Simulating and analyzing a psychological experiment

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This handout considers how and why we use simulations as part of psychological theory building. In addition, by using a simple simulation of a psychological research problem, we consider how the investigator needs to choose the variables of interest to study as well as issues in design. We conclude with a brief example analysis of one possible experimental 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, Amaral, & Turriff, 1976; Revelle, Humphreys, Simon, & Gilliland, 1980; Wilt, 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. The student's 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.

How does this simulation work?

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.

What are the variables in this simulation?

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.

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 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 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.

Experimental and Subject Variables

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; Revelle, Condon, & Wilt, 2012; Revelle et al., 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 nonreward 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, Takahashi, & Pauli, 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.

What should you test?

Any experiment pits power against practicality. That is, the more subjects that are studied, the more statistical power that one has to detect an effect. However, subjects are not an unlimited resource. They are hard to recruit and they are time consuming to run. This is reflected in the *cost* of the experiment. In addition, for a particular number of subjects, as the number of variables that are examined increases, the potential number of higher order relationships (interactions) increases dramatically at the same time that the power to detect these interaction decreases because of the limited number of subjects in any one condition.

A reasonable approach is do 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.

How do I run the simulation?

The simulation is available as a web based simulation that starts at `http://personality-project.org/revelle/syllabi/205/simulation/simulation.experiment.php`. It consists of three pages:

1. A set of instructions describing the experiment (somewhat redundant with this handout) and a request to specify how many subjects you want to run. Enter this number (e.g., 100) to continue on to the next page.

2. A list of each of the subjects that you asked to run. For each pseudo participant you have the option of letting the computer randomly assign them to a condition, or you may assign them to a condition. For each participant and for each variable you may take the default option (random assignment) or specify by clicking the appropriate radio button. When you are finished selecting the conditions for all the subjects, select the "submit" button. This takes you to the next page where you will be shown the data for all the subjects.

If you want to assign subjects to conditions using *block randomization* you can use the `block.random` function in the psych package to do so. For more information on using the `block.random` function, either see the supplementary material on the syllabus, or by using the help function in R `?block.random`.

3. The final page has columns labels for the variables and then one row of data for each subject. You may select the entire page and copy and paste it into the text editor of your choice to save it for later data analysis. Or you may paste it directly into R using the `read.clipboard` function from the **psych** package. See the supplementary handout on using R for data analysis in research methods. It is important to save this page in your favorite tex editor if you want to do further analyses of these data at a later time.

How do I analyze the results?

The simulation produces a page of data with column labels. This page may be selected and saved to your hard disk (remember the name) for later analysis. Alternatively, you can copy the page (use the copy command in your browser) and then paste it into R using the `read.clipboard` function. (Make sure you have made the *psych* active first).

The analyses you choose to do depend upon what you studied, but in general you will probably want to do the following steps. (These are discussed in more detail in the tutorial prepared by Katharine Funkhouser: Analyzing the simulation experiment or in slightly more detail in the tutorial for 205.

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