

LE/EECS 4443: Mobile User Interfaces (LAB)

Week 10: Empirical Research Methods & An Introduction to Scientific Writing

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Introduction

By the end of this tutorial, you will be able to...

- 1 Understand empirical research methods
- 2 Design and carry out a user study
- 3 Write a research paper / proposal

Introduction

Through the **scientific method**, empirical research aims to:

- 1 Methodologically develop and formulate problems
- 2 Generate testable hypotheses
- 3 Collect data for analysis through experiments which are used to accept or reject the hypotheses

Types of Observable Data

- 1 **Nominal (Categorical) data** represents arbitrary codes which are assigned to attributes. As a result, the count(s) of each label are the measure of interest in identifying patterns.
- 2 **Ordinal (Ranking) data** associates a numerical, “hierarchy” to attributes. As a result, we can make comparisons of “greater than” or “less than.”
- 3 **Interval data** represents a scale where there is equal distance between adjacent values but **no absolute zero**. Statistical means (averages) can be calculated using this type of data, however, ratios are not supported.
- 4 **Ratio data** represents interval data, except that **it has an absolute zero**. Thus, many more calculations are supported.

Types of Observable Data

- **Nominal (Categorical Data)**: Types of fruit, gender, eye colour, etc.,
- **Ordinal (Ranking Data)**: 5-star rating scale
- **Interval data**: Strongly Disagree (1) - Strongly Agree (5)
- **Ratio data**: Temperature, income, height, weight

Research Questions

The first step in conceptualizing a user study is to identify the proper research questions to answer. This will help you identify:

- 1 Independent Variables & Levels
- 2 Dependent Variables
- 3 Hypotheses
- 4 Apparatus (Software & Hardware)
- 5 Procedure (Ethics & Informed Consent)
- 6 Study Design

Your research questions must be **testable**....

Research Questions

In defining the research question and identifying the study design, you must balance:

- 1 Internal Validity:** The ability for your results to be reproducible with a strong cause-and-effect relationship.
- 2 External Validity:** The ability for your results to generalize to others.

Every study design has its own set of limitations... The point is that we mitigate them as much as possible and discuss them.

Acknowledge them; don't try to play it off.

Answering Research Questions

The statistical test we use to answer our research question(s) depends upon the underlying assumptions made on the type of data:

1 Parametric tests

- Normal Distribution
- Homogeneity of Variance
- Independent Sampling

2 Non-Parametric tests

- Also referred to as, “distribution-free tests”, we use non-parametric tests if the above assumptions fail

Answering Research Questions

1 Parametric tests

- Normal Distribution
 - Shapiro-Wilk, Skewness, Kurtosis
- Homogeneity of Variance
 - Levene's Homogeneity Test
- Independent Sampling
 - The observations within each of your groups should be independent from each other

2 Non-Parametric tests

- Also referred to as, “distribution-free tests”, we use non-parametric tests if the above assumptions fail

Answering Research Questions

- Significant effects occur when $p < 0.05$
- Non-significant effects occur when $p \geq 0.05$
 - If $F < 1$, write “ns” instead of providing a p-value
 - If $F > 1$, write “ $p > 0.05$ ”

Introduction

Typically, your research paper will have the following sections:

- 1 Abstract
- 2 Introduction
- 3 Related Work
- 4 Methods
 - Participants
 - Hypothesis Statement
 - Apparatus
 - Procedure
 - Design
- 5 Results & Discussion
- 6 Conclusion
- 7 References

Abstract

- A short summary (≈ 150 words) outlining:
 - 1 What was done
 - This study addresses...
 - Users are able to...
 - 2 What was found
 - Experiments show that users are able to...
 - The results indicate that...
 - Our findings are significant as...

Introduction

- Opening comments which characterize the current state-of-the-art. You should indicate why the subject matter is interesting and relevant
- Identify a problem or challenge that will be used to develop the remaining sections of the paper
- Clearly state the contributions of your work
- **You are expected to use citations to validate facts, statistics, or examples.**

Related Work

- Discuss earlier published work related to the subject matter of your paper
- Your analysis of the related work should emphasize brevity; write and analyze each paper with a clear purpose

Methods I

- Tells the reader **how** the experiment was designed and carried out
 - 1 How were participant recruited? What was the target demographic? How many participants were included in your study?
 - 2 What hypotheses are you testing? What statistical test will you use to accept or reject the null hypothesis? Why are you using that particular test?
 - 3 What tools did you use to carry out the study? What version(s) of the software were used? Did you rely on external validated questionnaires?

Methods II

- 4 Tell us what happened exactly with each participant? How was informed consent obtained? Were they briefed on the objectives of the study? Did they have to fill in a questionnaire? Clearly define the tasks.
- 5 What study design did you use? What are the independent and dependent variables? How did you account for an order of effect (only do this if applicable to your work)? How many trials were required to carry out your user study?

Results & Discussion

- Order the results and discussion based on your **dependent variables**
- Begin with a broad observation (overall mean) and move into the finer details
- Explain the outcomes related to the interaction effects. **It does not matter if the results were positive or negative. Either scenario can help us identify new research directions or interests.**
- Compare the results of your work with other research. Is your new interaction technique faster or more efficient (performance)?

Conclusion

- Summarize what you did and restate important findings/contributions of your research
- Briefly identify topics or areas of future work. This can be done by assessing the limitations of your work.
- **Do not develop new ideas here**

Data Visualization

- Choosing the correct **chart, graph, or map** to visualize your results is critical in communicating important information efficiently
- Your tables or figures should communicate information that:
 - 1 Presents trends in a **small space**
 - 2 Reveals the data at **several levels** of detail
 - 3 **Truthfully** represents what the data has to say

Data Visualization

Some useful tools that you can explore data visualization with include:

- 1 Plotly Express
- 2 matplotlib
- 3 seaborn
- 4 bokeh
- 5 Tableau

Data Visualization

To pick the best graph or chart that works for you, you must consider:

- 1 The research question that you are trying to answer
- 2 The properties of your data

As a general rule of thumb:

- **Line charts** are good at visualizing changes over time
- **Scatter plots** are good for visualizing correlation between two variables
- **Bar charts** are good for visualizing magnitudes or deviations between different conditions
- **Histograms** are good for visualizing distributions.

Data Visualization

Some other resources that you might find useful include:

- 1 Tableau - What Chart is Right for You?
- 2 Choosing the Right Chart Type: A Technical Guide
- 3 EECS6414 — Information Visualization (Part II)
- 4 Graphpad Prism

To be honest, you can just use Google Sheets or Excel as well...
There's no need to overcomplicate things if you are happy with the
limited selection of charts.

Data Visualization

Advice

It is generally recommended to export your charts as **vector** or **raster** images. Both formats save the image in high resolution and are generally able to scale with little to no artifacting.

In general, a minimum resolution of **300 dpi** is required for images to be acceptable when submitting your manuscript to a journal.

Read: <https://pmc.ncbi.nlm.nih.gov/articles/PMC9132506/>

Conclusion

Thank you for your time!
It has been a pleasure being your TA

Take care of yourself!
I look forward to hearing great things about you :)