Impact of Demographic Factors on Perception of Tertiary Colors

A two – way ANOVA

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Introduction

- Understanding the factors influencing color perception has been a subject of interest in various studies, with age and sex our primary focus in this report.
- Previous studies suggested that females observe more shades of colors and utilize a greater color spectrum than males.
- Other studies concluded pronounced differences due to varying age.
- In view of these insights, we decided to test for the presence of statistical disparity in color perception across different sexes and age groups by examining differences in the mean number of different tertiary colors correctly reported in a provided painting.

Methodology

- A sample of 120 individuals was gathered, distributed into 4 equal sized groups categorized by age (older/younger) and sex (male/female).
- A summary statistics of the data is provided, and results are interpreted.
- Visualization of data is performed via boxplots and interaction plots.
- Upon inspection of summary statistics, normality and equal variances tests are performed.
- Outlier analysis is performed to identify extreme values in the data.
- Under appropriate conditions established by previous tests, a balanced two – way ANOVA is conducted to explore effects of age and sex on perception of tertiary colors. Results are interpreted accordingly.
- Ad – hoc tests will be employed if the ANOVA provides significant results.
- All tests are subject to a 5% significance level.

Male		*Female*	
Older	*Younger*	*Older*	*Younger*
8	2	4	6
1	7	4	11
1	2	4	11
2	3	5	11
2	3	5	11
2	3	5	11
2	3	5	11
3	4	6	10
3	4	6	10
3	4	6	10
3	4	6	10
3	4	6	9
4	2	7	10
4	5	5	9
4	5	7	9
4	5	7	12
0	5	7	12
4	5	7	12
5	6	8	12
5	6	8	12
5	6	8	13
5	6	8	13
5	6	8	15
6	7	9	13
6	7	9	14
6	7	9	14
6	7	9	17
7	8	10	7
7	8	11	7
6	10	10	7

Summary statistics

Sex	Age	Sample Size	Mean	SE Mean	Standard Deviation	Minimum	Q1	Median	Q3	Maximum	IQR	Skewness	Kurtosis (excess)
Female	Older	30	6.967	0.351	1.921	4.000	5.000	7.000	8.250	11.000	3.250	0.21	-0.78
	Younger	30	10.967	0.451	2.470	6.000	9.750	11.000	12.250	17.000	2.500	0.09	0.33
Male	Older	30	4.067	0.362	1.982	0.000	2.750	4.000	6.000	8.000	3.250	-0.07	-0.61
	Younger	30	5.133	0.364	1.995	2.000	3.750	5.000	7.000	11.000	3.250	0.28	-0.29

Key Insights

Data Symmetry and possible Normality

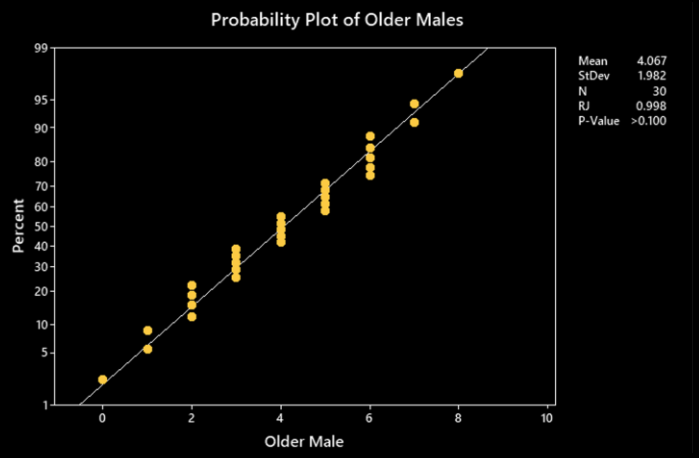
- Mean and Median are nearly equal per group.
- Skewness and (excess) Kurtosis are close to zero per group, suggesting symmetry and almost normal tails, respectively.

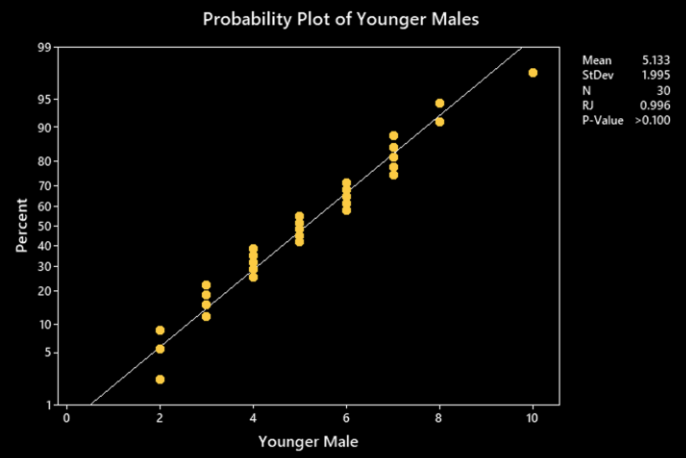
Differences in Sex alter the effects of Age

