Program Description I

Program Title GRAECO-LATIN SQUARE

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Program Description, Equations, Variables A Graeco-Latin square permits a three-way control in the variation of experimental units, i.e. row effects, column effects and "layer" effects. A Graeco-Latin square defines a restricted randomization procedure whereby p treatments are assigned to p^2 experimental units so as to obtain balance along three dimensions. From the point of view of construction such a square is a composite of two orthogonal Latin squares. Independent randomization of rows and columns is required before the resulting composite square is used in practice. In order to maintain the identity of the squares which are combined to form the composite, the cells of one square are desginated by Latin letters, and the cells of the second square by Greek letters. Thus for two 3 x 3 squares

1

a	b	c
b	c	a
c	a	b

2

α	β	γ
γ	α	β
β	γ	α

Composite

$a\alpha$	$b\beta$	$c\gamma$
$b\gamma$	$c\alpha$	$a\beta$
$c\beta$	$a\gamma$	$b\alpha$

The sample problem given illustrates the use for a 4 x 4 Graeco Latin square.

The equations used are:

1. Row Sums = RS_i = x_i i= 1,2,.....n (a)
2. Col Sums = CS_j = x_j j= 1,2,.....n (b)
3. TR_1 Sums = TR_1 = x_{tr1} 1,2,.....n (c)

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4. TR_2 Sums = TR_2 = x_{Tr2} = 1,2,.....n (d)

5. Total Sums = (a) + (b) = (e)

The sum of squares for each of the above equations = $(a)^2$, $(b)^2$, $(c)^2$, $(d)^2$, and $(e)^2$ respectively.

Variations.

6. Row Variations = $\frac{(a)^2}{n^2}$ (f)

7. Col Variations = $\frac{(b)^2}{n^2}$ (g)

8. Treatment 1 = $\frac{(c)^2}{n^2}$ (h)

9. Treatment 2 = $\frac{(d)^2}{n^2}$ (i)

10. Total = $\frac{(e)^2}{n^2}$ (j)

11. Error variation = (j) - (f) - (g) - (h) - (i)

where n = no. of rows

11. Degrees of freedom for error = $(n^2-1) - 4(n-1)(n-3)$

12. Mean Square = $\frac{\text{Variation}}{\text{df}}$

13. F ratio = $\frac{\text{Mean Square}}{\text{df} - 1}$

Correction of erroneous data input. Note that there is no automatic correction label. If an error is input and it is not desired to start afresh summing the data the following routine will delete the error - Re-enter the erroneous data and do (Sto - 1) (x^2) (Sto-6) (Rcl 2) (1)(-)(Sto 2). The program can then continue in the normal way.

Note also that this correction process is easily carried out with all data entries except the final one (to complete col. row etc. summing) This is because the program automatically halts. In the latter case advantage must be taken of the pauses to press (R/S) and then the correction routine. Otherwise the program automatically proceeds to the next step at this stage and you will therefore miss the opportunity of correcting the erroneous input. That is the only reason for the inclusion of the "pauses" in the program.

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Problem: In the following table A,B,C,D represent four different types of gasoline, the Greek letters denote different roads used, and the numbers represent mileages obtained in an experiment using four different drivers in four different cars.
Use a Graeco-Latin square design to ascertain by analysis of variance if differences exist between the various types of gasoline.

Drivers

Cars	1	2	3	4
1	Bγ 19	Aβ 16	Dδ 16	Cα 14
2	Aδ 15	Bα 18	Cγ 11	Dβ 15
3	Dα 14	Cδ 11	Bβ 21	Aγ 16
4	Cβ 16	Dγ 16	Aα 15	Bδ 23

Solution: Load Card (both sides)

Enter No. of rows 4 (A)

Sum row mileages - 19 (E) 16 (E) 16 (E) 14 (E) output = 65
15 (E) 18 (E) 11 (E) 15 (E) output = 59
14 (E) 11 (E) 21 (E) 16 (E) output = 62
16 (E) 16 (E) 15 (E) 23 (E) output = 4

Sum col. mileages= 19 (E) 15 (E) 14 (E) 16 (E) output = 64
16 (E) 18 (E) 11 (E) 16 (E) output = 61
16 (E) 11 (E) 21 (E) 15 (E) output = 63
14 (E) 15 (E) 16 (E) 23 (E) output = 4

