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Introduction to Cognitive Science

Assignment 1

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Summary

In this project, we investigated human sensitivity to facial identity using morphs between face pairs and tested how different experimental manipulations affect recognition performance. The core concept explored is **perceptual sensitivity**—specifically, how accurately participants can distinguish between two identities under different visual conditions. To quantify this sensitivity, we applied two complementary methods: **psychometric curve fitting** using a sigmoid function to estimate the sensitivity parameter (β), and **Receiver Operating Characteristic (ROC) analysis** to compute the area under the curve (sROC), which reflects decision-level separability.

The analysis proceeded in several stages. First, we visualized and fit sigmoid functions to each subject's responses across morph levels to estimate β as a measure of perceptual sensitivity. We then analyzed how β varied across spatial frequency conditions (intact, low-pass, and high-pass filtered images) and tested several predefined hypotheses using statistical methods such as the Friedman test and Wilcoxon signed-rank test. In the second stage, we evaluated sensitivity using ROC analysis, focusing on the area under the ROC curve (sROC) without relying on model fitting. This provided an alternative and robust way to quantify recognition accuracy. Finally, we formulated and tested a new hypothesis relating sensitivity to participant age. This allowed us to explore individual differences and propose a novel cognitive factor influencing facial recognition performance. The overall goal of these analyses was to understand how both stimulus properties and subject characteristics shape face perception sensitivity.

Question 1 - Psychometric Fitting

Evaluation of Identity Sensitivity Using Psychometric Functions

1-1. Comparing Sigmoid and Gaussian Models for Curve Fitting

To assess the quality of psychometric fits, we compared three models for describing the relationship between morph level and participant response: the **simple sigmoid**, **generalized sigmoid**, and the **Gaussian cumulative distribution function (CDF)**. We evaluated model fit using information-theoretic criteria—**Akaike Information Criterion (AIC)** and **Bayesian Information Criterion (BIC)**—which penalize model complexity. For each subject and condition, we fit all three models and selected the one with the lowest AIC and BIC. Results showed that in many cases, the generalized sigmoid or Gaussian CDF (specially the second one) provided a better fit than the simple sigmoid, suggesting the importance of flexible models in capturing behavioral data.