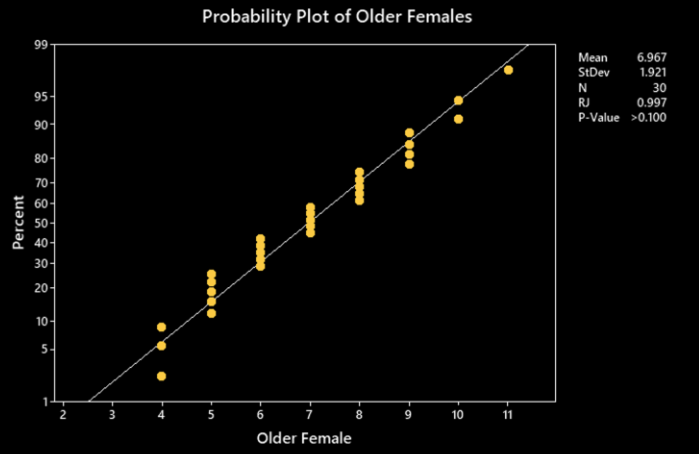
- For younger individuals, mean differences between sexes is nearly twice that of older individuals.
- For females, mean differences between age groups is nearly four times that of males.

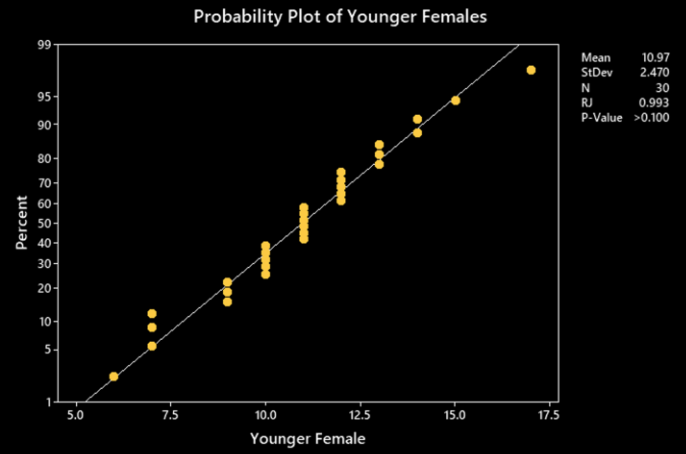
Consistent Variability among all Groups

- All groups have nearly the same standard deviation.
- All groups have nearly the same interquartile range (IQR).





