University of Tehran
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Introduction To Cognitive Neuroscience

Assignment 1

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Introduction

In this assignment we study what features impact facial identity recognition by Conducting a psychophysics experiment where we show pictures with different morph levels continuously to the subject, and marking down their response and implementing several hypothesis tests.

We used two methods for this:

1- Firstly, plotting the probability of perception on a psychometric function (the probability of choosing a face on a specific morph level) . fitting a sigmoid (S Shape) curve to the psychometric function and analyzing the slope (Beta) of it.

2- Secondly, we use the ROC (Receptive Operating Curve), where we plot the times the subject guessed correctly what the face was (Hit rate) against the times it falsely recognized it (False alarm), and afterwards we analyze the area under curve.

Task 1: Psychometric Fitting

In this Section, the analysis and procedure of fitting a curve to psychophysics data is explained.

1-1. Overall Procedure

Firstly, we load the Data and separate each subject, for each subject in each morph level, we calculate the probability of perception, we do this by dividing the number of times that subject guessed a face (Hasan or Goli) by the total guesses in that morph level.

We Also removed the mix labels.

This is the y axis, and then the x axis is the morph levels, we plot this and fit a curve on it, extract the beta of the fitted curve and analyze that.

We Partition our data set according to the specific hypothesis, for example if we are testing the signifance of using which hand, we partition our data to left hands and right hands.

We also do each fitting twice, one for Abha scale, and one for Mahgol scale.

The larger the beta, the more sensitivity that person had, meaning he/she were better at identifying the faces.

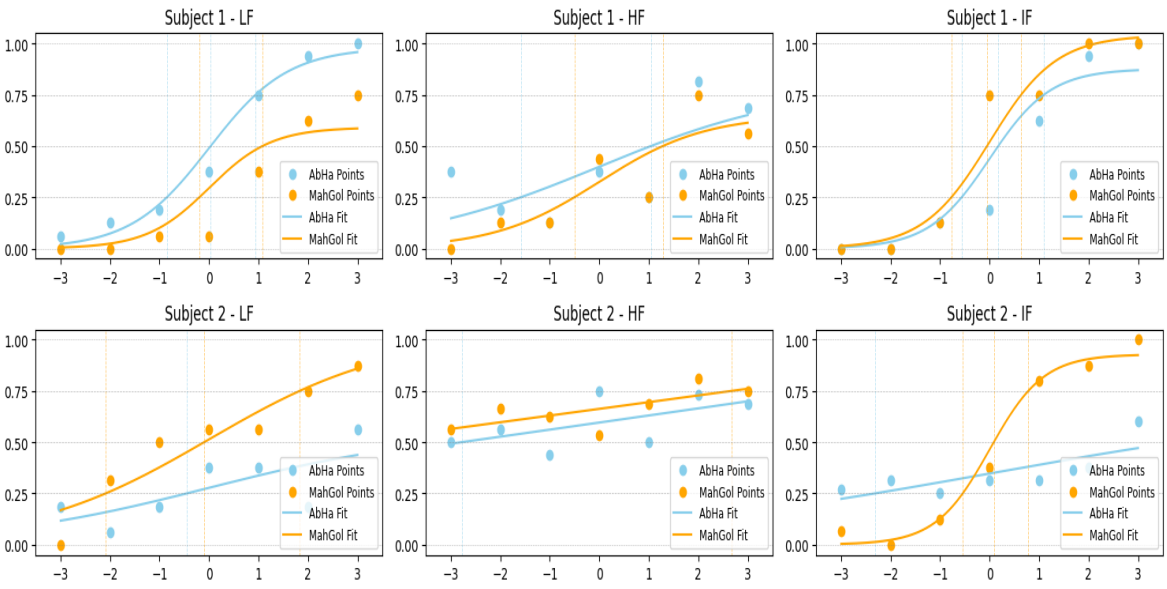

Figure 1: An example of fitted psychometric curves across varying spatial frequencies is presented

1-2. Hypothesis Testing:

In this section we tested several hypotheses, using different statistical test and varies partitioning of our data.

Firstly, we tested if the data is normally distributed, because this plays a crucial part for our choice of statistical test. We use the **Shapiro-Wilk Test** to determine this. Also it is specifaclly created for normal distribution testing unlike other tests and its good for small sample sizes.

As it shows in Table 1 all P–Values are smaller than the Signifance level (0.05) therefore we reject the null hypothesis which is the data is normally distributed.

And from this hear we will only use non-parametric tests that do not assume the distribution of the data.

Important note: Besides the first and last hypothesis, we used Wilcoxon test for the rest, Wilcoxon test is the non-parametric equivalent to the paired (dependent) t test, and our examination are paired, because we analyze if for example subject 1's sensitivity were different in one frequency compared to another frequency, because the test subjects are the same they are paired.

Table 1: Normal Distribution Testing P - Values

Frequency and Spectrum	P - Value
Low and AbHa	0.022
High and AbHa	0
Intact and AbHa	0
Low and MahGol	0.115
High and Mahgol	0.068
Intact and Mahgol	0

1-2-1. Does the sensitivity to detecting identity from different spatial frequency bands differs:

After Partitioning our data by their different spatial frequencies, firstly we conducted a **Friedman Chi-Square test**, because we are testing three dependent variables and they are not normally distributed (this is the non-parametric equivalent to the repeated-measures anova test), also because we are examining a subject in different frequencies, they are paired (dependent).

As the result show in Table 2, both P-values are significantly smaller than the significance level so we reject the null hypothesis that is there is no significant difference between the frequencies, so there is, because of the nature of the Friedman chi-square test, at least one variable different from the others.

Table 2: P values for Friedman Chi-Square test

Spectrum	P-Value
Abha	0.001503
Mahgol	0.00000000001

This is also shown in the paired-lines visualization on Figure 2. Where the movement of of the lines change when going from on frequency to the other (Constantly going up or down).