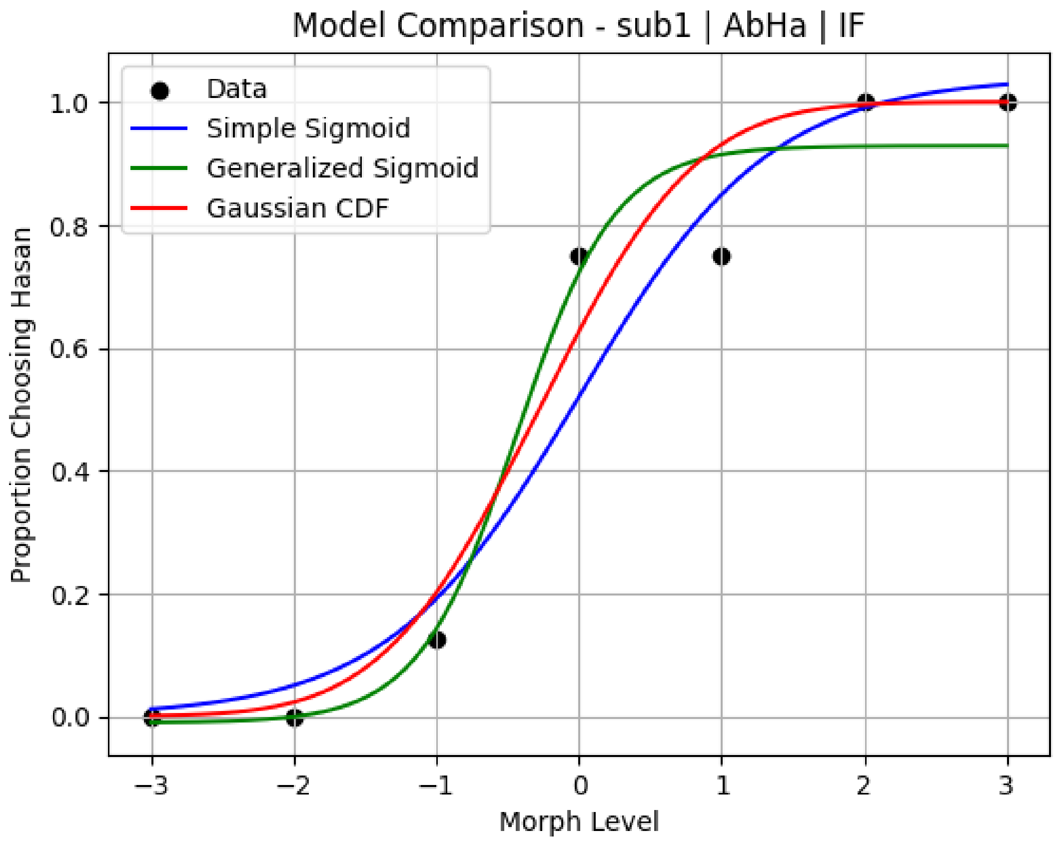

Figure 1 – Three models for subject 1, AbHa pair and IF frequency

1-2. Hypothesis 1 – Effect of Spatial Frequency on Sensitivity

We first investigated how spatial frequency influences the estimated sensitivity parameter (β) obtained from psychometric curve fitting. An average β value was computed for each subject and spatial frequency condition. Pairwise comparisons using the Friedman test revealed highly significant differences between intact and both filtered conditions. Specifically, when comparing intact frequency (IF) and low-pass filtered images (LF), the test yielded a statistic of 23.00 with a p-value of 4.66×10^{-9}. Similarly, for IF versus high-pass filtered images (HF), the statistic was 30.00 with a p-value of 1.48×10^{-8}. However, the comparison between LF and HF conditions did not reach significance (statistic = 345.00, $p = 0.720$). These findings indicate that participants' identity sensitivity is greatest with intact images, while performance is comparably lower and statistically indistinguishable between low- and high-pass filtered images.