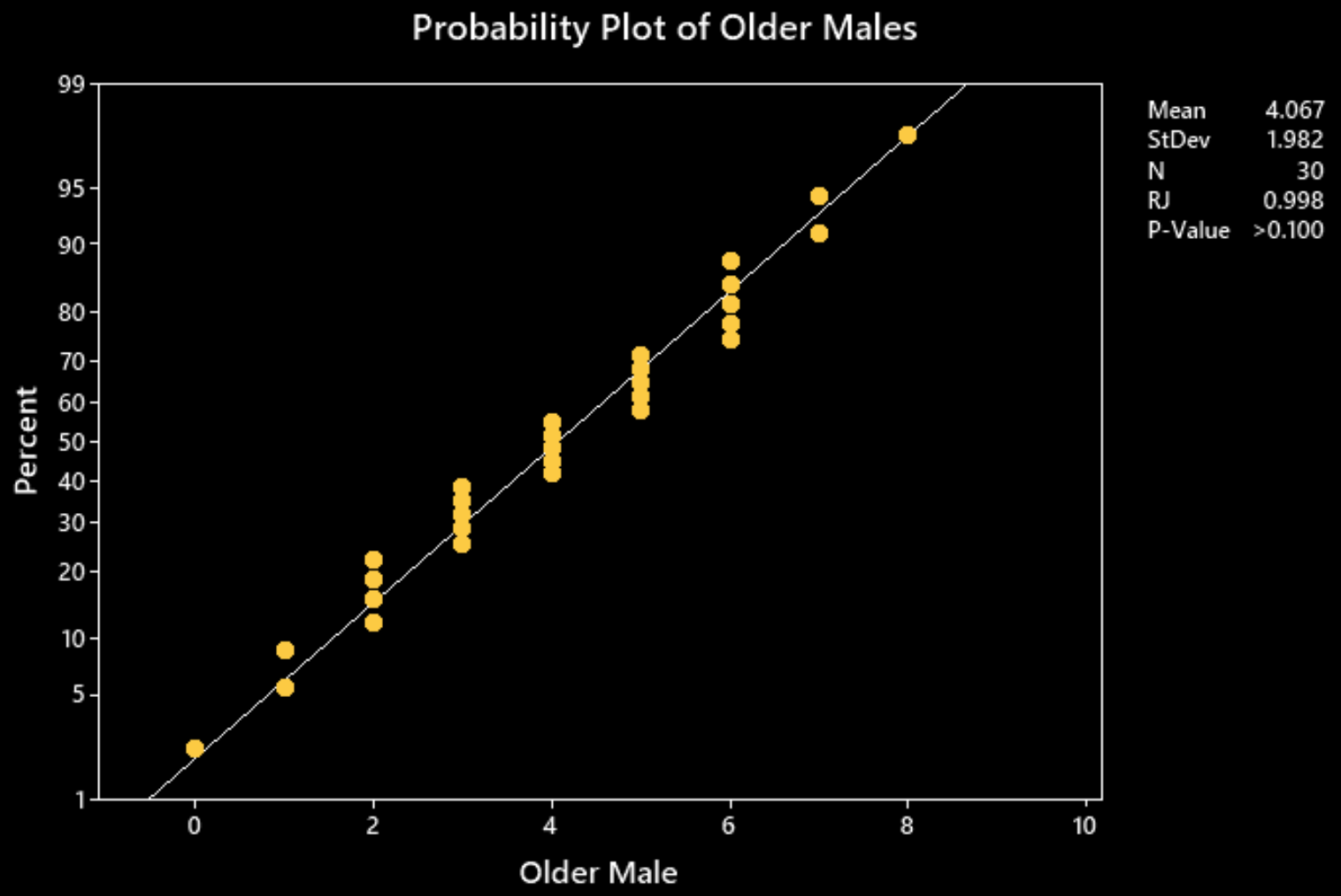




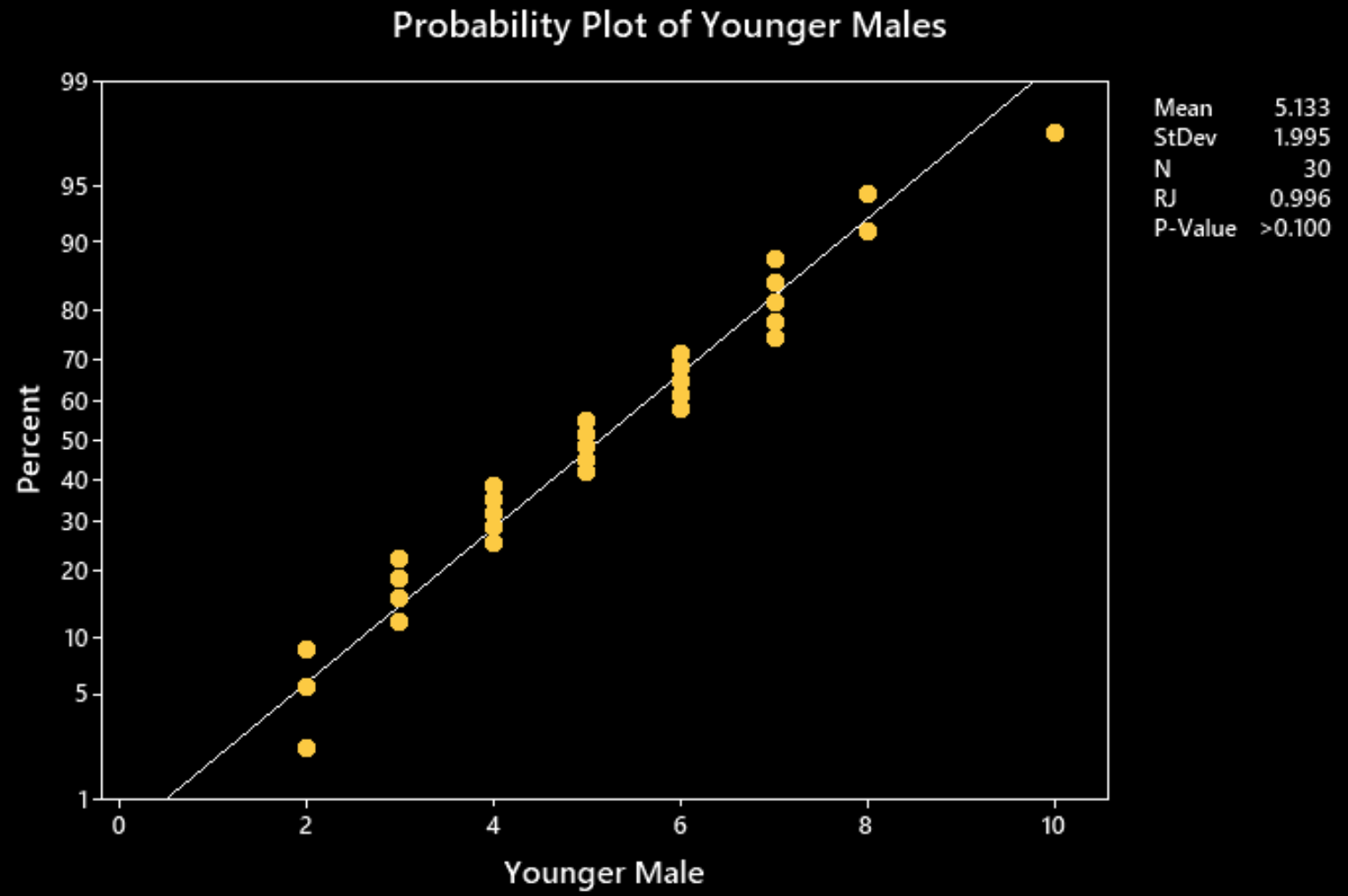
Normality Test

- Motivated by observations of summary statistics and wanting to perform a valid ANOVA, a normality test is carried.
- A Ryan – Joiner test was applied to test the normality of every group.