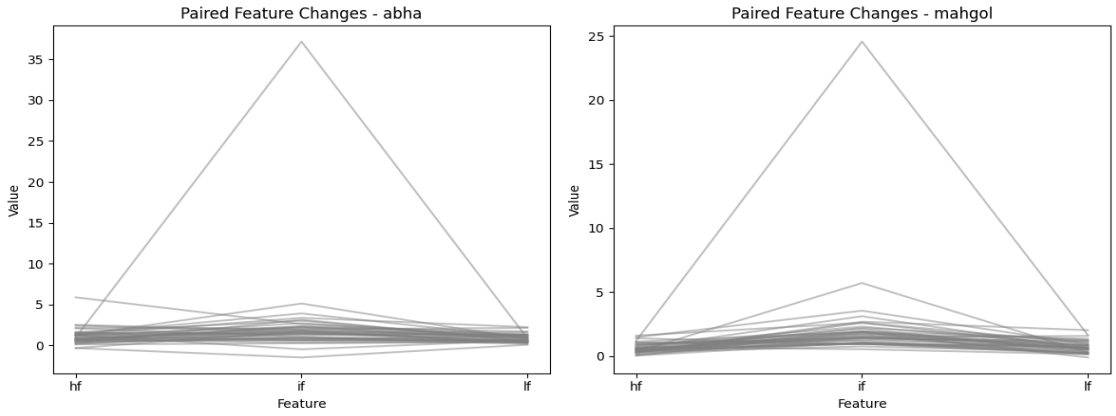

Figure 2: Paired Lines for different frequencies

A Unique observation is that going from going from low to intact the value is getting higher and it getting lower when going away from intact, and they do not change that much when going from low to high, to further investigate these we use a **Wilcoxon test** for every two-by-two pair of the frequencies.

Wilcoxon test is the non-parametric equivalent to a two variable paired t-test. Which is the perfect test for here because we are testing two frequencies at a time, and they are dependent and the data is not normally distributed.

Table 3 tells the story that we expected, between low and high for both are bigger than the significance level so we cannot reject the null hypothesis, so there is no significant difference between them but between intact and all the others, there is a significant difference.

Table 3: P-Values for paired frequencies.

Frequency and Spectrum	P-Value
High vs Intact and AbHa	0.01484
High vs low and AbHa	0.2674
Intact vs Low and Abha	0.00002
High vs Intact and MahGol	0.0000000004
High vs low and MahGol	0.3279
Intact vs Low and Mahgol	0.000000000014

Another analytic is the median of each beta, if the median is high, that means people are more sensitive in this level which means people detect faces better in that frequency, as shown in Table 4, the median is higher for intact compared to the other two.

Table 4: Median for different Frequencies

Average Frequency median between AbHa and Mahgol	**Median**
Low	0.77
High	1.58
Intact	0.68

Final Conclusion: There is a significance difference between the frequencies, but only between Intact and the other two, also Intact has higher sensitivity.

1-2-2. whether people are more adept at identifying images of their conspecific or hetero-specific gender.

After just differentiating our data to male and female parts, and doing two **Wilcoxon Test** because we are testing two dependent sets, once examine subjects that are males on the AbHA(male) and MahGol(female) spectrum, once examine the females on the two spectrums, we get the result in Table 5:

Table 5: P-values for same gender testing

Gender	P-value
Male	0.45
Female	0.17

The P-values are way high so the data does not show significant difference between subjects identifying same gender faces.

As shown in Figure 3, the data has no pattern going from abha to mahgol, suggesting there is no significant difference between recognizing conspecific or hetero-specific gender.

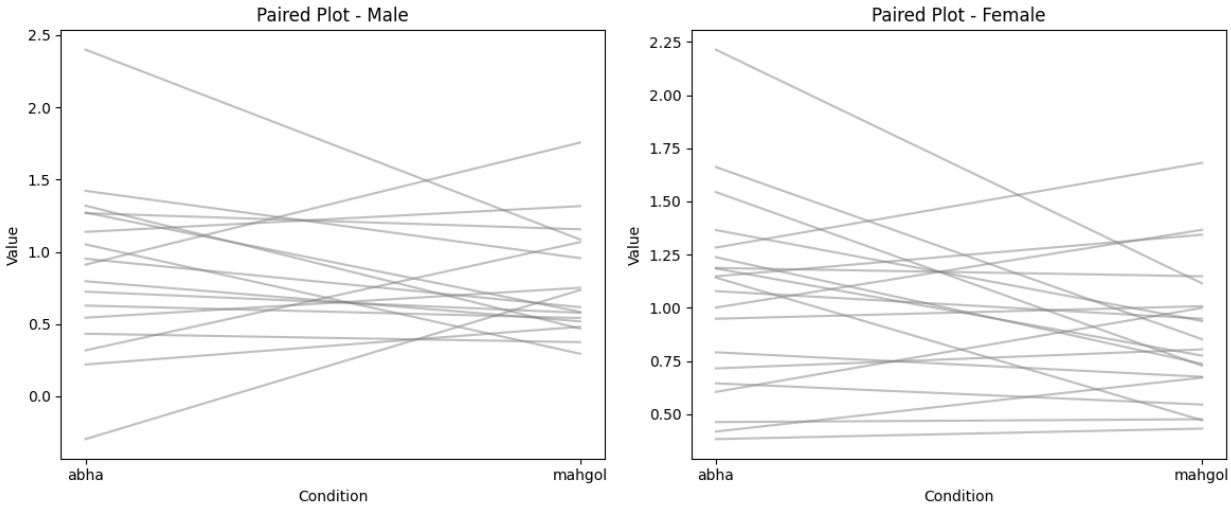

Figure 3: Paired lines for conspecific or hetero-specific genders.

Final Conclusion: although because of the lower p-value of females we are less confident that there is a difference for this gender but nonetheless this data shows no notable difference for same gender or opposite gender recognition.

1-2-3. whether subjects can better detect identities in a specific spectral band if they use their left hand.

For each frequency we differentiated each subjects left hand trials and right-hand trials then we applied Wilcoxon test to each subject when they used their left or their right.

As shown in Table 6, for the reason that the p values are high, they do not show any significant difference between people who used their left or their right.

Table 6: P-Value for Left and Right Hand analysis

Frequency and Spectrum	P-value
Low and AbHa	0.95
High and AbHA	0.54
Intact and AbHa	0.30
Low and MahGol	0.90
High and MahGol	0.19
Intact and MahGol	0.50

This is also backed by the box plot in Figure 4which shows similar distribution and median of the data between left and right:

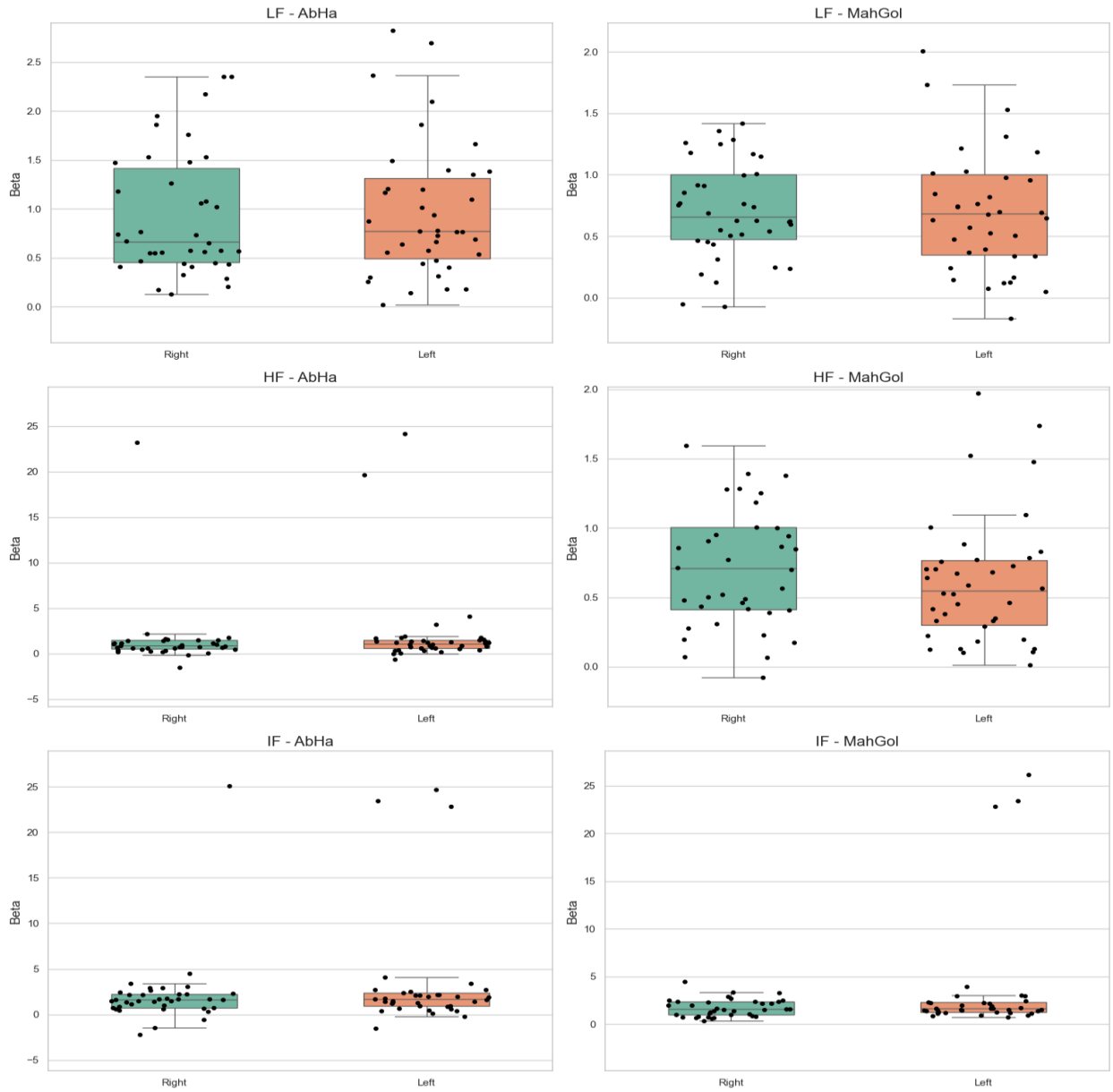

Figure 4: Box plots for Left-Right hand analysis

Final Conclusion: The data shows no notable difference between using right or left hand.

1-2-4. whether subjects can better detect identities in a specific spectral band if they use their dominant hand.

After checking if the hand the subjects used in a trial was their dominant hand and mapping the label to dominate, we partitioned them just like the last part, but the difference was we used dominate and non dominate as the labels besides right and left. As demonstrated in Table 7, after the Wilcoxon test is done, the p-values are humongous, therefore we do not reject the null hypothesis.

Table 7: Table for Dominate Hand analysis

Frequency and Spectrum	P-value
Low and AbHA	0.56
High and AbHA	0.73
Intact and AbHA	0.36
Low and Mahgol	0.76
High and Mahgol	0.42
Intact and Mahgol	0.88

This Demonstration is correctly shown in Figure 5, where the box plot distributions are very similar and there is no pattern to the paired lines.

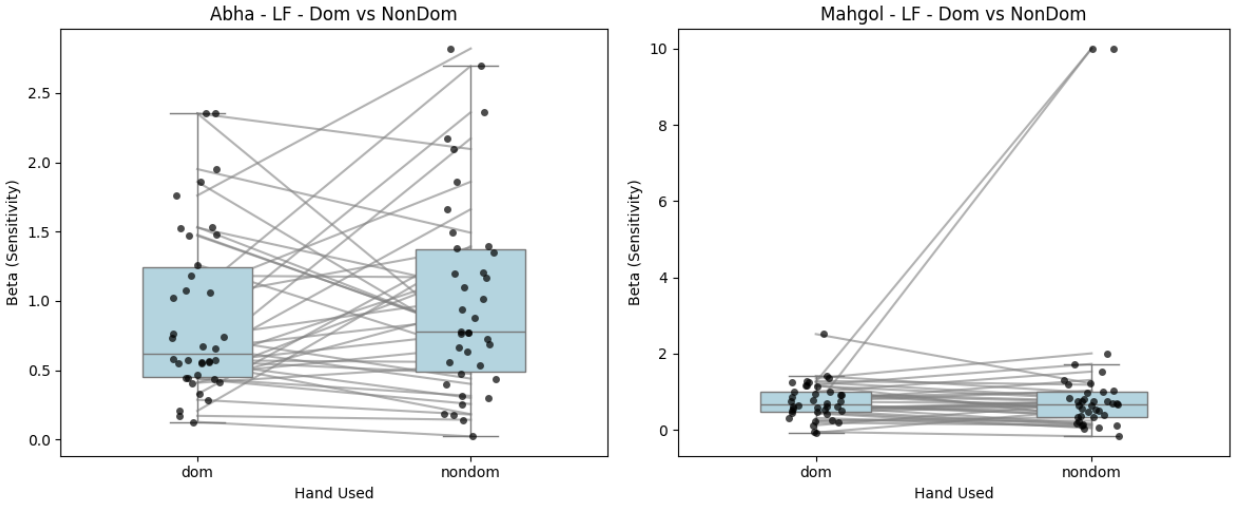

Figure 5: Dominate hand visualization

Final Conclusion: It does not matter if you use your dominated hand or not.

1-2-5. whether women are significantly better than men in the task of identity detection

Ah and finally, the last hypothesis, this part was fairly easy, we just computed the curves for abha and mahgol, partitioned by gender and conducted a **Mann-Whitney U test**, First of all because its non-parametric, second of all because our experiment is no more paired, we are examining two different groups by together.

And contrary to the some peoples beliefs, there is no difference, the p values shown in Table 8 show we cannot reject the null hypothesis.

