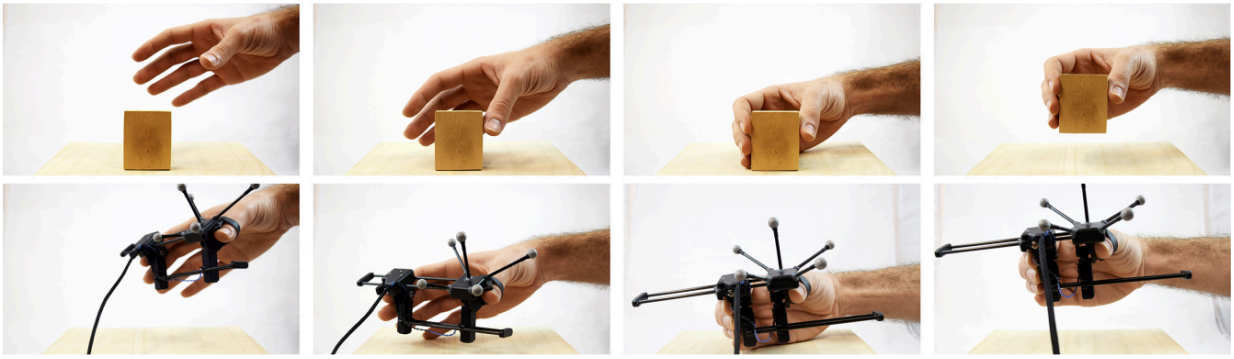
Mini Project 1: Psychophysical Experiment

Motivation

Imagine you work for a company designing a cutting-edge haptic gripping device that brings dynamic gripping sensations to teleoperation systems. Your challenge? Engineer a slidable braking mechanism that precisely mimics the feeling of gripping objects of different sizes. To achieve this, you'll need to integrate a slide encoder, allowing the system to monitor and control the exact distance between the fingers. A fully realized version of your invention could look something like this:



"Inrak Choi, Heather Culbertson, Mark R. Miller, Alex Olwal, and Sean Follmer. 2017. Grabity: A Wearable Haptic Interface for Simulating Weight and Grasping in Virtual Reality. In Proceedings of the 30th Annual ACM Symposium on User Interface Software and Technology (UIST '17)"

But hold on! Your company isn't keen on wasting time and resources on endless prototypes. You have a limited budget, and before diving into full-scale development, they challenge you to answer a critical question:

"How precise does our device really need to be??"

Your task is to find out—because designing the perfect haptic system starts with understanding human perception.

Overview

Working in groups of three, you'll **design, execute, and analyze** a **psychophysical experiment** to determine just how finely people can detect changes in finger separation distance.

Each team will be assigned **two reference values** and must conduct a **two-alternative forced-choice (2AFC) experiment**, where participants compare a test stimulus against a

known reference. Using physical props provided to you, you'll measure the **Just Noticeable Difference (JND)**—the smallest change in distance that users can reliably perceive.

To get started, check out an example experimental prop and the recommended hand pose below:

Example pose that participants should use to gauge finger separation distance.

Details

Teams

Four teams will cover a combined 5 reference finger separation distances: 5mm, 10mm, 20mm, 40mm, and 80mm. Each team will cover 2 references, with some overlap with other teams, as given below.

	Group 1	Group 2	Group 3	Group 4
Stimuli References	5mm, 10mm	10mm, 20mm	20mm, 40mm	40mm, 80mm
Members	Maria	Dakarai	Xiping	Seung Heon
	Diego Alonso	Woolin	Nimra	Simon
	Yanjun	Ruohan	Kojo Egyir	Samuel

Design of Experiment

Pilot

You are free to choose many different parameters for your experiment. Please collect and report a small amount of pilot study data while you set up your protocol. This can be 1 or 2 staircases, which are not used in the final main study, but show that participants are converging.

Please formulate and report the exact wording of the question you ask participants. For example: “Which stimulus feels wider between your fingers, 1, or 2?”

Some parameters you might consider playing with are:

- Dynamic step size (within the prop limitations you are given)
- It’s recommended that you interleave at least two staircases at a time, and collect at least 4 staircases (2 sets of 2 interleaved) per participant, per reference.
- Using two alternative (one in each hand) or two interval (one stimuli followed directly by another one)
- Inspection time (how long users have to feel per trial)
- Visual or audio cues, or blocking of vision and audio
- Number of reversals before terminating a staircase (you may use a minimum of 8 reversals)

Main Study

For the main study, you must gather data from at least 3 participants (i.e. all group members), but are free to gather more. Step size is limited by the size of props given to you, but you may reach out to Prof Shultz on email or Campuswire if you want different sizes. You should make some effort to block a user’s vision during the experiment. Blocking or augmenting audio is up to your discretion, as you may want to use audio to cue or communicate with participants.

