

PSYC 51.09: Problem Set 3

Introduction

This problem set is intended to solidify the concepts you learned about in this week's lectures and readings. *After attempting each question on your own*, you are encouraged to work together with your classmates in small groups, consult with ChatGPT or other tools, and/or to post and answer questions on the course's Canvas site.

Please upload your problem set to Canvas (as a Word or PDF file) before the due date. No late submissions will be accepted.

Readings and ungraded questions

Links to the readings and materials referenced below may be found on the course GitHub page.

1. Read Chapter 3 of *Foundations of Human Memory*. What were your thoughts on the reading? For example, did you learn something interesting? Were you surprised by something? Do you disagree with the author? Did you think some concept was described especially well (or confusingly)? **(Ungraded)**
2. Blei (2012) describes a "topic model," which is a computational algorithm that can mathematically discover and describe "topics" or "categories" by analyzing a large collection of documents. Read the paper (skimming or skipping the equations and the descriptions of "graphical models"). What did you think? **(Ungraded)**
3. Mitchell et al (2008), Huth et al. (2012), and Huth et al. (2016) all describe techniques for decoding which word someone is thinking of using their brain activity (recorded using a technique called functional magnetic resonance imaging, or fMRI). This technique allows researchers to obtain a 3D "snapshot" of someone's brain activity about once per second during an experiment. Read one or more of these papers to get the high-level ideas (skimming the equations or any other methods that you don't understand). What did you think? What are the ethical implications of these papers? You may also be interested in checking out this web demonstration of where in the brain different concepts are represented: <https://gallantlab.org/huth2016/>. **(Ungraded)**
4. Optional: submit a multiple-choice question based on the materials covered in this week's lectures, readings, and this problem set. You should calibrate the difficulty so that 60–70% of your classmates answer it correctly on an exam. If your question is chosen and you hit your target, you will receive an extra credit point on that exam. **(Ungraded)**

Graded questions

Show all work and provide answers rounded to the nearest thousandth (third decimal place).

1. After studying a list of 4 items during a trial of a Sternberg task, a participant's memory matrix M is given by

$$M = \begin{pmatrix} 8 & 1 & 1 & 2 \\ 7 & 6 & 4 & 3 \\ 4 & 3 & 1 & 2 \\ 8 & 8 & 6 & 5 \\ 5 & 7 & 4 & 0 \end{pmatrix} \\ = \begin{pmatrix} \mathbf{m}_1 & \mathbf{m}_2 & \mathbf{m}_3 & \mathbf{m}_4 \end{pmatrix}$$

- (a) Suppose the probe item is the target \mathbf{m}_3 . Compute the similarities to \mathbf{m}_1 , \mathbf{m}_2 , and \mathbf{m}_4 using **distance-based similarity** (let $\tau = 0.25$):

$$\text{similarity}(\mathbf{a}, \mathbf{b}) = e^{-\tau \|\mathbf{a}-\mathbf{b}\|} = e^{-\tau \sqrt{\sum_{i=1}^N (a(i)-b(i))^2}}.$$

- (b) Compute the same similarity values using **cosine-based similarity**:

$$\cos \theta(\mathbf{a}, \mathbf{b}) = \frac{\mathbf{a} \cdot \mathbf{b}}{\|\mathbf{a}\| \|\mathbf{b}\|}, \text{ where} \\ \mathbf{x} \cdot \mathbf{y} = \sum_{i=1}^N x(i)y(i), \text{ and} \\ \|\mathbf{c}\| = \sqrt{\sum_{i=1}^N c(i)^2}$$

- (c) Consider your calculations in (a) and (b). Would choosing one similarity metric (versus the other) have led to any different predictions about similarity or memory judgements? Explain (1-2 paragraphs).
- (d) Suppose the participant instead receives the probe item \mathbf{p}_1 :

$$\mathbf{p}_1 = \begin{pmatrix} 9 \\ 8 \\ 1 \\ 3 \\ 0 \end{pmatrix}.$$

If the participant's summed similarity decision threshold is 0.5, do you predict that they'll call the probe item old or new? Use distance-based similarity (with $\tau = 0.25$) to justify your prediction.