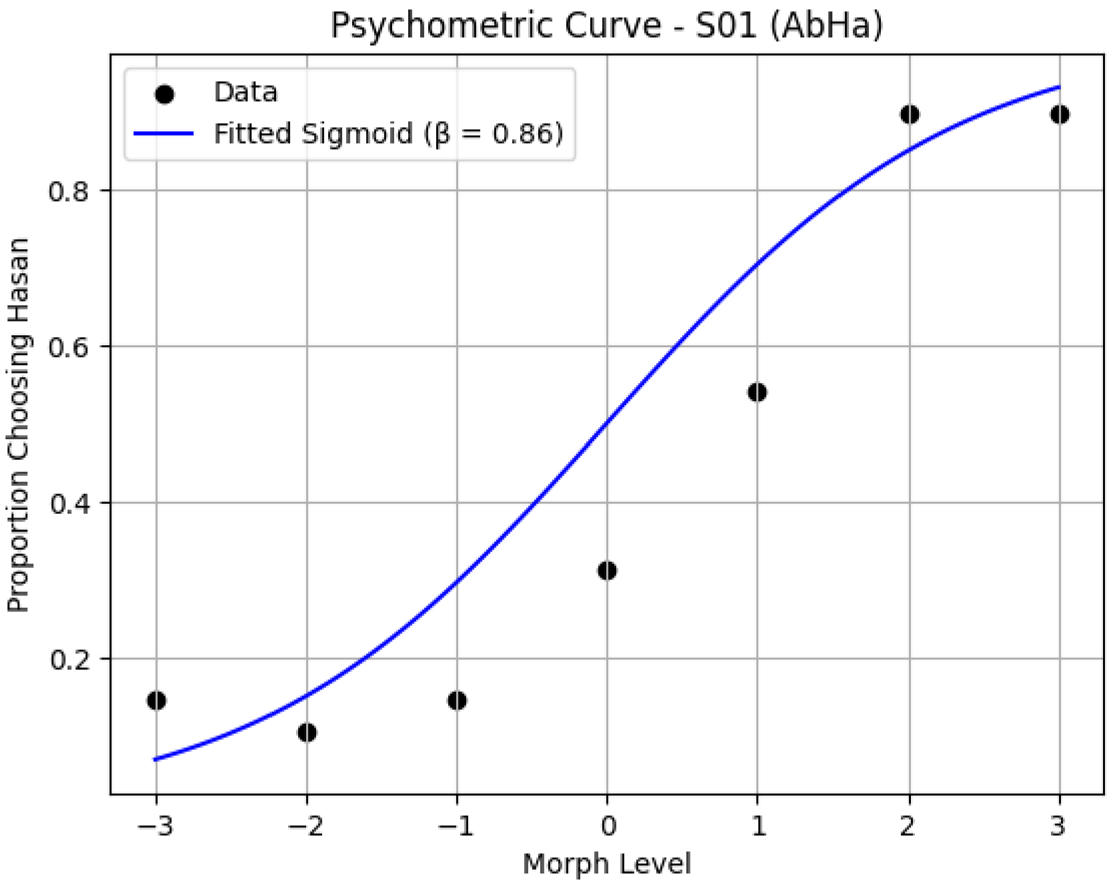

Figure 2 - PSYCHOMETRIC CURVE FOR SUBJECT 1 AND PAIR ABHA

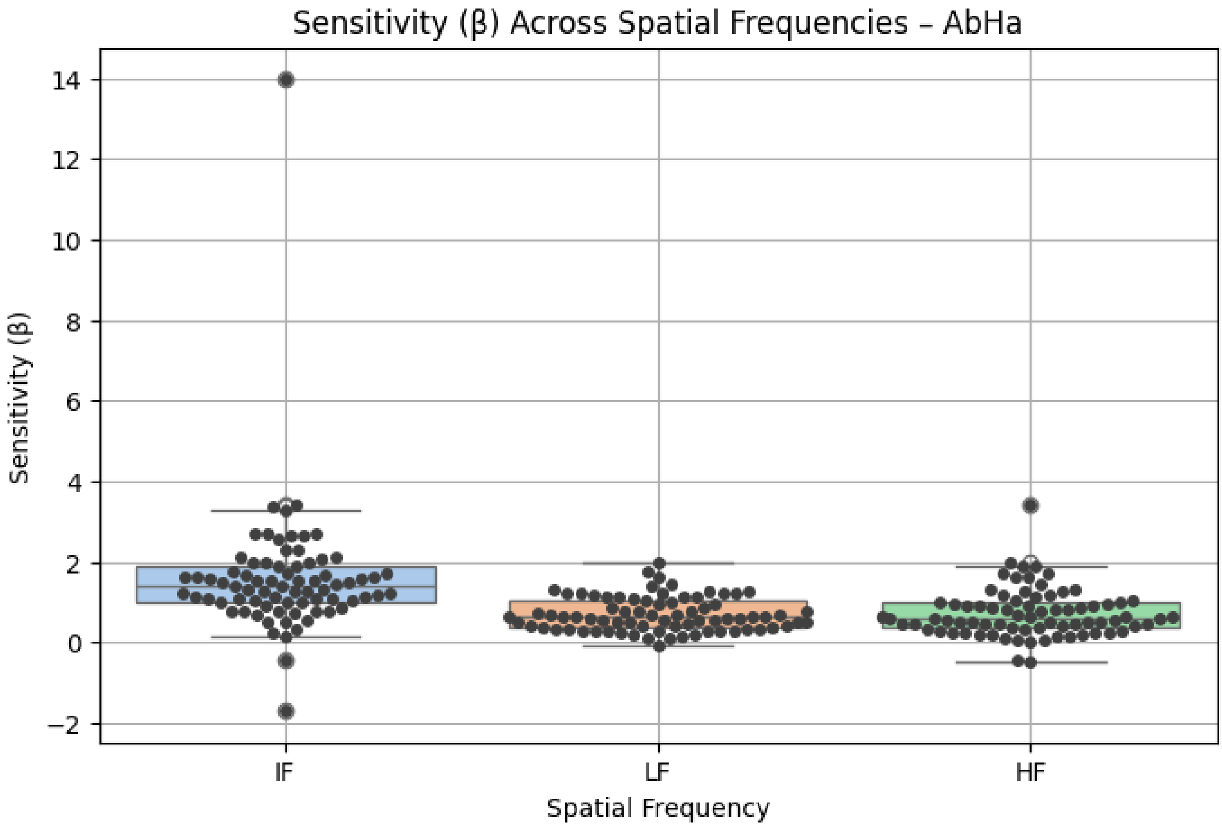

Figure 3 - BOX PLOT OF SENSITIVITY BASED ON DIFFERENT FREQUENCY

1-3. Hypothesis 2 – Same-Gender vs. Opposite-Gender Recognition

We examined whether subjects’ sensitivity differs when the gender of the presented face matches their own compared to when it does not. After grouping the data according to whether the face’s gender was the same as or opposite from that of the participant, a Wilcoxon signed-rank test was conducted. The analysis produced a test statistic of 6144.00 and a p-value of 0.478, indicating no significant difference between same-gender and opposite-gender recognition performance. Thus, the data do not support the hypothesis that a gender match between the observer and the face enhances identity discrimination.

1-4. Hypothesis 3 – Hand Used to Respond (Left vs. Right)

To explore whether the hand used to respond affects identity sensitivity, we computed separate β values for left-hand and right-hand responses. The resulting comparison using a Wilcoxon signed-rank test yielded a statistic of 333.00 with a p-value of 0.596, indicating that there is no significant difference in sensitivity between left- and right-hand responses. This suggests that, within our dataset, the hand used to make a decision does not systematically influence facial identity discrimination.

1-5. Hypothesis 4 – Dominant vs. Non-Dominant Hand

In order to test whether participants perform better when using their dominant hand, we attempted to compare β values between dominant and non-dominant hand responses. However, due to insufficient data (one of the groups had an inadequate number of observations), it was not possible to perform a reliable statistical analysis. Consequently, no conclusion can be drawn regarding the effect of hand dominance on facial identity sensitivity from the current dataset.

1-6. Hypothesis 5 – Gender Differences in Overall Sensitivity

Finally, we examined whether overall sensitivity to facial identity differs between male and female participants. Overall sensitivity was calculated by averaging the β values across conditions for each subject, and the groups were compared using a Mann–Whitney U test. The analysis revealed a test statistic of 5303.50 and a p-value of 0.0235, indicating a significant difference between genders. This finding suggests that overall facial identity sensitivity differs between male and female subjects, with one group (as detailed in the Discussion) performing significantly better than the other.

