., laser position and firing) are made instead by a pseudorandom number generator.

Simulations should be matched on as many experimental parameters as feasible (e.g., delay factor, number of games) as well as on as many extraneous factors as possible (e.g., time of day, ambient disturbances, etc.).

RECOMMENDATIONS

We recommend that Ongoing RNG Verification be undertaken before, during, and after each experimental series. These data should be reported to show that the RNG device in the experiment indeed approximates the randomness that is assumed. We further recommend that experimental data be matched with an identical, or several identical, set(s) of simulations. Differences between the "experimental" and "simulations" could then be viewed as the critical comparisons, as opposed to matching the experimental data against a theoretical baseline only.

REFERENCES

Davis, James W., and Akers, Charles. Randomness and tests for randomness. Journal of Parapsychology. 1974, 38(4), pp. 393-407.

UNDERLYING THEORY

Introduction

When we evaluate the RNG by comparing its output during a psi test with the random distribution we expect, we are assuming that its "ordinary" performance, when no attempt is being made to "influence" it, is random in the sense that the trials are independent of each other and the output on any individual trial cannot be predicted from the outputs of previous trials because all possibilities are theoretically equally probable. The random analysis tests provided with PsiLab // are tests of these assumptions.

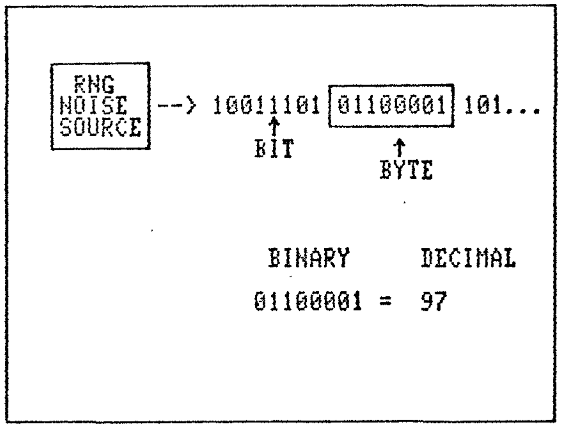
There is an extensive literature in computer science on the generation and testing of sequences of random numbers. Knuth (1981) provides an excellent overview, and Nance and Overstreet (1972) offer a more comprehensive bibliography. A good deal of this literature is concerned with computer-generated sequences of pseudorandom numbers; these sequences are produced by completely deterministic algorithms, but appear to be random in that a given trial's output cannot be predicted from the results of previous trials. Most of the statistical procedures that have been devised to assess the degree of randomness in pseudorandom sequences apply equally well to the outputs of "true" random processes such as the thermal noise generators used in the PsiLab // RNGs. It appears that a small selection of the fundamental randomness tests, tailored to our particular needs, will prove adequate.

Frequency Tests

Looking At "Bytes"

A single output from the RNG's noise diode is either a 0 or a 1 -- a single binary-digit, or "bit." The random numbers we use are derived by combining eight consecutive bits into a "byte", an eight-digit binary number that is equivalent to a decimal integer between 0 and 255.

FIGURE 1



A Random Number "Byte"

The most fundamental analysis of a sequence of random bytes is a straightforward count of the number of times each of the 256 possible byte-values occurs. Over a large number of trials, _n_ , we would expect each value to occur n/256 times by chance. The observed frequencies can be readily compared with the expected frequencies by a standard chi-square test with 255 _df_.

Grouping Bytes Into "Cells"

When an experimental procedure uses less than 256 possibilities, the byte values are grouped into _cells_, and the chi-square test compares the obtained and expected frequencies of the cells. PSI INVADERS, for example, uses a binary task, analogous to a heads-vs-tails coin toss. In this case, the byte is divided into two cells, with byte-values from 0 to 127 in one cell and values from 128 to 255 in the other. With two cells, the expected frequencies become n/2 , and the chi-square test has _df_ = 1. With four cells, the byte-values are grouped from 0 to 63, 64 to 127, 128 to 191, and 192 to 255; the expected frequencies are n/4 , and the chi-square test has 3 _df_.

(Grouping the byte-values this way amounts to using only some of its bits. In the two-cell example, only the eighth bit, the one that changes from 0 to 1 as the decimal number goes from 127 to 128, actually counts [see Figure 2]. In a four-choice [four-cell] situation, only the seventh and eighth bits count, and so on.)

FIGURE 2

BINARY	=	DECIMAL
Bit number:		
8 7 6 5 4 3 2 1		
0 0 0 0 0 0 0 0		0
0 1 1 1 1 1 1 1		127
1 0 0 0 0 0 0 0		128
1 1 1 1 1 1 1 1		255

The Eighth Bit Distinguishes Between
Top-Half and Bottom-Half "Cells"

PsiLab // Analyses

The PsiLab // Frequency Analysis automatically evaluates four different groupings of the byte-values from each "control" run, using 2, 4, 16, and 256 (i.e., ungrouped) cells, generating chi-squares with df = 1, 3, 15, and 255.

Serial Tests

Serial Analysis

A natural extension of these simple frequency count analyses involves checking for possible serial dependencies by examining pairs, triples, quadruples, etc. of succesive random numbers. The frequency with which the various pairs, triples, etc., actually occur can be compared with their expected frequencies.

Straightforward chi-square tests are inappropriate, however, because the frequency counts are based on overlapping sets of serial observations. Suppose, for example, that the triplet 101 occurs. Since the next step is to move the "triplet window" one bit to the right, the next triplet will have to begin with 01, and the one after that (moving the "window" one more bit to the right) will have to begin with 1. The statistical analysis must take into account the fact that the bits 01 are involved in more than one frequency count.

The proper analysis for this "generalized" serial test was derived by Good (1953, 1957) and is presented in an appendix to Davis & Akers (1974). The statistic involved is chi-square distributed, with the number of degrees of freedom depending on the serial depth.

The deeper one goes, however, the greater the computational demands. In order to stay within the memory limitations of an

Apple II computer and still be able to sample random numbers at a reasonable rate, the PsiLab // Serial Analysis program examines only one of the eight bits in each random byte generated. Restricting the analysis to a single bit enables us to examine the data to a serial depth of 8 (i.e.: singlets, doublets...octuplets). The user can specify which bit to test; in a binary task, for example, we recommend testing the eighth ("high") bit since this is the critical bit in the two-cell breakdown mentioned above. If desired, however, separate serial tests can be done on each of the eight bit-positions.

PsiLab // Analyses

Generalized Serial Test: The PsiLab // serial analysis program counts the frequencies of singlets, pairs, quadruplets, and octuplets, generating adjusted chi-squares with df = 1, 2, 4, and 64.

Runs Test: The generalized serial analysis is supplemented by a simple runs test (see, for example, Gibbons, 1971, pp. 50-58). In this test the program counts the number of times the bit-sequence changes from 0 to 1 or from 1 to 0. (For example, there is one such change in the sequence 111000, two in the sequence 110011, etc.) The total number of "runs" of consecutive 0's or 1's, which is one more than the number of changes, has a distribution which is approximately normal, and is converted to a standard Z-score for probablilty assessment.

Kolmogorov-Smirnov Tests

Introduction

In order for our statistical tests to be highly sensitive to small but persistent deviations from randomness, they should be applied to data obtained from a large number of observations -- the larger the better. On the other hand, the use of very large samples tends to "average out" and mask any short-term nonrandom tendencies. To resolve this conflict, we follow a procedure recommended by Knuth (1981) which is designed to reveal both local and global deviations from randomness.

We begin with several samples of moderately large size, each yielding a single observed value of the test statistic. The cumulative frequency distribution of these observed test values is then compared to the theoretical distribution of the test statistic. That is, if the test being evaluated is the chi-square from four-cell frequency analyses, the empirical distribution of chi-squares from many four-cell frequency analyses is compared with the theoretical distribution of chi-square with three df. A Kolmogorov-Smirnov test (K-S test) is used to make this comparison. This test measures how far the observed distribution deviates from the theoretical distribution, and gives the probability of obtaining a deviation that large. A statistically significant deviation indicates that the empirical distribution probably does not represent a sample from this theoretical distribution and that the RNG is not behaving in an adequately "random" manner. (In the example used above, for instance, we'd conclude that the obtained chi-squares are not typical of the chance output of a four-cell system.) Notice that this conclusion is not based on a single "bad" (i.e., significant) chi-square value, but on the fact that a set of chi-square values are not distributed as expected by chance.

PsiLab // K-S analyses are accompanied by a graph of the empirical and the theoretical distributions. When significantly large values of the K-S statistics indicate a poor fit between the two distributions, a visual inspection of these graphs can yield additional information.

The details of calculating and interpreting the K-S statistics and graphs are discussed in the next sections.

(It appears that use of the K-S test represents a more sophisticated approach than methods often used in the past, including the rather sound procedure illustrated in Davis & Akers [1974, pp. 404-5]. For a detailed description of the K-S test and a comparison with the chi-square goodness-of-fit test, see Knuth [1981, pp. 45-56] or Gibbons [1971, pp. 73-87]. Some good general remarks can also be found in Goodman [1954]. The article by Kaner, Mohanty, and Lyons [1980], mentioned in the discussion of the K-S statistics [below], describes a calculation error that is found in many social-sciences statistics texts.)

Cumulative Distribution Functions

A K-S evaluation of the degree to which an observed distribution deviated from a theoretical distribution is a "goodness of fit" test. The chi-square test is also a goodness of fit test, in that obtained values are compared to expected values. Chi-square is appropriate when the underlying data come from a discrete distribution; the K-S test is used when the underlying distribution is continuous. Rather than divide the data into independent cells and compare the observed and expected frequency counts in the various cells, the K-S test works with cumulative distribution functions (CDF's). The empirical CDF is constructed from the observed data values and is compared to the theoretical CDF. Essentially, the K-S statistic measures the largest deviation between the two functions.

FIGURE 3

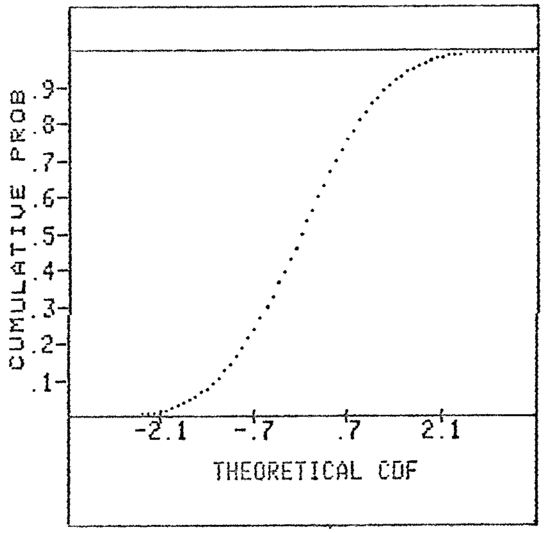
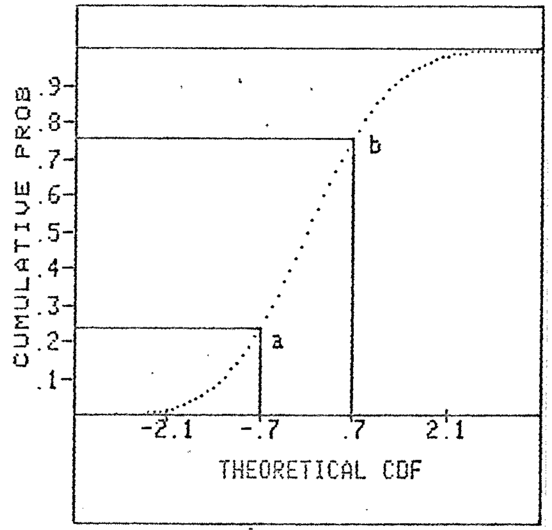


FIGURE 3a

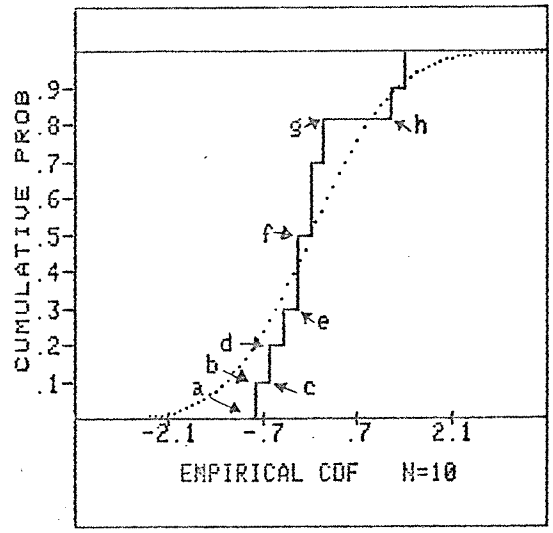


<u>The</u> <u>Theoretical</u> <u>CDF</u>: Figure 3 shows a theoretical CDF. The numbers on the X-axis are values of the statistic being measured; if this were the theoretical CDF of, say, chi-square with 15 <u>df</u>, the numbers on the X-axis would be chi-square values. (Actually, the X-values in Figure 3 are clearly not chi-square values, since half of them are negative.) The Y-axis shows cumulative proportions -- as shown in Figure 3a, for example, the height of the curve at the point marked "a" indicates that approximately 24% of the X-values fall at or below -.7 and the height of the curve at the point marked "b" indicates that aproximately 76% of the X-values fall at or below +.7. These cumulative proportions can be stated as probabilities (e.g., the probability of obtaining an X-value equal to or less than +.7 is .76), and we can define the CDF as a curve giving the probability that the random variable X is less than or equal to some specified value.

FORMALLY:

If we let F denote the theoretical CDF, then for each real number c, F(c) gives the probability that an observed value of X will be less than or equal to c. In symbols, F(c) = Pr{ X <= c }.

FIGURE 4



<u>The Empirical CDF</u>: Figure 4 shows an empirical CDF for a sample of size 10; it is superimposed on the theoretical CDF from Figure 3. Again, the numbers on the X-axis are values of the statistic being measured and the Y-axis shows cumulative proportions. Like the theoretical CDF, the curve rises as it moves to the right, starting at $y = 0$ on the left and rising to $y = 1$ on the right. While the theoretical curve rises in a continuous smooth manner, the empirical CDF, especially when based on relatively few cases, resembles a rising staircase.

The empirical CDF "staircase" is constructed by ordering the n observed values of the statistic being measured, from smallest to largest. In order, the ten X-values in the distribution shown in Figure 4 are -.8, -.6, -.4, -.2, -.2, 0, 0, +.2, +1.0, and +1.2. Since there are no values smaller than -.8, the "staircase" begins at the point marked "a", indicating that the probability of obtaining a value smaller than -.8 is 0. There is one value of -.8, so the probability of obtaining a value of -.8 <u>or less</u> is one in ten, or .1, and the first "tread" of the staircase begins at the point marked "b" (coordinates $x = -.8$, $y = .1$). There are no more X-values between -.8 and -.61, so the "tread" continues to the point marked "c", indicating that the probability of obtaining a value of -.61 or less is still .1. The next X-value is -.6. Since there are two values equal to or smaller than -.6 (i.e., -.6 and -.8), the next "tread" begins at the point marked "d" (coordinates $x = -.6$, $y = .2$), indicating that the probability of obtaining a value of -.6 or less is .2.

FORMALLY:

If we label the empirical CDF for a sample of size n as Fn , then for each real number c , $Fn(c)$ will be the probability that any item in our sample will be less than or equal to c. Order the observed X-values from smallest to largest; call the ordered X-values $x(1)$, $x(2)$,..., $x(n)$. If c is less than $x(1)$, there are no items less than or equal to c and $Fn(c)$

must be 0; if c is equal to or greater than x(n) , all the items are less than or equal to c and Fn(c) must be 1. Values of c between x(1) and x(n) must fall on an X-value , x(j) , or between two X-values, so that x(j) <= c < x(j+1). The total number of data values at or below c is therefore j , and Fn(c) = j/n .

Note that the staircase "riser" between points "e" and "f" in Figure 4 is twice the height of the "riser" between points "a" and "b". This is because the sample contains <u>two</u> instances in which the X-value is -.2, so that while the proportion of cases at or below -.4 is 3/10 or .3, the proportion of cases at or below -.2 is 5/10 or .5. Similarly, the long "tread" between point "g" and point "h" occurs because there are no X-values between +.2 and +1.0.

FIGURE 5

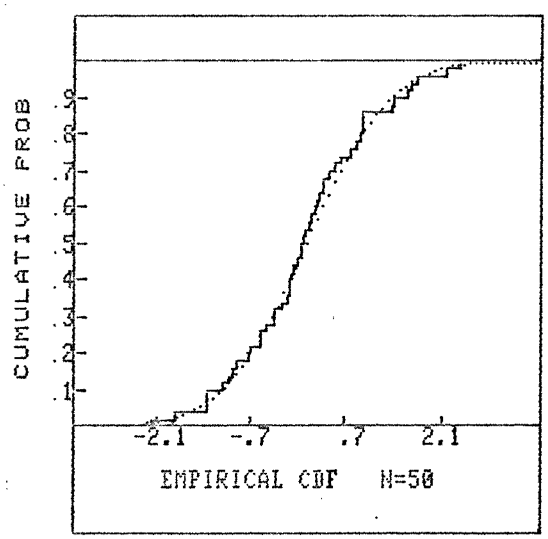
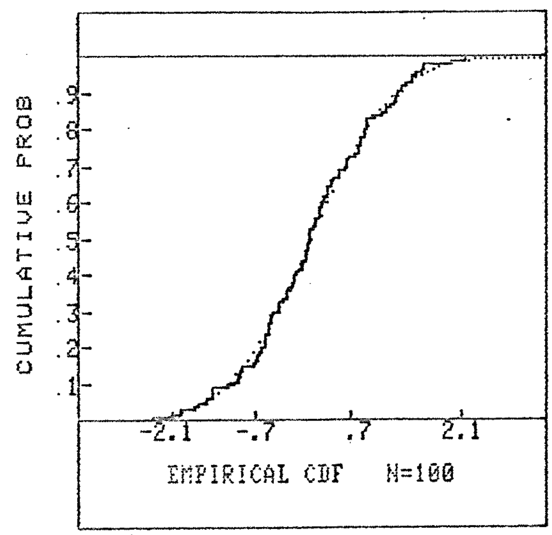


FIGURE 6



<u>Comparing CDFs</u>: Figures 4, 5, and 6 show empirical CDFs based on samples of size 10, 50 and 100. The empirical CDFs are shown superimposed on the theoretical CDF from Figure 3. In Figure 4, the "staircase" appearance of the empirical CDF is quite pronounced. It is still evident in Figures 5 and 6, but less exaggerated; the empirical curves in Figures 5 and 6 (with samples of size 50 and 100) seem to provide reasonable approximations to the theoretical curve. In general, we can expect that an empirical CDF based on a (sufficiently) large sample will give a good fit to the theoretical CDF for the population from which the sample was drawn, and the larger the sample the better the fit. By the same token, if the sample being examined is drawn from a population <u>other</u> than the one described by the theoretical CDF, its empirical CDF should not be a good fit to the theoretical CDF (unless, of course, the population from which the sample really does come is very similar to the one described by the theoretical CDF).

<u>The K-S Statistics D+ and D-</u>: It soon becomes clear that

simply "eyeballing" the graphs is not an adequate way to judge how well the empirical CDF fits the theoretical CDF (partly because it is difficult to make proper adjustments for sample size), and that we need some objective measure. The K-S statistics provide such a measure.