Sum Latin letters A's 15 (E) 16 (E) 15 (E) 16 (E) output = 62
B's 19 (E) 18 (E) 21 (E) 23 (E) output = 81
C's 16 (E) 11 (E) 11 (E) 14 (E) output = 52
D's 14 (E) 16 (E) 16 (E) 15 (E) output = 4

Sum Greek letters α's 14 (E) 18 (E) 15 (E) 14 (E) output = 61
β's 16 (E) 16 (E) 21 (E) 15 (E) output = 68
γ's 19 (E) 16 (E) 11 (E) 16 (E) output = 62
δ's 15 (E) 11 (E) 16 (E) 23 (E) output = list

see next page

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Variations	16.50	***
	6.50	***
	111.50	***
	7.50	***
	6.00	***
	148.00	***
Degrees of Freedom	3.00	***
	3.00	***
	3.00	***
	3.00	***
	3.00	***
Mean Squares	5.50	***
	2.17	***
	37.17	***
	2.50	***
	2.00	***
F Ratios	2.75	***
	1.08	***
	18.58	***
	1.25	***

These may be conveniently set up in the following tableau form:

	Variation	D/F	Mean Square	F ratio
Cars	16.50	3.00	5.50	2.75
Drivers	6.50	3.00	2.17	1.08
Gasolines	111.50	3.00	37.17	18.58
Roads	7.50	3.00	2.50	1.25
Error	6.00	3.00	2.00	
Total	148.00			

Sketch(es)

Sample Problem(s) (continued)

We have therefore Critical $F_{.95,3,3} = 9.28$

and Critical $F_{.99,3,3} = 29.50$

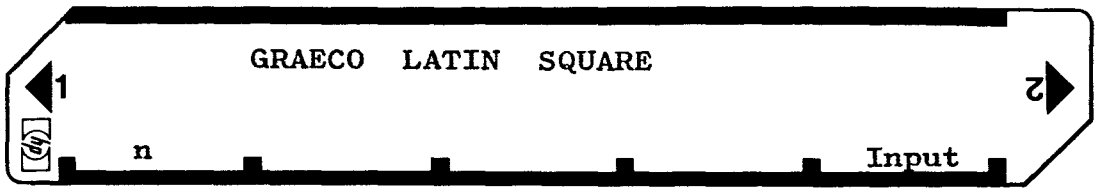
Thus we can reject the hypothesis that the gasolines are the same at the 0.05 level but not at the 0.01 level.

Solution(s)

Reference(s) Probability and Statistics (Murray R. Spiegel) Schaum's outline Series p. 328 ff.

For a detailed treatment of this subject see "Statistical Principles in Experimental Design" by B.J.Winer (mcGraw Hill - 1971) Chapter 9.

User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1.	Load Card (both sides)			
2.	Input number of rows	n	A	n
3.	Sum row data	data	E	4
4.	Sum column data	data	E	4
5.	Sum Latin Letter data	data	E	4
6.	Sum Greek Letter data	data	E	list
7.	(Optional) set up list from step 6 in tableau format (manual step)			
8.	(Optional) to correct erroneous data otherwise go to Step 2 and start afresh Perform the following steps: Re-enter the error ST-1 35-45 01 53 ST-6 35-45 06 RCL2 36 02 01 -45 STO2 35 02 51 ~~Note: This may be done when program is halted or when program is "pausing"~~ For a new case go to Step 2.			

