the data is an estimate of the population variance, just as for a given factor, if that factor has no effect on the dependent variable in terms of population means, the mean square due to that factor should be an estimate of the population variance. We are therefore able to divide our interaction mean square by MSW to test for the presence of an interaction. This F-test was just like all the previous F-tests that we did.

Finally, we discussed higher order designs. In general, we saw that they were just extensions of lower order designs, the main new feature being that there were increasingly exotic, complicated, and unwieldy higher order interactions with which to deal.

PROBLEMS

1. A psychologist is interested in the effects of socioeconomic status (SES) and motivation on memory. She uses a free-recall task in which a subject is presented a list of 20 words and is asked to recall as many of the words as possible. The dependent variable is thus the number of words recalled. The design is 2 × 2. Subjects are high or low SES. In addition, subjects have either high motivation (they're given 10 cents for each word they remember) or low motivation (they're given 1 cent for each word they remember). There are 10 subjects in each of the four conditions.

		Socioeconomic Status: High	Socioeconomic Status: Low	
Motivation	Low	I $T_{11} = 20$ $M_{11} = 2$	II $T_{12} = 80$ $M_{12} = 8$	$T_{R1} = 100$ $n_{R1} = 20$
	High	III $T_{21} = 100$ $M_{21} = 10$	IV $T_{22} = 120$ $M_{22} = 12$	$T_{R2} = 220$ $n_{R2} = 20$
		$T_{C1} = 120$ $n_{C1} = 20$	$T_{C2} = 200$ $n_{C2} = 20$	$T = 320$ $n = 40$

For questions a and b of this problem, you can view this design as a one-way design:

Condition			
I. Low motivation high SES	II. Low motivation low SES	III. High motivation high SES	IV. High motivation low SES
$T_1 = 20$ $M_1 = 2$	$T_2 = 80$ $M_2 = 8$	$T_3 = 100$ $M_3 = 10$	$T_4 = 120$ $M_4 = 12$

Assume SSW = 3600.

a. What is the value of SSB? What df is associated with SSB?
b. Compute MSB and MSW. What is F? Is it significant?

For parts c–f consider this as a two-way (2 × 2) design and refer to the data in the 2 × 2 table.

c. Compute the sum of squares corresponding to the motivation (row) variable. How many dfs does this sum of squares have?
d. What is the mean square for the motivation variable? What is the F? Is this F significant?
e. Compute the SS and MS for the SES (column) variable. What is the F for this variable? Is this F significant?
f. Compute the SS and MS for the interaction. What is the F for the interaction? Is it significant?

2. An experiment is done to test the effect of age and dress of a speaker on attitude of the audience. Groups of college students listen to a speaker talk on why Smith should be president. The speaker is either neatly dressed (tie and jacket) or grubbily dressed (blue jeans and t-shirt). Additionally, the speaker is either in his 20s, 30s, or 40s. After the talk the subjects rate their attitude about whether Smith should be elected, on a scale ranging from 0 (should not be elected) to 7 (should be elected).

There are two subjects per group. The data are as follows:

		Speaker's Age		
		20s	30s	40s
Speaker's dress	Grubby	5 5	3 4	2 1
	Neat	0 1	1 1	2 1

a. Plot means and 95% confidence intervals for the six cells.
b. Test the effects of age, dress, and interaction on attitude scores.

3. An experiment is done to test whether marijuana has any effect on perceived time duration. To test this, marijuana is given to one group of subjects and a placebo to another. Additionally, half the subjects in each group are males and the other half are females. The design is thus 2 × 2: male/female × drug/placebo. There are six subjects in each cell. All subjects sit in a room and are asked to talk into a tape recorder until they think 10 minutes has elapsed. The dependent variable in the experiment is then the actual amount of time spent in the room. The data are as follows:

	Drug			Placebo		
Males	5 6	3 6	4 7	11 13	9 11	8 10
Females	8 6	7 8	9 9	11 13	14 12	9 10

a. Plot means and 95% confidence intervals for the four cells.
b. Perform the appropriate analysis to determine whether there are significant effects of sex, drug, and interaction.

4. A physiological psychologist is interested in the effects of three types of brain lesions on learning in rats. He is also interested in testing out the brain lesions on three types of rats: rats bred to be dumb, rats bred to be moderately intelligent, and rats bred to be smart. He has, therefore, a 3 × 3 design: three levels of lesion crossed with three levels of intelligence. Assume there are five observations per cell, and that SST = 262.