Table 8: P-Values for gender comparison as a whole

Spectrum	P-Value
Mahgol	0.35
AbHa	0.27

This is also backed by the similar distribution shapes in the violins in Figure 6.

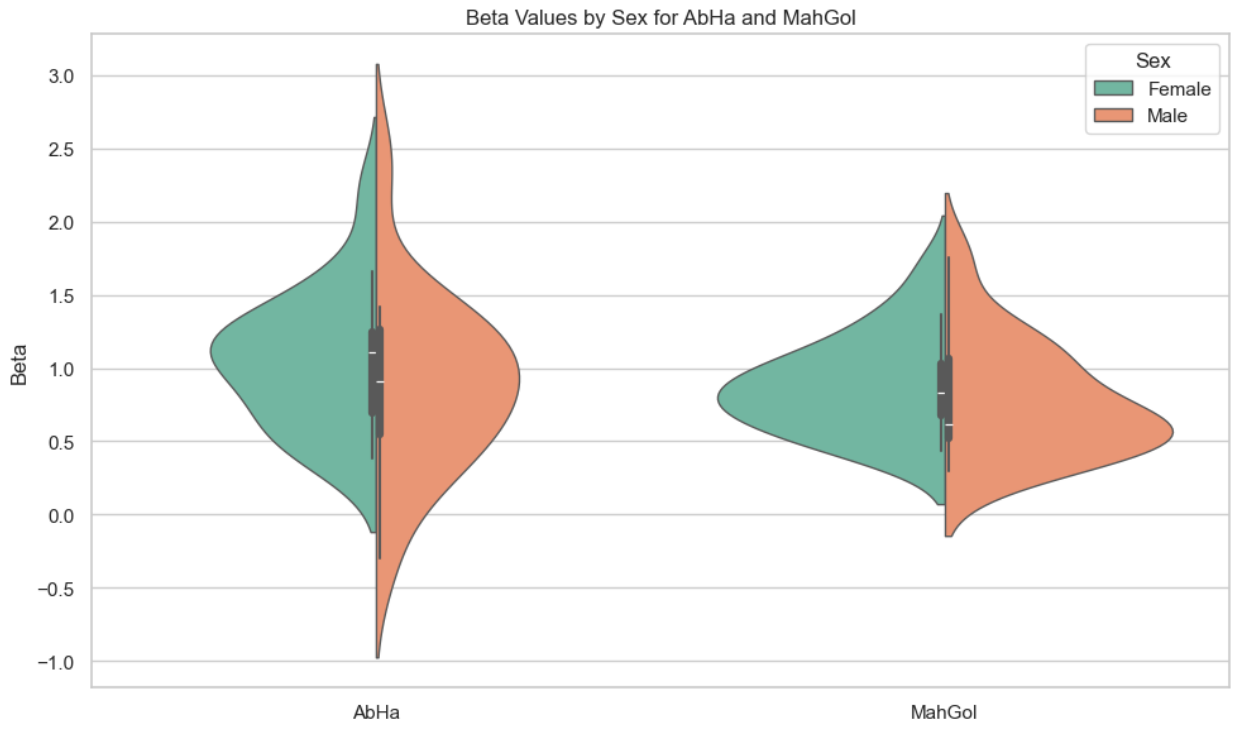

Figure 6: Violin Visualization to see if there is a difference between men and women

Final Conclusion: No difference shown between men and women in this task!

Task 2: Evaluation of Subject Sensitivity using Receptive Operating Curve (ROC)

In this section, we assess subject sensitivity using the Area Under the ROC Curve (AuROC).

The bigger the area under it, the more sensitive the subject is in that feature.

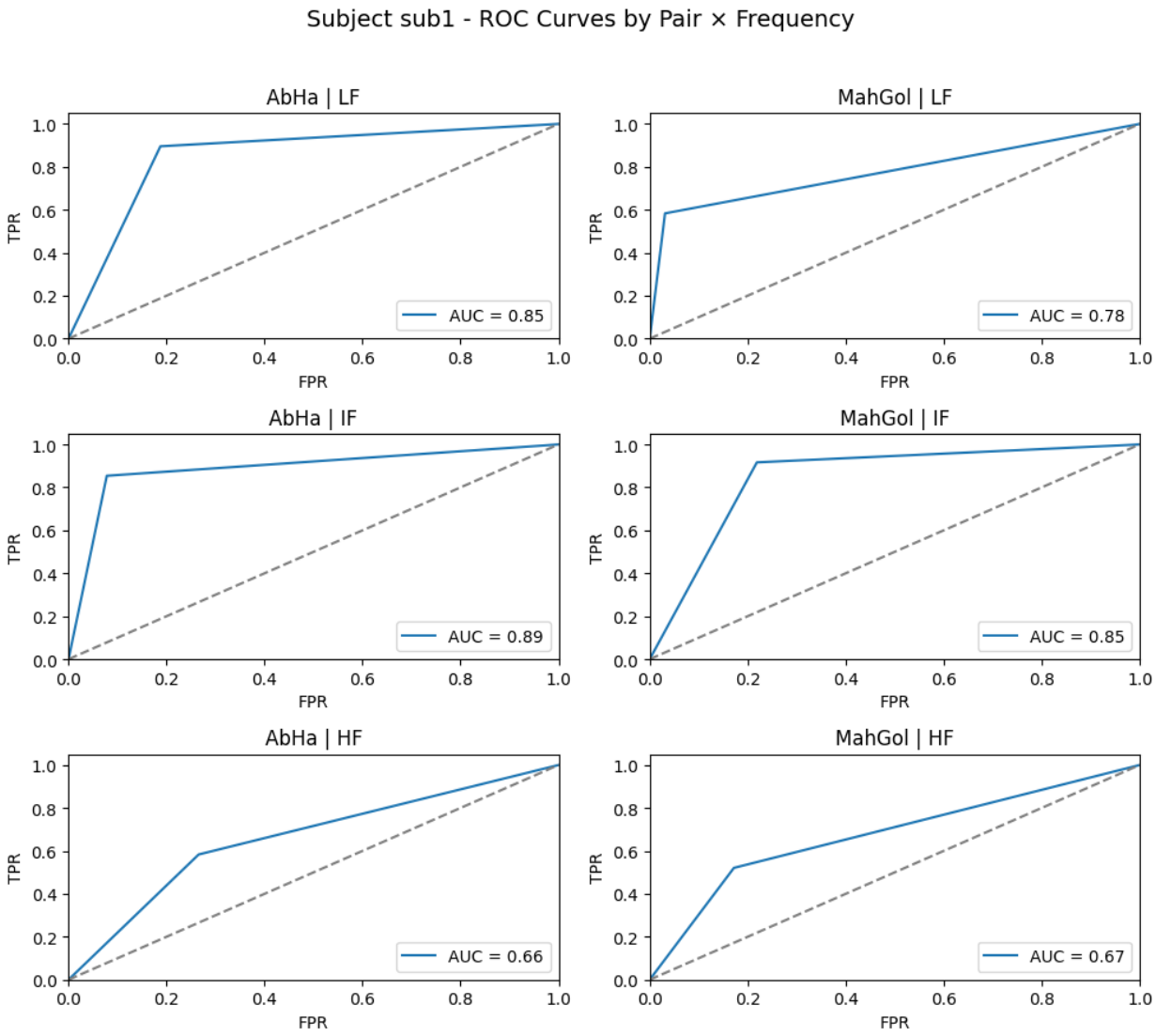

Figure 7: Sample for the ROC curve.

