# Assignment 2: Experimental Design

## DESCRIPTION

In this assignment, you will follow the steps described in the "Step-by-Step Experimental Design" lecture to design an experiment. These steps will provide you with a clear procedure to experimental design, which is often done in a haphazard manner. You will start with formulating a research question or a problem statement. You will then identify and formally define the variables of interest in this research question, namely, the factors and response variables, and develop hypotheses that predict the relationship between these variables. Next, you will determine an experimental design, the configuration, in which the predicted relationships will be empirically tested, and design an experimental task that provides a theoretically representative context for this testing. Finally, you will identify the appropriate measurements and participant population for this testing. Following these steps and documenting the experimental design decisions you make, you should be able to create the majority of the content that an empirical research paper would include in its "Method" section. Therefore, your goal in this assignment will be to write up the "Method" section of an imaginary research paper.

Note that the goal of this step-by-step process is to guide you though your first experimental design task. The steps described here typically take place in a more organic fashion — they might overlap and each step could involve a number of iterations. My hope is that, with the experience you gain in this assignment and in your project, you will be able to gain experience with these tasks and eventually complete them in a more organic way.

### EXPECTED OUTCOME

To complete this assignment, you might need to dedicate some time to researching and looking through empirical research papers and use them as examples for different steps in designing your experiment. Expected outcome is a one-page write-up that resembles the "Methods" section of a research paper. This section should reflect all the design decisions you made and follow the style and format that an empirical research article would follow (see template). Submit your write-up following the naming convention "Assignment2-StudentLastName.docx."

### RESOURCES

See the Assignment 2 Moodle page for resources including the Step-by-Step experimental design lecture notes and the assignment submission template.

## STEP 1: FORMULATE RESEARCH QUESTION(S)

All research begins with a question. However, formulating a good research question is not trivial. A good research question should be specific enough so that the main variables of interest are identifiable. On the other hand, it should be open-ended enough to be answered with different hypotheses. Good research questions also specify the conditions under which a study will be performed. Below is one of the many possible templates for a research question:

How does X affect Y under condition(s) Z?

In this template, X and Y are the variables of interest and Z indicates the conditions under which X might affect Y.

In this assignment, you will formulate a research question following this template on a topic of your choice that is somehow relevant to the field of HRI. **You cannot use your project topic as a research question** although you could use a question related to your project topic. If you are struggling to come up with ideas, re-read Goodrich's "Human-Robot Interaction: A Survey" (Reading 1), which outlines several open questions in HRI research. For instance, you might be interested in understanding how interruptions to perform robot maintenance affect work performance in small industrial organizations. Following the above template, an appropriate research question for this problem would be "How do interruptions due to robot maintenance affect the work performances of workers in small industrial organizations?"

### STEP 1 INSTRUCTIONS

Formulate a research question with identifiable variables and conditions under which these variables should be studied.

Below are a few examples of research questions.

- How does the presence or absence of information on the situational awareness of a user operating a telepresence robot affect how fast people are able to get the user's attention?
- How does framing whether a robot is owned or rented affect the amount of disclosure by people in the robot's environment?
- How does whether people think that they are chatting with a human agent, robot, or virtual avatar over IM affect their use of certain linguistic markers?

## STEP 2. IDENTIFY VARIABLES

Experiments involve two kinds of variables: independent and dependent variables. An independent variable is one whose variation does not depend on other variables. A dependent variable, on the other hand, is one whose variation is affected by other variables. In experiments, the dependent variable is typically the variable being manipulated or changed and the dependent variable is the observed results of the manipulation of the independent variable.

An alternative set of terms that can be used for independent and dependent variables are factors and response variables respectively. Factors cause response variable to vary and the variation in response variables depend on factors. For instance, in the research question "How does the presence or absence of information on the situational awareness of a user operating a telepresence robot affect how fast people are able to get the user's attention?" the independent variable or the factor is "the presence/absence of information on the situational awareness of a user operating a telepresence robot" and the dependent variable or the response variable is "how fast people are able to get the user's attention." The variation in factors can be described in different levels and different levels are expected to have different effects on the response variables. The two levels in the above example would be "presence of information" and "absence of information."

In this step of the assignment, you should identify and formally define all the variables — independent and dependent variables, factors and their levels, and response variables — that your research question includes. In the lecture, we discussed the advantages and disadvantages of experiments that involve single and multiple factors (i.e., factorial designs). Following these guidelines, you should identify at least two factors with two or more levels each and one response variable. To accommodate the factorial design, you may need to modify your research question. The variables described in your research question might be higher-level variables than your factors and might be encompassing them. Another way of representing multiple factors in a research question is formulating different research questions for each factor.

### STEP 2 INSTRUCTIONS

Identify the factors, their levels, and response variables that your experiment will involve.

## STEP 3. GENERATE HYPOTHESES

Hypotheses describe provisional relationships between your factors and response variables. You can think of a hypothesis as an interim answer to your research question. For instance, a possible hypothesis for the research question "How does X affect Y under conditions Z?" is "X affects Y in R way under conditions Z." R involves a description of how different levels of factor X might affect the response variable Y.

