

Two questions. Each sub-question is worth 3 points.

### Question A

Ken Koedinger, from Carnegie-Mellon University, presented an ICS colloquium last Friday.

Ken and his associates have been implementing basic research in cognitive science in the development of “cognitive tutors” used in the public schools. These cognitive tutors are computer programs that help students work through a topic such as solving algebra equations. The tutor gives students feedback and hints based on cognitive research and distinctions made in cognitive science between declarative and procedural knowledge. The following experiment is representative of the kind of studies he reported in his talk, but has been substantially modified for the purpose of making a suitable test question for the topics we’ve recently covered.

The researchers randomly assigned students to work with one of three cognitive tutors: drill and practice only, a standard cognitive tutor, and a standard cognitive tutor that required students to provide justifications or explanations after each equation they solved. Students in each tutor group were further randomly subdivided to solve two different types of problems: either standard algebra equations such as  $3(2X + 5) = 9$  or equivalent algebra equations expressed as story problems. Each student worked at the computer with his or her cognitive tutor until a performance criterion was reached. The dependent variable was each student’s score on a transfer task that required a generalization of the algebra skills learned.

During the experiment, the researchers realized that some students, especially those using the tutor that required the additional justifications and explanations, were spending more time on the task. Also, some students were reaching the performance criterion after attempting fewer problems than other students. The researchers measured both variables as covariates.

In all, the following variables were available for analysis from a group of students:

Score	The student’s score (a continuous measure) on the transfer task
Time	The time (a continuous measure) it took the student to reach criterion performance
Problems	The number of problems (a continuous measure) the student attempted before reaching criterion performance
Cog	The type of cognitive tutor with three discrete levels: DRILL, TUTOR, or EXPLAIN
Alg	Type of algebra problem with two discrete levels: REGULAR or STORY

Use these variables to state the appropriate MODEL A/C comparisons one would use to answer the following research questions. Note that each variable name starts with a unique first letter so

you may use just those letters in stating your models. If you need to construct new variables or codes, be sure to provide definitions for those variables.

1. Ignoring which group a student is in, do the continuous variables (Time and Problems) predict a student's Score on the transfer task?
2. Still ignoring which group a student is in, does the effect of Time on Score depend on the number of Problems the student attempted?
3. Up to a point, more problems attempted is expected to be a positive indicator of ability to transfer to a new task because the student will have had more practice. But on the other hand, having to attempt a lot of problems to reach criterion implies that the student was making a lot of mistakes and so had a weak grasp of the material. Controlling for time on task and still ignoring which group the student is in, is there evidence that the strength and even the direction of the relationship between problems attempted and score on the transfer task changes as the number of problems attempted increases?
4. Now ignore the continuous covariates for the time being. In a complete analysis that would reproduce the six cell means, did requiring the explanations increase performance on the transfer task beyond the performance of those who just used the regular cognitive tutor that did not require explanations?
5. Continuing to ignore the covariates, does the answer to the prior question depend on whether students were doing regular algebra equations or story problems?
6. The researchers were particularly interested in the covariate of the number of problems attempted to reach criterion because it appeared to differ across conditions. On the whole, did the number of problems attempted vary across the six groups?
7. Does the answer to #4 persist when controlling for the number of problems attempted?
8. Because the covariate was measured during the experiment rather than before assignment to conditions, it is likely that the relationship between the covariate and the dependent variable may not be the same in each group. Test the homogeneity of regression assumption by determining whether the relationship between Problems and Score depends on which group a student is in.
9. Students from a number of different schools participated in the study and often there was more than one student participating at any particular school. Given that students working at computers often look at their neighbor's computer screen, it might have biased the results if they hadn't used the same type of cognitive tutor within each school. Hence, all students at any particular school used the same cognitive tutor. How would that have complicated the analysis? [This is not a MODEL A/C question.]

## Question B

Political psychologists are interested in how political action groups are perceived as a function of their efficacy in accomplishing their agenda. Additionally, how political action groups are seen ought to depend on the extent to which the perceiver is generally sympathetic versus not sympathetic with their cause.

A study is conducted to examine thoughts and feelings about the National Rifle Association (NRA). Half of the 100 participants are shown a series of news articles suggesting that the NRA is gaining in influence and largely accomplishing its goals; the other half of the participants are shown a series of news articles suggesting that the NRA is losing members and influence, and that its attempts to defeat gun control measures are largely being frustrated. Prior to the study, participants' attitudes on the issue of gun control are assessed. Additionally, each participants level of education is measured.

After having read the newspaper articles, the participants are asked to indicate the extent to which they hold strong stereotypes about the NRA and its members. Specifically, they are asked to indicate what proportion of NRA members they think have attributes stereotypic of the organization (politically conservative, opinionated, etc.). Assume that these have been pretested so that in fact they are known to be stereotypically associated with the NRA. An index is computed for each participant, averaging his or her estimated proportions.