2-1. Overall Procedure

In this section, we assess subject sensitivity using the Area Under the ROC Curve (AuROC). For each subject and morph level, we calculate hit and false alarm rates based on correct and incorrect face selections. Using these, we plot the ROC curve and compute the AUC as a measure of discriminability.

We analyze AbHa and MahGol separately, and partition data based on each hypothesis to compare sensitivity across conditions.

2-2. Hypothesis Testing

Nothing new same as the previous task, even the statistical tests we use are the same, the only thing that has change is our metric, which is now the area under the curve.

2-1-1. Does sensitivity to detecting identity from different spatial frequency bands differs.

The p-values shown in Table 9 just like the sigmoid curve show that there is a difference between the spatial frequencies, but it's more confident in its response due to lower p-value.

Table 9: AUC statistical test for different spatial frequencies

Spectrum	P-Value
Abha	0.0007
Mahgol	0

This is also proven in the visualization in Figure 8, where the medians and distributions differ between the frequencies.

Also, something that was proven in the first task, you can also see it here, the values going from low to intact increases but decrease when you go from intact to high.

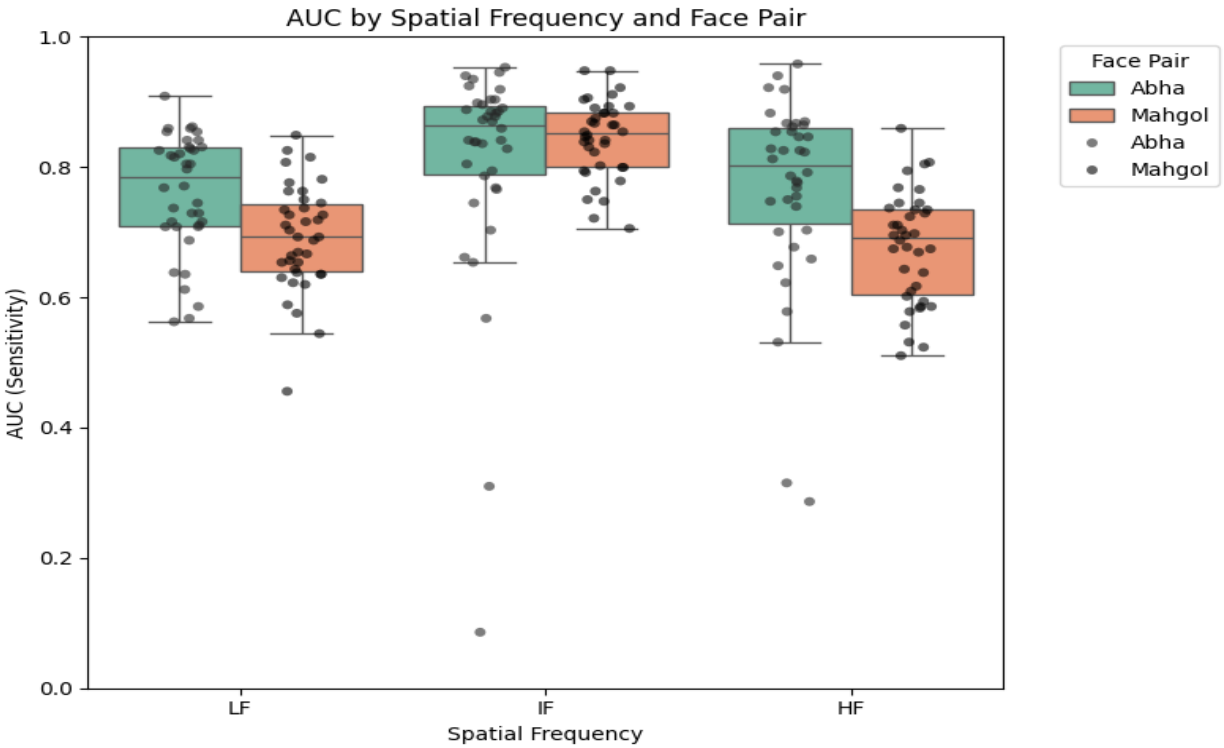

Figure 8: Box plots for different spatial frequencies distributions

Final Conclusion: Same as the first task but with more confidence.

2-1-2. whether people are more adept at identifying images of their conspecific or hetero-specific gender.

As shown in Table 10, there is an unexpected observation, the p-value for the female part is very low so we reject the null hypothesis, so there is a difference for when females are identifying their own gender or the opposite but this is different from the result in the sigmoid curve, which we did not reject the null hypothesis, so which one is true? This is discussed at the end of this task.

Table 10: P-Value for auc for conspecific or hetero-specific genders.

Gender	P-Value
Male	0.15
Female	0.0014

This is Also observable in Figure 9 where there is no pattern in the male section but almost a uniform pattern in the female section showing a difference.