Hypotheses can capture how different levels of a factor might affect a response variable. For instance, factor "robot appearance" might have two levels: "human-like robot" and "machine-like robot" and we might have different expectations of how these two levels will affect the response variable "how responsible people will feel for the robot." We could state this expectation as follows; "People will feel less responsible for the task when collaborating with a human-like robot partner than with a machine-like robot partner." Hypotheses can also capture how different levels of multiple factors might interact to affect the response variable. For instance, if we add a second factor "robot status" with levels "supervisor," "subordinate," and "peer" to the above experimental design, a possible hypothesis on how the levels in the two factors might interact to affect the response variable would be as follows: "People will feel the greatest amount of responsibility when collaborating with machine-like robot subordinates as compared with machine-like robot peers and supervisors; and as compared with human-like robot subordinates, peers, and supervisors."

Hypotheses should be supported by a description of their motivations. There are a few sources for such motivations; hypotheses can be based on findings of exploratory studies, on findings by prior work in a different area or application domain, and the intuitions of the researcher. Note that the last motivation does not provide the researcher with a free pass to postulate any hypothesis — the researcher should be prepared to support the hypothesis with a plausible story.

In this step of the assignment, describe your expectations of the relationship between the factors and the response variables you identified in the previous step. You can create a single hypothesis or multiple ones. You should explain where your hypotheses come from. Are they based on prior work, personal experience, or a reasonable deduction from a variety of facts and findings?

### STEP 3 INSTRUCTIONS

Generate hypotheses that explain the relationships between your variables. Make sure to have at least one hypothesis describing a main effect and one describing an interaction effect. Support your hypotheses with a reasonable story — either through logical reasoning from facts and findings or findings from prior work that you are aware of (a quick search on the topic in Google Scholar might provide you with enough background on the topic to use as a basis for hypotheses).

## STEP 4. DETERMINE EXPERIMENTAL DESIGN

The next step in designing your experiment involves making decisions on experimental complexity and how participants will be exposed to the different factors in your experiment. Experimental complexity determines whether an experiment is conducted using a simple design — one in which one factor is varied at a time — or using a factorial design — one in which multiple factors and their interactions are considered. The main drawback of a simple design is that it does not allow for studying interactions between factors and might produce misleading results in the presence of such interactions. On the other hand, factorial designs significantly increase the complexity of the experiment, particularly the size of the participant pool, the difficulty of administering the experiment, and the complexity of the statistical modeling. Overall, due to their ability to disentangle relationship between factors, factorial designs are preferred.

The next decision that you will have to make is how participants will be exposed to the different factors and levels in your experiment. Most empirical research follows three models: within-participants design, between-participants design, and mixed-model designs. Within-participants design refers to experimental setups in which each participant is exposed to all the factors and levels involved in the experiment. Between-participants design describes experimental situations in which participants are exposed to only one of the combinations of levels and factors that the experiment involves. The advantages and disadvantages of the two models can be described as a tradeoff between power and bias. In simple terms, within-participants designs provide higher power by controlling for differences across participants — the biggest source of variance in the data. On the other hand, these designs are extremely sensitive to different sources of bias such as transfer effects and demand characteristics. Between-participants designs minimize the effect that these sources have on the data. However, these designs do not offer high statistical power due to high variability across participants in the data. Mixed-model designs aim at drawing the strengths of the two models, using aspects of the two models when appropriate to find an optimal experimental configuration that minimizes bias and maximizes power.

In making experimental design decisions, a good heuristic to follow is to start with a within-participants design and identify comparisons (across factors and levels) in which bias might be particularly harmful to the experiment and administer these comparisons as between-participants. Similarly, you can start with a between-participants design and apply a within-participants model to comparisons in which risk of significant bias is low.

### STEP 4 INSTRUCTIONS

Determine the complexity and configuration of your experiment. Justify your decisions for choosing one model over another at different parts of your experimental design.

## STEP 5. DEVELOP EXPERIMENTAL TASK AND PROCEDURE

Descriptions of experimental task and procedure take up a significant portion of empirical research papers. One of the motivations for paying close attention to task and procedure is the importance of context in any study of social or cognitive activity. The experimental task is a highly controlled representation of the real-world context of the research question. Therefore, the task should provide a reasonable cognitive, social, or organizational context to test hypotheses. This similarity between the real-world context and the experimental context of the research is particularly important for being able to generalize the results of an experiment from the lab to the real world. Because experimental tasks involve situations that are isolated from the real world, they inherently lack the goals, motivations, and expectations of real-world situations. Therefore, the researcher has to explicitly build incentives—goals, motivations, and measures of success—into experimental tasks. These incentives might involve monetary compensation, fun, and educational, diagnostic, or treatment benefits.