- Results are shown in four different panels accompanied by probability plots per group.
- Test results are concluded via p – value comparisons.

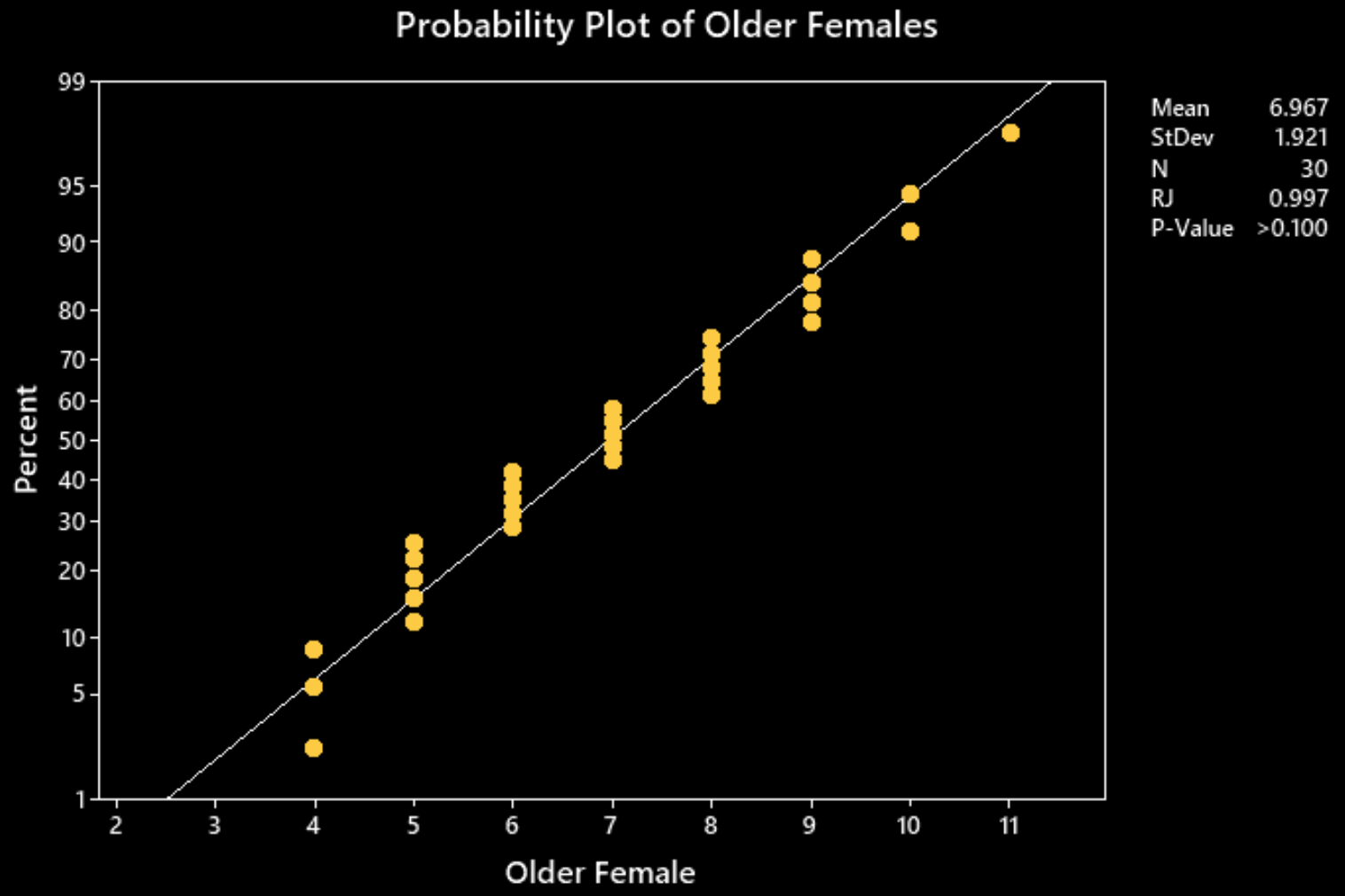
Results: p – values > 0.1 indicating ***no statistical evidence*** against normality, aligning with our observations.