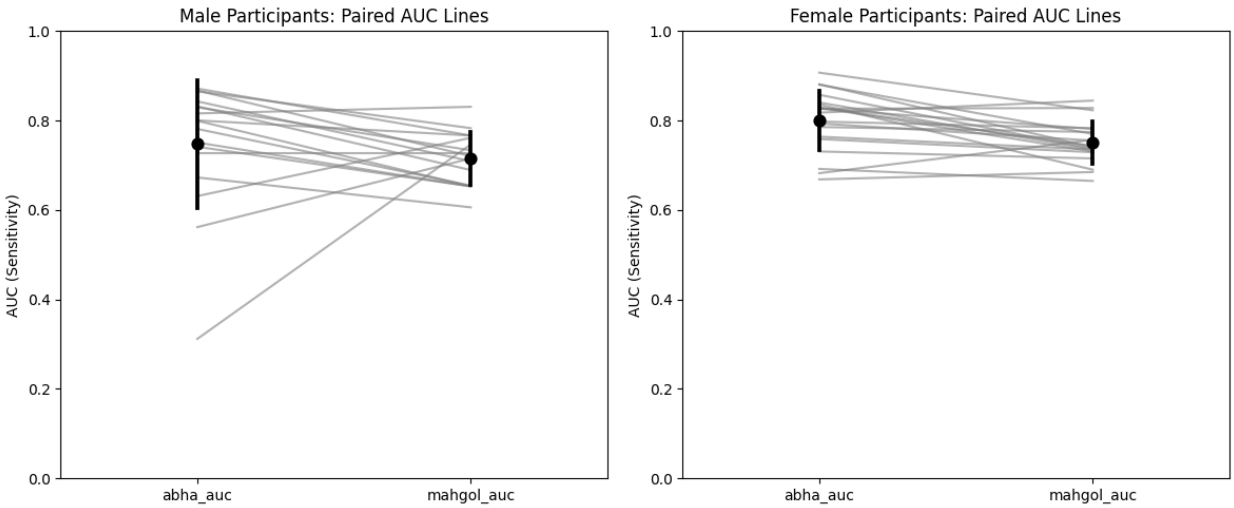

Figure 9: Figure showing difference for same gender or opposite gender recognition

Final Conclusion: It's the same in the male part as before but the auc curve, unlike the sigmoid, shows significant difference for the females.

2-1-3. whether subjects can better detect identities in a specific spectral band if they use their left hand.

As interprotrated in Table 11, shows that there is no significant difference between using right or left hand, same observation we did in the first task.

Table 11: P-value for differenet frequenceis test by measruing the left and right hand.

Frequency and Spectrum	P-Value
Low and AbHa	0.61
Intact and AbHa	0.46
High and AbHa	0.45
Low and MahGol	0.39
Intact and AbHa	0.37
High and AbHa	0.65

This is also shown in Figure 10, as it is obvious the distributions across are similar to each other showing there is no difference between using right or left hand.

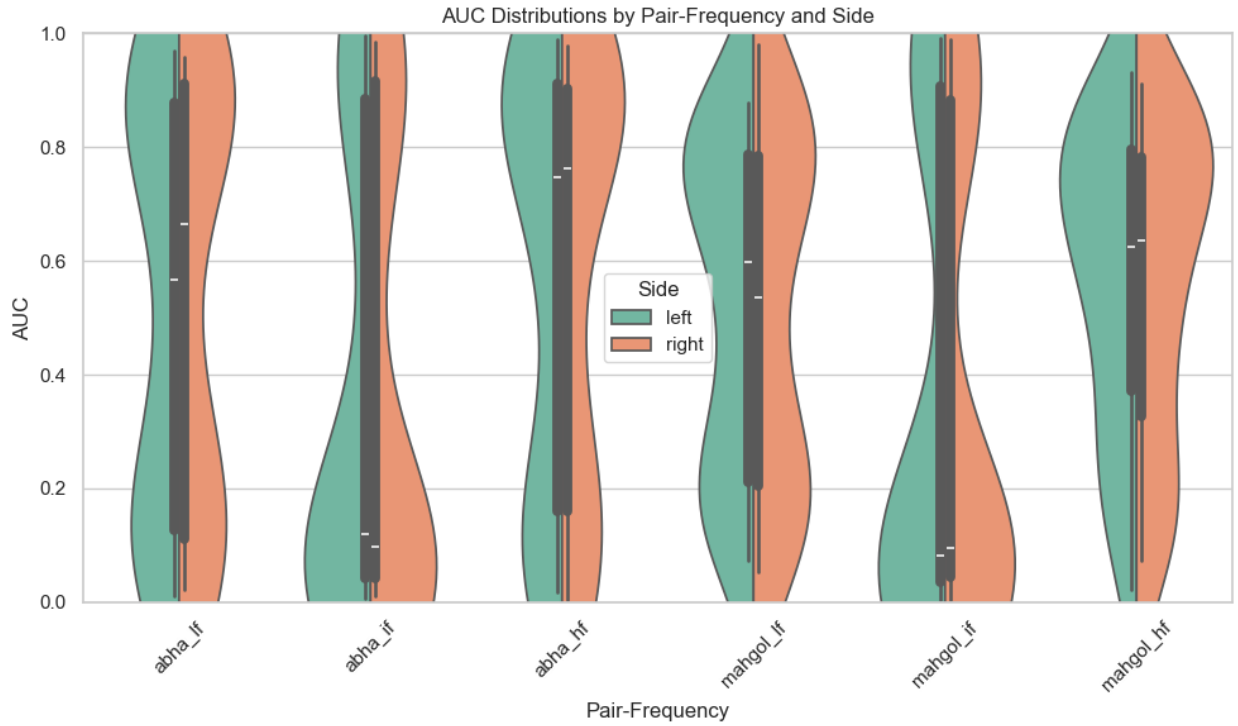

Figure 10: Violin visualization for left and right hand

Final Conclusion: Because all the p-values are above 0.05, we cannot reject the null hypothesis which is that there is no signific difference.

2-1-4. whether subjects can better detect identities in a specific spectral band if they use their dominant hand.

We do the same thing as the previous section but we use the dominated hand as the label except right and left hand, as shown in both Table 12, and Figure 11, all the p-values are above the signific level (0.05) and the distributions are alike.

Table 12: Statistical test analysis for dominated hand or not

Frequency and Spectrum	P-Value
Low and AbHa	0.43
Intact and AbHa	0.40
High and AbHa	0.34

