

Teaching research methods using simulation

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Abstract

A web based computer simulation of a psychology experiment is used in a research methods course to give students an appreciation of the complexities of research, including the challenges of integrating the available literature into a set of testable hypotheses. By using a simulation, the tedium of data collection is minimized and the power of statistical analysis is emphasized. Main effects, interactions, and confounding variables allow for a discussion of power and statistical inference. Students analyze their data using the open source statistical system R and are able to prepare publication ready graphical displays.

For those of us who teach research methods, the process of learning how to do research is the keystone of our psychological curriculum. Understanding how to do psychological research allows students to integrate the content of their substantive courses with the methods behind the findings discussed in those courses. Research methods considers the essence of experimental and correlational design and scientific inference. It is not a course to turn students into psychological researchers, rather it is a course to make our students intelligent consumers of science, whether it be psychological, physical, or biological. For teaching students the process of doing science in a particular field helps them appreciate the challenges and joys of science more broadly.

In this chapter I outline a web based simulation I have been using for a number of years that gives the students the experience of designing and analyzing their own experiment but with certain constraints. In addition, by using a simulation, I am able to know the “true” effects and can then discuss issues of power and inference.

At Northwestern, research methods (Psychology 205) is the fundamental course in our psychology curriculum. It is the second in three part sequence of research training,

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following a general introduction to statistics (201) , and preceding the third course (3xx) which uses research methodology in a substantive field (e.g., personality research, research in social psychology, research in memory, etc.). Research methods is the gateway course to the major and is prerequisite for almost all of our advanced courses.

The students are typically sophomore or junior psychology major or minors, although a few take it as part of requirements in other departments. The research methods course is taught in multiple sections every quarter with the typical class size of 25 students. Because it is critical for upper level courses, the faculty members of the psychology department agreed years ago on certain requirements for the course. These instructional guidelines include the need to cover correlational and experimental techniques, application of statistical reasoning, the ethics of human and animal research and a writing requirement. The guidelines include doing three separate studies, either correlational or experimental, each of which is then written up in a standard scientific style (e.g., APA, but other styles are introduced). Because of the writing requirement, the emphasis upon statistical analysis, formal methods and the need to actually do research, research methods at Northwestern is, like most such courses around the country the “organic chemistry” course of the psych major. That is, it is the hardest course in the major, but also the most important. Students typically dread taking the course but finish it with a degree of enthusiasm for research that they did not think possible when they started.

A challenge in teaching the course is coming up with example studies for the students to conduct and report. Over the years I have developed three types of studies for the students. The first is an actual experiment conducted in class on the first day. It is a replication and extension of the [Roediger & McDermott \(1995\)](#) study of false memories which I use because it introduces substantively interesting results and demonstrates within and between person analyses. To help them understand the results, I do all the analyses for the students and show them how to integrate the findings into a 10-12 page paper. The third study is a research project designed and executed by each student individually. Each student writes a brief research proposal which I review before they undertake the final project. The statistical tools they learn in the second study are used for analysis of this third study. The second study is a computer simulated experiment in which each student designs and executes their own study to test hypotheses discussed in class and in the readings for the assignment. The simulation uses a web based interface to a simple model that includes three Subject Variables (SVs), two Independent Experimental Variables (IVs), and three outcome measures (DVs). The names of the variables can be specified by the instructor, as may the underlying relationships between the SVs, IVs, and DVs. In parallel with real research, the overall simulation is too complicated for one massive study, and students are expected to choose a particular subset of variables from the broader set.

The simulation code is written in PHP¹ as a general mixed model of SVs, IVs with

¹PHP is an open source language that was originally written to allow for Personal Home Pages but in the Unix tradition has come to have a self recursive definition: PHP: Hypertext Preprocessor. It is a “server side” aid to allow dynamic features in HTML (Hyper Text Markup Language) and access to data

multiple DVs. The parameters of the model can be modified for any particular implementation. For my class, I have instantiated the simulation with variables similar to those examined over many years at the Personality, Motivation, and Cognition (PMC) lab at Northwestern and reported in a number of article and book chapters. The code however is written in a general manner that allows it to be modified easily for other specific examples.

The simulation

The basic simulation is a set of three interlinked PHP webpages that a) give an overview of the study and ask for the number of subjects to run, b) a data generation web page that prompts for specific values of the SVs and IVs and creates the values for three DVs; and c) a page that displays the results for each subject suitable for copying into R (R Core Team, 2018) for further analysis. From the students' perspective, they just need to go to the experiment at <https://personality-project.org/courses/205/simulation/simulation.experiment.php> and follow the instructions. From the instructors point of view, it is necessary to prepare a brief discussion of how the simulation works, what the variables are, etc. An example of such instructions is found at <https://personality-project.org/courses/205/simulation/simulating-experiments.pdf>. The PHP code for these pages are included in the appendix to this chapter.

What the students are told before doing the study:

Psychological theories are ways of organizing observable phenomena in terms of a limited number of unobservable constructs. In addition to describing known phenomena, theories allow for prediction of as yet unobserved phenomena. Theories may be stated as informal descriptions, or may be stated in formal propositional logic or in mathematical equations. Complex theories that involve many variables may be stated as dynamic processes that change over time and that can best be captured in computer simulations.