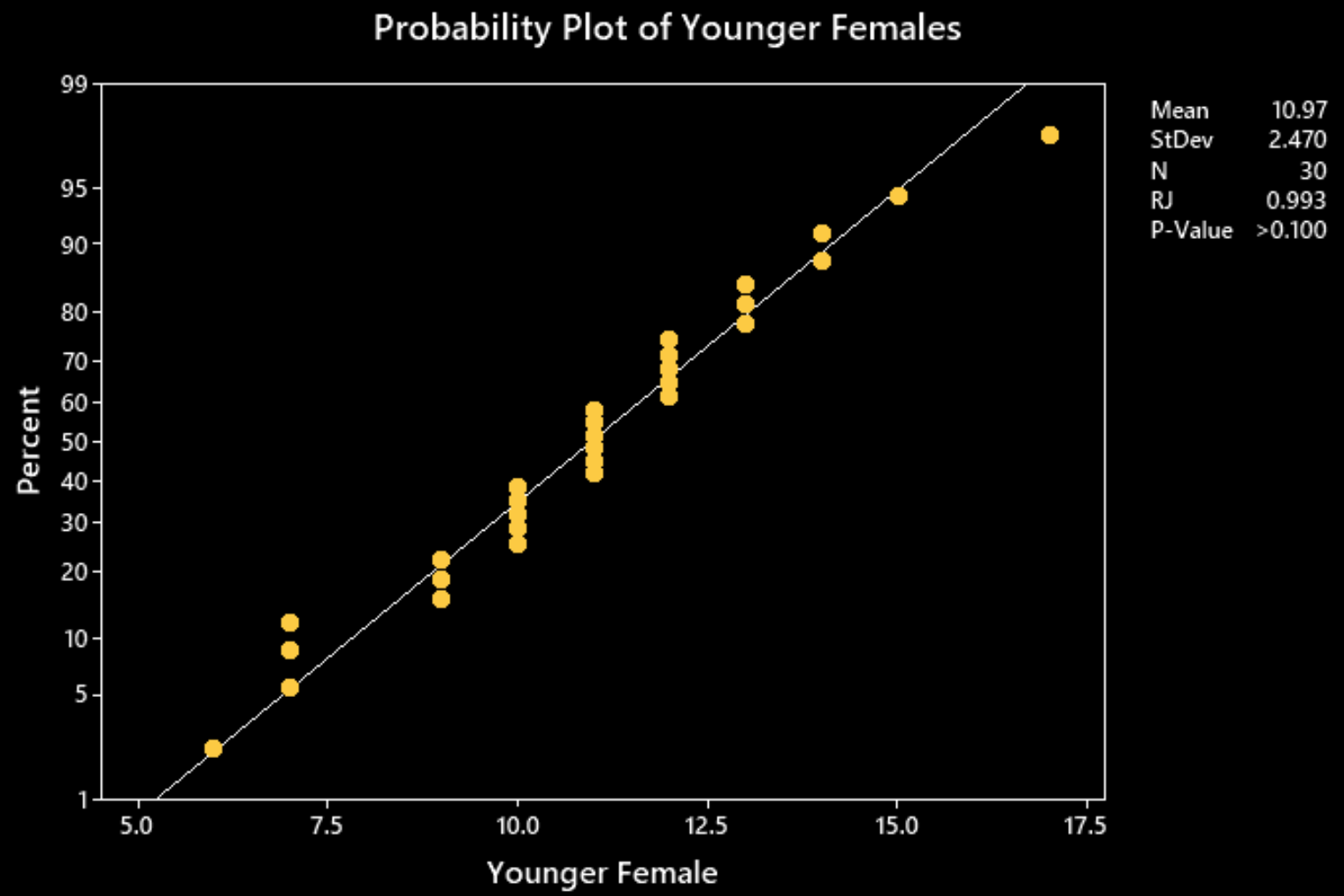
Normality Test (*Older Males*)



Normality Test (*Younger Males*)



Normality Test (*Older Females*)



Normality Test (*Younger Females*)

Equal Variances Test

- Multiple Comparisons and Levene tests were carried
- Results are shown on the right, accompanied by a 95% Bonferroni Confidence Intervals plot of standard deviations
- Test results are concluded via p – value comparisons.

Results: p – values for both tests exceed the significance level, indicating ***no statistical evidence*** against equality of variances, aligning our observations.