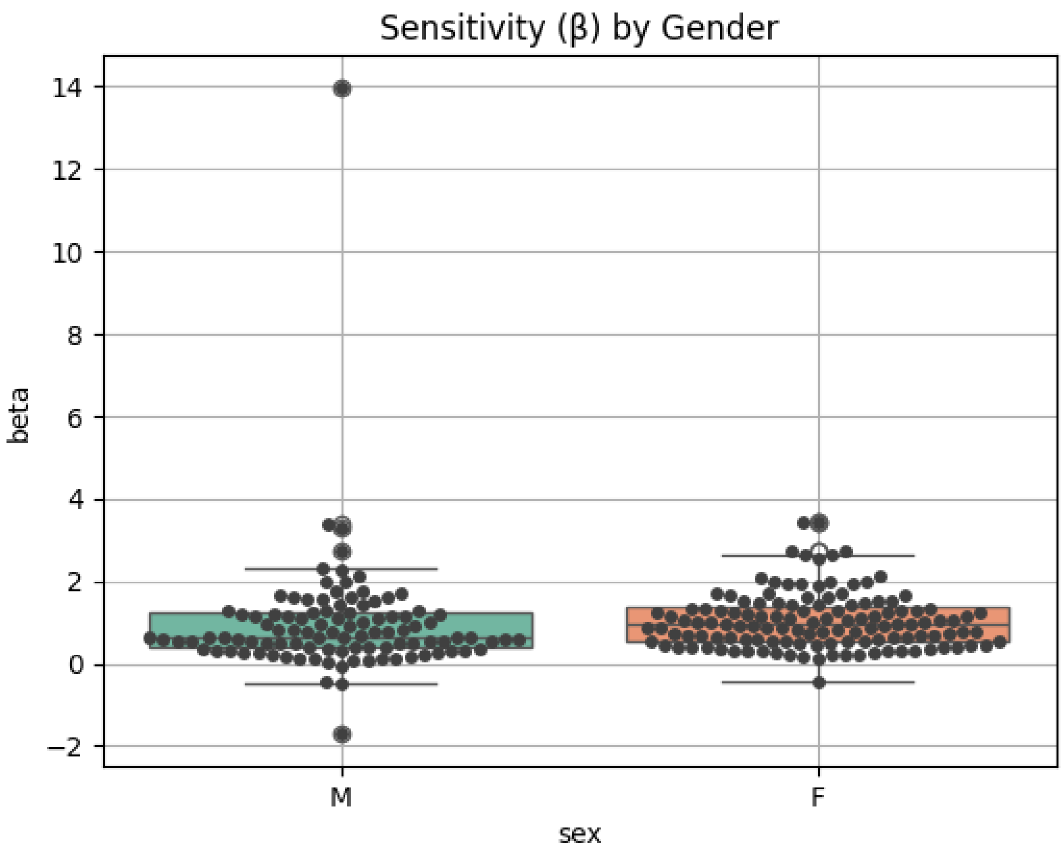

Figure 4 - BOX PLOT OF SENSITIVITY BASED ON DIFFERENT GENDERS

Question 2 - Subject Sensitivity using ROC

2-1. Hypothesis 1 – Effect of Spatial Frequency on Identity Sensitivity (sROC)

We first tested whether sROC values differed significantly across spatial frequency conditions (IF, LF, HF). For each subject, we averaged sROC across both face pairs for each frequency, and included only those with complete data across all three frequencies (n = 38). A **Friedman test** revealed a significant main effect of frequency:

stat = 46.1053, p = 9.74×10^{-11}

This highly significant result confirms that identity sensitivity—as measured by sROC—is affected by the frequency content of the images, with the highest sensitivity typically observed in the **intact (IF)** condition and lowest in the **high-pass (HF)** condition.