This experiment simulates the complexity of a real research program by simulating the complex relationships between a set of observed characteristics of individuals, how they react to situations in terms of their motivational state, and how motivational state, in turn, affects cognitive performance. Prior work in the Personality, Motivation, and Cognition Laboratory at Northwestern has allowed us to formulate a complex model of human cognition in response to stress (Anderson & Revelle, 1982, 1994; Revelle & Loftus, 1992; Revelle & Oehlberg, 2008; Revelle & Anderson, 1992; Revelle et al., 1976, 1980; Wilt,

bases such as MySQL and resides on a remote computer running a webserver such as Apache. From the end user's point of view, webpages appear as if they were written in normal HTML, but with dynamic features not available in HTML. As is true of much of the open source community, there are extensive help pages available on the web for programming assistance.

Oehlberg, & Revelle, 2011). This simulation is based upon that work. In a sense, the simulation is a theory of the relationship between these four sets of variables (person characteristics, situational characteristics, intervening motivational states, and cognitive performance). The parameters of the model have been set to reflect empirical estimates of the strength of various relationships. Several nuisance variables have been added to more properly simulate the problems of experimental design.

This simulation of the theory may be used as a test of the theory as well as a tool for understanding the complexity of research. That is, although one may want to study the full model, because of the limitations of one's time and energy, one may study only a limited aspect of the model. Your objective is two fold: to better understand a limited aspect of a particular psychological theory, and to try to understand what are the relationships that have been specified in the model.

Although the code is generic, the instantiation of the variables is shown in Table 1 and the particular model that is simulated is shown in Figure 9-1. Students are not shown this table nor the figure until after they have completed their papers.

The students are further told that

The simulation is a web based program that allows you to “collect” the data on the web and then save the resulting output file to your computer to do subsequent analyses. The biggest question is what should you study. To answer this, you need to consider the variables available. The underlying model is a function of the IVs and SVs. Your job is to try to estimate the underlying model. The model is psychologically plausible and is based upon prior results.

They are then given a description of the simulations:

Independent variables that are under control of the experimenter may be categorized as experimental variables and subject variables. *Experimental variables or IVs* may be manipulated by the experimenter. *Subject variables or SVs* are characteristics of the subjects that may be measured but not manipulated.

In this experiment the Independent Experimental Variables include Drug condition (placebo or caffeine), and Time of Day. Given the realities of volunteer subjects, Time of Day is assumed to vary only between 8 am and 10 PM (22.00 hours). The Subject Variables that are “assessed” in this study include Sex, Trait Anxiety, and Trait Impulsivity, and when the subject appears during the quarter (Subject Number). Subject Number increases for every subject run in a particular experiment. This is modeled in the simulation as one subject per day, so later subjects are run later in the quarter.

Table 1: The generic variables in the simulation with the specific values given to be compatible with the background literature. Students are not shown the generic values, just the specific implementation. The program uses the generic equations but reports the results in terms of the specific implementation. The instructor can change the generic equations as well as the variable names by modifying the PHP code. The students' task is to hypothesize and test for various IV, SV, DV relationships. Although the underlying relationships are generally monotonic, but non-linear with one non-monotonic effect, the students are encourage to fit the data with linear approximations.

Generic Variable	Specific Implementation	Possible Values
ntrials	Subject Number	1 ... max
SV0	Sex	1 - 2
SV1	Anxiety	0 - 10
SV2	Impulsivity	0 - 10
IV1	Caffeine	Placebo, Caffeine
IV2	Time of Day	8 - 22
DV1	Energetic Arousal	0 - 100
DV2	Tense Arousal	0 - 100
DV3	Cognitive Performance	0 - 100