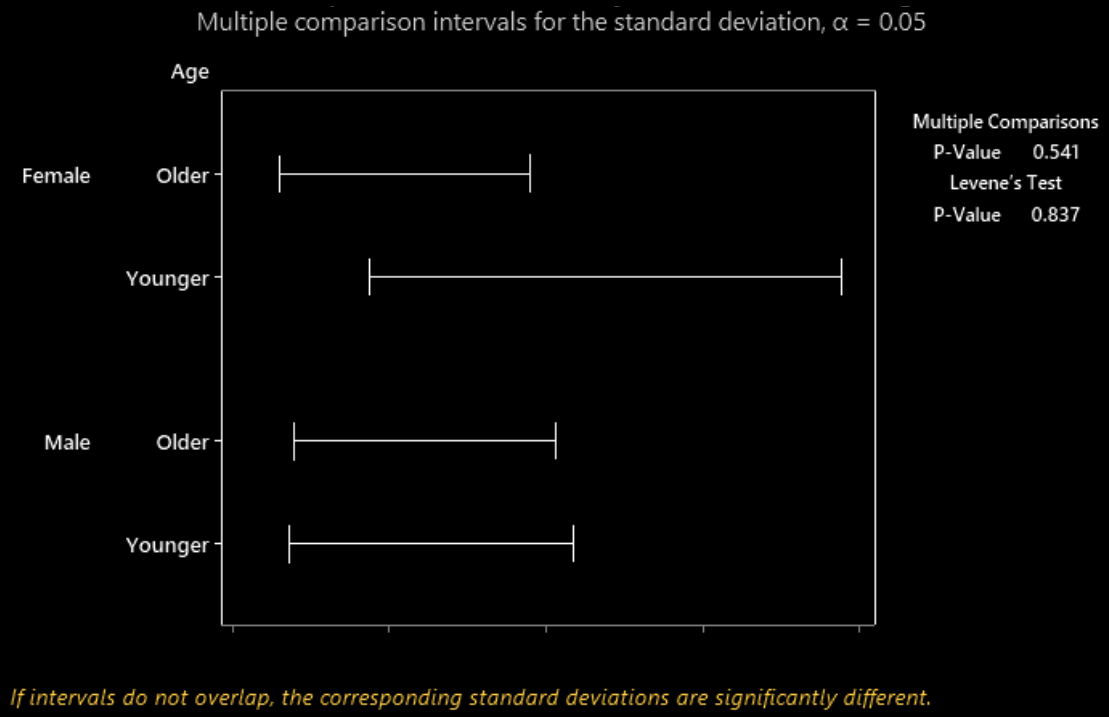
Sex	Age	StDev	CI
Female	Older	1.92055	(1.50769, 2.66864)
Female	Younger	2.47028	(1.77547, 3.74915)
Male	Older	1.98152	(1.53496, 2.79031)
Male	Younger	1.99540	(1.49913, 2.89715)

Method

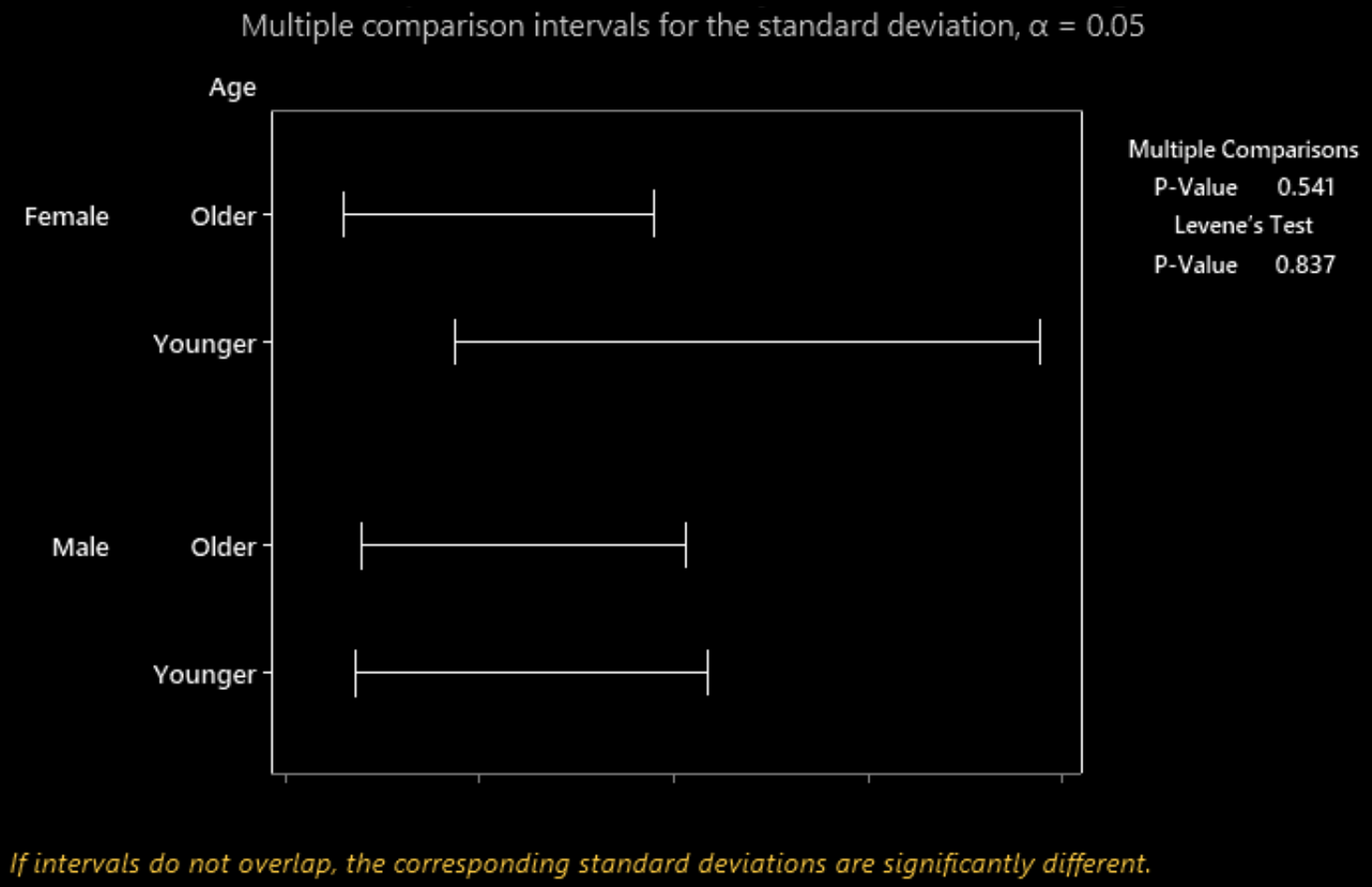
Null Hypothesis	**All variances are equal**
Alternative Hypothesis	**At least one variance is different**

