STAT582
HW3 - Project1

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1 Introduction

In this project, we analyze the image recognition by blind users using a Tactile Image Enhancer. Specifically, we will explore the impact of image type (symbol or picture form) and simplification level (original, edge detection, or segmentation) on the time (in seconds) it takes for users to accurately identify images once they are presented to the blind user.

2 Participant

We will recruit 20 students from the Indiana School for this experiment. We assume there is a pool to randomly extract these 20 students from. Therefore, we consider participants as a random factor. We will conduct the same experiment on the same group of participants twice to increase the degree of freedom. Even though these students are trained to use the Tactile Image Enhancer, the experimenter expects a lot of subject-to-subject variability.

3 Design of Experiment

The study will mainly utilize 2 (Image Type: Picture, Symbol) × 3 (Simplification Level: Original, Edge Detection, Segmentation) factorial design within subjects factors (participant), with repeated measures (two visits) as a blocking factor on both factors. Each participant will complete all combinations of the Image Type and Simplification Level factors twice - once during the first visit and again during the second visit. For clarity's sake, we name each condition as follows:

- 1 Picture - Original (P1)
- 1 Picture - Edge Detection (P2)
- 1 Picture - Segmentation (P3)
- 1 Symbol - Original (S1)
- 1 Symbol - Edge Detection (S2)
- 1 Symbol - Segmentation (S3)

Each participant can evaluate up to 20 images per visit, but will actually evaluate 18 images per visit. This will allow for 6 images per each of the 6 conditions (P1, P2, P3, S1, S2, S3) to be evaluated (6 x 3 = 18 images total). To control for learning effects and fatigue, the order of the 18 images will be randomized for each participant. The specific 18 images shown during the first visit will differ from those shown during the second visit. This avoids any learning effects from seeing the same images twice. The 18 images shown per visit will be determined by randomly selecting 3 rows from the Latin square provided below. Each combination of letters and numbers in the Latin square represents one of the 6 conditions. Selecting 3 rows ensures a balanced representation

of all 6 conditions across participants. This balances the conditions and controls for learning effects across the two visits.

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P1 P2 P3 S1 S2 S3
P2 P3 S1 S2 S3 P1
P3 S1 S2 S3 P1 P2
S1 S2 S3 P1 P2 P3
S2 S3 P1 P2 P3 S1
S3 P1 P2 P3 S1 S2
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4 Modeling

The primary measure of interest is the time in seconds it takes for participants to correctly identify each image, which we expect to be continuous and normally distributed. We will analyze the data using a two-way repeated measures ANOVA, with Image Type and Simplification Level as within-subject factors, while accounting for the interaction between these two factors. The repeated measures design allows us to control for inter-subject variability.
The model will be specified as follows:

$$\text{Time}_{ijkm} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \gamma_{k(i)} + \tau_m + \varepsilon_{ijkm} \tag{1}$$

Where:

- Time_{ijkm} is the response time for the m^{th} participant identifying the k^{th} image of the i^{th} image type with the j^{th} simplification level.
- μ is the overall mean response time across all conditions.
- α_i is the fixed effect of the i^{th} image type (i = picture, symbol).
- β_j is the fixed effect of the j^{th} simplification level (j = original, edge detection, segmentation).
- $(\alpha\beta)_{ij}$ is the interaction effect between the i^{th} image type and the j^{th} simplification level.
- $\gamma_{k(i)}$ is the random effect of the k^{th} image within the i^{th} image type.
- τ_m is the random effect of the m^{th} participant (assuming participants are random samples from a larger population).
- ε_{ijkm} is the residual error.

Assumptions for the random effects and the residuals are as follows:

- The random effect of the k^{th} image within the i^{th} image type, $\gamma_{k(i)}$, is assumed to be normally distributed with mean 0 and variance σ^2_γ:

$$\gamma_{k(i)} \sim N(0, \sigma^2_\gamma)$$

- The random effect of the m^{th} participant, τ_m, is assumed to be normally distributed with mean 0 and variance σ_τ^2:

$$\tau_m \sim N(0, \sigma_\tau^2)$$

- The residual error for the observation corresponding to the m^{th} participant, k^{th} image, i^{th} image type, and j^{th} simplification level, ε_{ijkm}, is assumed to be normally distributed with mean 0 and variance σ^2:

$$\varepsilon_{ijkm} \sim N(0, \sigma^2)$$

To assess the significance of the effects in the model, we will perform an analysis of variance (ANOVA). The ANOVA table summarizes the sources of variation and their associated degrees of freedom. The degrees of freedom (df) indicate the number of independent pieces of information available for estimating the population parameters. At this moment, we only specify the ANOVA table with only df. The ANOVA table for our model is as follows:

AOV	df	df calculation
Participant (Random)	19	$20-1$
Image Type (Fixed)	1	$2-1$
Simplification Level (Fixed)	2	$3-1$
Interaction	2	$(2-1)\times(3-1)$
Visits (Blocking)	1	$2-1$
Images (Random)	26	$(14-1)+(14-1)$
Error	669	$720-51$
Total	719	$(18-1)\times(20-1)\times 2-1$