Weights	Specific values
wt1	.3
wt2	.2
errorwt	.3

Generic Equation

$$DV1 = IV1 - \cos((IV2 - SV2)/4) + 1$$

$$DV2 = \frac{100}{(1 + \exp(3 - IV1 - wt1 * SV1 + wt2 * rnorm()))}$$

$$DV3 = \frac{100}{(1 + \exp(-DV1 + errorwt * rnorm()))}$$

Specific Implementation

$$\text{Arousal} = f(\text{Drug} + \text{Impulsivity} \times \text{Time})$$

$$\text{Tension} = f(\text{Drug} + \text{Anxiety})$$

$$\text{Performance} = f(\text{Arousal})$$

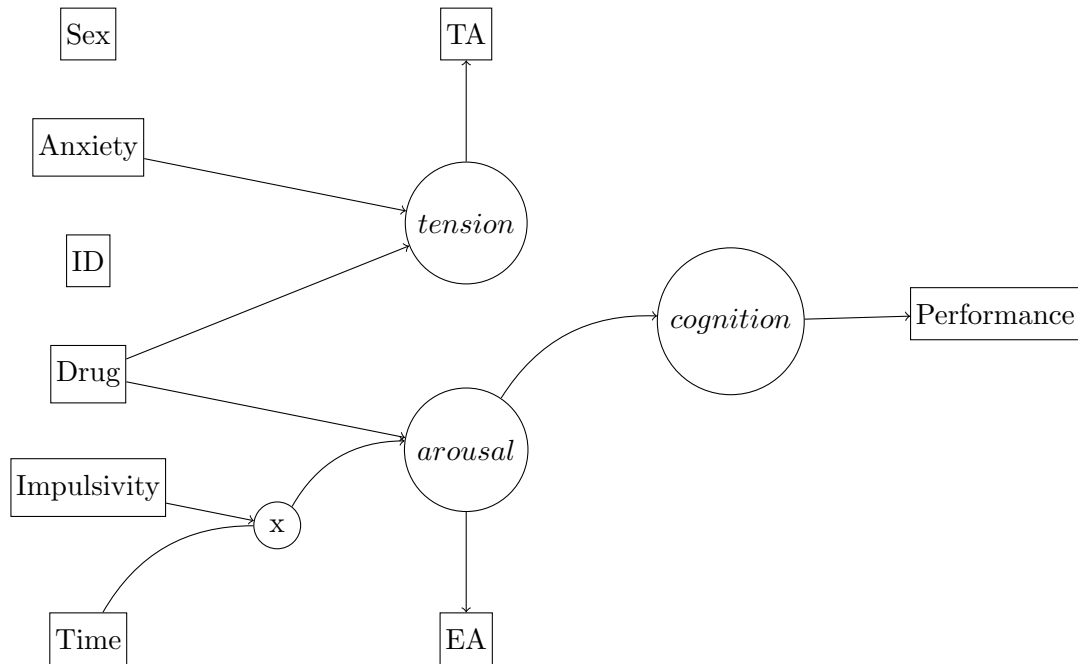


Figure 1. The simulation model as implemented. Boxes represent observed variables, circles latent variables. Straight arrows show linear effects, curved arrows are monotonic (arousal to cognition), or non-monotonic (time to arousal which is moderated by impulsivity). Some variables (i.e., Sex) have no effect, others (e.g., ID) have an effect if subjects are not assigned to condition. The specific values are calculated according to the formulae in Table 1.

The Dependent Variables are measures of motivational state (Energetic and Tense Arousal) as well as accuracy of Performance on a simple cognitive task (letter scanning). Energetic Arousal may be seen as reflecting how active and alert rather than sleepy and drowsy a subject reports being. Tense Arousal reflects how Tense and Frustrated rather than Calm and Relaxed a person reports being (Rafaeli & Revelle, 2006; Thayer, 1989) Both of these scales are reported in units ranging from 0-100. An additional variable is the Cost of running the experiment. This is a function of the scarcity of the subjects.

The values of the Independent and Subject variables may be specified by the experimenter for each subject, or may be allowed to vary randomly. If allowed to vary randomly, the experimental variables will be assigned values in a uni-

form random distribution. The subject variables may either be specified (this simulates choosing particular subjects based upon a pretest) or may be allowed to vary randomly. If varying, they will be assigned values based upon samples from a normal distribution. If subjects are selected for particular values on a personality dimension, this is the same as rejecting many potential subjects and thus the Cost of running grows more rapidly than the simple number of subjects who participate.

1. Drug has two levels (0=Placebo or 1=Caffeine). Caffeine is known to act as a central nervous system stimulant although it has some side effects such as tremor (Revelle et al., 1976, 2012, 1980).
2. Time of Day has 15 levels (8 AM ... 10 PM or 8 ...22). Although most cognitive psychologists do not examine the effects of time of day on cognitive performance, there is a fairly extensive literature suggesting that performance does vary systematically across the day (Revelle et al., 1980; Revelle, 1993).
3. Sex of subject sometimes interacts with characteristics of the experiment (sex of experimenter, stress of experiment, type of task) and has sometimes been associated with levels of anxiety. In this study, Sex varies randomly taking on the values of 1 or 2. (Using the mnemonic of the number of X chromosomes, that is 1=M and 2=F).
4. Trait anxiety is a stable personality trait associated with feelings of tension, worry, and somatic distress. Trait anxious individuals are more sensitive to cues for punishment and non-reward and are also more likely to experience negative affect than are less trait anxious individuals (Gray, 1991; Wilt, Oehlberg, & Revelle, 2011) . In this simulation, anxiety can take on values from 0-10.
5. Impulsivity is a stable personality trait associated with making up one's mind rapidly and doing and saying things with out stopping to think. It has been shown in prior work to relate to an inability to sustain performance, particularly in the morning Anderson & Revelle (1982, 1983). Theories of impulsivity have also suggested that impulsivity is related to a general sensitivity to cues for reward and to a greater propensity towards positive affect (Gray, 1991; Revelle, 1997; Wilt & Revelle, 2009; Zinbarg & Revelle, 1989). In this simulation, impulsivity can take on values from 0-10.

Dependent Variables

1. Energetic arousal reflects self reports of feelings of energy, activity, and alertness. EA has been shown to increase with exercise and to decrease with sleep deprivation (Thayer et al., 1988; Thayer, 1989). EA is also associated with feelings of positive affect (Rafaeli & Revelle, 2006; Watson & Tellegen, 1985; Wilt, Funkhouser, & Revelle, 2011).

2. Tense arousal reflects feelings of tension, frustration, and fear (Thayer, 1989) and is moderately associated with feelings of negative affect (Rafaeli & Revelle, 2006; Watson & Tellegen, 1985).
3. Performance in this simulation reflects accuracy on a simple decision task. A perfect score is 100, and performance deteriorates from that as a function of condition and motivational state. Abstractly, this may be thought of as accuracy on a vigilance task, or the ability to make accurate judgments on some sustained processing task (e.g., Anderson & Revelle, 1982, 1983, 1994; Humphreys & Revelle, 1984).
4. The cost of any experiment is a function of the number of subjects (it increases by 1 for every subject) and also of the scarcity of the subjects. Thus, if you choose to run just very high (10) and very low (1) anxiety subjects, this will require more prescreening to identify such subjects, and thus the cost will be higher than if you just chose average levels of anxiety, or if you just allowed anxiety to randomly vary. It is important to report the cost of the study you carry out.