Tests

Method	Test statistic	p – value
Multiple Comparisons	**___**	**0.541**
Levene	**0.28**	**0.837**



Bonferroni Confidence Intervals plot of StDevs



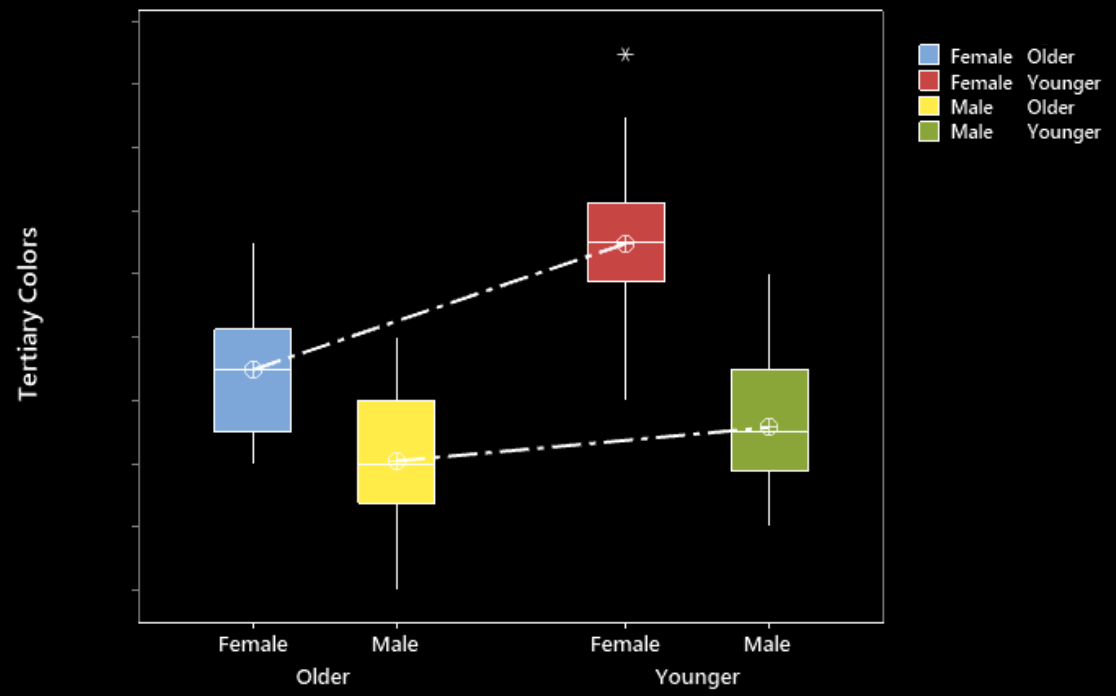
If intervals do not overlap, the corresponding standard deviations are significantly different.

Exploring Sex – Age Interaction and Outlier Analysis

From our boxplot, we observe:

- Younger people reported more tertiary colors than older people in both sexes.
- Females reported more tertiary colors than males in both age groups.
- Unparallel mean connecting lines suggests the possible presence of an interaction between the factors (difference between males and females in younger people differs from that of older people).
- The maximum value in the younger females' group may be an outlier. Under the normality assumption, we use Grubb's test and Dixon's Q test to check whether this maximum is an outlier.

Results: p – values for both tests exceed the significance level, indicating *no statistical evidence* that the maximum is an outlier. We will adopt this result in our analysis.