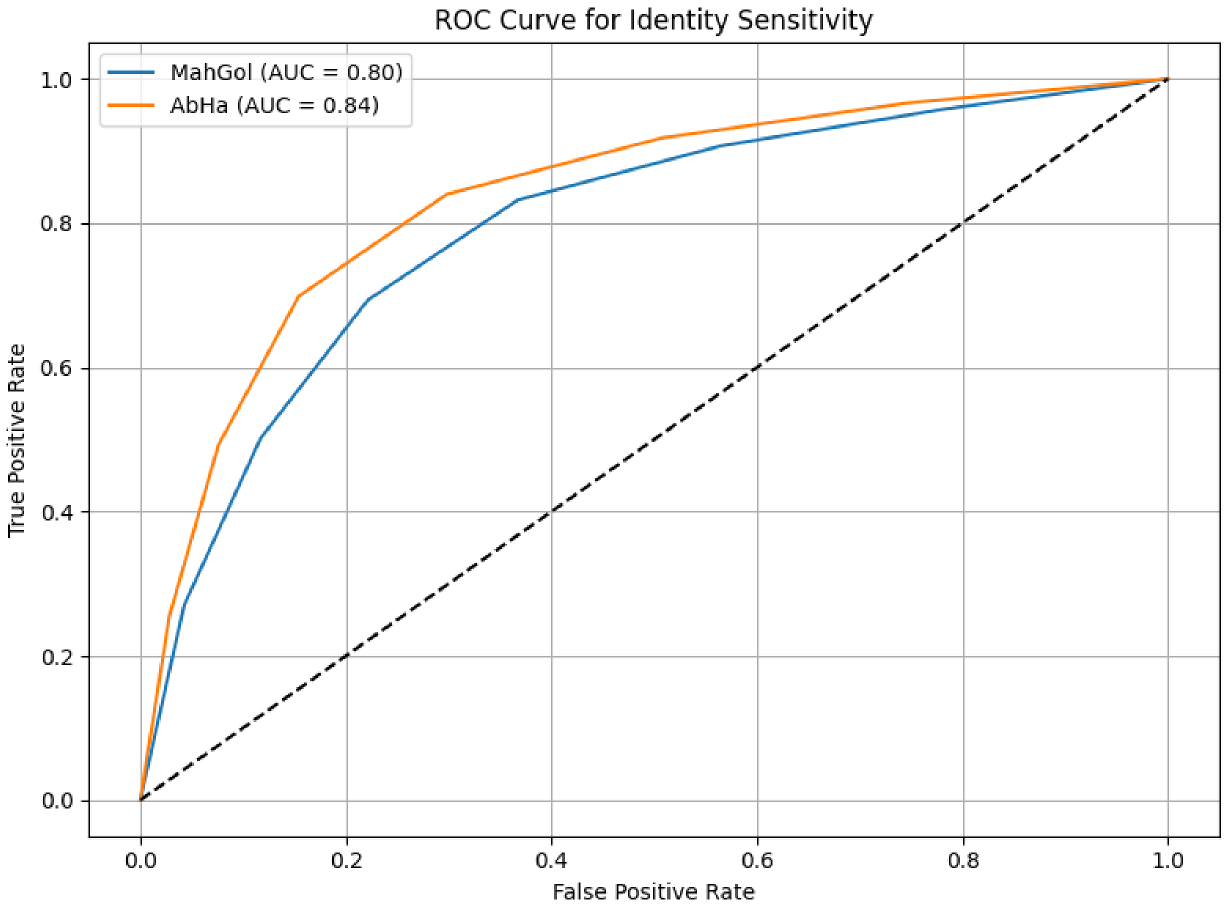

Figure 5 - ROC CURVE FOR IDENTITY SENSITIVITY

2-2. Hypothesis 2 – Same-Gender vs. Opposite-Gender Face Recognition

We next examined whether participants were more sensitive when recognizing identities of the **same gender** as themselves. Each trial was classified based on whether the participant's gender

matched that of the target face, and sROC values were averaged across same-gender and opposite-gender trials.
Among the 38 subjects with data for both conditions, a **Wilcoxon signed-rank test** showed no significant difference:
stat = 343.0000, p = 0.6986

Thus, there is no evidence that gender similarity between the observer and the target identity influences recognition sensitivity in this dataset.