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STEP	KEY ENTRY	KEY CODE	COMMENTS
001	001 *LBL A	21 11	INPUT No ROWS
	002 CF2	16 22 02	
	003 ENT↑	-21	
	004 CLRG	16-53	CLEAR REGISTERS
	005 P≠S	16-51	
	006 CLRG	16-53	
	007 STOD	35 14	STORE No. ROWS
	008 X²	53	
	009 P≠S	16-51	N^2
010	010 STO9	35 09	
	011 P≠S	16-51	
	012 1	01	SET FOR STORAGE
	013 0	00	OF COMPLETED SUMS
	014 STO1	35 46	IN SECONDARY REG.
	015 RCLD	36 14	
	016 RTN	24	
	017 *LBL 0	21 00	
	018 0	00	
	019 STO1	35 01	CLEAR SUMMING
020	020 STO2	35 02	REGISTERS AND
	021 STO3	35 03	CONTROL REG.
	022 STO5	35 05	
	023 STO6	35 06	
	024 STOE	35 15	
	025 P≠S	16-51	
	026 2	02	
	027 ST+7	35-55 07	
	028 RCL7	36 07	
	029 RCL9	36 09	
30	030 P≠S	16-51	
	031 X=Y?	16-33	
	032 GTO4	22 16 11	
	033 RCLD	36 14	
	034 RTN	24	
	035 *LBL E	21 15	
	036 ST+1	35-55 01	INPUT DATA
	037 X²	53	SUM AND SQUARE
	038 ST+6	35-55 06	
	039 1	01	TEST FOR ROW/COL/
040	040 ST+2	35-55 02	TR completion
	041 RCLE	36 02	
	042 RCLD	36 14	
	043 X=Y?	16-33	
	044 GTO5	22 12	
	045 R↑	16-31	
	046 X≠Y	54	SQUARESUM AND
	047 R/S	51	STOP
	048 *LBL E	21 12	
	049 R↑	16-31	
050	050 X≠Y	54	
	051 PSE	16 51	PAUSES FOR ERROR
	052 PSE	16 51	CORRECTION IF
	053 PSE	16 51	NEEDED
	054 RCL1	36 01	
	055 X²	53	
	056 RCLE	36 02	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	057 ÷	-24	
	058 ST+3	35-55 03	
	059 RCL1	36 01	
	060 STO+	35 04	
060	061 ST+5	35-55 05	
	062 RCL2	36 02	
	063 RCLE	36 15	
	064 +	-55	
	065 STOE	35 15	
	066 RCL2	36 02	
	067 2	00	
	068 STO1	35 01	
	069 STO2	35 02	
	070 CLX	-51	
070	071 RCL4	36 04	
	072 RCLE	36 15	
	073 P≠S	16-51	
	074 RCL9	36 09	TEST FOR COMPLET-
	075 P≠S	16-51	ION OF SUM.
	076 X=Y?	16-33	
	077 GTO8	22 08	
	078 R↓	-31	
	079 R↓	-31	DISPLAY SUM
	080 R/S	51	
080	081 *LBL 6	21 06	
	082 F0?	16 23 00	ROW SUM
	083 GTO0	22 13	
	084 F1?	16 23 01	COL SUM
	085 GTO0	22 14	TREATMENTS SUM
	086 GTO3	22 02	
	087 *LBL 2	21 02	
	088 SF9	16 21 00	RESET FOR REPEAT
	089 SF1	16 21 01	LATIN SQ. PROCESS
	090 GTO9	22 09	
090	091 *LBL 5	21 05	
	092 RCL6	36 06	COMPUTE SS (TOTAL)
	093 RCL5	36 05	ROUTINE
	094 X²	53	
	095 R↑	16-31	
	096 STO2	35 02	
	097 ÷	-24	
	098 STO1	35 01	
	099 -	-45	
	100 STO0	35 00	
100	101 RTN	24	
	102 *LBL C	21 13	
	103 SF1	16 21 01	FOR 2ND RUN
	104 CF0	16 22 00	
	105 GSB5	23 06	
	106 STO7	35 07	
	107 GSB7	23 07	
	108 *LBL 4	21 04	
	109 STO8	35 08	HOLD SUM
	110 STO0	22 00	TO CLEAR REG
110	111 *LBL 1	21 14	
	112 [illegible]	[illegible]	1ST. SUM COMPLETE

REGISTERS

0 USED	1 USED	2 USED	3 USED	4 USED	5 USED	6 USED	7 USED	8 USED	9 USED
S0 USED	S1 USED	S2 USED	S3 USED	S4 USED	S5 USED	S6 USED	S7 USED	S8	S9 N^2