Basically, the K-S statistics are obtained by measuring the largest vertical distance between the two curves. Actually, we compute two K-S statistics: one measures the largest vertical deviation of the staircase above the theoretical curve, and the other measures the largest deviation of the staircase below the theoretical curve. These maxima are usually labelled D+ and D- .

FORMALLY:

D+ is the largest value of $j/n - F(x(j))$, for $j = 1, 2, \ldots, n$, and D- is the largest value of $F(x(j)) - (j-1)/n$.

$F(x(j))$ is the height of the theoretical CDF at the X-coordinate corresponding to the leftmost end of the empirical CDF "tread" that extends from $x(j)$ to $x(j+1)$. j/n is the height of the empirical CDF at that tread. In Figure 4, for example, if $x(j) = +.2$, the calculation $j/n - F(x(j))$ compares the height of the empirical CDF at point "g" with the height of the theoretical CDF immediately below point "g". D+ is the largest vertical distance between the curves when we look only at regions where the empirical CDF is above the theoretical CDF,.

The formula for D- compares $F(x(j))$ with the previous "tread" of the empirical CDF "staircase" -- that is, with the "tread" defined by $x(j-1)$ rather than the "tread" defined by $x(j)$. In Figure 4, with $x(j) = -.6$, the calculation $F(x(j)) - (j-1)/n$ compares the height of the theoretical CDF just above point "d" with the height of the empirical CDF "tread" between points "b" and "c." D- is the largest vertical distance between the curves when we look only at regions where the empirical CDF is below the theoretical CDF,.

(Kaner, Mohanty, and Lyons [1980] point out an error in the discussions of the K-S test in many social-sciences textbooks. While the tables of critical values of D in these texts are based on the formulas given above, the texts' formulas use the same tread to calculate D- that was used to calculate D+ . Defining D- this way, however, yields critical values that differ from those in the tables.)

The K-S Statistics K+ and K-: The statistics D+ and D- have the same distributions, and their values are always between

0 and 1. The standard deviations of these statistics, however, depend on n ; they contain a factor proportional to the square root of n in the denominator. Knuth (1981) recommends normalizing the K-S statistics by multiplying D+ and D- by the square root of n . The <u>normalized K-S statistics</u>, called K+ and K- , are the ones used in the PsiLab // Random Analysis programs. The main advantage of using K+ and K- is that their standard deviations are independent of n. <u>Note that, unlike D+ and D-, K+ and K- can exceed 1</u>.

The values of K+ and K- determine how well the empirical CDF fits the theoretical CDF. If these values are reasonably small then we have a good fit; in our RNG testing, a good fit should lead us to conclude that the RNG has given us a data sample that probably does come from a population of random values. On the other hand, if either K+ or K- is too large, we can infer that the RNG's outputs may not be acceptably random.

How large K+ or K- must be to indicate inadequate randomness is decided in the usual manner by calculating the probability associated with obtaining a value at least as large as the one we have observed. If this probability is "too small" (say, less than .05) then the observed value of K+ or K- is "too large". The probabilities can be calculated from the theoretical CDF of the K-S statistics; formulas for this distribution are found in Knuth (1981, pp. 49 and 56), and the proper computational procedures have been included in the PsiLab // K-S programs. In the hardcopy printouts produced by the PsiLab // Random Analysis programs, each K+ and K- is accompanied by an appropriate one-tailed probability.

<u>Note that critical values for K+ and K- can not be obtained from tables of D+ and D- . The PsiLab // Random Analysis programs provide exact probabilities for K+ and K-</u> .

<u>Interpreting K-S Graphs</u>

The values of K+ and K- are only summaries indicating the goodness of fit of the empirical and theoretical CDFs. Additional information can be obtained by visually comparing the graphs of the two functions. For example, the K-S statistics provide information about the maximum vertical deviations between the two curves, but they say nothing about where these deviations occur; there are circumstances in which such information can be quite valuable. For example, a significantly large value of K+ or K- may or may not point to seriously nonrandom behavior of an RNG, depending on how the large deviation arose. For this reason, the PsiLab // K-S statistics are accompanied by graphs of the CDFs.

<u>Probability and CDF Slopes</u>: What distinguishes one CDF from another is the way the <u>slope</u> changes from place to place on the curve. The slope measures the rate at which the curve rises over a specified interval. In Figure 3, for example, the curve rises more steeply between points "a" and "b" than it does between point "b" and the right-hand end of the curve. The slope of the

interval from point "a" to point "b" is larger than that of the interval from point "b" to the right-hand end.

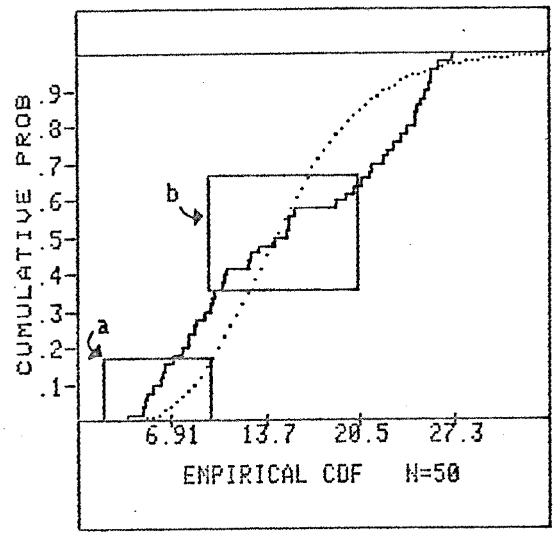
The CDFs we are working with graph the probability of obtaining data values at or below each X-coordinate. Where the curve is rising slowly, there must be relatively few data values in that range of the X-axis so that the probability of finding values in that range only increases a little. Where the curve rises quickly, the fact that the probability of finding values in that range is increasing sharply means that there are many data points in that range. The extra height of some of the staircase "risers" in Figure 4, for example, which increases the steepness (the slope) of the graph near those points, occurs because there are more X-values at those points than there are at points with smaller "risers."

<u>The Standard Normal Distribution</u>: The CDF of the standard normal distribution is a good illustration of the relationship between slope and probability. We are used to seeing this distribution presented as a bell shaped curve. The graph of the CDF for the normal distribution, however, is not at all bell shaped; it rises smoothly from left to right, steeply at its center and less steeply near its ends. In fact, the theoretical CDF in Figure 3 <u>is</u> the CDF for the normal distribution. This curve and the familiar bell shaped curve present essentially the same information, but they present it in rather different ways. The usual bell-shaped "normal curve" (which is the graph of the "probability density function" - the PDF rather than the CDF) is so familiar that we interpret it almost without thinking: to get a rough idea of the relative probability that X will take a value in some interval, we glance at the height of the curve over that interval. (Actually, the probability is equal to the area under the curve over that interval, but the height is a good rough indicator.) Near the center, the bell-shaped curve is highest, indicating high probabilities for intervals near the center, while small intervals out in either of the tails are associated with low probabilities, since the curve itself is so low there.

To obtain similar information from the graph of the CDF, we use <u>slope</u> rather than <u>height</u> as a visual cue. As Figure 3 shows, the CDF for the normal distribution rises most steeply in the center, where the bell-shaped curve curve is highest, but very gradually out near the tails, where the bell-shaped curve is very low. In fact, the height of the PDF curve at any given point actually gives the slope of the CDF curve at that point.

<u>Comparing CDFs</u>: Thus, to get a "feel" for the "shape" of a probability distribution from the graph of its CDF, we train our eye to attend to the slope of the curve. In comparing two CDF curves, we compare their steepness at corresponding intervals, looking to see where each rises sharply and where more slowly rather than where they have the same height.

FIGURE 7

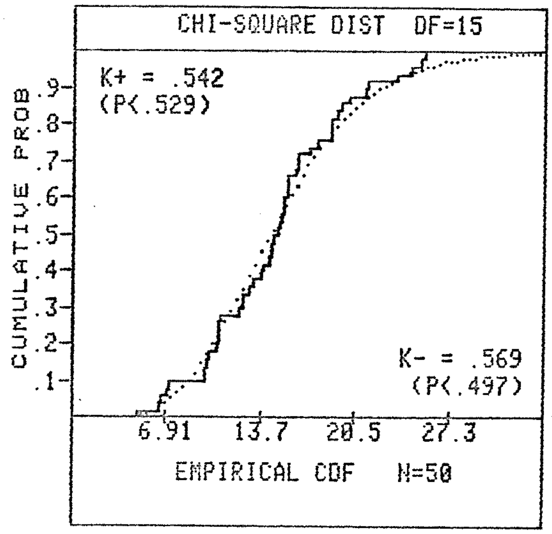


When the empirical CDF rises more slowly than the theoretical CDF over the same interval, as it does in the area marked "b" in Figure 7, we can see that we have fewer data points in the interval than would be expected if our sample really did come from this theoretical distribution. Similarly, the empirical graph rises more steeply than the theoretical curve in the area marked "a" , and we see that the observed frequency exceeds the expected frequency for that interval.

Such visual comparisons can be helpful in forming a rough impression of how well the empirical CDF fits the theoretical curve, although we use the more quantitative measure of goodness of fit provided by the K-S statistics K+ and K- to actually test the hypothesis that our sample was drawn from this particular theoretical distribution. In cases when the values of K+ or K- are unacceptably large, visual inspection of the graphs is especially helpful. Visual inspection is important because large values of K+ or K- can arise in several different ways, and some of these are of far less concern to us than others are. For example, a large K+ value can arise because there are too many very small data values. If the data values are chi-squares obtained from randomness tests, getting too many very small values might be quite acceptable, indicating that in this situation our RNG produced a distribution of byte values that was unusually close to the norm. In many circumstances, this would cause far less concern than a situation in which there were too many large chi-square values. Thus it will be a good idea to obtain some experience in interpreting the graphic displays, especially in cases when either K+ or K- is large.

Figures 8 through 13 illustrate various aspects of interpreting K-S graphs. Each of these graphs compares the theoretical CDF for chi-square with 15 df to an empirical CDF based on 50 RNG samples.

FIGURE 8

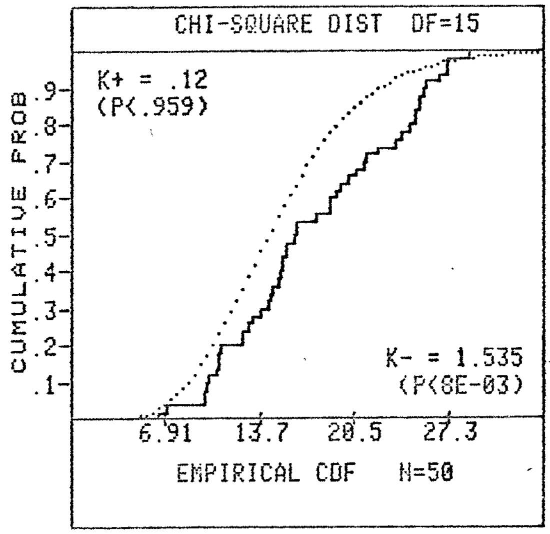


<u>Small K+ and K-</u> : The probabilities for the observed values of K+ and K- in Figure 8 are both around .5, indicating that the underlying data are about as close to being "middle of the road" as is possible. This suggests that there should be a fairly good fit between the empirical and theoretical curves. The graph seems to bear this out, since the empirical curve never deviates very much from the theoretical curve. It does wander about, as one would expect of an empirical curve, sometimes moving above the graph of the theoretical CDF, and sometimes below, but it never wanders very far. In fact, the empirical curve never gets any further above the theoretical curve than the distance measured by the value of K+ -- which is the definition of K+ . Similarly, K- tells us how far the empirical curve wanders below the theoretical curve.

When both K+ and K- are "small" (e.g., $p > .05$), the empirical CDF <u>must</u> be a good fit to the theoretical CDF, for the small K+ and K- <u>mean</u> that the empirical curve never gets very far above or below the theoretical curve. Instead, it lies entirely within a narrow band centered about the theoretical curve. We can think of the K+ and K- whose one-tailed probabilities are each equal to .05 as defining a "confidence band" on either side of the theoretical CDF. Empirical CDFs that produce <u>non</u>significant K+ and K- values will lie entirely within this band. If we make our significance criterion more stringent, using, say, .01 rather than .05, the confidence band is narrower, and the empirical curve must hug the theoretical curve more tightly.

Suppose, however, that one (or both) of the K-S statistics is large. This must mean that the empirical CDF is a poor fit to the theoretical curve, but there are a number of ways in which this can happen, and they tell us different things about the RNG's output.

FIGURE 9



Large K-: The empirical CDF pictured in Figure 9, yields a very large value for K- and a very small value for K+ . The one-tailed probability for this K- is less than .008; we would expect to get a K- this large by chance only 8 times in a thousand tries. The p-value for this very small K+ is nearly .96; we would expect to get a K+ at least this big simply by chance 96 times out of a hundred.

The graph is consistent with these K- and K+ values. The empirical curve is hardly ever above the theoretical curve, and even then only slightly, so we would expect a pretty small value for K+. But the empirical curve does wander pretty far below the theoretical curve (the maximum vertical deviation occurs at approximately X = 22), so we would expect a large value of K- . Just how large (in terms of p-values) is not clear from the picture, of course, but the really deviant fit suggests a highly significant value.

The graph also gives us information that we could not get from the K- and K+ values and their associated probabilities. For example, the empirical curve lies almost entirely to the right of the theoretical curve. The average data value is larger than it "should" be, which suggests that this empirical distribution probably comes from a population whose mean is higher than the mean of the theoretical distribution for chi-square with 15 df.

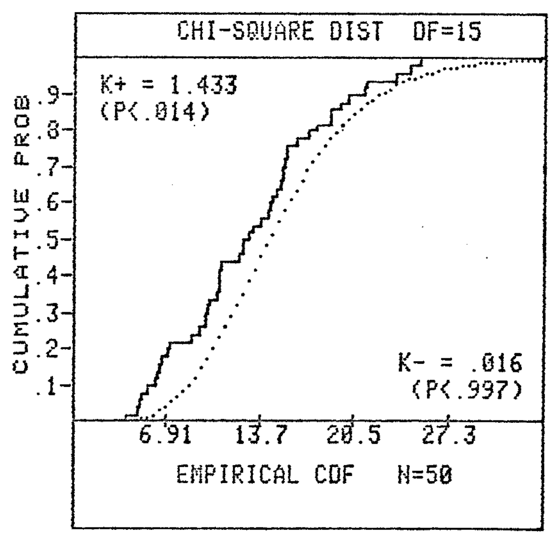
Quite a bit more can be seen by comparing slopes. The long "tread" over the interval from (approximately) 7 to 10 indicates a complete lack of data values in this interval, yet the same interval on the theoretical curve has a moderately steep slope. This discrepancy is partly offset by the steep rise of the empirical curve between (roughly) 10 and 12, but this is followed by another long "tread". Overall the empirical distribution seems to be deficient in data values less than about 13 or so. Similarly, the empirical curve is flat between 15 and 19, while the theoretical curve still has a large slope, indicating a scarcity of data values in this range. (The long "treads" from 21 to 23, however, do not indicate as much of a deficiency, because the slope of the theoretical curve over that interval is much smaller than it had been earlier.)

On the other hand, the empirical curve rises quite sharply from 23 to 26, just as the theoretical curve is flattening out; there are far too many data values in this range than there "should" be. In other words, it seems that the bad fit and significantly large K- occurs because there are <u>too few small data values and too many large ones</u>.

Suppose that these data values are chi-squares (df = 15) from frequency-analysis tests of an RNG. The chi-square values indicate how well the frequencies of the random numbers produced by the RNG on each test fit the frequencies expected by chance; the larger the chi-square, the poorer the fit. The differences between the empirical and theoretical CDFs indicate too few really good fits (small chi-squares) and too many fairly deviant ones (large chi-squares). It would be clear that the RNG is not functioning acceptably in these samples.

<u>Note that poor RNG performance of this sort might well pass unnoticed without a K-S analysis.</u> For example, suppose the RNG produced far more moderately large chi-square values than expected but only rarely gave a value large enough to be <u>individually</u> significant. If we looked only at whether or not the individual chi-squares were significantly large, the RNG might appear quite satisfactory, but with the focus shifted to the full set of chi-square values, as in a K-S analysis, such abberant behavior would be revealed.

FIGURE 10

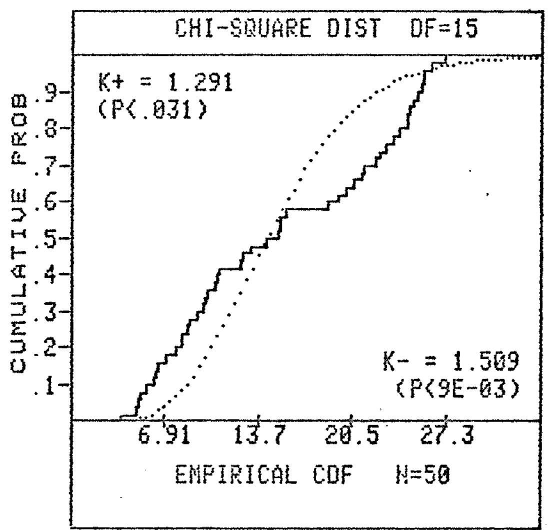


<u>Large K+</u>: Figure 10 shows another one-sided example; this time K+ is significantly large ($p < .014$) and K- is extremely small. As in Figure 9, we can see from the graphs that the values obtained for K+ and K- do make sense; we can see also that the large value for K+ seems to be attained at a data

value of about 7. This time, the empirical curve lies entirely to the left of the theoretical curve, so the empirical mean must be less than the theoretical mean. (Figures 9 and 10 make good teaching examples, but it is unusual for one curve to lie entirely to one side of the other. In general, it makes more sense to focus on slopes and the amount of vertical deviation than it does to look for overall left or right shifts.)

The major discrepancies in slope in Figure 10 seem to be in several intervals (5 to 7, 10 to 12, 14 to 16) where the empirical curve rises far more sharply than the theoretical curve, and a few, higher, intervals (16 to 19, 20 to 23) where the empirical curve is flatter than the theoretical one. This indicates that there are more data values than would be expected in the lower intervals, and fewer in the higher intervals -- the significantly bad fit here seems to be due to an overabundance of small chi-square values and not quite enough large ones.

FIGURE 11



<u>K+ and K- Both Large</u>: Figure 11 provides an example where both K+ and K- are significantly large ($p < .031$ and $p < .009$). An examination of the graphs quickly yields insight into what is happening here. There are both too many small data values and too many large ones, and not enough moderate-sized values. Contrast the empirical curve to the theoretical one: notice its sharp rise on the far left (say, from 5 to 8), its very shallow slope in the middle (from 12 to 20) and another sharp rise on the right (especially from 24 to 26).

Would this indicate unacceptable RNG behavior? Definitely, yes; such an RNG would be unsatisfactory simply because the excess of large chi-square values indicates that it deviates from theoretical expectation much too often.

(Such extreme swings might indicate that an erratic or defective electronic component in the RNG is malfunctioning intermittantly. "Diagnoses" like this are only suggestive, though; the statistics we are examining are several levels removed from the raw output of the RNG.)

Does Large K Always Mean Many Extreme Data Values? The overabundance of big data values in Figure 11 is accompanied by a large value of K-, and the large K+ value results from an excess of very small data values. Similarly, there are too many big data values and a large K- in Figure 9, and too many small data values and a large K+ in Figure 10. Is the apparent relationship generally true?

It is true that too many very small data values will yield a large K+, while too many very big ones result in a large K- . But it is not true that a large K+ always means too many small data values, or that a large K- always means too many large ones. Our illustration will focus on K-.