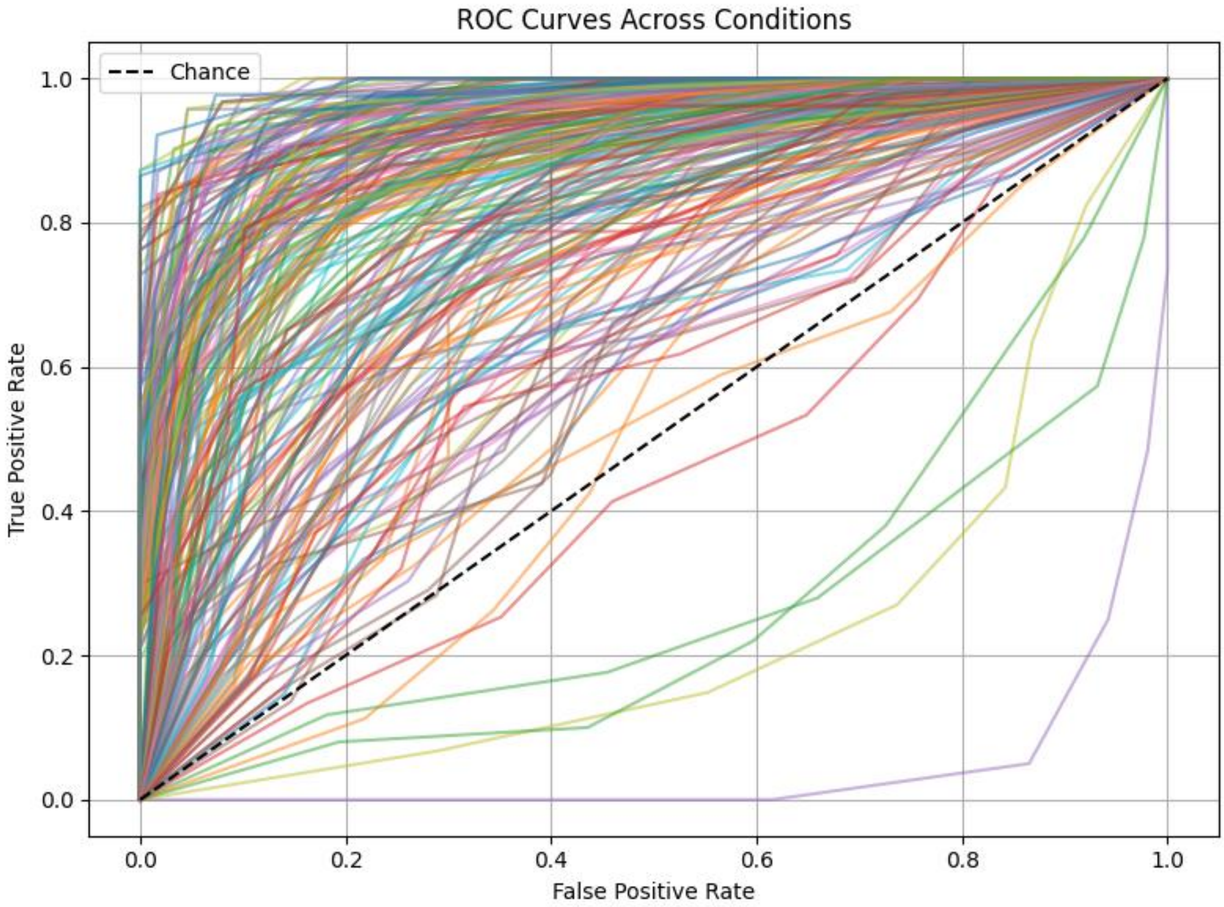

Figure 6 - ALL ROC CURVES

2-3. Hypothesis 3 – Effect of Response Hand (Left vs. Right) on Sensitivity

We tested whether the hand used to respond (left or right) had any effect on recognition sensitivity. sROC values were computed separately for left- and right-hand responses and compared using a **Wilcoxon signed-rank test** across 38 subjects who had responses with both hands. The result was:
stat = 369.0000, p = 0.9886

This indicates no significant difference in recognition sensitivity between responses made with the left versus right hand.

2-4. Hypothesis 4 – Dominant vs. Non-Dominant Hand

To test whether participants are more sensitive when using their **dominant hand**, we attempted to compare sROC values between dominant and non-dominant hand trials. However, due to a lack of data coverage, only one group (dominant) was present in the dataset for most participants: **Columns in dominant hand comparison: [False]**

Therefore, a proper statistical comparison could not be performed, and no conclusion can be drawn from this hypothesis in the current dataset.

2-5. Hypothesis 5 – Gender Differences in Overall Sensitivity

Finally, we tested whether **male and female participants** differ in their overall sensitivity to facial identity. We averaged sROC values across all conditions for each subject and grouped them by gender. A **Mann–Whitney U test** showed a marginally non-significant trend: **stat = 112.0000, p = 0.0527**

Although the result is close to the conventional significance threshold ($p = 0.05$), it does not provide strong statistical evidence of a gender effect. However, the trend could be worth exploring further with a larger sample or more targeted design.

Question 3- Make a Hypothesis

In this final section, we explored a new hypothesis beyond those explicitly defined in the assignment. Specifically, we investigated whether **age** is related to participants' ability to distinguish facial identities.

3-1. Hypothesis

Younger participants exhibit higher identity sensitivity than older participants, as measured by the area under the ROC curve (sROC). Previous research in cognitive science suggests that perceptual and cognitive processing speed may decline with age, particularly in tasks involving fine-grained visual discrimination such as face recognition. We hypothesized that this decline might be reflected in a negative correlation between age and identity sensitivity in our dataset.

3-2. Method

To test this, we computed **overall sensitivity per subject** by averaging their sROC values across all conditions (spatial frequencies and face pairs). This yielded one overall sensitivity score per subject. We then merged this data with each participant's demographic information, including age, from the subject information table.

We used both **Pearson** and **Spearman correlation** analyses to examine the relationship between **age** (treated as a continuous variable) and **overall sensitivity** (sROC). Pearson measures linear correlation, while Spearman captures monotonic relationships without assuming linearity.