Finally, they are told that

A reasonable approach is to have some theoretical reason to believe that a certain relationship exists, and then perhaps conduct a series of “pilot” studies to determine the sensitivity of certain parameter values.

The goal of this project is to try to determine at least some of the relationships that have been built into the model. You will be evaluated on principles of experimental design, not on the significance of the results.

They are instructed to form some specific hypothesis (or hypotheses) and then test this by running the simulation.

Literature review and methodology

The students are given some background literature but are encouraged to use various search engines (e.g. Google Scholar, Web of Science) to find more recent references and potential hypotheses. When reporting their methods they are required to report how they administered the caffeine and in what amounts (if they give caffeine), how they measured impulsivity or anxiety, and what were the measures of arousal and tension. The values they discuss in their paper need to be plausible. Thus, saying that they gave 0 or 1 milligram or 0 or 1 gram of caffeine suggests they have not read the literature enough to realize that 1 gram would be an overdose, or that 1 milligram would have no effect. The choice of a performance task is important, for the simulated one actually has a monotonic relationship with arousal, rather than some of the more complex relationships discussed in the personality x performance literature (e.g., Revelle et al., 1980). Thus, if students say

they used a complex reasoning task but then failed to find a drug x personality interaction, this is not surprising given that the underlying model does not have such an interaction.

Data Analysis

An important part of research methods is learning how to apply modern statistical procedures to analyze research. To do this, the research methods students are introduced to the R statistical system (R Core Team, 2018). R is an open-source interactive statistical system that allows students to do basic and advanced statistics. One of the particular powers of R is the ability to use the output of any function as the input of any other function. This allows for rapid development of new functions which add functionality to existing functions. Because of its open source nature and the existence of a central repository for shared code (the comprehensive R archive network or CRAN), the R system encourages the development of additional packages for specific applications. In addition, because R is used in some of our advanced and graduate courses and in many graduate training programs and occupations, students are encouraged to learn R in Psychology 205. Class readings and web pages devoted to the use of R in general and the *psych* package (Revelle, 2018) in particular are given as additional handouts. In the following pages, R functions are shown in boldfaced fixed pitch font.

Descriptive statistics

The last page of the simulation generates a web page with the data arranged by “subjects” and the columns represent the IVs, SVs and DVs. The student may select everything on the page and then copy to R using the `read.clipboard` function. They are then ready for basic descriptive statistics, both quantitative (e.g., `describe` and `describeBy`) as well as graphic (e.g., `pairs.panels`, `error.bars` and `error.bars.by`). The importance of screening data for errors at entry or outliers is discussed.

Although encouraged to test specific hypotheses, students are also shown how to examine the overall correlational structure of the data (Table 2). The more adventurous students will run 100 subjects as a pilot study, examine the correlational structure and systematically vary or control for specific variables in a subsequent study. The emphasis upon showing the correlations is for descriptive purposes and the use of “magic astericks” denoting statistical “significance” is discouraged.

Inferential Statistics

One of the many powers of R for teaching research methods is the emphasis upon the general linear model. Thus students are given the formulae for a single IV (1), two additive IVs (2), and then two IVs with interactions, and finally two IVs with an interaction and a covariate (4):

$$DV = Constant + IV_1 \tag{1}$$

Table 2: The observed correlations from 100 simulated subjects

Variable	sex	drug	time	anxty	impls	arosl	tensn	prfrm
sex	1.00							
drug	-0.07	1.00						
time	-0.14	0.13	1.00					
anxiety	-0.10	0.04	-0.06	1.00				
impulsivity	-0.04	0.00	0.14	-0.17	1.00			
arousal	-0.10	0.68	0.50	0.00	-0.07	1.00		
tension	-0.12	0.60	0.01	0.76	-0.10	0.37	1.00	
performance	-0.09	0.51	0.38	-0.03	0.03	0.68	0.23	1.00

$$DV = Constant + IV_1 + IV_2 \quad (2)$$

$$DV = Constant + IV_1 + IV_2 + IV_1 * IV_2 \quad (3)$$

$$DV = Constant + IV_1 + IV_2 + IV_1 * IV_2 + Z \quad (4)$$

and told how if there is just one dichotomous IV, then this is just the *t-test* they were taught in introductory statistics. If IV_1 is continuous, then this is regression. If IV_1 and IV_2 are both categorical, then this is just the Analysis of Variance they learned in their introductory statistics course.. If IV_1 or IV_2 are continuous, then this is multiple regression with or without moderation (Cohen et al., 2003). The use of R and the general linear model approach is introduced.