FIGURE 12

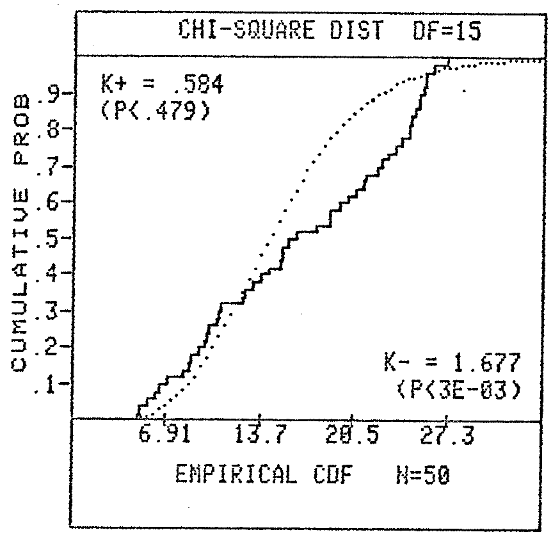
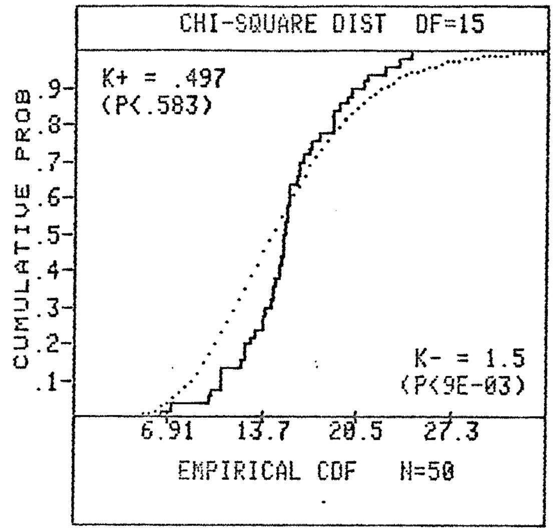


Figure 12 certainly lends further support to the idea that an excess of large data values is associated with a large value of K-. This time, K+ is neither too small nor too large (with a p-value around .5), so the size of K- can't be due to peculiarities in K+ . Judging from the slope of the empirical curve, small data values seem to be occurring at about the expected rate, middle values are too infrequent, and very large ones much too frequent. It looks as though the value of K- is attained somewhere around 20 (i.e. this is where the maximum vertical deviation seems to occur).

Notice that, since the height of the empirical curve at any point *is* the percentage of data items accounted for up to that point, the fact that empirical curve is "low" in the middle means that fewer than the expected percentage of data values have been accounted for -- which, in turn, means that there is a "high" percentage of data values above that point. ("Low" and "high", here, are relative to the theoretical CDF.) The fact that there are so many very big data values is responsible for the empirical curve being so low just before these values, when the unusually large number of big data values have not yet been accounted for. In fact, whenever we have a great many very large data values, the graph of the empirical CDF will be rather low just before these values occur. This low value of the empirical curve forces a large vertical deviation below the theoretical curve, resulting in a large value of K-.

FIGURE 13



An excess of large data values will produce a large value of K-. However, we should also be aware that large K- values can arise in other ways, so we should not simply look at K- and ignore the details of the graph. Figure 13 illustrates another situation in which K+ is "middle of the road", and K- is significantly large ($p < .009$). Yet Figure 13 looks quite different from Figure 12. This time, the large value of K- results from too few small data values rather than too many large ones. As a result of the lack of small values, far too many data points were still unaccounted for at the left end of the empirical curve, forcing it to be much lower than the theoretical curve. The deficiency is made up by an excess of medium-sized (but still individually nonsignificant) data values, and there don't seem to be many more moderately large and very large values than are expected. We would have no trouble concluding that an RNG producing the data shown in Figure 12 was not giving sufficiently random outputs, but we might be less concerned about one producing the data shown in Figure 13. In other words, just examining the values of K- and K+ in not enough for us to understand what is happening.

Recommendations for K-S Testing

There are other reasons for continued attention to the K-S graphs. For one thing, it is useful to have some feel for your RNG's range of typical behavior. This permits a more intelligent examination of its behavior in experimental tasks, as well as in control tasks. It is also possible that these analyses may be useful in comparing data from experimental and control conditions, or in examining results across subjects, or in a evaluating a series of tasks with an individual subject. There is no way to tell in advance if such analyses will be fruitful. Preliminary investigation is needed, and an informed judgement is indispensable in evaluating the data to decide if more extensive K-S analyses are worthwhile. And practice and experience is the only way to develop an informed judgement. Even if you do not need to worry about developing new applications of K-S analyses, it is still appropriate to gain familiarity with the tools you use.

The K-S test gives us a perspective on RNG behavior which we cannot gain by scrutinizing single data samples, no matter how great a number of trials are contained in the sample. Small but consistent patterns are revealed and the test statistic's variability is examined. At PRL we conduct "Ongoing RNG Verification" tests to assess the behavior of RNG that are being used in experiments. After a number of Frequency or Serial Analysis datasets are collected, a K-S analysis examines the distributions of results at various degrees of freedom. A single significant K-S pattern is not enough to indicate a problem with your RNG, however, since each K-S analysis is still only one sample of RNG output values. If, for example, a K-S test on Serial Analyses at depth 2 yields a significant K- , we suggest that you repeat the set of tests (i.e., same number of datasets, with the same number of trials per dataset) to see if you obtain the same pattern at least two out of three times before concluding that the RNG is not behaving satisfactorily.

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PSILAB //

PSI INVADERS

Psi Invaders

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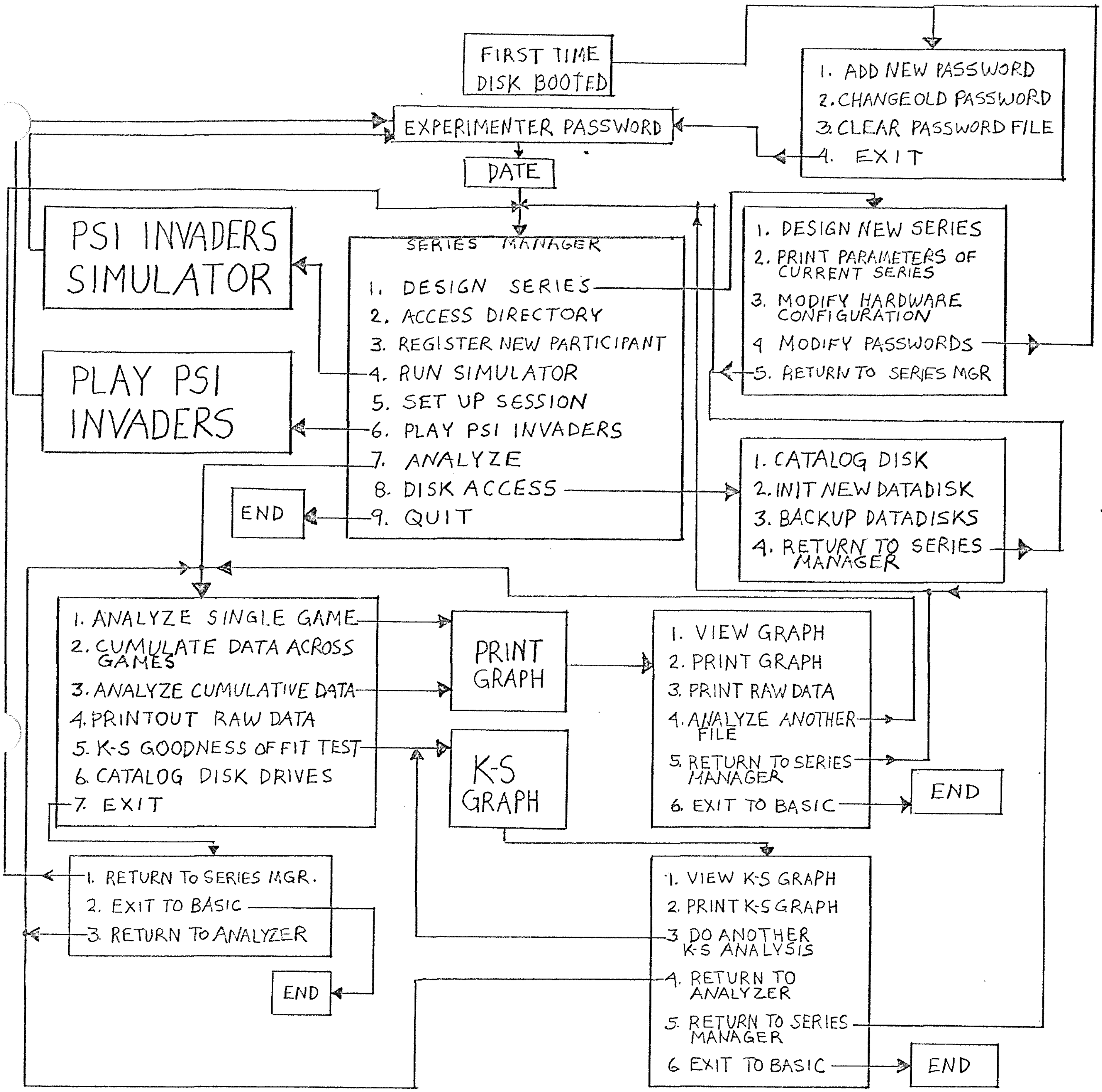
ACKNOWLEDGEMENTS

This disk contains a high-speed operating system called Diversa-DOS(tm), which is licensed for use with this program only. To legally use Diversa-DOS with other programs, you may send $30 directly to: DSR, Inc., 5848 Crampton Ct., Rockford, IL 61111. You will receive a Diversa-DOS utility disk with documentation.

This program incorporates machine language commands from The Toolbox Series, products of Roger Wagner Publishing, Inc.



PSI INVADERS PROGRAM FLOWCHART

Psi Invaders
GAME EXPLANATION

RNG Task

Psi Invaders is an adaptation of the popular arcade game "Space Invaders". The object of the Psi Invaders game is for the player to "shoot" incoming invaders while trying to avoid being "hit" by them. Players press a button on the game controller (game paddle) to "fire" their "laser". The psi task in Psi Invaders is to get the buttonpress to fire the laser, which is described as being "old and frequently misfires." Laser firing is contingent upon the output of the random number generator (RNG). With each press of the game controller button, the RNG is sampled one "run", with each run consisting of 100 binary trials; where $p = .5$. The high bit of the RNG sample byte is compared to a target bit which is complemented (oscillated) every sample (i.e, the target sequence will either be 101010... or 010101...). If the RNG sample bit and the target bit are the same, the sample is counted as a hit. Fig. 1 shows an example of how "hitting" is measured. Run scores of 51 hits or greater are required for the laser to fire. Run scores of 50 or less result in a "misfire". Only run scores (not the 100 binary trials which compose run scores) are saved as raw data.

Fig. 1. Example of 1 Run of 100 Binary trials

SAMPLE NUMBER->	1	2	3	4	5	6	7...100
TARGET BIT	1	0	1	0	1	0	1...0
RNG SAMPLE BIT	1	1	0	0	0	1	1...0
OUTCOME	HIT	MISS	MISS	HIT	MISS	MISS	HIT...HIT

Scoring

The "game score" is displayed at the bottom center of the game screen. The run score MCE is 50; the theoretical standard deviation is 5. Run scores ranging from 51-54 are worth an equal number of game points. Run scores from 55-59 (1-1.8 sd) yield 1000 points; 60-64 (2-2.8 sd) yields 2000 points; 65 and higher (3+ sd) yields 3000 points. A player is penalized 1000 points for run scores less than or equal to 40 (-2 sd) as well as losing 1000 points every time they are hit by the invaders. Game scores are only roughly correlated with the psi score (z-score) as points are given for all positive run scores while points are only subtracted for being hit and for negative run scores of 2 standard deviations or greater (to avoid negative game scores). Hence, it is possible for a player to receive a very large game score and have a chance, or below-chance, z-score.

Feedback

Players are rewarded with extra points for directional runs (greater than 50 hits/100) and receive audio feedback for all button presses. Players lose points for 2 standard deviation or greater negative run scores and all run scores of less than 51 receive an audio "misfire" sound. At the end of the 100-run game (when the "ammo" is depleted), the cumulative z-score (based on 10000 binary trials) is compared to an experimenter-preset "win threshold." If the player's z-score is greater than or equal to the win threshold, the player sees the "winner" animation sequence. Within a series of consecutive games (i.e., games played without returning to the Series Manager module) each win results in the win threshold being incremented by the experimenter-preset "win increment". For example, if the win threshold is set at .8 and the win increment at .2, a z-score of .9 will result in a winning game and the win threshold for the next game will be a z-score of 1. Setting the win increment at "0" will sidestep this function, allowing the experimenter to fix the threshold at the same value throughout. Setting this value to a negative number will cause the win threshold to auto-decrement. The rationale behind auto-incrementing the win threshold is to "shape" winning behavior, giving the player a low, and realistic, goal and gradually making the goal more "difficult".

Table 1. Psi Invaders Game Scoring

Run score	Points
<= 40	-1000
41-50	0
51-54	51-54
55-59	1000
60-64	2000
65+	3000
Hit by invader	-1000

Instructional set

Psi Invaders may be presented/conceived as either a PK or ESP task. That is, participants may be instructed to think of the task as either a PK task (i.e., feel that with each press they are "affecting" the RNG) or an ESP task (i.e., with each press they are anticipating the "right time" to press the button). Participants may be more comfortable with one of these models and PRL experimental protocol has been to suggest to participants that they model the process the way in which they feel most comfortable.

SETTING UP PSI INVADERS

The first step in setting up an experimental series of Psi Invaders is to BACKUP your Master disk(s).

--> IMPORTANT <--
MASTER DISKS ARE WRITE-PROTECTED AND SHOULD NOT BE USED EXCEPT TO CREATE WORKING DISKS!

MAKING WORKING/BACKUP COPIES

Working (and backup) disks may be created by booting the "PSILAB // UTILITIES DISK" and running the "Disk Muncher" copy program. This program will duplicate a disk in its entirety, including the DOS tracks (tracks 0-2) that are on the disk (or no DOS, in the case of some PsiLab // data disks).

** TO USE THE "DISK MUNCHER" COPY PROGRAM: **

----

1) Boot "PsiLab // Utilities" disk
2) Select "Disk Muncher copy program" from the menu
3) Select #3 (Copy Disk) from Disk Muncher menu
4) Press cntl-V to verify the copy. This will cause the flashing asterisks (*) to move counter-clockwise around the screen.
5) Make sure you have a disk in drive #2- Make sure the disk to be copied is in drive #1
6) Press the "return" key
7) Watch the screen. Any notation on the screen other than a period (.) indicates a read or write error. If all four columns fill with periods, you have a good copy.
8) After copy is made, press "ESC" to return to main menu, or "RETURN" to make another copy.

SETTING UP YOUR WORKING DISK

Upon booting a "virgin" Psi Invaders WORKING DISK (i.e., a COPY of the Master disk) you will first be presented with the "Modify Password" menu (Fig. 2). After creating your password(s), (explained in the following section) the disk will reconfigure itself so future uses will send the user to the standard prompt, requesting the input of a valid password.

Fig. 2. Menu for Modifying Passwords

```
<1> ADD NEW PASSWORD
<2> CHANGE OLD PASSWORD
<3> CLEAR PASSWORD FILE
<4> EXIT
```

CREATING YOUR PASSWORD FILE

To create your password(s), press #1 ("Add New Password") from the menu on the screen. You will be prompted to input your 3 character password. Your password MUST BE 3 CHARACTERS LONG! All alphanumeric characters are valid. Do not use control characters. After typing in your password, which should be something easy for you to remember but not so easy for a participant (even a psychic one) to second-guess, you will be asked if you want to add this password. If you say "Y" then the password will become a valid one. Other passwords can be added at this time by repeating the previous process. Passwords can be added or changed at a later date from within the Series Manager operating system by selecting this menu. Passwords are saved in Psi Invaders game datafiles to indicate which experimenter ran which participant. This allows experimental data to be sorted by experimenter.

--> IMPORTANT <---

AFTER ENTERING YOUR PASSWORD(S), MAKE SURE YOU ENTER #4 (EXIT) TO LEAVE THIS MODULE. THIS WILL CAUSE THE DISK TO BE RECONFIGURED SO THAT SUBSEQUENT USES OF THIS DISK WILL BOOT STRAIGHT TO "ENTER EXPERIMENTER PASSWORD".

CREATING AN EXPERIMENTAL DESIGN

The Series Manager

After booting the system disk and entering your password and the date, you will see the "SERIES MANAGER" menu appear on the screen (Fig 3).

--> IMPORTANT <--
BEFORE DOING ANYTHING ELSE WITH THIS SYSTEM, YOU MUST FIRST CREATE AN EXPERIMENTAL DESIGN BY SELECTING #1 FROM THE MENU.

Fig 3. Psi Invaders SERIES MANAGER Menu

```
PSI INVADERS
SERIES MANAGER
------ -------

<1> DESIGN SERIES
<2> ACCESS DIRECTORY
<3> REGISTER NEW PARTICIPANT
<4> RUN SIMULATOR
<5> SET UP SESSION
<6> PLAY PSI INVADERS
<7> ANALYZE DATA
<8> DISK ACCESS
<9> QUIT

------------
CHOOSE (1-9)
```

I. DESIGNING A NEW SERIES

Select #1 (DESIGN SERIES) from the menu. You will see a submenu (Fig. 4). Again select #1 (DESIGN A NEW SERIES). You will be asked to specify the design parameters for the experimental series.

Fig 4. Design Series Submenu

```
<1> DESIGN A NEW SERIES
<2> PRINT PARAMETERS OF CURRENT SERIES
<3> MODIFY HARDWARE CONFIGURATION
<4> MODIFY PASSWORDS
<5> RETURN TO SERIES MANAGER

  --<CHOOSE A NUMBER>
```

<u>TYPE OF STUDY</u>.

You have three choices for type of study: SCR (screening), PIL (pilot), and FML (formal). (At PRL we use PIL for casual testing and gathering pilot data; SCR for screening for potentially good participants; and FML for collecting formal experimental data). This label will be used throughout this experimental series as a suffix on the datafiles it creates. For example, if you select "PILOT" series, participant John Doe's first game of Psi Invaders will create a datafile called "INV.DOE J.PIL1", while a formal series would create "INV.DOE J.FML1".

<u>MAXIMUM NUMBER OF GAMES/PARTICIPANT</u>.

This sets the maximum number of games each participant will be allowed to do in this series. At the end of the last game in each participant's series, the message "You have completed the series!!!" is shown on the screen. The SERIES MANAGER will then prevent this participant from playing subsequent games in this series. If one attempts to set up a session (#5 in SERIES MANAGER) for a participant who has already completed the series, the message "(Participant's name) has completed the series" will flash on the monitor and will not allow the session to begin.

<u>MAXIMUM NUMBER OF PARTICIPANTS/STUDY</u>.

This sets the series' stopping point. If you try to register a new participant after this number is reached, the message "SERIES FULL!" will be printed to the screen and you will not be allowed to enter further participants.

Z-SCORE CRITERION FOR WIN.

This sets the "win threshold", i.e., the minimum terminal (end-of-game) cumulative z-score necessary to win a game during an experimental session. When using unselected participants, it is generally good to set this parameter relatively low, say .2 to .4, so winning will likely occur within the first session of play.

WIN INCREMENT.

Within each session, every winning game results in the win threshold being incremented by the "win increment," making each subsequent win within this session more difficult. At the beginning of each new session, the win criterion is reset to the original value. Win increment can be set to "0" to hold the win threshold to a fixed value. The win increment can also be set to a negative value to auto-decrement and make subsequent wins easier.