Software

It's suggested you use PsychoPy’s StairHandler class (psychopy.data.staircase — PsychoPy v2024.2.5) for the main logic of the experiment. You can print out visual commands for the experimenter to follow, and allow users to respond on a keyboard or audibly. I recommend you use a normal staircase, not a Quest or Quest+. Other software packages can be used if you find one that’s easier.

Simple means and standard deviations can be computed in python, MATLAB, or any other software package. It's recommended that you use glmfit in MATLAB (or an equivalent python package) for fitting a sigmoid to your total dataset.

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Deliverables

You will deliver:

1.) A Short (10 minute) in-class presentation which describes your experimental design, results, and discussion of your result as well as limitations and improvements.

2.) A Short 1-2 page report which covers. Introduction, Methods, Results, Discussion. Include figures and tables as needed. The document should stand-alone from the presentation.

Due Date

In-class presentations will be on **2/20**

The written report is due by midnight of **2/25**.

Email the assignment writeup and slide deck to shultz88@illinois.edu before the end of **2/25**

Results Reporting

JND and Weber Fraction for Finger Separation Width (2 references): You should report "within-subject" as well as "between-subjects" mean and standard deviation for each reference value. Report JNDs in terms of millimeters. These JND thresholds should come directly from your staircase experiments. Be sure to report at what point on the psychometric curve your reported JND is for (for example 70.7% for 1-up, 2-down). Also report the mean Weber Fraction as a percentage between all participants.

Psychometric Function Estimate, PSE and Any Potential Bias Observed in Subjects: You should save **all** of the trial data during your experiment. This includes the stimuli shown to the participant, and their answer. This total amount of data can be used to estimate a psychometric function directly by fitting a logistic sigmoid to the entire data set. This fitting can be achieved using the glmfit function in MATLAB (examples are given in the References Section). The actual output of 2AFC experiments are closer to binomial distributions, so use a binomial logistic regression. Other software packages can be used to perform this fitting if desired, just be clear with what was used.

Discussion Points

The following questions should be answered addressed in your presentation and written report:

1. What are at least 3 potential sources of bias that you encountered while designing the experiment, and how did you adjust your protocol to overcome these?
2. What 2-3 changes might you make to this experiment if it was to be part of a more rigorous psychophysical research paper?

3. How does the JND point from your Psychometric Function estimate compare to the JND directly from the staircase experiment? That is, can you compare JND from the raw psychometric fit and the means from your staircases?
4. Attempt to answer the original question in the motivation section for the higher ups: How precise does a gripping device really need to be?

Grading Expectations

Grading for the assignment is broken down into four components:

1. Design of Experiment (40%):

Develop a well-structured experiment using a validated protocol. Provide clear written instructions, effectively utilize participant time, and ensure that your method allows for meaningful interpretation of results.

2. Experimental Execution (40%):

Conduct the experiment with care to minimize biases, ensure reproducibility, and gather data from 3+ participants. Use sound analysis techniques and incorporate automation where applicable.

3. Report and Presentation (15%):

Present your findings clearly and professionally. Include well-formatted results, contextualize your conclusions, and ensure your presentation is well-organized.

4. Peer Assessment (5%):

Complete a peer assessment survey to provide feedback on your group's collaboration. A link to the peer assessment will be given on Campuswire at the end of the project.

Overall, focus on thorough planning, precise execution, and clear communication to achieve a high-quality project.

References

Get MATLAB:
University of Illinois Urbana-Champaign - MATLAB Access for Everyone - MATLAB & Simulink

PsychoPy:

Home — PsychoPy®

PsychoPy Staircase Tutorial. Note, you do not need to build stimuli for participants, but do need to manually present them to participants:
Tutorial 2: Measuring a JND using a staircase procedure — PsychoPy v2024.2.5

PsychoPy Staircase Documentation:

https://www.psychopy.org/_modules/psychopy/data/staircase.html

GLM Fitting Matlab. Example of Using GLM fit under the assumption of a binomial distribution:

Fitting Data with Generalized Linear Models

Additional GLM Fit Documentation:

https://www.mathworks.com/help/stats/glmfit.html