Thus, equation 1 is implemented as a `t.test` and may be displayed using the `error.bars.by` function. This allows a discussion of confidence intervals of the group means, and three different ways of displaying them (error bars representing one standard deviation around the mean, error bars representing 95% confidence versus ‘cats eyes’ showing 95% confidence).

```
my.data <- read.clipboard() #get the data from the web page
t.test(performance ~ drug, data = my.data) #perform the t.test
temp <- error.bars.by(performance ~ drug, data = my.data, sd=TRUE, eyes=FALSE) #1 sd error bars
error.bars.by(performance ~ drug, data = my.data, eyes=FALSE) #conventional error bars
error.bars.by(performance ~ drug, data = my.data) #cats eyes
```

Analysis of variance of categorical IVs with (equation 3) or without interactions (equation 2) is done by the `aov` function and the `error.bars.by` function may be used to show the means by group.

```
summary(aov(performance ~ sex+ drug, data=my.data)) #no interaction
summary(aov(performance ~ sex* drug, data=my.data)) #with interaction
error.bars.by(performance ~ sex* drug, data=my.data) #means plus cats eyes
```

The generalization to continuous IVs is discussed (Cohen et al., 2003). The concept of mean centering is introduced and examples of mean centering versus not mean centering are shown., as are various ways of graphically presenting the effects. They are then given

the R equivalent of equation 3 after zero centering and how to find the basic inferential statistics.

```
cen.data <- data.frame(scale(my.data,scale=FALSE)) # convert to a means centered data frame
mod1 <- lm(performance ~ drug * time* impulsivity, data=cen.data) #test for 3 main effects,
summary(mod1) #show the summary statistics
```

There are, of course, multiple ways to display the results of the linear model. If using one categorical variable (e.g. drug or sex) and one continuous variable (e.g. impulsivity), a convenient way is plot all of the data, and then draw regression lines for each group.

```
# plot the data
with(my.data, plot(performance ~ impulsivity, pch = 21 - drug, data = my.data,
                  main="Performance varies by impulsivity and drug"))
with(my.data, by(my.data,drug,function(x) abline(lm(performance ~ impulsivity,data=x) )))
#add the lines for placebo and caffeine
text(9,56,"placebo") #add a label at the x, y coordinates
text(9,73,"caffeine") #add another label
#draw it using setCor
setCor(performance ~ drug * impulsivity, data = my.data,
      main="Impulsivity x Caffeine effects", std=FALSE)
```

An alternative way to do and display linear model data is to use the `setCor` function which shows the results as path coefficients. A comparison of these two approaches is shown in Figure 9-2.

Power, Type I and Type II errors

The advantage of using a simulated experiment is that the instructor knows “truth”. That is, the underlying model used to generate the data (see Figure 9-1) is known to the instructor but not to the students. Some of the variables (e.g., sex) have no effect on the outcome, some relationships are confounded (e.g., tension correlates with arousal because both are increased by caffeine), some effects are small (e.g. the interaction of impulsivity and time of day), and some effects are actually mediated through intermediate variables (the effect of caffeine on performance is mediated by the effect of caffeine on arousal which in turn improves performance.) Furthermore, the ease of doing two - three way ANOVAs and regressions and the resulting increase in various comparisons increases the likelihood that variables that have no real effect will show “significant” effects.

Because each student is designing his or her own study, but because they are limited to the number of possible variables to study, at the end of second experiment, after all the results have been analyzed by the students and they have submitted their research papers, I conduct an informal meta-analysis of the results. That is, in class it is easy to do a box score count of how many people examined a certain variable or pair of variables, and how many obtained “significant” effects. It seems as if the most motivated students are the ones most likely to get Type I errors, because they have done the most complex designs. On the other hand, those students who do not expend very much effort in doing the simulations are much more likely to commit Type II errors because of a lack of power.

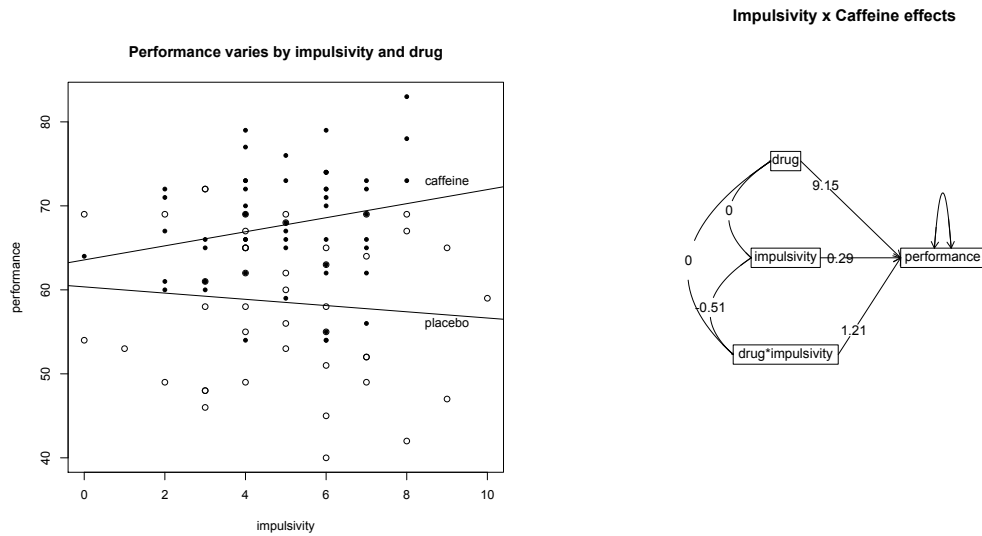


Figure 2. Two ways to show the results of a linear model. The left hand panel shows the regression lines for performance as a function of impulsivity for both placebo and caffeine. The right hand panel shows this as a path diagram with the interaction as a product term. By default, the `setCor` function standardizes the coefficients, and means centers the data, but they may shown as unstandardized by setting an option.