The dependent variable is number of trials needed to learn a maze, and the data are as follows (M_{ij} refers to the mean of a given cell):

		Type of Lesion		
		I	II	III
Intelligence	High	$M_{11} = 4$	$M_{12} = 2$	$M_{13} = 5$
	Medium	$M_{21} = 6$	$M_{22} = 5$	$M_{23} = 6$
	Low	$M_{31} = 6$	$M_{32} = 10$	$M_{33} = 7$

a. What are the cell and marginal and grand totals? Put them in a table like the one above.
b. Plot the data in two ways: with type of lesion on the abscissa and with intelligence on the ordinate. Compute 95% confidence intervals around all means.
c. What are SSB, SSR, SSC, SSI, and SSW? What are all the dfs and MSs? Put them all into an ANOVA table.
d. Compute the appropriate F's. What is significant?

5. A new drug is invented that will presumably speed up learning in rats. A group of 40 rats is subdivided into two groups: one group injected with the drug, the other with a placebo. Each of the two groups is further divided in half: Ten rats in each group are rewarded with a tasty sugar cube in maze-learning, whereas the other 10 are rewarded with a less interesting rat pellet. The design may thus be viewed as 2 (drug/no drug) × 2 (sugar/pellet). The data in terms of trials to learn the maze are as follows:

	Drug		No Drug	
Sugar	5	7	13	15
	9	6	10	9
	4	5	10	8
	4	6	11	13
	8	5	13	12
Pellet	8	9	10	16
	10	9	9	15
	11	12	12	9
	7	10	15	10
	8	13	8	12

a. Plot the four means along with 95% confidence intervals.
b. Perform a two-way analysis of variance on the data.
c. Describe how you would interpret the results.

6. The Gazelle Motorcycle Corporation is trying a new type of braking system for their motorcycles. The experiment involves comparing the stopping distance with the new versus the old braking system. Additionally, the two systems are compared for three sizes of motorcycles: 125, 500, and 1000 cubic centimeters. There are six motorcycles in each of the six cells, and the data are as follows:

Stopping Distance (feet)

	125 cubic centimeters		500 cubic centimeters		1000 cubic centimeters	
Old braking system	53	50	55	60	71	75
	48	50	61	60	72	61
	47	51	52	65	63	70
New braking system	54	42	51	55	49	45
	48	50	50	49	50	48
	55	45	52	51	55	53

a. Plot the means along with the 95% confidence intervals for the six cells.
b. Are there effects of size, type of braking system? Do these factors interact?
c. How would you describe the effect of the new braking system?

7. An experiment is done to investigate the effects of verbal description on person perception. The experiment works as follows. While waiting in an antechamber, a subject is approached by a confederate who begins a conversation. In the course of the conversation the confederate casually describes the experimenter using one of three adverbs (*somewhat*, *very*, or *extremely*) factorially combined with three adjectives (*nice*, *efficient*, or *nasty*). After going through a dummy verbal learning experiment, the subject fills out a questionnaire. Of interest is the answer to the question, "How did you like the experimenter?" The scale ranges from 0 (couldn't stand him) to 10 (loved him). Five subjects are assigned to each of the nine possible combinations of adjective and adverb. The data are as follows:

Rating Adjective

Adverb	Nice		Efficient		Nasty	
Somewhat	5	5	5	5	4	3
	6	5	6	4	3	6
	4		6		5	
Very	6	6	5	6	3	1
	9	5	6	7	3	2
	7		4		2	
Extremely	9	7	4	7	1	3
	8	8	5	8	2	1
	9		4		1	

a. Plot the nine cell means along with 95% confidence intervals.
b. Are there effects of adjective, adverb, and their interaction?
c. How would you interpret these results?

8. The city of Puyallup is trying to cut down on juvenile delinquency. To do this, it is planned to introduce a technique called "modeling therapy." Eight teenagers—four males and four females—are selected for an experiment to determine whether modeling therapy is effective in terms of reducing delinquent behavior. Half the males and half the females (the experimental groups) are provided with therapy for a year. The remaining subjects are not given therapy and constitute the control group. During the year the number of delinquent acts for each subject is recorded. The data are as follows:

		Factor 1 (treatment)	
		Experimental (therapy)	Control (no therapy)
Factor 2 (sex)	Male	2 3	3 6
	Female	1 5	8 6

a. Are there significant effects of treatment, sex, and interaction?
b. What is the 90% confidence interval for the cell means?
c. This experiment is repeated in Seattle, where it is known that the variance of the population of delinquent acts is $\sigma^2 = 1.0$. Only one subject is in each of the four cells with the following data:

		Factor 1 (treatment)	
		Experimental	Control
Factor 2 (sex)	Male	1	3
	Female	1	6

Are there significant effects of treatment, sex, and interaction?
d. How would you interpret all these results?