A	B	C	D N	E USED	I COUNTER

Program Listing II

STEP	KEY ENTRY	KEY CODE	COMMENTS
	113 LBL	16 22 01	
	114 GSB6	23 06	
	115 GSB7	23 07	
	116 ST09	35 09	
	117 GT00	22 00	
	118 *LBL7	21 07	
	119 RCL3	36 03	
120	120 RCL1	36 01	INDIVIDUAL SS.
	121 -	-45	
	122 ST-7	35-45 07	
	123 ST04	35 04	
	124 *LBL5	21 05	
	125 RCLi	36 45	TEST FOR EMPTY
	126 X=0?	16-43	STORAGE REGISTER
	127 GT03	22 03	
	128 ISZI	16 26 46	LOOP TO TEST
	129 GT05	22 05	
130	130 *LBL3	21 03	STORE SS. IN
	131 RCL4	36 04	NEXT AVAILABLE
	132 STOi	35 45	REGISTER
	133 GT04	22 04	
	134 *LBLa	21 16 11	PRINT ROUTINE
	135 PRTX	-14	
	136 SF0	16-11	
	137 RTN	24	
	138 *LBLa	21 16 11	COMPUTE ANOVA
	139 RCL0	36 00	TABLE
140	140 P≠R	16-51	
	141 ST05	35 05	
	142 RCL0	36 00	
	143 -	-45	
	144 RCL1	36 01	
	145 -	-45	
	146 RCL2	36 02	
	147 -	-45	
	148 RCL3	36 03	
	149 -	-45	
150	150 ST04	35 04	
	151 RCL2	36 14	
	152 1	01	
	153 -	-45	
	154 ST06	35 06	
	155 RCL0	36 00	
	156 GSBa	23 16 14	
	157 RCL1	36 01	
	158 GSBa	23 16 14	
	159 RCL2	36 02	
160	160 GSBa	23 16 14	
	161 RCL3	36 03	
	162 GSBa	23 16 14	
	163 RCL4	36 04	
	164 GSBa	23 16 14	
	165 RCL5	36 05	
	166 GSBa	23 16 14	
	167 RCL6	36 06	
	168 GSBa	23 16 14	

STEP	KEY ENTRY	KEY CODE	COMMENTS
	169 RCL6	36 06	
170	170 GSBa	23 16 14	
	171 RCL6	36 06	
	172 GSBa	23 16 14	
	173 RCL6	36 06	
	174 GSBa	23 16 14	
	175 RCL6	36 06	
	176 GSBa	23 16 14	
	177 RCL0	36 00	
	178 RCL5	36 06	
	179 ÷	-24	
180	180 STO0	35 00	
	181 GSBa	23 16 14	
	182 RCL1	36 01	
	183 RCL6	36 06	
	184 ÷	-24	
	185 ST01	35 01	
	186 GSBa	23 16 14	
	187 RCL2	36 02	
	188 RCL6	36 06	
	189 ÷	-24	
190	190 STO2	35 02	
	191 GSBa	23 16 14	
	192 RCL3	36 03	
	193 RCL6	36 06	
	194 ÷	-24	
	195 STO3	35 03	
	196 GSBa	23 16 14	
	197 RCL4	36 04	
	198 RCL6	36 06	
	199 ÷	-24	
200	200 GSBa	23 16 14	
	201 RCL6	36 06	
	202 1	01	
	203 -	-45	
	204 STO6	35 06	
	205 RCL0	36 00	
	206 X≠Y	-41	
	207 ÷	-24	
	208 GSBa	23 16 14	
	209 RCL1	36 01	
210	210 RCL6	36 06	
	211 ÷	-24	
	212 GSBa	23 16 14	
	213 RCL2	36 02	
	214 RCL6	36 06	
	215 ÷	-24	
	216 GSBa	23 16 14	
	217 RCL3	36 03	
	218 RCL6	36 06	
	219 ÷	-24	
220	220 GTOa	22 16 14	TO LAST PRINTOUT
	221 R/S	51	

LABELS

A INPUT N	B Σ Rate	C CONTROL	D	E INPUT DATA	0 CONTROL
a TABLE LIST	b	c	d PRINT	e	1 CONTROL
0 CLEAR REG.	1	2 FLAG RESET	3 SEC. REG STORAGE	4 CONTROL	2 CONTROL
5 STO. SUMS LOOP	6 Σ SS TOTAL	7 Σ SS IND	8 CONTROL	9	3

FLAGS

	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

SET STATUS

TRIG		DISP	
DEG	☒	FIX	☒
GRAD	☐	SCI	☐
RAD	☐	ENG	☐
		n	2