Having written a paper with a discussion of a result that turns out to be a Type I error is a particularly memorable experience for the best students. Although we are all susceptible to Type I errors, doing a simulation with a known model is the only time that we can be sure that what we found was indeed an error.

Confounding variables

The simulation is meant to simulate what happens if data are collected from real subjects, An unfortunate characteristic of many undergraduate subject pools is that the more anxious subjects volunteer earlier in the quarter than do the less anxious subjects, and the more impulsive subjects tend to put things off to the end of the quarter. This is simulated by inducing a slight negative correlation between anxiety and subject number and a slight positive correlation between impulsivity and subject number. This is not a problem if subjects are randomly assigned to condition, but does lead to a confound if all of one condition (e.g., placebo or caffeine, morning versus evening is done before the other condition).

The problem of how to create random numbers is addressed (even coin flips are not truly random) and computers generate pseudo random numbers. A problem of complete

randomness is the tendency for cell sizes to be unbalanced. This is particularly a problem with small samples. Randomization with filling out of cell sizes at the end of the study introduces systematic biases due to end of quarter effects. Students are shown examples of such confounding and encouraged to make use of the `block.random` function to help them assign subjects to control for this confound. The correlation of subject number with any of the experimental or subject variables should be near zero if the conditions are assigned by block randomization.

Mediation and Moderation

Although far beyond the scope of the normal research methods course, an occasional student will notice that caffeine and time of day affect arousal as well as performance. They then discover that the relationship between caffeine and performance is much weaker when they introduce arousal into their model. That is, they have discovered that arousal mediates the effect of caffeine and time of day on performance. This does not happen often, but they (and I) are very excited when they find this. I can then show them how to test mediation models using the `mediate` function which tests the mediation effect through bootstrap resampling (Figure 9-3).

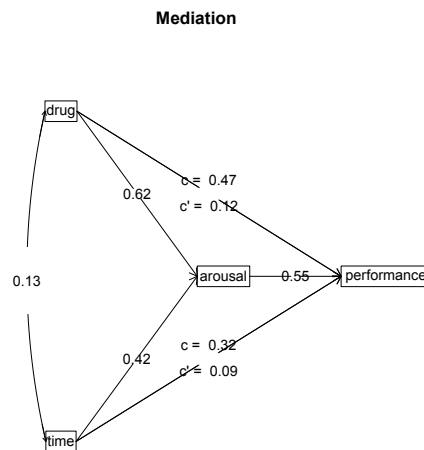


Figure 3. An analysis of the mediating role of arousal on performance. Both drug and time of day affect performance, but this effect is mediated through their effect on arousal. The direct effects of caffeine or of time are shown to vanish when controlling for the effect of arousal.

Conclusion

Learning how to do research is best done by doing it. Designing their own studies, running their own (simulated) subjects and analyzing their own data helps students appreciate the complexity of research. How to read the appropriate literature to generate hypotheses, how to operationalize these hypotheses in an experimental or correlational study, and then how to analyze and report their results are important part of doing science. In addition, in the process of analyzing and displaying their results, the students are also learning how to use modern statistical techniques and developing confidence in their ability to do real research.

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Appendix

Web based tutorials for the simulation and the data analysis

Following instructions at <https://personality-project.org/courses/205/simulation/simulating-experiments.pdf>, the simulation is run by going to <https://personality-project.org/courses/205/simulation/simulation.experiment.php>. Simplified instructions for analyzing the data are at <http://personality-project.org/revelle/syllabi/205/analysing-data.pdf> (a handout written by a former undergraduate). A slightly longer tutorial is at <http://personality-project.org/r/r.205.tutorial.html>, as well as a much longer tutorial on the of R in general <http://personality-project.org/r/>.

The PHP code for the simulation

The following three pages need to be installed on a remote web server that has initiated PHP.

Page 1 The basic description of the simulation and the names of the variables. The instructor can change these names to match the simulation.

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
    "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<head>
    <title>Simulating a Psychology Experiment - Preface</title>
    <meta name="generator" content="BBEdit 8.7" />
</head>
<body>
<?php
echo '
<head>
    <title>Simulating a
        Psychology Experiment - Preface</title>
    <meta name="generator" content="BBEdit 8.7" />
</head>
<p>
The simulation is a web based program that allows you to "collect" the data on the web
and then save the resulting output file to your computer to do subsequent analyses.
The biggest question is what should you study. To answer this, you need to consider
the variables available. Make sure to read the
<a href="https://personality-project.org/courses/205/simulation/simulating-experiments.pdf">handout</a>
discussing this experiment before starting.

<h2 align="left">What are the variables you can specify in this simulation?</h2>

<B> Independent variables</B> that are under control of the experimenter may be categorized
as <U>experimental</U> variables and <U>subject</U> variables. Experimental variables may
be manipulated by the experimenter. Subject variables are characteristics of the subjects that
may be measured but not manipulated. </P>
```

```

<P>In this experiment the Experimental Variables include
<ol>
<li> Drug condition (placebo or caffeine),
<li>Time of Day</B>. Given the realities of volunteer subjects, Time of Day is assumed to only
vary between 8 am and 10 PM (22.00 hours).