DELAY BETWEEN RNG TRIALS (sampling frequency).

This parameter sets the delay between each of the 100 trials/RNG run, setting the effective RNG "sampling frequency." The numbers used here are in "WAIT routine" units. (The delay uses the Apple monitor "WAIT" routine which is located at $FCA8. A detailed explanation of this function can be found in Apple // Monitors Peeled, Apple Computer, Inc., 1981). The conversions to actual sampling frequencies (in Hertz, or cycles/second) are given in Appendix 1 of this section. The PRL default is a delay of 5 (6700 Hz sampling rate). The Psi Invaders design module will restrict the delay rate to values between 5-15. Values greater than 15 will tend to slow the game play to unacceptable levels. This parameter is an excellent candidate for parametric evaluation.

NAMING YOUR SERIES.

After all parameters have been entered they will be presented on the screen and you will be asked "Use these parameters (Y/N)?" If you want to change any of them, enter "N" and the process will begin again. An answer of "Y" will prompt "SERIES FILE NAME:" where you should enter the name you want for this series. Names may not exceed 12 alphanumeric characters. The first character of the series name must be a letter. After entering your series name, the program automatically creates an empty series directory (which contains participants' names and other information), and the necessary Kolmogorov-Smirnov datafiles on the system disk. (See K-S Goodness of Fit test for more details, Section VII C). You are now (almost!) ready to enter participants into the new directory.

CHECK HARDWARE CONFIGURATION

Before you leave the Design module you should check the hardware configuration which passes values to the game program which must be correct. By selecting #1 (Design Series) from the Series Manager and then selecting #3 (MODIFY HARDWARE CONFIGURATION) you can change the default printer slot from 1 to any value 1-7. The current values will be printed to the screen and you will be prompted whether you want to change them. Most importantly, you should make sure that the RNG slot is the slot in which your RNG is located. The default slot value is 4.

--> IMPORTANT<--
FAILURE TO INDICATE THE CORRECT RNG SLOT WILL CAUSE THE PSI INVADERS GAME PROGRAM TO HALT WITH THE MESSAGE "NO RNG FOUND!"

II. REGISTER NEW PARTICIPANT

After selecting #3 from the SERIES MANAGER (REGISTER NEW PARTICIPANT) you will be presented with a new screen (Fig. 5). On the top it shows "# RECORDS CURRENT" (the current number of participants inclusive of the one you are registering), and "# MAX" (the number you specified in "MAXIMUM NUMBER OF PARTICIPANTS/STUDY" in the series design). Individual participants need only be registered once in the directory; subsequent attempts to register the same participant will result in the message "PARTICIPANT ALREADY REGISTERED!". Input the participant's last name then first initial. Entries are limited to 12 characters maximum for last names. First names are saved as first initial. You will next be asked for "ID number" or identification number. THIS NUMBER MUST BE NUMERALS ONLY (NOT LETTERS) AND MUST NOT EXCEED 3 DIGITS). If the participant has no ID number, press "RETURN" and the number "0" will be assigned.

{A highly unlikely, but possible, circumstance is that you will have two participants with the same last name and first initial. This system would treat these two individuals as the same person. If such a case arises it is suggested that either the last name be slightly altered (e.g., Smith2) or the first initial be altered.}

Fig 5. Screen for Registering New Participant

```
      ENTER NEW PARTICIPANT RECORD(S)
----------------------------------------
# RECORDS CURRENT: 1        # MAX: 40
----------------------------------------
        (PRESS RETURN TO ABORT)

LAST NAME?
```

III. <u>ACCESS DIRECTORY</u>

Selecting #2 (ACCESS DIRECTORY) from the SERIES MANAGER will present a screen asking you for the sort key, i.e., whether you want to see the directory listed in alphabetical order (select "N" for name) or by ID number (select "I"). The directory may be printed to the screen or to your printer.

IV. <u>INITIALIZE A DATADISK</u>

Before you begin collecting data you should initialize a few datadisks. Datadisks are created by the system with no DOS (to leave more space on the disk for data) and are <u>not bootable</u>. To initialize disks, select #8 (DISK ACCESS) from the Series Manager menu. Select #2 (INIT NEW DATADISK) from the sub-menu. Place the disk to be initialized in disk drive #2, and press the key after the prompt. You may repeat this process as many times as you wish.

V. <u>SET UP SESSION</u>

Once participants are registered in the directory, they can play games of Psi Invaders. The experimenter must first set up the session by selecting #5 (SET UP SESSION) from the SERIES MANAGER. Enter the participant's last name, then first name, EXACTLY as it was entered in the directory (12 characters maximum for last names). <u>It is important to enter the complete first name at this point as the full name will later be used to greet the participant in the game program</u>. The program will then show "(Name) has completed N games" if the participant has already completed some games in this series or "(Name) has not done any games to date" if he or she has completed games. A flashing asterisk next to "SET UP SESSION" in the SERIES MANAGER menu indicates that this step has been accomplished.

VI. PLAY PSI INVADERS

Once the session has been set up (#5 in SERIES MANAGER) you are ready to begin the experimental session. Enter #6 (PLAY PSI INVADERS) from the SERIES MANAGER menu. (If you did not set up session first, you will receive the message "SET UP SESSION FIRST!") The program will now check the datadisk in drive #2 to verify that it has adequate free space for the maximum number of possible games for this session (i.e., 20, see below). If there is not adequate space, (the disk can hold 105 games maximum) you will receive further instructions (see INADEQUATE FREE SPACE, Section VIII A, for more details). (Note: PRL recommends no more than 5 games per day per participant when collecting formal data). With adequate disk space you will see the Psi Invaders Logo appear on the screen with the instructions, "Press paddle 0 button to begin." This is the screen the participant should see first. When the participant presses the button on game controller #0, he or she will be greeted by name. The current series' high score will be shown and the participant will have the option to see instructions or begin the game.

--> IMPORTANT <---

BEFORE RUNNING EITHER EXPERIMENTAL OR SIMULATION GAMES THE PROGRAM CHECKS THE DATADISK FOR FREE SPACE. IN THE CASE OF EXPERIMENTAL GAMES, IT VERIFIES THAT THERE IS ENOUGH SPACE TO ALLOW FOR 20 GAMES DURING THE SESSION. (THIS NUMBER WAS CHOSEN TO BE HIGHER THAN THE MAXIMUM GAMES ONE IS LIKELY TO ATTEMPT DURING ONE SITTING. THIS LIMIT WAS SET AFTER ONE PARTICIPANT ATTEMPTED MORE THAN 20 GAMES IN A SITTING AND HAD TO BE LATER SCRAPED OFF OF HIS CHAIR WITH A SPATULA). IF YOU ARE TOLD THERE IS NOT ENOUGH SPACE, AND WANT TO RUN THAT MANY GAMES ANYWAY, SIMPLY INITIALIZE A NEW DATADISK (USING DISK ACCESS, #8 FROM SERIES MANAGER) AND USE THE NEW DATADISK.

VII. ANALYZE DATA

NOTE: A detailed description of the Psi Invaders datafile structure can be found in Appendix 3. A shell of a program which can be used to read Psi Invaders datafiles and can be modified for your own uses can be found on the "PsiLab // Utilities" disk and documentation in the section called "Utilities."

At the end of each experimental session the experimenter can analyze the data, either with the participant present or not, by selecting #7 (ANALYZE DATA) from the SERIES MANAGER. The program will then read disk drive #2 and present the Analyzer menu (Fig. 6).

Fig. 6. ANALYZER MAIN MENU

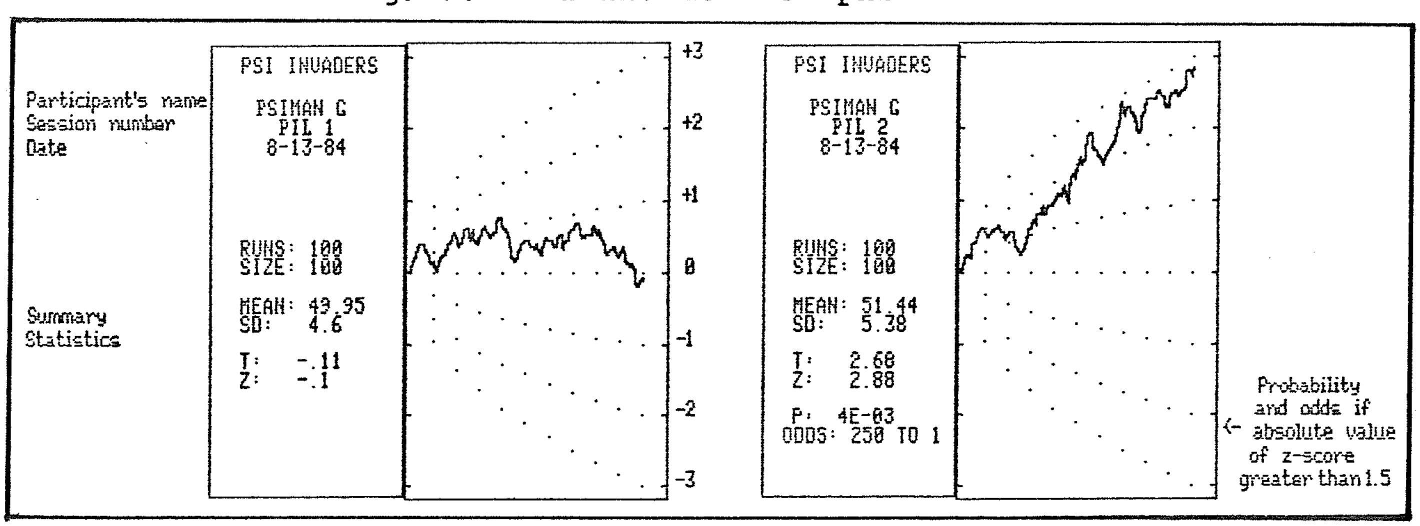
```
        PSI INVADERS
          ANALYZER
          --------

<1> ANALYZE SINGLE GAME
<2> CUMULATE DATA ACROSS GAMES
<3> ANALYZE CUMULATIVE DATA
<4> PRINTOUT RAW DATA
<5> K-S GOODNESS OF FIT TEST
<6> CATALOG DISK DRIVES
<7> EXIT

  --<CHOOSE A NUMBER>
```

Selecting #1 (ANALYZE SINGLE GAME) will allow the experimenter to graph the data from individual as well as simulated games of Psi Invaders. The program will ask you to enter the participant's last name and first initial in this format: "JOHN SMITH" would be entered "SMITH J". A list of John Smith's game files will be presented with index numbers and instructions to "select one" or "press return to abort". Select the number next to the game you wish to analyze then press "return." The program will then read in the selected data file and draw a graph of the cumulative z-score for the game (Fig. 7). If the terminal cumulative z-score has an absolute value greater than 1.5, the probability and odds will also appear on the graph.

Fig. 7. Psi Invaders Graphs



Pressing any key will reveal the analyzer submenu options (Fig. 8).

Fig. 8. Analyzer SubMenu

```
DO YOU WANT TO:

<1> VIEW GRAPH
<2> PRINT GRAPH
<3> PRINT RAW DATA
<4> ANALYZE ANOTHER FILE
<5> RETURN TO SERIES MANAGER
<6> EXIT TO BASIC

  --<CHOOSE A NUMBER>
```

--Option 1 allows you to see the graph again.
--Option 2 prints a copy of the graph to your graphics-compatible printer.
--Option 3 will print out the 100 run scores either to the screen or printer. Two-standard-deviation run scores are bracketed for easy identification.
--Option 4 returns you to the Analyzer main menu
--Option 5 returns you to the SERIES MANAGER
--Option 6 exits to BASIC

Selecting #2 (CUMULATE DATA ACROSS GAMES) from the analyzer main menu allows the concatenation of an individual's data for sessions or complete series as long as all the games are consecutively numbered and on the same disk. (If you want to concatenate datafiles which are on separate disks, use the Apple utility "FID" to transfer all the desired files onto an Invaders-initialized datadisk). This allows the experimenter to look for trends across games which may not be apparent at the single-game level. (Simulated games <u>may not</u> be concatenated with this program. To do so, use the "Invaders Simulator Concatenator" on the "PsiLab // Utilities" disk).

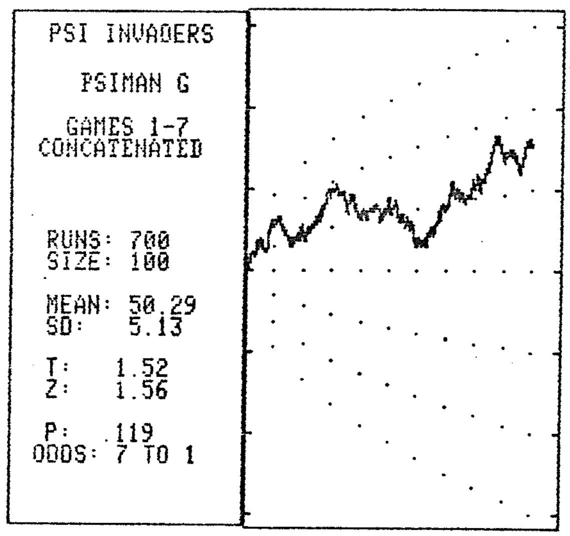
NOTE: YOU MAY ONLY CONCATENATE UP TO 10 GAMES AT A TIME USING THE PSI INVADERS ANALYZER. TO CONCATENATE MORE, USE THE "LARGE N INVADERS CONCATENATOR" ON THE "PSILAB // UTILITIES" DISK!

To concatenate data, specify the type of datafiles you are concatenating (FML, PIL, or SCR) and then enter the participant's name the same way as for individual analyses. (If you are unsure of the datafile type or the name's spelling, you can check it by using #6 "CATALOG DISK DRIVES" from the analyzer menu). You will then be prompted for the starting and ending game number. These are the last numbers on each datafile, e.g., INV.JONES J.PIL3 is game #3. After concatenation is completed you can view the data by selecting #3 (ANALYZE CUMULATIVE DATA) from the analyzer menu.

A. <u>ANALYZE CUMULATIVE DATA</u>

Once data have been concatenated using #2 (CUMULATE DATA ACROSS GAMES) you may graphically present them by selecting #3 (ANALYZE CUMULATIVE DATA). (See Fig. 9) This option requires you to input the participant's name in the usual format (last name, first initial) and then presents an indexed list of available concatenated files for the selected participant. Concatenated files bear the suffix ".CTGT" plus the range of concatenated game numbers. For example, concatenating John Smith's 1st 5 games will produce the file INV.SMITH J.CTGT1-5. Select the desired file by inputting its index number and pressing "return". The program will read in the data and plot it graphically (Fig. 9). After the graph is presented, a keypress will reveal the grapher menu options (see previous description).

Fig. 9 Sample Psi Invaders Concatenated Data



B. <u>PRINTOUT RAW DATA</u>

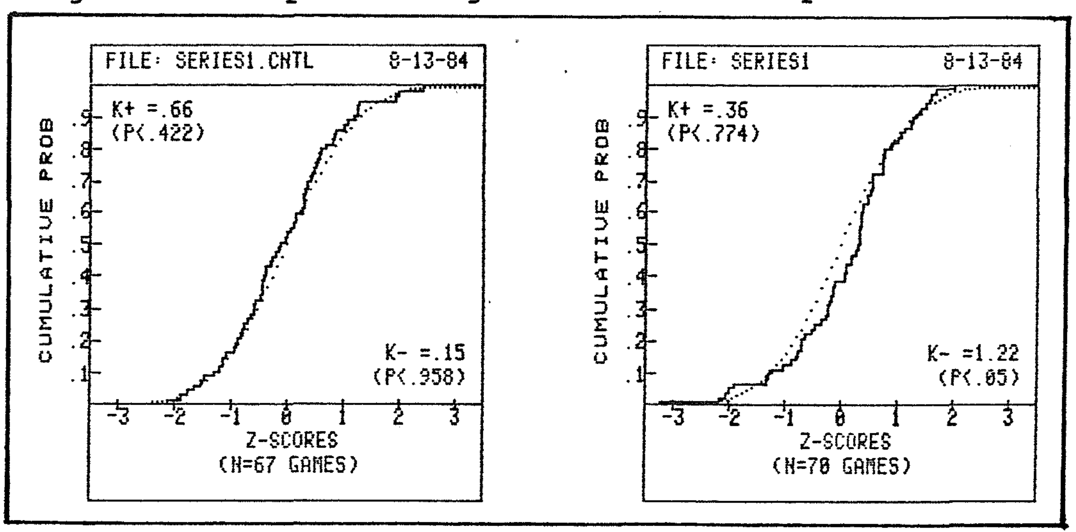
Selecting #4 from the Analyzer main menu (PRINTOUT RAW DATA) allows you to skip the graphing process and view the raw data from individual or concatenated files. The participant's name is entered (last name, first initial) and the program will ask if you want to view "Individual" or "Cumulative" (concatenated) files. Select the type you want and an indexed list of the available files will be presented. Select the number of the desired file and press "return". The data will be read in and the program will ask you whether you want the data printed to "Screen" or "Printer". If you select screen you will be given an opportunity to get a printer hardcopy at the end of the screen print.

C. K-S GOODNESS OF FIT TEST

Selecting #5 from the analyzer menu will run the Kolmogorov-Smirnov Goodness of Fit test module. With every Psi Invaders series created, 2 files are created on the system disk ("Series name.KS" and "Series name.CNTL.KS"). In the first file, terminal (end-of-game) cumulative z-scores from all experimental games in the current series are saved. In the second, terminal z-scores from all simulated (control) games are stored. The K-S test graphs the empirical distribution of these z-scores against the expected distribution and yields 2 statistics. (See Random Analysis Theory Section for an in-depth explanation of the Kolmogorov Smirnov analysis.) Ten games of Psi Invaders are required as a minimum before the program will produce a K-S analysis.

After selecting the K-S option, the program will prompt you for the "date to stamp the K-S graph." This allows you to date the graph with any date, in case today's date is inappropriate. (You may want to date the graph for the date the data were taken). The program will read in K-S filenames from the system disk and present them in an indexed list. To select one, type its index number. (A "0" typed here will return you to the ANALYZER menu). The file will then be read in and the K-S graph presented (Fig. 10).

Fig. 10. Sample Kolmogorov-Smirnov Graphs



A keypress will reveal the menu shown in Fig. 11:

Fig. 11. K-S Grapher Submenu

```
DO YOU WANT TO:

<1> VIEW K-S GRAPH
<2> PRINT K-S GRAPH
<3> DO ANOTHER K-S ANALYSIS
<4> RETURN TO ANALYZER
<5> RETURN TO SERIES MANAGER
<6> EXIT TO BASIC

  --<CHOOSE A NUMBER>
```

--Option 1 allows you to view the graph again
--Option 2 will print a copy of the graph to your graphics-capable printer
--Option 3 will allow you to do another K-S analysis
--Option 4 return you to the ANALYZER program
--Option 5 returns you to the SERIES MANAGER program
--Option 6 will exit to BASIC

D. CATALOG DISK DRIVES

Selecting #6 from the analyzer menu allows you to view the contents of either disk drive #1 or #2. A "free sector count" is displayed at the top of the catalog listing.