Method

Null Hypothesis	**No outliers are present**
Alternative Hypothesis	**The maximum value is an outlier**

Tests

Method	**p – value**
Grubb's	**0.154**
Dixon's Q	**0.160**

Balanced Two – Way ANOVA

Under the normality, equal variances and no – outlier assumptions, we perform a Balanced Two – Way ANOVA. Results are shown below.

Analysis of Variance

Source	DF	SS	MS	F	p
Gender	1	572.033	572.033	129.28	< 0.001
Age	1	192.53	192.533	43.51	< 0.001
Interaction	1	64.53	64.533	14.58	< 0.001
Error	116	513.27	4.425		
Total	119	1342.37			

Model Summary

S	R^2	R^2 (Adj)
2.10350	61.76%	60.78%

The F – statistic of the model is given by:

$$F_{model} = \frac{\left(\frac{SS_{Total}}{DF_G + DF_A + DF_{G*A}}\right)}{MSE} \approx 62.46$$

The model critical F – value is 2.683.

RESULTS:

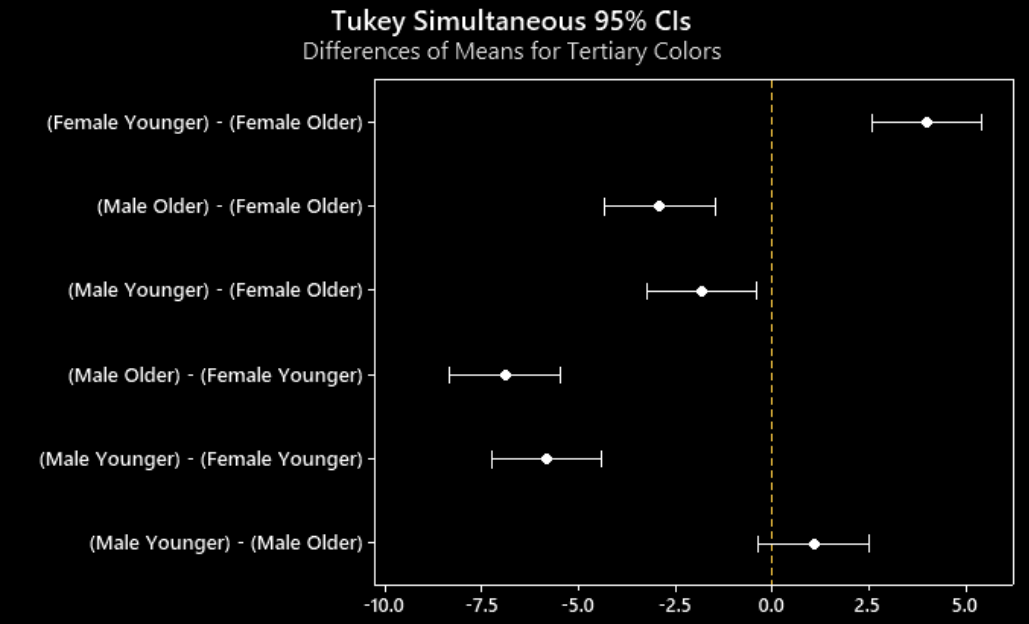
- $F_{model} > F_{\alpha,3,116}$ so our model is significant (valid statistical evidence that mean differences are well assessed).
- Main effects and interaction are significant (p – values < 0.001).
- $R^2 = 61.76\%$ indicating more than 50% of the groups' variability is explained by our model.
- High significance in interaction level implies that each factor influences the effect of the other.

Tukey Pairwise Comparison Test

- Since the interaction is significant, we perform a Tukey Pairwise Comparison Test on the interaction to see which factor pairs contribute significantly to the observed interaction.
- Results: all group differences are ***significant*** except for the mean difference between younger and older males (all p – values are less than the significance level except the younger and older males p – value).

Tukey Simultaneous Tests for Differences of Means

	Differences of Means	SE of Difference	Simultaneous 95% CI	Adjusted P – Value
(F – Y) – (F – O)	4.000	0.543	(2.583, 5.417)	< 0.001
(M – O) – (F – O)	-2.900	0.543	(-4.317, -1.483)	< 0.001
(M – Y) – (F – O)	-1.833	0.543	(-3.250, -0.416)	0.005
(M – O) – (F – Y)	-6.900	0.543	(-8.317, -5.483)	< 0.001
(M – Y) – (F – Y)	-5.833	0.543	(-7.250, -4.416)	< 0.001
(M – Y) – (M – O)	1.067	0.543	(-0.350, 2.484)	0.208



If an interval does not contain zero, the corresponding means are significantly different.

Conclusion

Our findings align with previous studies:

- Sex and Age impact the number of perceived tertiary colors by individuals.
- For each age group, females tend to perceive more tertiary colors than males.
- For each sex group, younger individuals perceive more tertiary colors than older individuals.
- Sex alters the effect age has on an individual’s ability to perceive tertiary colors (and vice versa).
- Sex effects are more pronounced in younger individuals than older individuals.
- Effect of age is significant in females, whereas males show no significant difference.