Low and MahGol	0.65
Intact and MahGol	0.56
High and MahGol	0.42

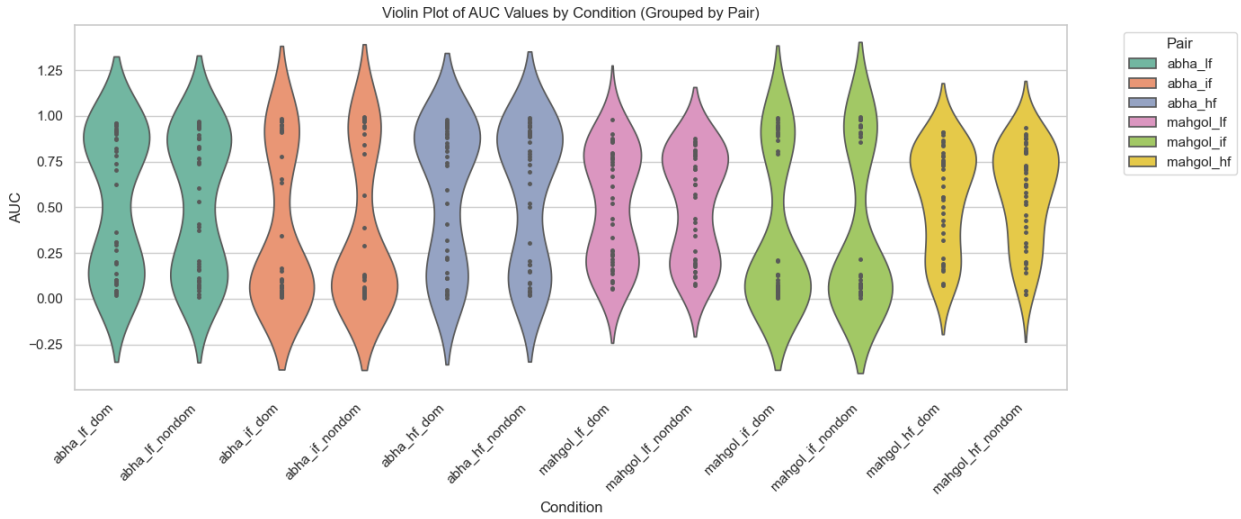

Figure 11: Violin plots for dominated hand or non dominate

Final Conclusion: We cannot reject the null hypothesis so there is no significant difference between using dominated hand or non-dominated hand.

2-1-5. whether women are significantly better than men in the task of identity detection.

And now for the grand finally!

In the previous section (Sigmoid) when we analyzed this part we came to the conclusion that there is no difference, but Table 13, tells another story, a story similar to 2-1-2 where we might reject the null hypothesis because it's really close to the significance level, the auc here shows that there might be a difference for between females and male in identifying the female spectrum. This observation is more backed up by the Figure 12, where it shows difference between the female and male identity ability.

Table 13: Statistics tests to determine the significance difference between male and female

Spectrum	P-Value
AbHa	0.36

MahGol	0.05

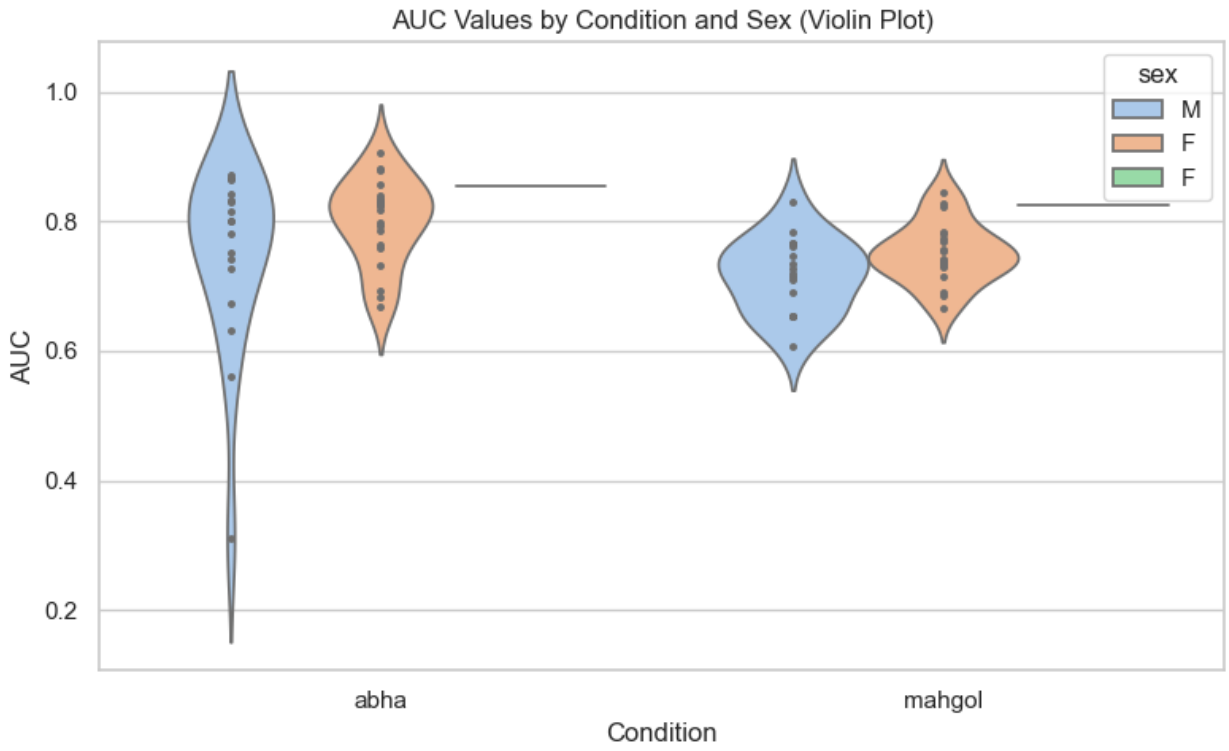

Figure 12: Distribution for the auc for men vs women

FINAL CONCLUSION: threshold-independent measure of a system's ability to discriminate between different stimulus conditions. It summarizes the overall performance across all possible decision thresholds, making it robust to variations in criterion placement and class imbalance. This can be advantageous in situations where the exact threshold is uncertain or when comparing systems with different operating points, and that is why we trust auc more.

Task 3: My Own Hypothesis!

It is expected that participants will perform worse in the mixed blocks compared to the same-frequency blocks when identifying faces. This may be because the mixed blocks require more mental effort participants need to switch between different types of images, which can increase cognitive load**.** As a result, this added difficulty could reduce their ability to accurately recognize facial identities.

The P-values in Table 14, show that there is a significant difference between the two types of blocks, which is strongly supported by the difference in distribution in Figure 13:

Table 14: Test Statistics for Different Block Types

Spectrum	P-value
AbHa	0.005
MahGol	0.003

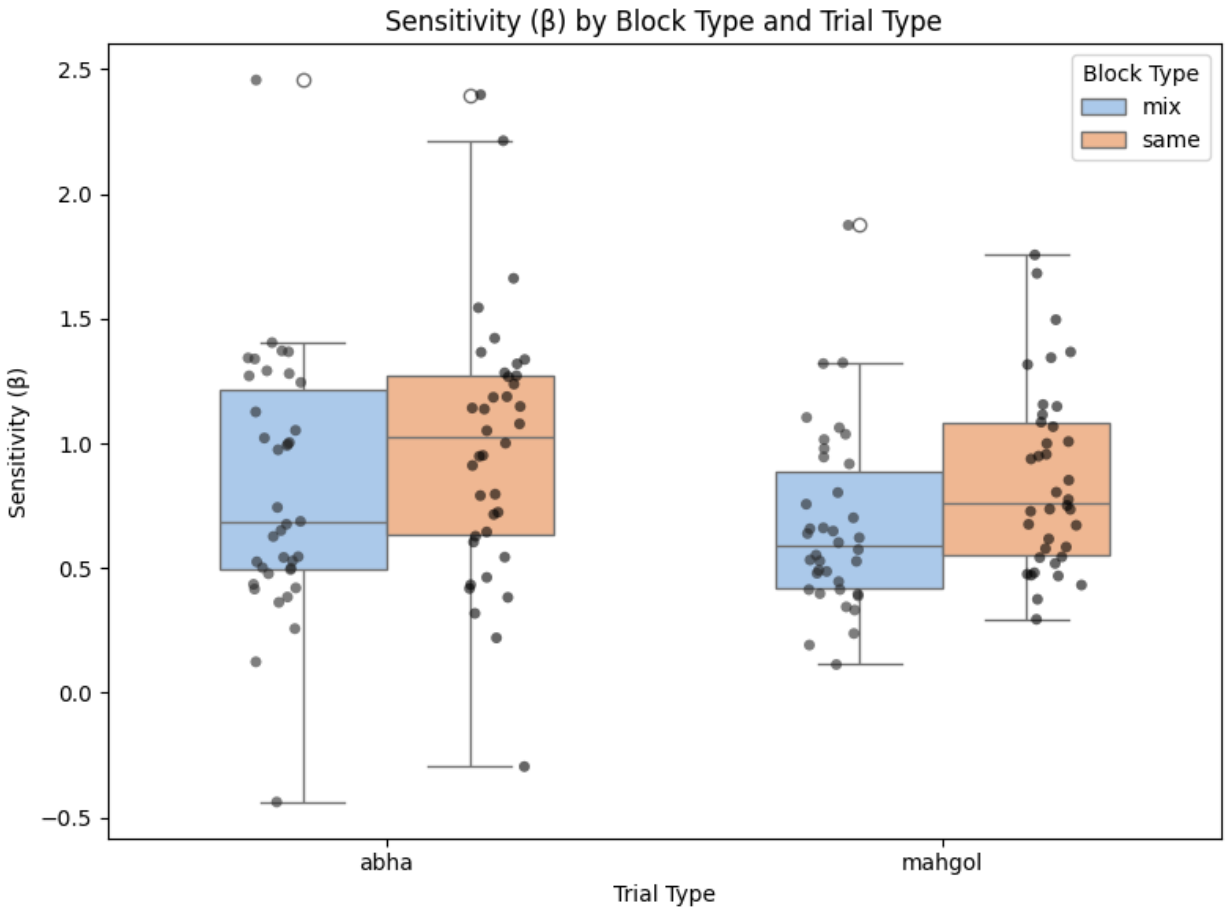

Figure 13: Box plot visualization for block types

We did expect this, and according to Table 15, the median for same is higher, indicating better sensitivity.

Table 15: Median for different block types

Block Type and Spectrum	Median
Same and Abha	1.02
Same and MahGol	0.76
Mix and Abha	0.68
Mix and Mahgol	0.58

But just like the some of the previous questions, there is another story in the auc, as you can see in the mahgol section in Table 16, we cannot reject the null hypothesis, this is also the case in Figure 14, where the abha distributions are not similar but the mahgols are.

Table 16: Auc p-values for different blocks

Spectrum	P-value
AbHa	0.0011
MahGol	0.13

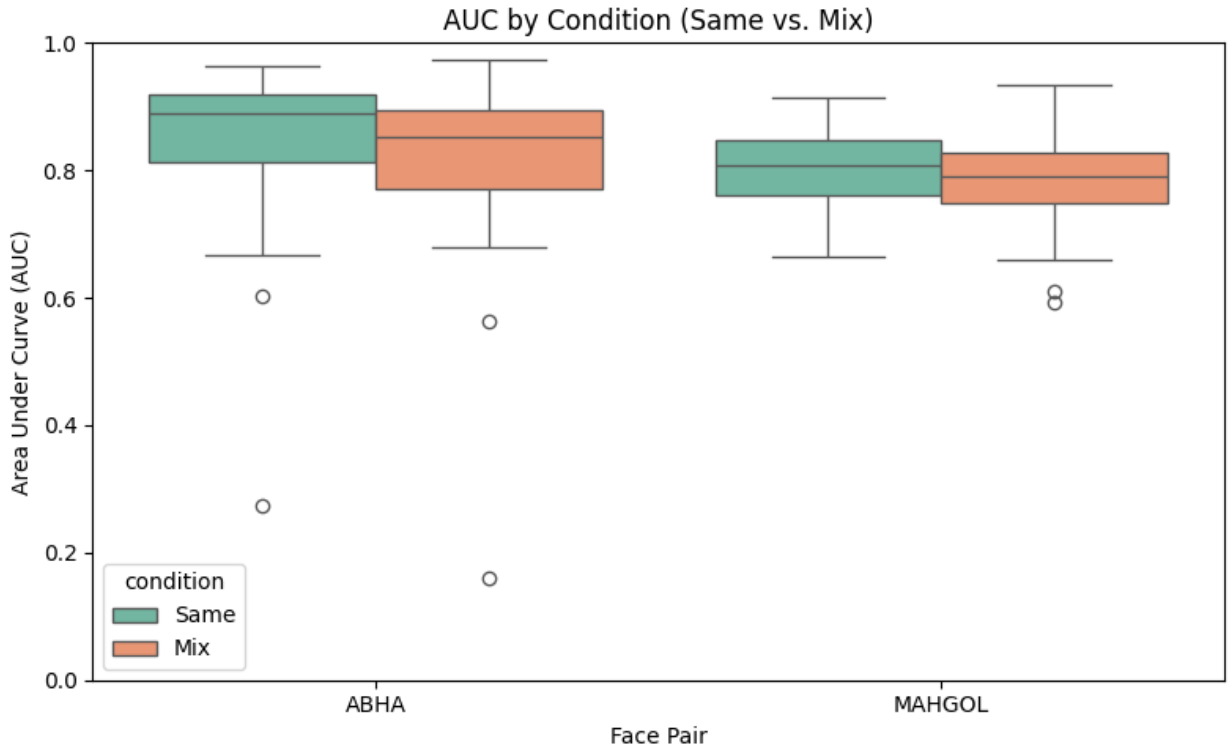

Figure 14: Box plot visualization for the auc's of different blocks

Final Conclusion: as the auc curve is more trustworthy, we say that there is no difference on the mahgol scale but a significant different on the abha scale.