E. EXIT

Selecting #7 from the analayzer menu will allow you to:

<1> return to SERIES MANAGER
<2> exit to BASIC
<3> return to the Analyzer

VIII. RUN SIMULATOR

Selecting #4 (RUN SIMULATOR) from the SERIES MANAGER runs the Psi Invaders program in the SIMULATION (control data) mode. (See section on "Random Analysis Theory" for rationale). In this mode, an experimenter-preset number of games are generated without a participant. Participant "decisions" (e.g., location of laser and button firing) are made on a pseudorandom basis by the program. This allows the experimenter to generate "matched" "control" data which can be analyzed with the Psi Invaders analyzer as well as the Kolmogorov Smirnov analysis. During simulations, the only information displayed on the monitor is:

-PSI INVADERS-
DO NOT DISTURB: COLLECTING CONTROL DATA
GAME #x

Upon selection of #4 (RUN SIMULATOR), the program asks for the number of simulated games and then checks the datadisk in drive #2 to make sure that there is sufficient space available.

All simulation games conducted during an experimental series are consecutively numbered in their filenames. If you run 10 simulations on Day 1, when you run simulations on Day 2 the first will be simulation game # 11.

A. <u>INADEQUATE FREE SPACE</u>

Before attempting to run either simulations or experimental games of Psi Invaders, the program will check the datadisk in drive 2 for adequate free space. If it is not adequate, (i.e., doesn't have enough space for either 20 experimental games or the number of specified simulations) a menu will appear (Fig. 12).

Fig. 12. Inadequate Free Space Menu

```
YOUR DATADISK DOESN'T HAVE ENOUGH SPACE
FOR -40- GAMES! THERE IS ENOUGH SPACE
LEFT FOR -10- GAMES.

DO YOU WANT TO:

<1> INIT NEW DATADISK

<2> TRY ANOTHER DISK

<3> DECREASE NUMBER OF CONTROL GAMES

<4> RETURN TO SERIES MANAGER

  --<CHOOSE A NUMBER>
```

--Option 1 will allow you to create a new datadisk in disk drive #2. Datadisks are initialized with no files and NO DOS (and are therefore NOT BOOTABLE!). After initializing a disk, you will be returned to the SERIES MANAGER.
--Option 2 allows you to check for freespace on another disk.
--Option 3 allows you to reduce the number of simulated games to fit onto a specific datadisk.
--Option 4 returns you to SERIES MANAGER.

IX. DISK ACCESS

Selecting #8 (DISK ACCESS) from the SERIES MANAGER will present a submenu (Fig. 13).

Fig. 13. Disk Access Submenu

```
DO YOU WANT TO:

<1> CATALOG DISK
<2> INIT NEW DATADISK
<3> BACKUP DATA DISK
<4> RETURN TO SERIES MANAGER

  --<CHOOSE A NUMBER>
```

--Option 1 allows you to catalog the contents of drive 1 or 2 then returns you to SERIES MANAGER.
--Option 2 (INIT NEW DATADISK) allows you to create new DATADISKS from within the Psi Invaders system. Datadisks thus created have NO DOS and are NOT BOOTABLE!.
--Option 3 (BACKUP DATA DISK) will run a copy program for making archival copies of DATADISKS and can also be used to back up system disks. After making a copy, you will be returned to SERIES MANAGER.

--> IMPORTANT <---
IT IS RECOMMENDED THAT BACKUP COPIES OF DATADISKS BE FREQUENTLY MADE!

X. SECURITY ALARM

Psi Invaders includes a system to detect possible attempts at cheating. Once the #6 (Play Psi Invaders) option has been selected from the Series Manager, a file is created which contains the participant's name. If the game is exited abnormally for <u>any</u> reason (pressing reset, an error of some sort, removing the data disk before the data are stored, or a power failure) the game is not <u>normally</u> exited, an alarm will sound and the Apple will "lock-up". Only turning the Apple off will turn off this alarm. (A control-open Apple-reset sequence will reboot on an Apple //e). If the alarm is triggered and the experimenter is not notified, the experimenter <u>will</u> be notified the next time the system is powered-up. After the password is entered, the system will give the message "There is a discrepancy in the system! (Subject's name) started a game of Psi Invaders and did not finish it! Clear the check file? (Y/N)". Specifying "Y" will clear the participant's name from the file so subsequent power-ups will not present the same message.

If someone attempts to prevent data from being recorded either by hitting reset at the end of the game, or by removing the data disk before data are recorded, the alarm will sound. If the participant turns the machine off to quiet the alarm and then turns the power back on, the system requires the experimenter password. If a false password is entered and fails three times, the alarm will sound again. If someone replaces the datadisk with another to avoid saving bad data that game's data will be missing from the datadisk and can be easily detected.

In the event the alarm is triggered during the game the monitor will be cleared to the text screen and the message "Error= (error number)" will be displayed. The Psi Invaders program has been extensively debugged and tested, so errors due to programming are extremely unlikely to occur.

--> IMPORTANT <---
THE ALARM FEATURE MAY HELP US TRAP POTENTIAL CHEATERS. THIS FEATURE WILL BE EFFECTIVE TO THE EXTENT THAT IT REMAINS SECRET. WE REQUEST THAT NO MENTION OF THIS FEATURE BE MADE TO EITHER PARTICIPANTS OR "OUTSIDERS".

XI. MODIFY PASSWORDS

--> IMPORTANT <---
YOUR PASSWORD FILE IS THE CRITICAL SECURITY ELEMENT OF THE PSI INVADERS SYSTEM. UNAUTHORIZED USERS WILL BE UNABLE TO ENTER THE SYSTEM WITHOUT KNOWLEDGE OF A VALID PASSWORD. WHEN THE PROMPT FOR EXPERIMENTER PASSWORD IS ON THE SCREEN, THE USER WILL HAVE 3 ATTEMPTS TO ENTER A VALID PASSWORD, AFTER WHICH THE MACHINE WILL LOCK-UP AND MUST BE POWERED-DOWN (EXCEPT ON AN APPLE //E, WHICH CAN BE BOOTED WITH CONTROL-OPEN APPLE-RESET).

The Modify Passwords sub-menu appears when booting a "virgin" copy of Psi Invaders. It may also be invoked by selecting #1 (DESIGN SERIES) from the Series Manager and then selecting #4 (MODIFY PASSWORDS). A menu will be presented on the screen (Fig. 14).

Fig. 14. Modify Passwords Submenu

```
<1> ADD NEW PASSWORD
<2> CHANGE OLD PASSWORD
<3> CLEAR PASSWORD FILE
<4> EXIT
```

--Option 1 allows you to add new passwords. Each password must be 3 alphanumeric characters. Do not use control characters.
--Option 2 allows you to delete old passwords
--Option 3 clears the entire passord file so you can create a fresh one.
--Option 4 exits this program. If you entered this menu by booting a "virgin" disk, it will reconfigure the disk so that the next time the disk is booted, it will send you to the "Experimenter password:" input.

APPENDIX 1

RNG SAMPLING FREQUENCIES FOR PSILAB // SOFTWARE

Delay Value	Effective Sampling Frequencies in Hz		
	Invaders	Frequency Analyzer	Serialyzer
1	30800	13097	12719
2	18535	10318	10081
3	12414	8170	8021
4	8907	6546	6449
5	6707	5318	5254
6	5234	4382	4338
7	4200	3659	3629
8	3445	3093	3072
9	2877	2644	2629
10	2439	2283	2272
15	1252	1234	1231
20	*	766	765
25	*	520	520
50	*	146	146
100	*	39	39
150	*	17	17
200	*	10	10
250	*	6	6

The above approximate sampling frequencies for the Random Analysis programs (Frequency Analyzer and Serialyzer) were determined by timing the program with a clock for 200,000 samples. These figures are approximate. The amount of time used for the clocking and other program overhead was not taken into consideration. Thus the actual frequency is slightly higher than those listed. In the event that your computer's clock is not exactly 1.023 MHz, these estimates will be slightly different.

The sampling frequency listed for the Invaders program was determined from theoretical considerations. These too are approximate. For a detailed discussion fo the Apple's "Wait" routine, see Apple II Monitors Peeled.

* Invaders program maximum allowed delay value is 15 (higher delays make the game too slow)

APPENDIX 2

PSI INVADERS DATAFILE STRUCTURE

Datafiles created by the Psi Invaders program on disk drive #2 will have the filename "INV.LASTNAME FIRSTINITIAL.STUDY TYPE+GAME NUMBER" (e.g., INV.JONES J.FML3). These sequential text files contain the game's raw data as well as statistical test results.

During all experimental and simulation games, two sets of data are actually collected and analyzed. One set is referred to as the "contingent" sample because the display to the subject and the game score is contingent upon the outcome of the sample while the other is referred to as "noncontingent". More detailed explanations of noncontingent data may be found in Appendix 3 (Explanation of Noncontingent Data) and Appendix 4 (Brief Review of Noncontingent Effects). For simulations, the game score is always dependent on the contingent sample. The "hidden" sample is not displayed. At the beginning of each game, a pseudorandom function determines whether the first or second sample will be the contingent one. Thus during a game, each button press generates two, hundred-bit samples from the RNG. These are analyzed and stored as shown below. The Utilities Section contains two programs which read Invaders data files and concatenated data files.

Rec-ord	Variable type	Contents
1	numeric	mean run score RNG sample 1
2	numeric	mean run score RNG sample 2
3	numeric	standard dev. RNG sample 1
4	numeric	standard dev. RNG sample 2
5	numeric	t-test RNG sample 1
6	numeric	t-test RNG sample 2
7	numeric	z-score RNG sample 1
8	numeric	z-score RNG sample 2
9	numeric	correlation of run scores RNG1 & RNG2 (Pearson r)
10	numeric	t (corresponding to Pearson r)
11	numeric	number of trials per run
12	numeric	delay between RNG trials
13	numeric	contingent sample (1 or 2)
14	string	experimenter password
15	string	date of game
16	numeric	number of runs per game
17	numeric	total hits RNG sample 1
18	numeric	total hits RNG sample 2

Record	Variable type	Contents
19	numeric	firing rate (i.e., for contingent sample--number of runs with hits greater than or equal to 51)
		Records 20-24 refer to the contingent sample with runs with positive standard deviation (i.e., scores above 50)
20	numeric	number of runs with 1<=S.D.<2
21	numeric	number of runs with 2<=S.D.<3
22	numeric	number of runs with 3<=S.D.
23	numeric	total of records 20, 21, 22
24	numeric	total of records 21, 22
25	numeric	no longer used
26	numeric	no longer used
27	numeric	game score
28	string	label "RNG1"
29-128	numeric	run scores for RNG1
129	string	label "RNG2"
130-229	numeric	run scores for RNG2

EXPLANATION OF NONCONTINGENT DATA

Psi Invaders collects RNG data which is used to determine the display to the subject during the game. These RNG results are referred to as "contingent" data (i.e., all feedback to the subject during the game is contingent upon these results).

RNG runs are also collected which are not displayed or otherwise fed back to subjets; in fact, subjects do not need to be informed about them at all. These runs are referred to as "noncontingent", since scoring on them is not contingently-linked to the subjects' ability to play Psi Invaders. Each time the button is pressed during a game, two 100-bit trial runs are collected from the RNG. One of these runs is "contingent" and the value of its score determines whether the player's "laser cannon" will fire or not, while the other run is "noncontingent" and has no effect on the game. (At the beginning of each game, a pseudorandom function determines which of the two runs will be "contingent" and "noncontingent.")

This "contingent/noncontingent" comparison provides a basis for exploring various feedback and motivational effects. Stanford's PMIR model would lead us to expect psi effects on the "contingent" runs but not on the "noncontingent" runs since the former but not the latter can be considered "need relevant", assuming subjects are motivated to play the game. The Observational models would aslo predict stronger psi effects on the "contingent" data since the displays triggered by above chance "contingent" scoring provide subjects with feedback which is totally absent in the "noncontingent" data. Feedback is, of course, assumed by the Observational models to be a necessary condition for PK, and this assumption is implicit in some previous applications involving noncontingent trials, such as Richard Broughton's (1982) "simultaneous control condition."

A number of previous studies have found stronger effects with the no-feedback data. Appendix 4, taken from the PRL 1983 Annual Report, briefly describes these findings. It is worth noting that at the 1984 PA convention, papers by Heseltine (1984) and Broughton and Perlstrom (1984) indicated possible effects in the nonfeedback conditions. At present, we have no good theoretical model for these findings, but these results are strong enough to encourage us to pursue the topic.

REFERENCES

Broughton, R. S. (1982, March-April). Computer methodology: Total control with a human face. Parapsychology Review, pp. 1-6.

Broughton, R. S., & Perlstrom, J. R. (1984, August). Results of a special subject in a computerized PK game. Paper presented at the 27th Annual Convention of the Parapsychological Association, Dallas, TX.

Heseltine, G. L. (1984, August). PK success during structured and non structured RNG operation. Paper presented at the 27th Annual Convention of the Parapsychological Association, Dallas, TX.

Psychophysical Research Laboratories. (1983). Annual Report. Princeton, NJ.

APPENDIX 4
BRIEF REVIEW OF NONCONTINGENT EFFECTS

With the exception of Psi Ball (see Section 2.12 of PRL 1983 Annual Report), all of the RNG psi studies done by PRL to date have compared 2 observational conditions. In one condition, participants receive trial by trial and/or cumulative feedback reflecting RNG performance criteria (FBK condition). The other (NOFBK) condition is identical except that it minimizes or eliminates real-time feedback to the participant. Identical RNG sampling parameters are employed in both conditions and the order of execution is randomized.

Despite major differences between studies in type of feedback, RNG sampling rate, performance criteria, and participant orientation, the studies completed thus far consistently show stronger RNG effects in the NOFBK condition.

In the EEG-gating study (Varvoglis, in press), the FBK condition provided participants with feedback to the absolute (unsigned) deviation from chance for the most recent 100 RNG samples. Participants were completely unaware of the NOFBK condition, which was observed only by the experimeter in the form of statistical summaries. While significant departures from randomness occurred in the study overall ($p < .009$), and in each condition, the effect was stronger in the NOFBK condition ($z = 2.628$, $p < .01$) than in the FBK condition ($z = 2.011$, $p < .05$).

In the PKMETER study (Honorton, Barker & Sondow, 1983), the FBK condition provided participants with directional feedback to each binary sample. Participants were informed about the NOFBK condition and received delayed feedback in the form of an end-of-run statistical summary. The study served, in part, as a test of the common practice of selecting participants on the basis of screening. There were 3 series: Series 1, with participants who satisfied the performance criterion set for the screening series; Series 2, with participants who failed the screening criterion; and Series 3, with unscreened participants. RNG effects were predicted only for Series 1. Series 2 and 3 yielded no evidence of RNG effects. Nearly signficant overall effects occurred in Series 1 ($z = 1.78$, $p = .087$, 2-tailed). Stronger overall effects occurred in the NOFBK condition ($t[99] = 1.56$, $p < .12$) than in the FBK condition ($t[99] = .73$). Participants showed a significant decline in performance overall ($t[48] = 2.73$, $p< .008$) and contrary to expectation, this decline in performance occurred primarily in the FBK condition ($t[48] = 2.48$, $p <.017$).

Recently, as described on pp. 11-12 of the 1983 PRL Annual Report, we have found significant RNG effects in the NOFBK condition but not the FBK condition of the first VOLITION series.

These data are consistent with those reported by other researchers. While most RNG psi experiments have provided participants with real-time feedback to the momentary state of the RNG, at least 10 previous studies have been reported indicating that significant RNG effects can occur with minimal or no feedback to the participant.

Significant RNG effects (defined as absolute or unsigned deviation) occurred without feedback or participants' awareness of an RNG task in two studies in which RNG activity was tied to participants' conscious efforts to increase EEG alpha rhythm activity (Honorton & Tremmel, 1978). Subjects performed a biofeedback task and received auditory feedback for alpha activity. Unknown to the subjects, RNG activity was concurrently sampled and gated in relation to the biofeedback conditions. In both studies, significant RNG deviations occurred in those trials in which subjects successfully met the EEG feedback conditions and were receiving EEG feedback (study 1: chi-square = 145.7, 100 df, p=.002, 2-tailed; study 2: chi-squre = 159.2, 120 df, p = .005, 2-tailed). No RNG effects were observed in trials in which subjects failed to meet EEG feedback conditions.

Significant RNG effects were found on trials without subject feedback and chance results on trials with feedback in two studies involving prerecorded targets (Houtkooper, et al., 1980). Deviant RNG effects occurred only in the 'hidden' or no feedback condition in both experiments. The effects were bidirectional; positive in the first study (z = 3.23, p=.0013, 2-tailed) and negative in the second (z= -2.45, p=.014, 2-tailed).

Similar though weaker effects occurred in two RNG precognition studies (Bierman, 1977; 1978) designed to test Feinberg's 'advanced wave' hypothesis of precognition. Subjects received trial-by-trial feedback for half of the trials and an end-of-run statistical summary for the other half. More hits occurred in the minimal feedback condition in both studies, though only the first study approached statistical significance (z=1.93, p<.05, 1-tail).

Braud & Braud (1978) found RNG effects only in conditions of minimal or no subject feedback in two studies. The first study compared trial by trial vs. minimal (end of session) feedback, and showed significant RNG effects only in the minimal feedback condition (t[9]=2.7, p<.05). Significant RNG effects occurred also in the second study with no subject feedback (t[19]=1.89, p<.05).

In the "Observational Theories" (OT), feedback is postulated to be a necessary condition for psi to occur (see summary in Appendix 2 of PRL 1983 Annual Report). In order to account for the type of findings summarized above within the framework of OT, it is necessary to identify the experimenter rather than the participants as the active psi sources since the former but not the latter subsequently received feedback through the analysis of the data. As indicated in Appendix 2 (of PRL 1983 Annual Report), attempts to experimentally manipulate "analyzer" effects have, to date, been at best equivocal and serious questions have been raised concerning the meaningfulness of the feedback construct in OT; for example, in the absence of known boundary conditions, virtually any information concerning results (statistical summaries, journal articles, etc.) can be construed as feedback. Other logical objections are discussed in Appendix 2 (of PRL 1983 Annual Report).

Evidence for sytematic relationships between RNG performance and individual differences among participants is not easily reconcilable with the hypothesis that the psi source is the experimenter. Rather, such findings suggest that the effects are participant-related and that feedback is not a necessary condition for psi to occur. While the evidence is not yet compelling, further confirmation of individual difference patterns in unobserved RNG data may require abandonment of observational theories.

PsiLab // UTILITIES
TABLE OF CONTENTS

INTRODUCTION

The PsiLab // Utilities disk contains some useful adjunct programs for use with PsiLab //.

DISK MUNCHER COPY PROGRAM is an extremely useful copy program which replaces Apple's 'COPYA' program. This program is infinitely faster and, unlike COPYA, verifies the copy to make sure no errors occurred. Detailed documentation on how to use DISK MUNCHER may be found on page 4 of the PSI INVADERS section of this manual. When you run the program, instructions will also appear on the screen.

PSI INVADERS SUPPLEMENTARY ANALYZER allows you to concatenate games from the Psi Invaders simulator as well as concatenate large numbers of experimental games. The Analyzer on the Psi Invaders disk works with the data in memory, and consequently, can only process a limited number (10) of games at once. The supplementary analyzer processes the data in "real time," that is, reads the data straight from the disk to the screen. This allows concatenations of hundreds of games of Psi Invaders. The disadvantage is that one cannot printout the raw data using this utility (you can printout the individual game's raw data using the Psi Invaders Analyzer).

PSI INVADERS DATAFILE READER is a shell of a program for allowing you to customize you own analysis program for Psi Invaders datafiles. It documents each of the variables to be found in the files and allows you to manipulate them at will. Psi Invaders datafiles contain summary statistical data as well as run score data for each game.

PSI INVADERS CONCATENATED DATAFILE READER does the same as the one above except with concatenated datafiles (which do not contain any summary statistical data).