</ol>

<p> The <B>Subject Variables</B> are that are "assessed" are:
<ol>
<li> Sex (Male=1, Female=2)
<li> Trait Anxiety (0-10)
<li> Trait Impulsivity (0-10)
<li> Subject Number reflects when the subject appears in the quarter.
</ol>

<p> The <B>Dependent Variables</B> are measures of motivational state and cognitive performance
<ol>
<li> Energetic Arousal
<li>Tense Arousal)
<li> Performance (accuracy on some attention task)
</ol>

<P>The values of the IVs and DVs may be specified by the experimenter for each subject, or
may be allowed to vary randomly. If allowed to vary randomly, the experimental variables will
be assigned values in a uniform random distribution. The subject variables may either be specified
(this simulates choosing particular subjects based upon a pretest) or may be allowed to vary randomly.
If varying, they will be assigned values based upon samples from a normal distribution.
If subjects are selected for particular personality types,
this is the same as rejecting many potential
subjects and thus the Cost of running grows more
rapidly than the simple number of subjects who participate.</P>

It is a good idea to think carefully about your design before you run it.

<U><P>Subject Number</U> increases for every subject run in a particular experiment. Currently, it can
not exceed 1000, but most runs will use less than 100. You will be asked to specify the
number of subject that you want to run.

<h2 align="left">Run the experiment</h2>

<p> How many subjects do you want to run?

<form action="simulation.specification.php" method="post">
<input name="ntrials" type="text" size="4" maxlength="4" />
<input type="submit" name="enter the data"></button>
</form>
';
?>
</body>
</html>

```

Page 2

```

<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
    "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<head>
    <title>Specify the Experimental and Subject Conditions</title>
    <meta name="generator" content="BBEdit 8.7" />
</head>
<body>
<?php
#simulation of personality by drug study
#converted from Pascal to php November 1, 2007
#Annotated July, 2018

#this file collects the data from the user

#the generic model can be made specific by specifying the names
#Here we specify particular ranges (and names) for the IVs
#Change the names and ranges of the variables to fit the model
#The current names of variables are
#Sex (SV1) 1 or 2
#Drug (IV1) Placebo or Caffeine
#Time of day (IV2) 8 - 22
# Anxiety (SV2) 0 - 10
# Impulsivity (SV3) 0 - 10
#The current names of variables and their ranges match prior work in the PMC lab
#And the 2018 chapter

#Fix these to match the particular study

function show_the_selection($num) {
for ($snum=1; $snum < $num+1 ; $snum++ ) {
echo '<p>
Enter the conditions for the subject ', $snum, '
<form action="simulating.personality.results.php" method="post">
<br> Sex Random <input type = "radio", name= "sr', $snum, '" , value = -1 checked="yes"> or
Male <input type="radio" name="sr', $snum, '" value = 1 />
Female <input type="radio" name="sr', $snum, '" value =2 />
<br> Drug Random <input type = "radio", name= "dr', $snum, '" , value = -1 checked="yes"> or
Placebo <input type="radio" name="dr', $snum, '" value=0 />
Caffeine <input type="radio" name="dr', $snum, '" value=1 />
<br> Time of Day Random <input type = "radio", name= "tr', $snum, '" , value = -1 checked="yes">
or Fixed
8 <input type="radio" name="tr', $snum, '" value =8 />
9 <input type="radio" name="tr', $snum, '" value =9 />
10 <input type="radio" name="tr', $snum, '" value =10 />
11 <input type="radio" name="tr', $snum, '" value =11 />
12 <input type="radio" name="tr', $snum, '" value =12 />
13 <input type="radio" name="tr', $snum, '" value =13 />
14<input type="radio" name="tr', $snum, '" value =14 />
15 <input type="radio" name="tr', $snum, '" value =15 />
16 <input type="radio" name="tr', $snum, '" value =16 />
17 <input type="radio" name="tr', $snum, '" value =17 />
18 <input type="radio" name="tr', $snum, '" value =18 />
19 <input type="radio" name="tr', $snum, '" value =19 />
20 <input type="radio" name="tr', $snum, '" value =20 />
21 <input type="radio" name="tr', $snum, '" value =21 />

```

```

22<input type="radio" name="tr',$snum,'" value =22 />
<br> Anxiety Random <input type = "radio", name= "ar',$snum,'" value = -1 checked="yes"> or
Fixed
0 <input type="radio" name="ar',$snum,'" value=0 />
1 <input type="radio" name="ar',$snum,'" value=1 />
2 <input type="radio" name="ar',$snum,'" value=2 />
3 <input type="radio" name="ar',$snum,'" value=3 />
4 <input type="radio" name="ar',$snum,'" value=4 />
5 <input type="radio" name="ar',$snum,'" value=5 />
6 <input type="radio" name="ar',$snum,'" value=6 />
7 <input type="radio" name="ar',$snum,'" value=7 />
8 <input type="radio" name="ar',$snum,'" value=8 />
9 <input type="radio" name="ar',$snum,'" value=9 />
10 <input type="radio" name="ar',$snum,'" value=10 />
</br>
<br> Impulsivity Random <input type = "radio", name= "ir',$snum,'" value = -1 checked="yes"> or
Fixed
0 <input type="radio" name="ir',$snum,'" value=0 />
1 <input type="radio" name="ir',$snum,'" value=1 />
2 <input type="radio" name="ir',$snum,'" value=2 />
3 <input type="radio" name="ir',$snum,'" value=3 />
4 <input type="radio" name="ir',$snum,'" value=4 />
5 <input type="radio" name="ir',$snum,'" value=5 />
6 <input type="radio" name="ir',$snum,'" value=6 />
7 <input type="radio" name="ir',$snum,'" value=7 />
8 <input type="radio" name="ir',$snum,'" value=8 />
9 <input type="radio" name="ir',$snum,'" value=9 />
10 <input type="radio" name="ir',$snum,'" value=10 />
<br> <br>
';