In sum, the following variables define the dataset:

NEWS	News stories read by the participant: -1 if the news stories described the NRA as losing influence, +1 if the news stories described the NRA as gaining influence.
ATT	Prior attitudes on the issue of gun control, on a -5 to +5 scale, with -5 indicating attitudes strongly opposing gun control and +5 indicating attitudes strongly favoring gun control.
EDUC	Level of education completed: 1 = high school degree or less; 2 = some college; 3 = college degree or higher.
STER	The extent to which the NRA and its members are seen in a stereotypic way. Values range from 0 to 100, with higher numbers indicating that participants have stronger stereotypes about the NRA.

For purposes of analysis, the following additional variables are compute from these:

ED1	Education linear code: -1 if EDUC = 1; 0 if EDUC = 2; +1 if EDUC = 3.
ED2	Education quadratic code: -1 if EDUC = 1 or 3; +2 if EDUC = 2.
NED1	NEWS * ED1
NED2	NEWS * ED2

NATT	NEWS * ATT
AED1	ATT * ED1
AED2	ATT * ED2
NAED1	NEWS * ATT * ED1
NAED2	NEWS * ATT * ED2

The SAS output on the following pages gives the mean values of ATT and STER for the six cells defined by crossing the three levels of EDUC with the two levels of NEWS.

Additionally, output from the following PROC REG models is given:

```
Model STER=NEWS ED1 ED2 NED1 NED2/PCORR2 SS2 TOL;
Model STER=NEWS ED1 ED2 NED1 NED2 ATT/PCORR2 SS2 TOL;
Model STER=NEWS ED1 ED2 NED1 NED2 ATT NATT AED1 AED2 NAED1
      NAED2/PCORR2 SS2 TOL;
```

In light of this output, answer the following questions:

1. Based on the ANOVA model, with EDUC and NEWS as the crossed factors, what do you conclude about the effects of these two categorical variables on STER? (Also interpret the regression coefficient(s) associated with any significant effect(s).)
2. Given this ANOVA model, is there a significant simple linear difference in STER as a function of educational level among participants in the NEWS = 1 condition?
3. Within educational levels and the NEWS factor, is there a relationship between attitudes on gun control and the degree to which the NRA is stereotyped? (Present PRE, F\*, and interpret the coefficient, if significant.)
4. Once ATT is controlled, what is the predicted (or adjusted) mean value for STER according to Model 2, for participants who have a college degree or more and who get the news stories that the NRA is gaining in power and influence?
5. Do attitudes towards gun control vary as a function of EDUC, NEWS and their interaction? (Present PRE and F\*.)
6. Given the ANCOVA model (Model 2), provide a test of the homogeneity of regression assumption in analysis of covariance. (Present PRE and F\* and a statistical conclusion.)
7. One reasonable prediction in this experimental context is that the degree to which a group is stereotyped depends jointly on whether the group is seen as increasingly influential and one's attitude towards the issue the group espouses. Specifically, more influence should lead to stronger stereotypes of the NRA among those having pro-gun control attitudes, but weaker stereotypes among those whose attitudes are anti-gun control. Is there any evidence in the present data for this hypothesis? (Provide PRE, F\*, and interpret the appropriate regression coefficient.)

----- NEWS=-1 EDUC=1 -----

Variable	N	Mean	Std Dev	Minimum	Maximum
ATT	19	-0.1052632	1.9970739	-3.0000000	4.0000000
STER	19	74.1321274	6.3964377	60.4028671	84.7107417

----- NEWS=-1 EDUC=2 -----

Variable	N	Mean	Std Dev	Minimum	Maximum
ATT	8	-0.1250000	1.8850919	-3.0000000	2.0000000
STER	8	72.5273393	6.3224945	64.4999370	80.3095933

----- NEWS=-1 EDUC=3 -----

Variable	N	Mean	Std Dev	Minimum	Maximum
ATT	23	0.8260870	2.1030751	-2.0000000	5.0000000
STER	23	70.4882299	6.2423610	58.4492863	82.5517502

----- NEWS=1 EDUC=1 -----

Variable	N	Mean	Std Dev	Minimum	Maximum
ATT	17	-0.5294118	1.7719215	-3.0000000	2.0000000
STER	17	69.0059480	9.8230084	50.7514628	83.0923922

----- NEWS=1 EDUC=2 -----

Variable	N	Mean	Std Dev	Minimum	Maximum
ATT	10	-0.1000000	1.7919573	-3.0000000	2.0000000
STER	10	72.8461413	9.6385867	54.1064526	85.9786127