FAST RNG SAMPLING PROGRAM is a shell of a BASIC program which shows you how to append an assembly language program for sampling the RNG to the end of your BASIC program.

RNG VERIFICATION PROGRAM is the assembly language subroutine used by all PsiLab // software for verifying the presence of a PsiLab // RNG in the specified slot.

INVDATA READER

```
----------------------
10    REM  THIS PROGRAM PROVIDES A SIMPLE WAY TO READ THE PSI INVADERS DATA
            FILES
----------------------
11    REM  LINES 100 TO 300 DO THE ACTUAL READING
----------------------
12    REM  LINES 50 THRU 82 DESCRIBE THE VARIABLES IN THE FILE
----------------------
13    REM  FOR ADDITIONAL INFORMATION, CONSULT THE PSILAB // DOCUMENTATION
            PACKAGE
----------------------
50    REM  M1-MEAN RUN SCORE OF SAMPLE 1
----------------------
51    REM  M2-MEAN RUN SCORE OF SAMPLE 2
----------------------
53    REM  S1-STANDARD DEV OF SAMPLE 1
----------------------
54    REM  S2-STANDARD DEV OF SAMPLE 2
----------------------
55    REM  T1-T-TEST OF SAMPLE 1
----------------------
56    REM  T2-T-TEST OF SAMPLE 2
----------------------
57    REM  Z1-Z-SCORE OF SAMPLE 1
----------------------
58    REM  Z2-Z-SCORE OF SAMPLE 2
----------------------
59    REM  R-CORRELATION BETWEEN SAMPLE 1 AND SAMPLE 2
----------------------
60    REM  T-T-VALUE CORRESPONDING TO PEARSON R
----------------------
61    REM  NT-NUMBER OF TRIALS PER RUN
----------------------
62    REM  DL-DELAY BETWEEN TRIALS
----------------------
63    REM  CS-CONTINGENT SAMPLE (1 OR 2)
----------------------
64    REM  PW$-EXPERIMENTER PASSWORD
----------------------
65    REM  DA$-DATE
----------------------
66    REM  N-NUMBER OF RUNS PER GAME
----------------------
67    REM  H1-TOTAL HITS SAMPLE 1
----------------------
68    REM  H2-TOTAL HITS SAMPLE 2
----------------------
69    REM  FR-FIRING RATE (I.E., FOR THE CONTINGENT SAMPLE--THE NUMBER OF
           RUNS WITH HITS GREATER THAN 50)
----------------------
70    REM   N1-NUMBER OF RUNS 1<=S.D.<2 (CONTINGENT SAMPLE, POSITIVE
             DEVIATIONS)
----------------------
71    REM   N2-NUMBER OF RUNS 2<=S.D.<3 (CONTINGENT SAMPLE, POSITIVE
             DEVIATIONS)
----------------------
72    REM   N3-NUMBER OF RUNS 3<=S.D. (CONTINGENT SAMPLE, POSITIVE
             DEVIATIONS)
```

```
--------------------
73    REM  N4=N1+N2+N3
--------------------
75    REM  N5=N2+N3
--------------------
76    REM  DU-DUMMY VARIABLE, NO LONGER USED
--------------------
78    REM  GS-GAME SCORE
--------------------
79    REM  L1$-LABEL "RNG1"
--------------------
80    REM  R1(I)-RUN SCORES FOR SAMPLE 1
--------------------
81    REM  L2$-LABEL "RNG2"
--------------------
82    REM  R2(I)-RUN SCORES FOR SAMPLE 2
--------------------
100   INPUT "INVADERS DATA FILE>";A$
--------------------
110   D$ = CHR$ (4)
--------------------
120   PRINT D$"OPEN"A$
--------------------
130   PRINT D$"READ"A$
--------------------
140   INPUT M1
    : INPUT M2
    : INPUT S1
    : INPUT S2
--------------------
150   INPUT T1
    : INPUT T2
    : INPUT Z1
    : INPUT Z2
--------------------
160   INPUT R
    : INPUT T
    : INPUT NT
    : INPUT DL
    : INPUT CS
--------------------
170   INPUT PW$
    : INPUT DA$
--------------------
180   INPUT N
    : DIM R1(N),R2(N)
--------------------
190   INPUT H1
    : INPUT H2
    : INPUT FR
--------------------
200   INPUT N1
    : INPUT N2
    : INPUT N3
    : INPUT N4
    : INPUT N5
--------------------
210   INPUT DU
    : INPUT DU
    : INPUT GS
```

```
---------------------
220    INPUT L1$
---------------------
  0    FOR I = 1 TO N
     :   INPUT R1(I)
     : NEXT
---------------------
240    INPUT L2$
---------------------
250    FOR I = 1 TO N
     :   INPUT R2(I)
     : NEXT
---------------------
300    PRINT D$"CLOSE"A$
```

CONCAT FILE READER

```
---------------------
10      REM   THIS PROGRAM PROVIDES A SIMPLE WAY TO READ DATA IN CONCATENATED
                 FILES
---------------------
15      REM   AS OF JAN 85, THE CONCATENATOR PROGRAM ONLY UTILIZES CONTINGENT
                   DATA
---------------------
20      REM  LINES 50 THRU 54 DESCRIBE THE VARIABLES
---------------------
25      REM  LINES 100 THRU 200 DO THE ACTUAL READING
---------------------
50      REM  A$ IS THE NAME OF THE CONCATENATED FILE
---------------------
51      REM  B$ IS CURRENTLY THE WORD "CONTINGENT"
---------------------
52      REM  C$ IS THE RANGE OF GAME NUMBERS CONCATENATED
---------------------
53      REM   RS%(I) RAW RUN SCORES
---------------------
54      REM  N IS THE TOTAL NUMBER OF RAW SCORES (100 PER GAME)
---------------------
100     INPUT "CONCATENATED DATA FILE>";A$
---------------------
110     D$ = CHR$ (4)
---------------------
120     PRINT D$"OPEN";A$
---------------------
130     PRINT D$"READ";A$
---------------------
140     INPUT N
      : DIM RS%(N)
---------------------
150     INPUT B$
      : INPUT C$
---------------------
160     FOR I = 1 TO N
      :   INPUT RS%(I)
      : NEXT
---------------------
200     PRINT D$"CLOSE"A$
```

FAST RNG SAMPLING PROGRAM

```
--------------------
10    REM BASIC INTERFACE FOR RNG.TASC
--------------------
20    REM
           (cJ)LOADS RNG.TASC AT END OF CURRENT BASIC PROGRAM
--------------------
21    REM AND RESETS LOMEM TO PROTECT IT
--------------------
30    LOMEM: PEEK (175) + PEEK (176) * 256 + 50
--------------------
40    RNG = PEEK (175) + PEEK (176) * 256
--------------------
50    PRINT CHR$ (4)"BLOADRNG.TASC,A"RNG
--------------------
60    HOME
    : INPUT "TRIALS/RUN: ";TR
    : REM    SET NUMBER OF TRIALS (1-255)
--------------------
70    INPUT "DELAY: (5-255) ";DE
    : REM       SET DELAY 5-255
--------------------
80    INPUT "RNG SLOT";SL
    : REM  SLOT MAY BE 1-7
--------------------
90    POKE 6,TR
    : POKE 7,DE
    : POKE 235,0
    : POKE 236,192 + SL
--------------------
100   AIM = (AIM = 0)
    : REM  OSCILLATE AIM OF STARTING TRIAL- SUBSEQUENT TARGETS OSCILLATED TRI
         AL BY TRIAL
--------------------
110   CALL RNG
--------------------
120   HITS = PEEK (9)
--------------------
130   PRINT
    : PRINT "NUMBER HITS: "HITS" OUT OF "TRIALS" TRIALS"
--------------------
135   PRINT
    : PRINT "PRESS ANY KEY TO CONTINUE";
    : GET A$
    : PRINT
--------------------
140   GOTO 60
```

```
                 *****************************
                 *
                 *  RELOCATABLE RNG SAMPLER
                 *
                 *         'RNG.TASC'
                 *
                 *         09/17/83
                 *
                 * ----------------------------
                 *
                 *  FROM BASIC:
                 *  ---- -----
                 *  POKE TRIALS,N:POKE DELAY,D
                 *     POKE AIM,A
                 *
                 *  BLOAD "RNG.TASC"
                 *  POKE $EB,0: POKE $EC,192+RNG SLOT
                 *
                 *  RETURN TO BASIC:
                 *  ------ -- -----
                 *  HITS RETURNED IN 'HITS' ($09)
                 *****************************
                 *
                 TRIALS   EQU  $06
                 DELAY    EQU  $07
                 AIM      EQU  $08
                 HITS     EQU  $09
                 *
                 RNG      EQU  $EB        ;RNG LOBYTE ADDRESS=$EB, HIBYTE=$EC
                 WAIT     EQU  $FCA8
                 *
      A0 00               LDY  #0         ;ZERO Y AND HIT-
  02: 84 09               STY  HITS       ; COUNTER
8004: A6 06               LDX  TRIALS     ; X=TRIALS
8006: A5 08               LDA  AIM
8008: F0 11               BEQ  LOAIM
                 *
800A: B1 EB      HIAIM    LDA  (RNG),Y    ;GET RANDOM BYTE
800C: C9 80               CMP  #$80
800E: 90 02               BLT  DLY        ; HIT=HIBIT ON
8010: E6 09               INC  HITS
8012: A5 07      DLY      LDA  DELAY
8014: 20 A8 FC            JSR  WAIT
8017: CA                  DEX
8018: D0 01               BNE  LOAIM
801A: 60                  RTS
                 *
801B: B1 EB      LOAIM    LDA  (RNG),Y    ;GET RANDOM BYTE
801D: C9 80               CMP  #$80
801F: B0 02               BGE  DLY2       ; HIT=HIBIT OFF
8021: E6 09               INC  HITS
8023: A5 07      DLY2     LDA  DELAY
8025: 20 A8 FC            JSR  WAIT
8028: CA                  DEX
8029: D0 DF               BNE  HIAIM
802B: 60                  RTS

--End assembly--

44 bytes

Errors: 0
```

PsiLab //
HARDWARE

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PsiLab // RNG Limited Warranty

The PsiLab // Random Number Generator has been subjected to hardware inspection and modifications (see "Modifications to the RIPP Apple Random-Number Generator Boards, p. 3). It has been tested and passed a battery of tests of randomness prior to shipping. With proper handling, it should remain random. PRL warrants the RNG to be free of defects for a period of ninety (90) days from the time of receipt. Any defects found and reported to PRL during the warranty period will be repaired or replaced free of cost.

If any indications of hardware malfunction become evident during the course of use (e.g., consistent patterning in random analysis tests), please contact PRL to discuss the problems. We will advise you regarding whether the problem requires repair, and if repair is advised, will refer you to NWS Associates. NWS can make necessary repairs and bill you as well as provide you with prior cost estimates, if requested.

INTRODUCTION

The PsiLab // Random Number Generator (RNG) is a "Bierman-RIPP"-type RNG which has been component tested and modified to our specifications.

THEORY OF OPERATION

The PsiLab // Random Number Generator board converts the analog noise voltage from two independent avalanche noise diodes into two digitized data-bit streams. The high frequency noise components from each diode are coupled into LM311 comparators, which perform the digitization of the random analog input noise voltages. The outputs of the LM311s are 'LS/TTL compatible, and their risetimes are further improved by two successive 'LS/TTL buffers. Each RNG board has two independent generators, whose bit streams are latched during periods free of computer-generated EMI, and fed into binary dividers to reduce first-order effects (unbalance of 1s or 0s). The two data streams are then combined in an exclusive-or (half-adder) circuit to further reduce first-order effects. The combined random digital data stream is clocked into an eight-bit shift register at a bit rate given by the Apple clock divided by 32. Eight new data bits (a fresh data output byte) are accumulated at a rate of approximately 4 kHz (4000/second). Independent bits are available at approximately 32 kHz (32000/second). Appropriate filtering, decoupling, and shielding are included on the RNG board.

Modifications to the RIPP Apple Random-Number Generator boards, performed by NWS Associates, Inc., New Woodstock, NY.

The boards are given a thorough inspection for broken or damaged components, for burrs on printed-wiring runs, and for solder splashes and cold-soldered joints (as evidenced by solder-joint graininess, by concave menisci at component leads indicating poor wetting, and by fracturing of the solder joint where component wires have been cut). All defects are repaired and any suspicious solder joint is retinned/resoldered.

The Zener diodes are checked for proper avalanche noise generation, and for freedom from 1/f (or 'excess') noise, and for freedom from baseline-shifting ('popcorn' noise). Diodes with inappropriate characteristics are replaced.

The LM311 comparators are checked for excessive offsets of input voltage and input current, and for proper operation over extremes of temperature greater than will be encountered in practice. Comparators with unacceptable characteristics are replaced.

The Zener diode coupling capacitors are changed from 1 uf to 0.0022 uf, to further insure against signal-processing problems from low-frequency noise components.

Two 0.1 uf disc capacitors are added to the +5 V. lines in the digital section, and a 1 uf capacitor is added at the power pins.

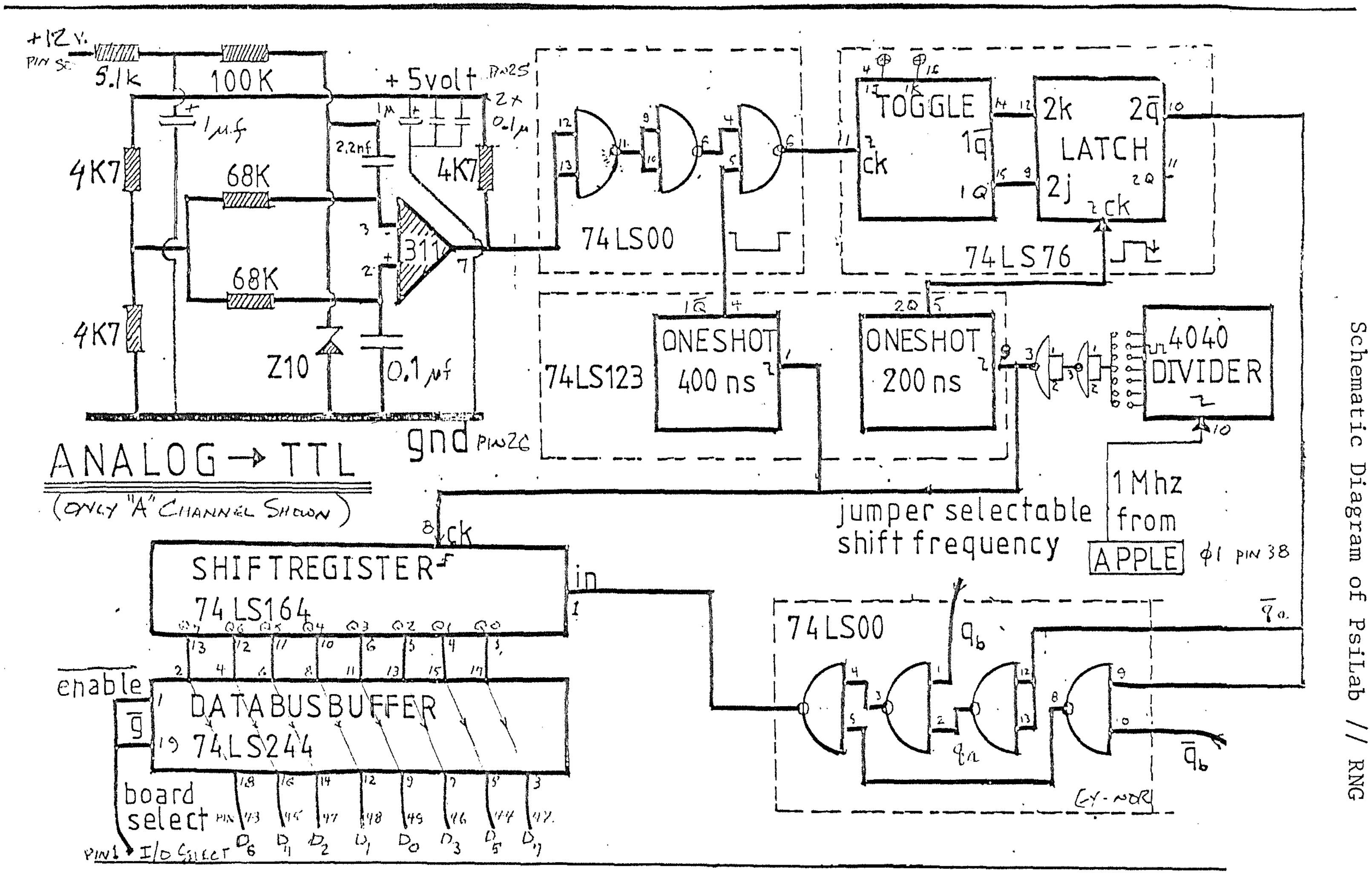
Filtering of the power for each Zener diode is provided by adding a 5.1 kohm resistor in series between the +12 V. supply and the present 1 uf capacitor at each diode.

A buffer is added (using the two spare 74LS00 sections) between the output strap of the 4040 divider and the five LS-TTL loads it previously was required to drive. This modification improves noise margin and reliability of operation over temperature to an acceptable degree.

The divider output rail is strapped to pin #3 of the 4040 divider for a bit-sampling rate of 1/32nd of the Apple clock rate. This gives a bit rate of 32 kbits/sec, or a byte availability of 4 kbytes/sec.

Operation of the modified RNG is tested at each individual generator output and at the combined output in a special test fixture. Operations (including all digital timings) are checked in an Apple][+ computer, to insure proper RNG performance.

An insulated electrostatic and magnetic shield is added over the sensitive analog-section components.



PSILAB RANDOM NUMBER GENERATOR

Schematic Diagram of PsiLab // RNG

REFERENCES

Articles which are relevant to understanding the PsiLab // RNG design are listed below. One article, "Random-Number Generator Critical Checklist for Designers and Experimenters" has been reprinted in this section.

Chevako, R. J. (1984) Random-number generator critical checklist for designers and experimenters. Presented as a poster session at the 27th annual convention of the Parapsychological Association, Aug. 6-10, Dallas, TX. Available from N.W.S. Associates, P.O. Box 280, School St., New Woodstock, N.Y., 13122.

Chevako, R. J., & Morris, R. L. (1984) Some guidelines for the construction and use of random-number generators. (Unpublished) Copies available from N.W.S. Associates, P. O. Box 280, School St., New Woodstock, N.Y., 13122

Murry, H. F. (1970) A general approach for generating natural random variables. IEEE Transactions on Computers, Vol C-19, pp. 1210-1213.

Random-Number Generator Critical Checklist for Designers and Experimenters.

R.J. Chevako
Communication Studies Lab
Syracuse Univ.

ABSTRACT

Requirements for proper operation of an electronic-noise RNG are given in checklist form. Discussion and examples are also presented for selected topics. The material should allow a series of quick determinations to evaluate the appropriateness of any given electronic RNG design.

CONTENTS

ANALOG NOISE CHARACTERISTICS FOR BIT-STREAM RNGS USING ZERO-CROSSING DETECTION TECHNIQUES.

--> MAKE SURE YOUR ANALOG NOISE IS WELL-BEHAVED, HAVING NO UNDUE PHASE COHERENCIES. PROBLEMS WHICH CAN BE ENCOUNTERED INCLUDE:

OSCILLATIONS OR TIME-STRUCTURED OUTPUT.

MISMANAGEMENT OF 'EXCESS' OR '1/F' LOW-FREQUENCY NOISE COMPONENTS.