This step in experimental design is also where the representativeness of the experimental task might affect the design of the experiment. For instance, the experimental task might represent only one instance or context that the expected relationship between the factor and the response variable might arise. However, to ensure the reliability of the experiment, the task might be extended into different contexts and replicated with different configurations, confederates, equipment, and so on. These different representations of the real-world context of the research problem are modeled using random factors. In contrast, levels of interest in a factor (e.g., human-like and machine-like as levels of robot appearance) are modeled as fixed factors. More discussion on fixed and random factors is provided in the related lecture slides.

Another important element of experimental design is determining and explicitly communicating all the procedures that will be followed in the experiment in great detail. This element is important for two reasons. First, experimental procedures allow other researchers to replicate the original research. Second, experimental procedures can be extremely revealing of different sources of bias and error, therefore, can serve as a means for analyzing the validity of the experimental design. A description of the experimental procedure should include all the steps involved in the experiment in a level that is sufficient for other researchers to use to replicate the experiment. This description should provide enough detail about how the experimental task was introduced to the participants, their involvement in the task, experimenter's actions, the equipment used to create experimental stimuli, when measurements are taken, and so on.

### STEP 5 INSTRUCTIONS

Determine an experimental task that closely represents the real-world context of your research question. Create a variety such tasks (along an axis that you are particularly interested in generalizing — e.g., a study on the effects of teachers' hand gestures in classroom communication might use a number of teachers with different characteristics such as male, female, junior, senior, Caucasian, and African-American teachers as confederates). Finally, write up a detailed description of the experimental procedure.

## STEPS 6 & 7. DETERMINE MANIPULATIONS, MEASUREMENTS, AND PARTICIPANTS

In this step of designing your experiment, you will finalize your experimental variables, how response variables will be measured, and the target participant pool. An important — and often neglected — step in finalizing the experimental variables is assessing the experimental design for appropriate control variables. These variables are those that are not varied in any way across different trials of the experiment. They also provide the researcher with a baseline for comparing how different manipulations might affect response variables. For instance, if you are interested in assessing whether a new Firefox extension you designed is improving its users' search task, some possible control variables would be the use of Firefox without the extension that you designed or the use of Firefox with another extension with a similar functionality to the one you designed.

The researchers in this step will also have to determine the forms of measurement that need to be used to capture how different factors and levels affect the response variables. These forms can be categorized as objective, behavioral, and subjective measures. Objective measures quantify what can be objectively determined through observation. Some examples of objective measures are assessments of recall of information, response time to stimuli, accuracy and speed in completing a task, and so on. Objective measures are considered to be highly valid, mainly because these measures can be quantified in a very easy and precise way. Behavioral measures capture a quantitative assessment of how people behave, particularly high-level behaviors such as task/goal-related behaviors (e.g., whether participants use information provided by a robot in completing the task) and low-level behaviors such as verbal and nonverbal acts and psychophysical cues (e.g., how frequently participants use particular words or brain activity generated by a particular stimulus). These measures can also be considered as objective measures. However, extra steps will have to be taken to establish and validate the objectivity of these measures. Finally, subjective measures quantify people's own accounts of how they think and feel and of their goals, expectations, and motivations. Well-designed experiments use all three forms of measurements and triangulate their results to reach to more valid and reliable conclusions.

Another task for the researcher is to determine the target participant pool. This population should represent the population to which the results of the research that the researcher wants to generalize. For instance, a study aimed at understanding how teenagers use mobile phones for coordination should not be administered with non-teenagers as the main experimental population. The number of participants is also an important element that the researcher has to determine prior to the experiment. The rule of thumb in determining the number of participants is to administer the experiment with a minimum of eight participants for each unique comparison condition. For instance, for a two-by-two, between-participants experiment an appropriate, rough number of participants to include in the experiment might be 32 (2x2x8) with eight participants in each condition. Alternatively, a total of eight participants might be sufficient for the an experiment with the same number of conditions but a within-participants design.

### STEPS 6 & 7 INSTRUCTIONS

Finalize your experimental design and variables. Assess whether your design involves reasonable control conditions. Determine the kinds of measurements you will use, at which stage these measurements will be administered, and what you expect these measurements to capture. Finally, describe your target experimental participant population.

## WRITE-UP

Write a one-page "Methods" section of an imaginary research paper describing your experimental design. Your research question must be somehow related to the field of HRI, but cannot be the same as that your team has been working on. Describe all the design decisions you made following this step-by-step guide. Follow the general writing style used in empirical research (search for examples and/or use readings we have discussed in class as templates). Your report should provide a clear and detailed description of all aspects of your experimental design. Submit your write-up following the naming convention "Assignment2-StudentLastName.docx" to the Assignment 2 submission link on Moodle.

### GRADING (100 POINTS TOTAL)

- Rigor and consistency in each step of the experimental design process (60/100)
  - Formulating the research question (10/60)
  - Identifying variables (10/60)
  - Generating hypotheses (10/60)
  - Determining experimental design (10/60)
  - Develop experimental task and procedure (10/60)
  - Determine manipulations, measurements, and participants (10/60)
- Following the conventions of empirical research writing in the write-up (20/100)
- Quality of the written report (20/100)