3-2. Result

The correlation analyses revealed **no significant relationship** between age and identity sensitivity:

- **Pearson correlation**:
  r=−0.112r = -0.112r=−0.112, p=0.504p = 0.504p=0.504
- **Spearman correlation**:
  ρ=−0.041\rho = -0.041ρ=−0.041, p=0.807p = 0.807p=0.807

Although both coefficients were negative (in line with the hypothesis), the results were **not statistically significant**, indicating that there is **no clear evidence** in this dataset that age influences identity sensitivity.

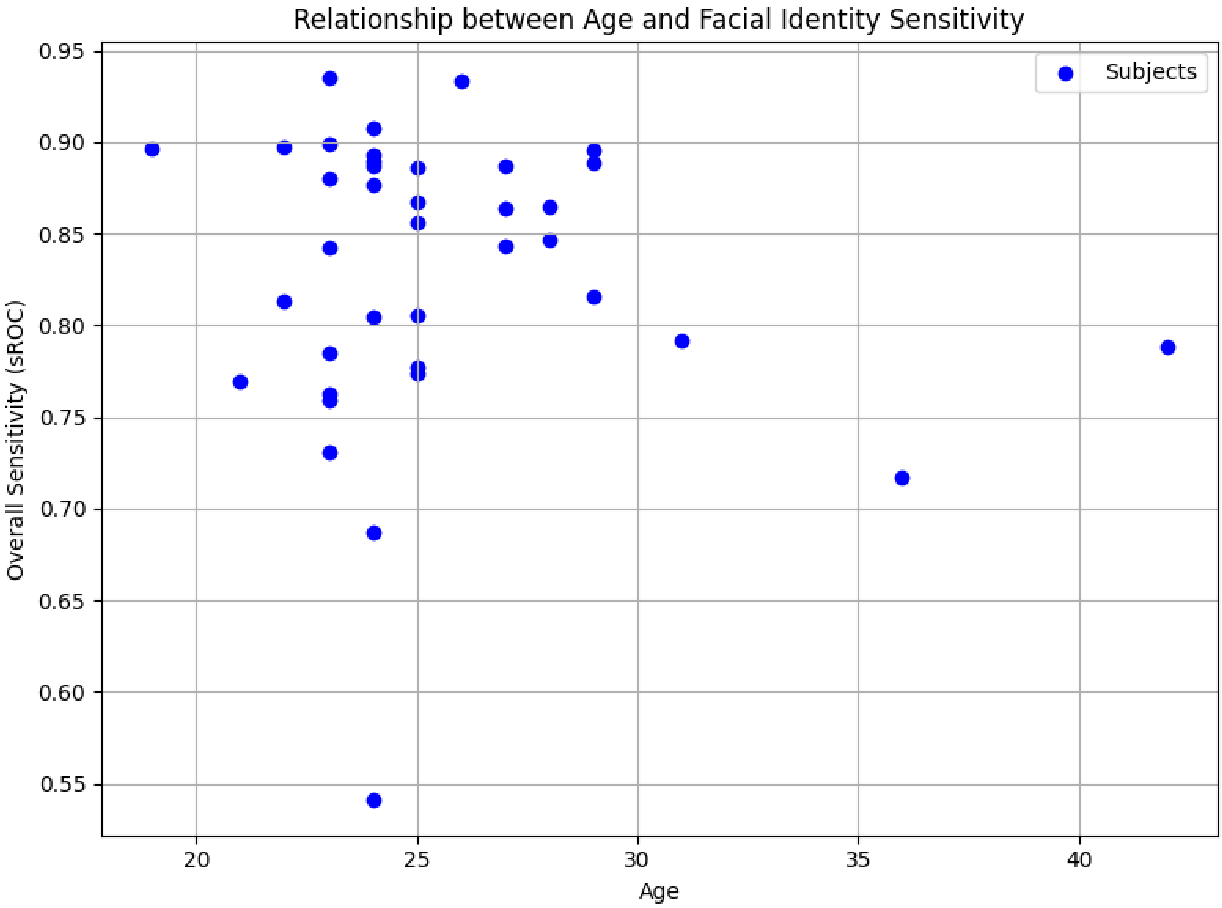

Figure 7 - EFFECT OF AGE IN SENSITIVY