TOO FAST A DATA RATE WITH RESPECT TO THE HIGH-FREQUENCY CUTOFF OF THE ANALOG NOISE VOLTAGE.

POWER LINE HUM, EMI (ELECTRO-MAGNETIC INTERFERENCE), OR RFI (RADIO-FREQUENCY INTERFERENCE) IN THE ANALOG NOISE VOLTAGE.

IN GAS TUBE RNGS, MAKE SURE LOW-FREQUENCY NOISE AND INSTABILITIES FROM POSITIVE ION EFFECTS ARE UNDER CONTROL (USUALLY ACCOMPLISHED VIA MAGNETIC MEANS).

--> IN SHORT, MAKE SURE THAT YOU HAVE A ZERO-MEAN, SPECTRALLY FLAT (WHITE), BAND-LIMITED GAUSSIAN NOISE SOURCE IF YOU INTEND TO APPLY STANDARD STATISTICAL TESTS TO YOUR RESULTANT EXPERIMENTAL DATA.

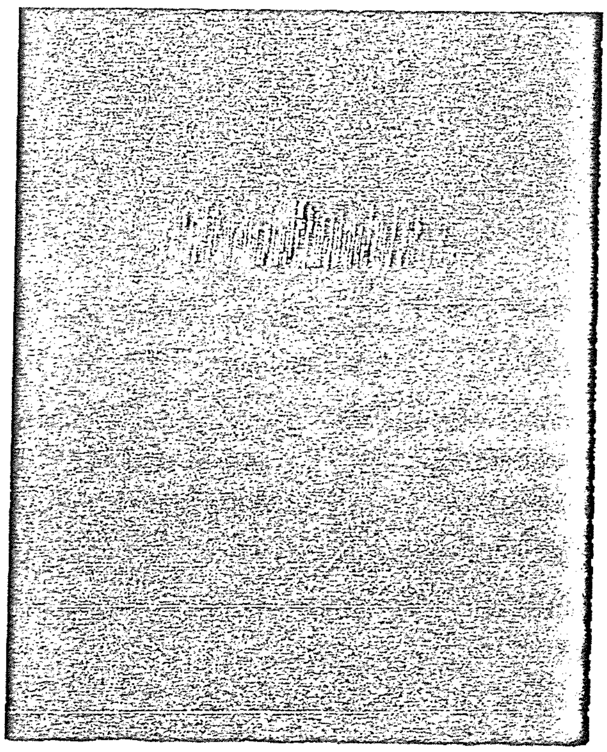
NOISE DIODE OSCILLATIONS AND STRUCTURING

--> THERE ARE A VARIETY OF PROBLEMS WHICH CAN SHOW UP AS STRUCTURED OUTPUT FROM A ZENER DIODE, EXPECIALLY AT LOW LEVELS OF DIODE CURRENT. (WE USE THE COMMON TERM OF ZENER DIODE FOR BOTH THE HIGH-FIELD-EMISSION DIODE AS WELL AS THE AVALANCHE BREAKDOWN DIODE).

INSUFFICIENT CURRENT TO SUSTAIN A PROPER DIODE DISCHARGE CAN RESULT IN A RELAXATION OSCILLATION.

VERTICAL:

0.05 V/DIV



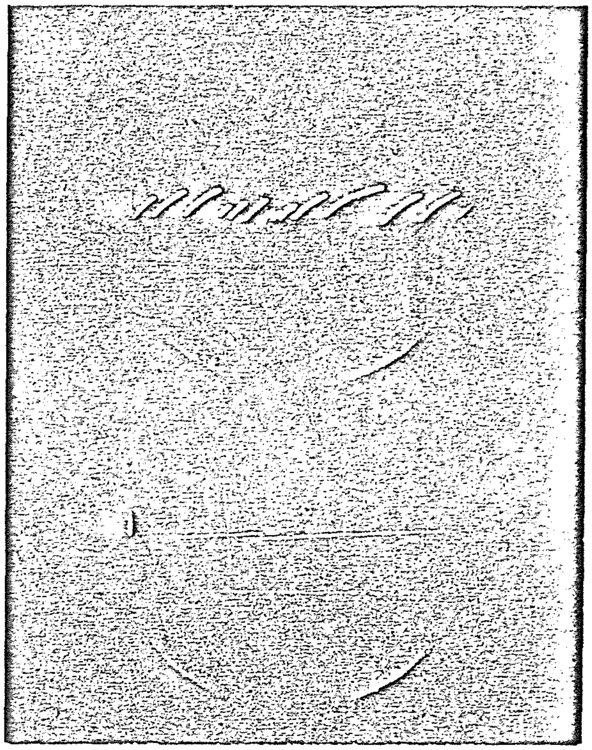
HORIZONTAL:

5 USEC/DIV

0.5 USEC/DIV

OSCILLOSCOPE & PLUG-IN: TEKTRONIX 585-A/82

ARBITRARY REPLACEMENT OF A DIODE CAN LEAD TO UNSUSPECTED DIFFICULTIES -- THIS IS THE OUTPUT VOLTAGE FROM A NOMINALLY SIMILAR DIODE. NOTE THE DRASTIC CHANGE IN TIME SCALE.



HORIZONTAL:

5 USEC/DIV

VERTICAL:

0.05 V/DIV

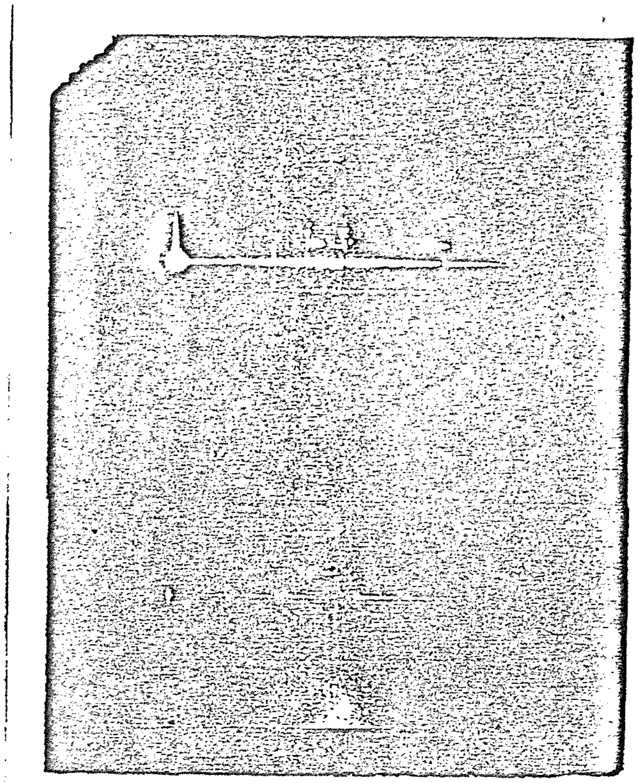
0.5 USEC/DIV

(BOTH DIODES ARE NOMINALLY 10 V. UNITS, AND WERE POWERED FROM A +12 V. SOURCE THROUGH A 100 KOHM LOAD RESISTOR.)

SPIKING OR PULSING OUTPUTS CAN ALSO RESULT. THE CHARACTERISTICS OF THE TIME-WAVEFORM ARE USUALLY STRONG FUNCTIONS OF THE DIODE CURRENT AND TEMPERATURE.

VERTICAL:

0.05 V/DIV



HORIZONTAL:

5 USEC/DIV

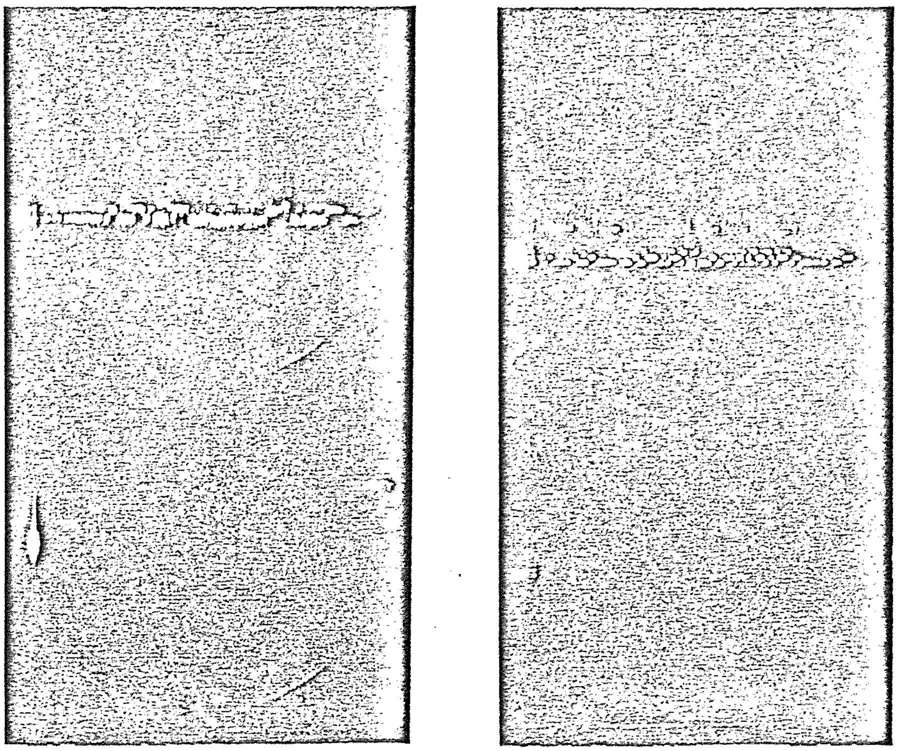
0.5 USEC/DIV

(THIS DIODE WAS A 10 V. UNIT, AND WAS OPERATED FROM A +12 V. POWER SUPPLY THROUGH A 16 KOHM LOAD RESISTOR).

BASELINE SHIFTS ON TIME SCALES FROM MICROSECONDS TO SECONDS CAN OCCUR (SO-CALLED 'POPCORN' NOISE, FROM ITS SOUND IN LOW-LEVEL AUDIO EQUIPMENT). THE DIODE ON THE RIGHT EXHIBITS MULTIPLE VOLTAGE LEVELS.

VERTICAL:

0.05 V/DIV



HORIZONTAL:

5 USEC/DIV

0.5 USEC/DIV

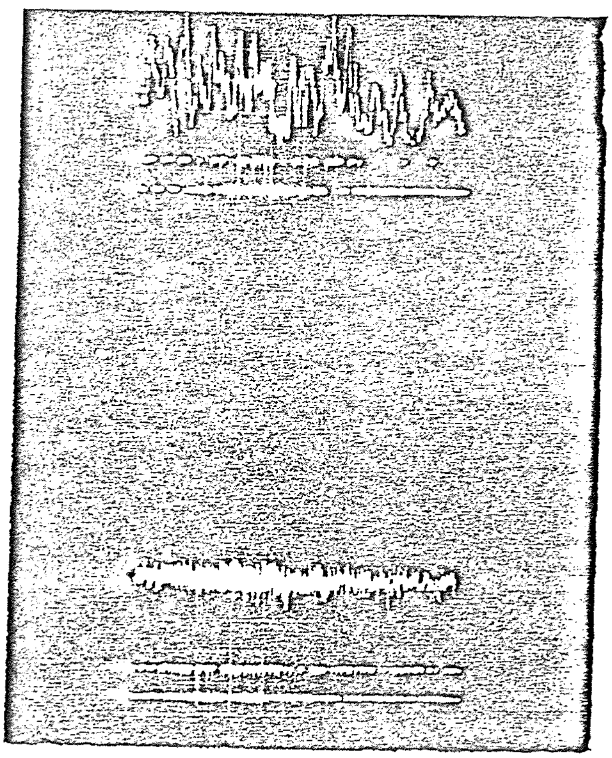
(BOTH DIODES ARE NOMINALLY 10 V. UNITS, AND WERE SUPPLIED FROM +12 V. LOAD RESISTORS WERE: LEFT, 20 KOHMS; RIGHT, 25 KOHMS.)

Strong 'excess' or 'current' or '1/f' noise can give undesired effects in an analog-noise RNG.

--> Avoid using a low-frequency cutoff below the 1/f knee of the noise source employed.

Keep in mind that strong 1/f characteristics or time-structuring can drive the analog noise voltage above or below the comparator threshold for relatively long periods of time. If data collection is attempted at rates faster than allowed by such periods, strange and unexpected correlations (ie, higher order non-randomness) may appear in the output data. This can be difficult to detect in block testing of RNG output data, since the effect may occur rarely but give a short stream of highly correlated data bits when it does occur.

Diode Noise and Comparator Output



Diode with strong 1/f noise

Spectrally flat Diode

Diodes: 10 V. units, +12 V. source, 100 kOhm load.

Vert: 10 mV/div. Horiz: 200 usec/div. Oscilloscope: Tektronix 555

--> USE A MAXIMUM DATA SAMPLING RATE SUFFICIENTLY BELOW THE HIGH-FREQUENCY CUTOFF OF THE NOISE PASSBAND.

THE CORRELATION BETWEEN DATA SAMPLES DECREASES EXPONENTIALLY WITH THE TIME INTERVAL BETWEEN THEM. FOR A SYSTEM UPPER BANDWIDTH OF $F_0 = W_0/2\pi$, THE CORRELATION BETWEEN DATA POINTS SAMPLED T_0 APART IS:

$$R(T_0) = E^{-T_0 W_0} \quad \text{OR} \quad LN(1/R) = T_0 W_0$$

FOR SAMPLE-TO-SAMPLE CORRELATION LESS THAN 10^{-6}, THE UPPER PASSBAND MUST BE AT LEAST 2.2 TIMES THE SAMPLING FREQUENCY. FOR 10^{-9} CORRELATION, THE RATIO IS 3.3. THESE ARE MODEST REQUIREMENTS, AND THE USUAL RATIO IS HIGHER THAN THIS, WITH THE HIGH-FREQUENCY CUTOFF AS HIGH AS CAN BE OBTAINED PRACTICALLY.

--> MAKE SURE THAT THERE IS NO OTHER PERIODIC CONTENT IN THE ANALOG NOISE VOLTAGE.

POWER-LINE HUM CAN ORIGINATE FROM:

- INADEQUATE POWER-SUPPLY FILTERING
- INDUCTION BY MAGNETIC FIELDS FROM TRANSFORMERS OR FAN MOTORS
- GROUND-LOOP OR GROUND-FAULT LEAKAGE CURRENTS

EMI CAN RESULT FROM EITHER INDUCTION OR RADIATION OF AN UNDESIRED SIGNAL INTO THE RNG CIRCUITRY.

RFI IS USUALLY THE TERM MORE NARROWLY APPLIED TO STRAY SIGNALS ORIGINATING FROM RADIO, TELEVISION, OR RADAR TRANSMISSIONS.

Analog Signal Circuit Characteristics

--> The analog circuitry which couples the noise source to the comparator can be simple in extent or complicated, depending upon the detailed requirements for each particular RNG. The circuitry can range from simple passive coupling, to complex filtering and amplification.

The analog noise voltage must be limited in frequency content. Certain precautions must be followed in the design and application of these filters.

The desirable state of affairs in analog-noise RNG operation is to use an appropriately band-limited, zero-mean Gaussian noise source, and a comparator with very low offset, very low input noise, and very fast and symmetrical switching characteristics.

If a noise source has insufficient amplitude for the input requirements of the comparator employed, then an amplifier must be used between the noise source and the comparator. In addition to contributing to the frequency bandwidth/phase problem, the noise generated within the amplifier itself must be properly managed.

RESONANCES AND UNDERDAMPING IN THE ANALOG SIGNAL CIRCUITRY

--> THE ANALOG NOISE VOLTAGE MUST BE CONTROLLED IN FREQUENCY CONTENT, USUALLY WITH LIMITING FILTERS AT BOTH HIGH AND LOW FREQUENCY EXTREMES (SO-CALLED BAND-LIMITING). LOW-ORDER, WELL-DAMPED FILTERS MUST BE USED, TO AVOID OVERSHOOT, RINGING, AND LONG PERIODS OF COHERENCE IN THE OUTPUT SIGNAL FROM THE FILTER. THE COMBINATION OF STRONG IMPULSIVE NOISE AND A POORLY DESIGNED FILTER CAN GIVE STRONG COHERENCE (IE, LACK OF INDEPENDENCE IN SUCCESSIVE SAMPLES) OVER UNEXPECTEDLY LONG PERIODS OF TIME.

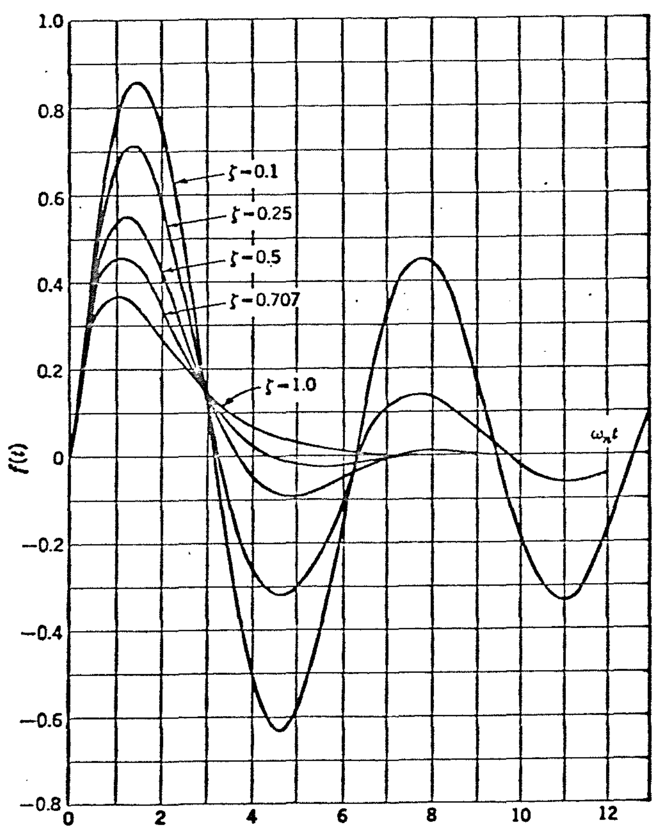
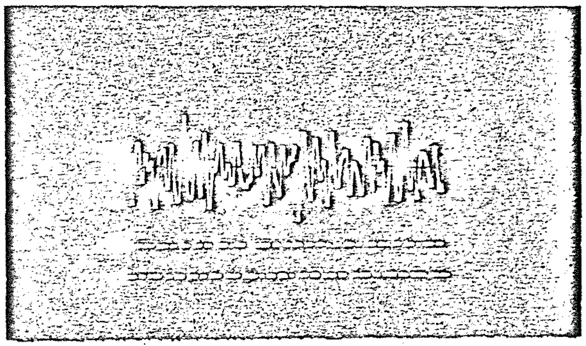


FIG. 4-8. Response to an impulse for $F(s) = \omega_n^2/(s^2 + 2\zeta\omega_n s + \omega_n^2)$.

D'AZZO & HOUPIS, FEEDBACK CONTROL SYSTEM ANALYSIS AND SYNTHESIS, MCGRAW-HILL, P. 86. § = DAMPING COEFFICIENT; Q = 1/2§

NARROW-BAND FILTERING OF NOISE (OR A RESONANCE WITHIN AN OTHERWISE FLAT PASSBAND) WILL GIVE A QUASI-PERIODIC OUTPUT AND ALSO MUST BE AVOIDED.