);
echo '
<input name="ntrials" type="hidden" value =',$snum,' />
<br> Ok, I am finished, show me the data <input type="submit" value="submit" " /></p>
</form> ';
); #end of get the selection

#these are global parameters
#this first part is the basic model with no interactive input
#first lets get some basic parameters
#then we set some weights
#
#not clear if these actually do anything
$IV2wt = 1;
$SV2wt=.3;
$errorwt=.3;
$tensewt = .2;
$n =10;
$dynamic = FALSE;
$total_cost =0;
$snum = 1;
$max_trials = 10;

$ntrials = $_POST['ntrials'];

```

```

#echo 'ntrials = ' , $ntrials;

echo 'This form will allow you to run up to the ', $ntrials, ' subjects that you specified.
For each simulated participant you need to specify the experimental conditions.
When you are finished with specifying all the subjects, you can enter submit (at the end of the page).
  If you specify less than ', $ntrials, ' participants, the last N will be filled with random participants.
  You can edit these out later in the statistical analysis if you choose.' ;

show_the_selection($ntrials);

?>
</body>
</html>

```

Page 3 This page actually does the simulation and reports the results.

```

<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<head>
  <title>Simulating Personality - the Results (copy to R for analysis) </title>
  <meta name="generator" content="BBEdit 8.7" />
</head>
<body>

<?php

#first we create a function to produce N(0,1) numbers
#Based upon the central limit theorem that the distribution of means tends towards normal
function rnorm() { $x = 0;
for ($i=1; $i < 17; $i++ ) { $x = $x + mt_rand();}
$x = ($x )/16; #find the mean of the 16 replications
$x = $x/32768; #convert to sd 1
$x = ($x -32768)/ 32768;
return $x/.144;
};

#alternatively
# function rnorm() {return stats_rand_gen_normal ( 0,1 )}

#this next function gets the data from the posting and stores as an array
function post_the_data($snum) {
$sr = $_POST['sr' . $snum];
$dr = $_POST['dr' . $snum];
$tr = $_POST['tr' . $snum];
$ar = $_POST['ar' . $snum];
$ir = $_POST['ir' . $snum];
$values = array($snum, $sr, $dr, $tr, $ar, $ir);
return($values);
}; #end of the post_the_data function

#these are global parameters

```

```

#this first part is the basic model with no interactive input
#first lets get some basic parameters
#then we set some weights
#
$IV2wt = 1;
$SV1wt = .3;
$SV2wt=.3;
$errorwt=.3;
$tensewt = .2;
$n =10;
$dynamic = FALSE;
$total_cost =0;

#now process the data

$ntrials = $_POST['ntrials'];
#echo 'ntrials = ' , $ntrials;
$trials = $ntrials-1;
#first echo out titles
#change if using different IVs, SVs, and DVs
#These are the variable labels
# Change the following to match your experiment

# echo 'Trial SV1 IV1 IV2 SV2 SV3 DV1 DV2 DV3 DV4';
#e.g.,
echo 'snum sex drug time anxiety impulsivity arousal tension performance cost';

#$trials =100;
#begin Trials loop
for ($i=1; $i < $trials + 1; $i++ ) {
$result[$i]= post_the_data($i);

$resarray = array_values($result[$i]);
$trialnum = $resarray[0];
$sr = $resarray[1];
$dr = $resarray[2];
$tr = $resarray[3];
$ar = $resarray[4];
$ir = $resarray[5];

# convert the input into our IV and SV values
#cost increases if we select subjects
$cost =1;
if ($sr < 0) {$sex = mt_rand(1,2) ;} else {$sex = $sr; $cost=$cost+1;}
if ($dr < 0) { $IV1 = mt_rand(0,1);} else { $IV1 = $dr; $cost=$cost+1;};
if ( $tr < 0) { $IV2 = mt_rand(8,22);
} else { $IV2 = $tr; $cost=$cost+1;}

if ($ar < 0 ) { $SV1 = intval(2* rnorm() +5 -$i/$ntrials);} else { $SV1 = $ar; $cost=$cost+1;}
if ($ir < 0 ) { $SV2 = intval(2* rnorm() + 5 + $i/$ntrials);} else { $SV2 = $ir; $cost=$cost+1;}
#Echo the condition and then the results

echo '<br>', $trialnum, ' ', $sex, ' ', $IV1, ' ', $IV2, ' ', $SV1, ' ', $SV2, ' ';

#Find the DVs as functions of the IVs
#this section can be modified by the instructor to specify the particular model

```

```
$DV1 = $IV1 - $IV2wt * cos(($IV2 - $SV2)/4)+1; #curvilinear function
$DV1 = $DV1/3;

$DV2 = 100/(1+exp(3 -$IV1 - $SV1wt* $SV1 + $tensewt * rnorm())); #monotonic function
$DV3 = intval(100/(1+ exp(-$DV1+ $errorwt* rnorm()))); #monotonic of DV2

#show the results
echo intval($DV1*100), ' ', intval($DV2), ' ', $DV3, ' ', $cost, ' ';

}
#end of trials loop

?>
</body>
</html>
```