----- NEWS=1 EDUC=3 -----

Variable	N	Mean	Std Dev	Minimum	Maximum
ATT	23	0.6521739	1.9910869	-3.0000000	5.0000000
STER	23	73.9367163	6.7197431	62.4993811	90.8529693

Model: MODEL1  
 Dependent Variable: STER

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	385.53112	77.10622	1.381	0.2383
Error	94	5246.94651	55.81858		
C Total	99	5632.47763			

  

Root MSE	7.47118	R-square	0.0684
Dep Mean	72.12065	Adj R-sq	0.0189
C.V.	10.35928		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob >  T
INTERCEP	1	72.156084	0.81025092	89.054	0.0001
NEWS	1	-0.226482	0.81025092	-0.280	0.7805
ED1	1	0.321718	0.83198015	0.387	0.6999
ED2	1	0.265328	0.65251531	0.407	0.6852
NED1	1	2.143666	0.83198015	2.577	0.0115
NED2	1	0.192941	0.65251531	0.296	0.7681

Variable	DF	Type II SS	Squared Partial Corr Type II	Tolerance
INTERCEP	1	442676	.	.
NEWS	1	4.361205	0.00083050	0.85023645
ED1	1	8.346468	0.00158820	0.99556092
ED2	1	9.229210	0.00175588	0.98688944
NED1	1	370.567463	0.06596645	0.98389988
NED2	1	4.880320	0.00092926	0.85328296

Model: MODEL2  
 Dependent Variable: STER

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	6	1368.78439	228.13073	4.976	0.0002
Error	93	4263.69324	45.84616		
C Total	99	5632.47763			

  

Root MSE	6.77098	R-square	0.2430
Dep Mean	72.12065	Adj R-sq	0.1942
C.V.	9.38841		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob >  T
INTERCEP	1	71.985775	0.73523401	97.909	0.0001
NEWS	1	-0.068707	0.73510361	-0.093	0.9257
ED1	1	-0.550880	0.77719289	-0.709	0.4802
ED2	1	0.443403	0.59261001	0.748	0.4562
NED1	1	2.040325	0.75433660	2.705	0.0081
NED2	1	0.103730	0.59167486	0.175	0.8612
ATT	1	1.651915	0.35670271	4.631	0.0001

Variable	DF	Type II SS	Squared Partial Corr Type II	Tolerance
INTERCEP	1	439486	.	.
NEWS	1	0.400505	0.00009393	0.84841022
ED1	1	23.033447	0.00537320	0.93704478
ED2	1	25.666217	0.00598369	0.98273444
NED1	1	335.406236	0.07292868	0.98303886
NED2	1	1.409100	0.00033038	0.85237845
ATT	1	983.253270	0.18739533	0.93205077

Model: MODEL3  
 Dependent Variable: STER

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	11	2479.98775	225.45343	6.293	0.0001
Error	88	3152.48988	35.82375		
C Total	99	5632.47763			

  

Root MSE	5.98529	R-square	0.4403
Dep Mean	72.12065	Adj R-sq	0.3703
C.V.	8.29900		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob >  T
INTERCEP	1	72.339442	0.66320835	109.075	0.0001
NEWS	1	0.116143	0.66320835	0.175	0.8614
ED1	1	-0.790497	0.69548499	-1.137	0.2588
ED2	1	0.285920	0.52783728	0.542	0.5894
NED1	1	1.266467	0.69548499	1.821	0.0720
NED2	1	0.107546	0.52783728	0.204	0.8390
ATT	1	1.953668	0.36019901	5.424	0.0001
NATT	1	1.707006	0.36019901	4.739	0.0001
AED1	1	-0.459076	0.35275992	-1.301	0.1965
AED2	1	0.119519	0.29709169	0.402	0.6884
NAED1	1	-0.905502	0.35275992	-2.567	0.0120
NAED2	1	0.032019	0.29709169	0.108	0.9144

Variable	DF	Type II SS	Squared Partial Corr Type II	Tolerance
INTERCEP	1	426208	.	.
NEWS	1	1.098648	0.00034838	0.81446243
ED1	1	46.280239	0.01446814	0.91434582
ED2	1	10.511359	0.00332322	0.96792574
NED1	1	118.790980	0.03631329	0.90363606
NED2	1	1.487159	0.00047152	0.83688659
ATT	1	1053.871259	0.25054227	0.71422555
NATT	1	804.555800	0.20332234	0.70836208
AED1	1	60.671037	0.01888204	0.90885777
AED2	1	5.797765	0.00183573	0.74375193
NAED1	1	236.042939	0.06965933	0.85447360
NAED2	1	0.416111	0.00013198	0.73555676