NARROW-BAND NOISE

COMPARATOR OUTPUT

HORIZONTAL: 100 USEC/DIV.
NOISE BANDWIDTH: 20-30 KHZ
VARIABLE BAND-PASS FILTER: KHRON-HITE 310-AB
RANDOM-NOISE GENERATOR: GENERAL RADIO 1390-B
OSCILLOSCOPE: TEKTRONIX 555

--> AN APPROPRIATE AMPLIFIER MUST BE USED IF THE OUTPUT LEVEL OF THE NOISE SOURCE IS TOO LOW FOR THE COMPARATOR EMPLOYED, EITHER BECAUSE OF SIGNAL-TO-OFFSET PROBLEMS, POOR COMPARATOR SPEED AT LOW INPUT LEVELS, OR EXCESSIVE COMPARATOR INPUT CIRCUIT NOISE.

IF AN AMPLIFIER IS EMPLOYED, IT MUST HAVE BANDWIDTH AND PHASE-VS-FREQUENCY CHARACTERISTICS COMPATIBLE WITH THE REQUIRED SYSTEM NOISE BANDWIDTH, AND MAINTAIN A FLAT NOISE SPECTRUM. IT MUST HAVE A GAIN LARGE ENOUGH THAT THE SIGNAL PRESENTED TO THE COMPARATOR HAS SUFFICIENT AMPLITUDE. IT MUST ALSO HAVE A LOW ENOUGH INTERNAL NOISE, AND AN ACCEPTIBLE EXCESS NOISE CONTENT.

THE NOISE OF THE AMPLIFIER CAN BE COMPARED TO THE INPUT SOURCE NOISE (WHICH IS REALLY A 'SIGNAL' FOR THE AMPLIFIER) BY A COUPLE OF DIFFERENT MEASURES (IE, 'SIGNAL'-TO-AMPLIFIER-NOISE RATIO; NOISE FIGURE). THE AMPLIFIER CONTRIBUTION TO THE COMPARATOR INPUT ACTS TO CORRUPT THE OUTPUT DATA STREAM, SINCE THE AMPLIFIER NOISE CAN CHANGE DECISION POINTS NEAR THRESHOLD FROM ONE SIDE TO THE OTHER. IN THIS SENSE, THE ALLOWABLE AMPLIFIER NOISE LEVEL DEPENDS ON THE TOTAL AMOUNT OF DATA WHICH WILL BE ACCUMULATED IN USE FROM THE RNG; THE GREATER THE DATA BASE, THE SMALLER MUST BE THE AMPLIFIER NOISE CONTRIBUTION IN ORDER TO MAINTAIN THE AMPLIFIER CORRUPTION OF THE RNG DATA BELOW A SIGNIFICANT LEVEL.

IF A GENERALIZED VIEW OF THE 'SOURCE' OF THE ELECTRONIC NOISE IS ACCEPTIBLE, THEN NO DIFFERENTIATION NEED BE MADE AMONG DIODE NOISE AND AMPLIFIER NOISE, NOR NEED ANY PRECAUTIONS BE TAKEN TO MINIMIZE AMPLIFIER NOISE.

IN ASSESSING COMPARATOR OFFSET, BOTH VOLTAGE AND CURRENT OFFSETS MUST BE CONSIDERED IN THE WORST-CASE COMBINATION (IE, IN OPPOSITION). TEMPERATURE EXTREMES OF BOTH, AND THE MAXIMUM AND NOT TYPICAL VALUES OF MANUFACTURER'S SPECIFICATIONS, MUST BE USED. AND FINALLY, A COMFORTABLY LARGE DESIGN RATIO OF NOISE AMPLITUDE TO ALLOWABLE OFFSET MUST BE EMPLOYED.

THE COMPARATOR MUST HAVE A SWITCHING SPEED FAST ENOUGH (OR A LATENCY SMALL ENOUGH) NOT TO DEGRADE ITS OPERATION AT THE EXPECTED DATA RATE. A USUAL ADJUNCT OF SLOW SWITCHING IS AN ASSYMETRY IN RISE AND FALL TIMES (AS WELL AS ASSYMETRIES IN RISE- AND FALL-TIME DEPENDENCIES ON INPUT AMPLITUDE). SUCH FACTORS, AS WELL AS THE PRESENCE OF A FINITE OFFSET, WILL AFFECT THE RATIO OF THE YIELD OF 1S AND ØS IN THE RAW BIT STREAM.

THE USE IF A FAST COMPARATOR WILL HELP AVOID THE POSSIBILITY OF OSCILLATIONS IN THE COMPARATOR CIRCUIT. GOOD HIGH-FREQUENCY DESIGN PRACTICE IS ALSO IMPORTANT HERE, AS IS CAREFUL TESTING TO INSURE THAT OSCILLATIONS DO NOT TAKE PLACE UNDER SELECTED COMBINATIONS OF COMPARATOR INPUT VOLTAGES. THE INCLUSION OF A SMALL AMOUNT OF HYSTERESIS IN THE COMPARATOR SWITCHING CHARACTERISTIC WILL HELP TO GIVE WELL-DEFINED AND OSCILLATION-FREE OUTPUT TRANSITIONS.

ONE ALTERNATIVE TO APPROXIMATING AN (OPEN-LOOP) MINIMIZATION OF THE COMPARATOR OFFSET (AS BY TRIMPOTS, TEMPERATURE COMPENSATION, ETC.) IS TO EMPLOY AN ADAPTIVE FEEDBACK CIRCUIT TO OBTAIN A SELF-ZEROING THRESHOLD. SUCH A CIRCUIT MUST BY DEFINITION HAVE A LOWER BOUND ON USEFUL LOW-FREQUENCY CUTOFF IN THE APPLIED ANALOG NOISE VOLTAGE, SINCE IT IS ESSENTIALLY A SWITCHED OSCILLATOR DRIVEN BY THE INPUT NOISE VOLTAGE. AS LONG AS THE COMPARATOR TRANSITIONS ARE DOMINATED BY THE INPUT SIGNAL (IE, THE LONGEST NOISE TRANSITION DURATION IS SIGNIFICANTLY SHORTER THAN THE FREE SWITCHING PERIOD OF THE FEEDBACK CIRCUIT), THE CIRCUIT DOESN'T KNOW IT IS A SWITCHED OSCILLATOR INSTEAD OF A COMPARATOR.

THE FOLLOWING LIST SUMMARIZES SOME POINTS TO CHECK IN DETERMINING THE APPROPRIATENESS OF ANY GIVEN RNG CIRCUIT TO ITS INTENDED OPERATING ENVIRONMENT (OR VICE VERSA).

USE VERY CONSERVATIVE RATINGS WITH RESPECT TO SEMICONDUCTOR SPECIFICATIONS. BE SURE TO FOLLOW ACCEPTED DESIGN PRACTICES.

USE A MAIN POWER SYSTEM WITH ADEQUATE EMI REJECTION AND POWER-LINE TRANSIENT SUPPRESSION.

USE LOCAL OR ON-CARD POWER REGULATION FOR ANALOG CIRCUITS.

DON'T USE BATTERIES FOR POWER -- THEIR ATTENDANT RISKS AREN'T WORTH ANY POTENTIAL GAINS IN SYSTEM ISOLATION.

USE ADEQUATE FILTERING, ISOLATION, AND SHIELDING (BOTH ELECTROSTATIC AND MAGNETIC, IF NEED BE). USE FEED-THROUGH FILTERS AND FERRITE-BEAD ATTENUATORS.

USE COMPARATOR DECISIONS MADE DURING QUIET PERIODS OF ASSOCIATED DATA-PROCESSING EQUIPMENT CLOCK CYCLES.

INCLUDE SOME FORM OF FIRST-ORDER CORRECTION FOR UNEQUAL YIELDS OF 1S AND ØS FROM THE RAW COMPARATOR OUTPUT.

AVOID OFF-SYSTEM OUTPUT-DATA STRAY-CURRENT PATHS (SUCH AS GROUND LOOPS) BY USING DIGITAL OPTO-ISOLATORS. REFRAIN FROM ASSUMING THE BURDEN OF THEIR DISADVANTAGES (MAINLY COST AND SLOW RESPONSE) IN COMMON-GROUND SYSTEMS WHERE THEIR ONE PARTICULAR ADVANTAGE IS NOT REQUIRED.

OTHER ELECTRONIC RNG SYSTEMS

--> THERE ARE TWO COMMON TYPES OF RNGS WHICH USE RELATIVELY INFREQUENT EVENTS TO STOP A FAST COUNTER AND GENERATE A RANDOM OUTPUT DIGITAL WORD. THE RADIOACTIVE DECAY RNG USES A SOURCE OF LOW-LEVEL RADIOACTIVITY AND A RADIATION DETECTOR TO GENERATE THE RANDOM TIMING PULSES. THE EXTREME-EVENT RNG USES A RANDOM ELECTRONIC NOISE SOURCE, BUT HAS A TRIGGER CIRCUIT (COMPARATOR) WITH A THRESHOLD SET RELATIVELY HIGH WITH RESPECT TO THE AVERAGE NOISE AMPLITUDE.

IN BOTH CLASSES OF RNGS, CARE MUST BE TAKEN TO DESIGN DIGITAL ELECTRONIC CIRCUITS WHOSE OPERATIONS ARE NOT SUSCEPTIBLE TO EFFECTS FROM DIFFERENCES IN LOGIC RISE AND FALL TIMES. IT IS ALSO ADVISABLE TO USE FAST DIGITAL LOGIC FAMILIES, TO MINIMIZE THE POSSIBILITIES OF SUCH PROBLEMS. IN PARTICULAR, BE SURE TO USE SYNCHRONOUS COUNTERS AND AVOID RIPPLE COUNTERS, WHOSE VARIATIONS IN STATE SWITCHING TIMES CAN BE TRANSLATED INTO UNEQUAL PROBABILITIES OF OCCURRENCES OF THE OUTPUT STATES (DATA WORDS) OF THE SYSTEM.

IN RADIOACTIVE DECAY RNGS USING GEIGER-MUELLER TUBES: REALIZE THAT THE G-M TUBE HAS A RELATIVELY LONG OUTPUT-PULSE-AND-RECOVERY TIME PERIOD, AND DON'T PRESS THESE LIMITS IN ATTEMPTING TO OBTAIN A FAST OPERATING RATE.

IN SOLID-STATE DETECTOR RNGS: DETERMINE IF YOUR DETECTOR CHARACTERISTICS AND YOUR PARTICLE BEAM GEOMETRY/COLLIMATION YIELD ESSENTIALLY FULL ENERGY DEPOSITION IN THE ACTIVE VOLUME OF YOUR DETECTOR. IF NOT, THRESHOLDING WILL BE NECESSARY IN THE PULSE AMPLIFIER CHAIN. MAKE SURE YOUR THRESHOLD IS STABLE OVER TIME AND TEMPERATURE, AND IS PRECISELY RESETTABLE IF IT IS VARIED TO CONTROL THE AVERAGE COUNT RATE.

PsiLab //
PARTICIPANT MEASURES

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PsiLab //
PARTICIPANT MEASURES

INTRODUCTION

A serious problem in evaluating variability across laboratories in psi research has been the absence of systematic description of subject populations being studied.

When subject characteristics are unspecified, it is not possible to assess the likelihood that a subsequent procedural replication in another laboratory failed to replicate the original findings because its subjects were drawn from a different population. Unfortunately, there has been little uniformity in reporting subject characteristics even in the more homogeneous research domains (e.g., ESP ganzfeld, RNG PK research). Descriptions of subject characteristics in the research literature vary from detailed psychometric breakdowns to nothing more than the number of otherwise anonymous subjects/operators. PRL addresses this problem through standardized participant registration procedures.

PARTICIPANT REGISTRATION PROCEDURES:

We are including a copy of the PIF which can be photocopied and used intact. You may want to use the sample cover letter to create your own.

New participants in the PRL program complete a 55-item Participant Information Form (PIF) prior to participating in PRL experimental research projects. The PIF provides information concerning demographics, basis of recruitment, attitudes toward psi, personal psi experiences, and experience with potentially relevant personal practices such as stress management, biofeedback, etc. The PIF also includes information on medical history, sleep patterns and dream recall.

The PIF data are stored in a hierarchical computer database (currently the "General Manager" database for Apple //) and constitutes each participant's base record. Subordinate records are added to a participant's file as s/he contributes to PRL test series. Those who participate in more than one experimental series complete the Myers-Briggs Type Indicator (MBTI), a well-established psychological inventory designed to assess cognitive and perceptual characteristics (see PRL Annual Report, 1982, Section II for description of the MBTI). MBTI data are filed in the participant's PIF record.

Psychophysical Research Laboratories

301 College Road, East
Princeton, N.J. 08540
(609) 452-8144

We're pleased to have you as a potential participant in our research here at PRL.

As a first step, we'd like to gather some information about you. Some of this information will help us to understand you a little better; some of it will be compared with the responses given by other research participants in order to help us understand better how people's attitudes and experiences affect their ESP.

All of the information you give us will be kept strictly confidential--no one except PRL staff will be able to find out what responses you gave to any of the questions unless we have asked for and received your permission in writing to release that information.

Thank you for your cooperation.

The PRL Staff

Date ____________________

1. Name: ____________________

2. Address: ____________________

____

3. Phone: ____________________

4. Date of Birth: ____________________

5. Place of Birth: ____________________

6. If you sometimes think in a language other than English, please specify:

____

7. Occupation: ____________________

8. Education: ____________________

9. What was the source of your referral?

   Media - if so, which?
   Word of mouth (who?)
   Scientific literature ____________________
   Staffer (who?)
   Other (please specify)

10. Please describe briefly the basis of your interest in this research:

____

____

____

11. At what times are you available to participate in this research?

____

Please use the following definitions for the purpose of answering the next three questions.

PSI: Direct interactions between mental processes and the physical world occurring outside currently understood channels.

PSI is commonly divided into two categories:

Extrasensory Perception (ESP): Reception of information without the use of the known senses or logical inference.

Psychokinesis (PK): Mental influence on the physical world.

ESP is for convenience further subdivided into three categories:

TELEPATHY: ESP of the thoughts, feelings or behavior of another person.

CLAIRVOYANCE: ESP of distant physical events or objects.

PRECOGNITION: ESP of the future.

12. Using the following scale, rate the strength of your belief in psi:

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Don't Believe			Neutral			Believe Very Strongly

13. Have you had experiences which you thought involved psi?

Yes__________ No__________

14. If you have had experiences which you thought involved psi, which of the following do you feel you have experienced? (Please check)

☐ (a) Telepathy
☐ (b) Clairvoyance
☐ (c) Precognition
☐ (d) Psychokinesis
☐ (e) Other (Please specify) ______________________________

If you would like to share your experiences with us, please do so on the back of this sheet.

15. In general, how often do you experience coincidences?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Never			Occasionally			Frequently

16. In your experience do coincidences come in clusters or occur fairly regularly?

____

17. Are you aware of any special circumstances associated with your experience of coincidences?

____

____

18. Have you ever participated in casual testing of psi phenomena? (E.g., card-calling games with friends)

Yes__________ No__________

If yes, please describe:______________________________________

____

19. Have you ever participated in formal laboratory testing of psi phenomena?

Yes__________ No__________

If yes, please describe:____

____

20. Do you have any special dietary habits?

Yes__________ No__________

If yes, please describe:____

____

21. Do you take nutritional supplements (e.g., vitamins)?

Yes__________ No__________

22. Please check the medical problems you have or have had:

	Currently	1-5 Years	More than 5 Years
Diabetes			
Epilepsy			
Heart trouble			
Back trouble			
Mental disorder			
Loss of hearing			
Poor eyesight			
Colorblindness			
High blood pressure			
Respiratory disease			
Cancer			
Nervousness			
Other (Explain)			

____

23. Are you currently taking prescription or nonprescription medications?

Yes__________ No__________

If yes, please specify:____

24. Do you use drugs other than the medications listed above? If so, do you consider your use (please check)

	Occasional	Mild	Moderate	Heavy
Alcohol				
Caffeine				
Tobacco				
Other drugs				

25. Do you have regular sleep habits?

Yes__________ No__________

26. On the average how many hours a night do you sleep?

____

27. Do you feel you get enough sleep?

Yes__________ No__________

28. Have you ever practiced any form of mental discipline, e.g., meditation, biofeedback, hypnosis, relaxation exercises?

Yes__________ No__________

28.(a) If yes, what kind?______________________________

28.(b) If yes, consistently or sporadically?______________________

29. Have you ever studied any physical regimen such as hatha yoga, tai chi, aikido, etc?

Yes__________ No__________

29.(a) If yes, what kind?______________________________

30. Have you ever taken part in a formal self-improvement program such as TM, psychotherapy, est, etc.?

Yes__________ No__________

30.(a) If yes, please specify:__________________________

31. How often do you recall specific content of your dreams?

☐ 1 Rarely	☐ 2	☐ 3	☐ 4 Once a Week	☐ 5	☐ 6	☐ 7 Almost Every Day

32. To what degree do your dreams differ from your ordinary everyday experience?

☐ 1 Not at all	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7 Very much

33. How often are you aware that you have dreamed without being able to recall the dream's content?

☐ 1 Rarely	☐ 2	☐ 3	☐ 4 Once a Week	☐ 5	☐ 6	☐ 7 Almost Every Day

34. Have you ever had a dream in which you were aware you were dreaming?

Yes__________ No__________

35. If you have had a dream in which you were aware you were dreaming, how often does this occur?

☐ 1 Rarely	☐ 2	☐ 3	☐ 4 Once A Week	☐ 5	☐ 6	☐ 7 Almost Every Day

36. How often do you daydream?

☐ 1 Rarely	☐ 2	☐ 3	☐ 4 Daily	☐ 5	☐ 6	☐ 7 Hourly

37. Please rank order from 1 through 4 the thematic content of your daydreams where (1) is most frequent and (4) is least frequent:

(a) Past events
(b) Possible futures
(c) Fantasy
(d) Other (please specify)__________________________

1. __________
2. __________
3. __________
4. __________

38. Do you enjoy activities which require an involvement in fantasy?

☐ 1 Not at all	☐ 2	☐ 3	☐ 4 Neutral	☐ 5	☐ 6	☐ 7 Very Much

39. How often do you lose awareness of your surroundings when you get involved in an activity?

☐ 1 Never	☐ 2	☐ 3	☐ 4 Half the time	☐ 5	☐ 6	☐ 7 Always

40. How often do you lose your sense of time when you get involved in an activity?

☐ 1 Never	☐ 2	☐ 3	☐ 4 Half the time	☐ 5	☐ 6	☐ 7 Always

41. Do you believe that

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Things "just happen"						People make things happen

42. Are you usually:

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Early			On time			Late

43. How strongly do you believe in luck?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Don't Believe						Believe Very Strongly

44. Are you a lucky person?

Yes__________ No__________

45. How frequently do you have accidents?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Never			Weekly			Daily

46. Do you like to participate in a situation in which something important to you is at risk? (See the list below for examples)

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Don't like at all			Neutral			Like very much

47. Please check those activities you enjoy:

☐ (a) Gambling
☐ (b) Games of chance (no monetary risk)
☐ (c) Speaking or performing in public
☐ (d) Activities involving physical risk

48. On the following continuum, where would you place yourself?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Outgoing						Reserved

49. On the following continuum, where do you place yourself?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Not Competitive						Highly Competitive

50. Have you played video games?

Yes__________ No__________

51. If you have played video games, which ones have you played?

____

52. If you have played video games, where have you played?

____

53. If you have not played video games, would you like to?

Yes__________ No__________

54. How do you express your creativity?

____

____

____

____

____

____

____

____

(If you need more space, please use the back of the page)

55. If there is anything else you think we should know, please use this space:

____

____

____

____

____

____

____

____