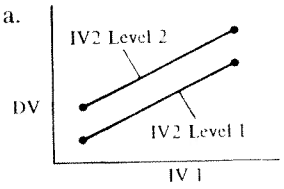
9. An experiment is done to test the effect of varying amounts of light on electrical activity in Merkin plant leaves. Three different light levels—no light, medium light, and bright light—are presented to Ralph and Irving, two different Merkin plants. Each plant goes through each condition twice. Due to an error in procedure, however, Ralph goes through the bright light condition six times rather than twice. The data recorded are voltage amplitudes on the leaves and are as follows (numbers represent millivolts):

	Light Condition		
	No light	Medium light	Bright light
Ralph	11 9	10 10	11 10 9 11 10 9
Irving	1 3	2 2	1 3

a. Compute a mean for each column.
b. Compute a mean for each condition for each plant (thereby getting two numbers per plant for each condition). Compute a mean for each condition by taking the mean of these two numbers.
c. Looking at the data, do you think there is an effect of amount of light? Why or why not?
d. Compute sums of squares for between rows, columns, interaction, and within. Do not be alarmed if something strange happens.
e. Why do you think it is a bad thing to have unequal cell frequencies in this kind of design?
f. What would you do to correct this shortcoming?

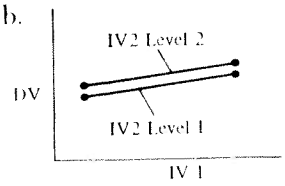
10. The following graphs represent data from 2 × 2 designs. In each case assume SSB = 100. Make rough guesses as to what the sums of squares are for independent variable 1 (IV1), independent variable 2 (IV2), and the interaction.

a.



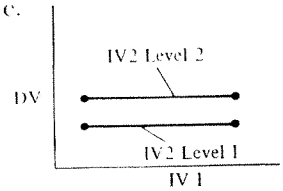
Sums of squares
IV1:
IV2:
Interaction:

b.



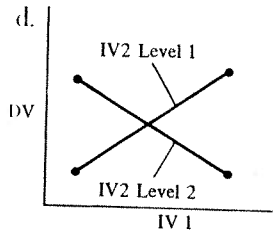
Sums of squares
IV1:
IV2:
Interaction:

c.



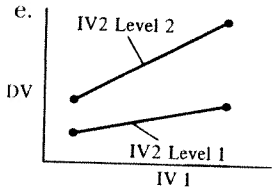
Sums of squares
IV1:
IV2:
Interaction:

d.



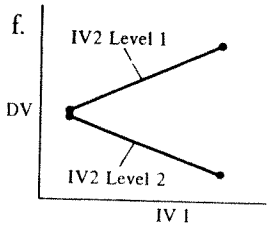
Sums of squares
IV1:
IV2:
Interaction:

e.



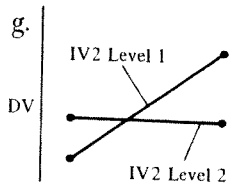
Sums of squares
IV1:
IV2:
Interaction:

f.



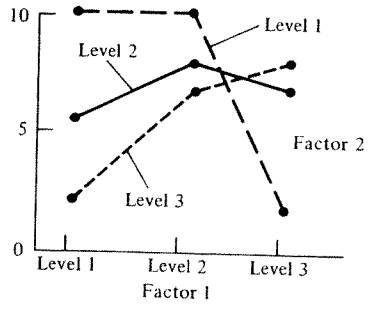
Sums of squares
IV1:
IV2:
Interaction:

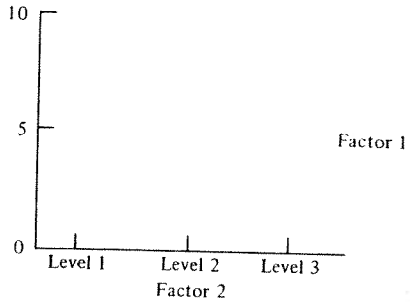
g.



Sums of squares
IV1:
IV2:
Interaction:

11. Here are data from a 3 × 3 design:





Redraw these data on the right-hand graph, with factor 2 on the abscissa and factor 1 as the curve parameter.