A Comparative Analysis for Eye Movements of Ethical Groups based on Data Science Techniques

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Abstract

Studies on eye movements experimentations for discrete ethical groups can clarify and reveal a number of perspectives regarding human cognition as well as human interaction that comes from these ethical groups. In this eye movements study, we analyzed comparatively the data collected from eye movements experiments of participants who belonged to different ethical groups. Further, we tested the collected eye movements data and confirmed our hypothesis that the eye movements of individuals related to dissimilar ethical groups were of different nature quantitatively as well. The observed facts and analyzed data established the validity of hypothesis significantly by the precise techniques of data science.

Keywords: *Eye movements, Data science, Cognition, Visual perception*

1. Introduction and background

Research studies on eye movements have turned towards diverse paths and prospects in this day and age, so are the modern sophisticated tools and techniques for better comprehension of underlying mechanism of visual perception and the dynamics of human cognition. The trends of novel practices and handlings are applied and established for endeavoring undiscovered challenges in eye movements researches. Recently, eye tracking inventions and advanced researches are highly dependent on the latest means, measures, and procedures of statistics, data science, and machine learning to enhance the precision and efficiency of outcomes quantitatively [1-8].

Human eye is an index of mind that gets visual perception by cognitive data processing through underlying mechanism within the brain. Being one of the senses in human, the eyes can visually see the objects and perceive visual contexts and assist in human visualization as well. Human eyes shift their gazes and visual focus moves for intended specific purposes to retrieve information. The fixations and saccades are two basic activities within every eye movements. The tendency for information seeking and gaining visual attention and visual perception are the processes that are continuously dominating along with other coexisting cognitive processes. The movements of eyes are recorded by eye tracking system. Such tracked movements of eyes give important insights about the triggering and underlying processes that get involved during scene viewing [9-21].

Cited literature studies on eye movements of people from different cultural, social, geographical, and ethnic origins have revealed a number of significant factors. It turned out that there were plenty of differences in their eye movements. Further, the studies based on these groups were based on a number of other perspectives except ethical disciplines and practices of these groups [22-28].

However, Ethical manners, work cultures, behaviors, and attitudes of people heavily rely on the people's mindsets, beliefs, social customs, traditions, rituals, habits, social and moral societies, environmental backgrounds, civilizations. This is why the current research is significant in finding the key differences, if there exist, in the eye movements of these groups of different ethical origins. In addition, the eye movements reflect the attitudes and behaviors of these people, and in turn, their ethical characteristics. Moreover, the methodologies and computational procedures were in need of more precise and accurate scientific computations based on sophisticated tools and techniques of data science.

Exploration of data from a number of perspectives can enlighten human cognition and human interaction. In the current study context, the main purpose is to put forward the facts and figures for our proposed hypothesis along with bringing about the potentiality of data insights through Data Science tools and techniques. By employing Data science tools and techniques, we initiate and

process the eye movements data for understanding different perspectives of eye movements. The quantitative measurements with precise values and procedures to compute these values are competent and supportive in understanding the dynamics of human cognition during visual perception with a high level of confidence and consistency [1-8] [29-35].

2. Present study plan

In this research study, we propose a hypothesis based on 2 major groups that are related to different ethical perspectives. The first major group (Group1) belongs to the people who have similar ethical origins, like mindsets, work cultures, manners, attitudes, behaviors, despite their different geographical locations and countries (Mostly from South Asia, South East Asia, Central Asia). The second major group (Group2) belongs to the people who have ethical similarities of different kind like, manners, mindsets, work cultures, traditions, habits, behaviors, and attitudes despite different geographical locations and countries (Mostly from Middle East Asia, North Africa).

For the proposed hypothesis testing, we initiate with our null hypothesis by assuming that the means for both ethical groups as equal. Therefore, the difference for the means of both ethical groups should be zero. This means, there is no difference in the characteristics of both groups in the contexts of visual perception and the both groups are equivalent as per the statistical consideration. Further, this indicates that there is no dependency on eye movements of both ethical groups respectively and no difference in the eye movements of both ethical groups. The Greek symbol μ indicates the mean of respective samples (of Group1 and Group2).

$$H_0 : \mu_{Group1} = \mu_{Group2}$$
$$H_0 : \mu_{Group1} - \mu_{Group2} = 0$$

On the contrary of our null hypothesis, we put our proposed hypothesis that there is significant difference in the means of both ethical groups. The difference in the means of both ethical groups is our nonzero quantity or value. Further, the difference in the means of both ethical groups indicates that the eye movements of these ethical groups are not the same and have no similar characteristics in terms of visual perception.

$$H_1 : \mu_{Group1} - \mu_{Group2} \neq 0$$

At first, we investigate the eye movements data collected from participants' eye movements of these major groups. The data is analyzed quantitatively using the data science tools and techniques. The data analysis based on descriptive and comparative approaches that are engaged on the eye movements data can illustrate and elucidate the characteristics and relationships among various variables of eye movements data and their interdependencies for these groups and test the proposed hypothesis.

With the tools and techniques of data science, like R programming, RStudio, we begin with descriptive analysis of both datasets related to ethical groups. Later, we start the testing of proposed hypothesis by taking into account various variables of eye movements data. These measurements are essential part of this research work. By analyzing the data, we can explore the data insights that are significant for establishing the inherent mechanism of cognitive processes and the dynamics of visual perception for both ethical groups. Therefore, the hypothesis testing outcomes decide the dependencies of processes associated with visual attention and visual perception, in terms of eye movements [36-44].

A normality check (normal distribution) of datasets for both ethical groups is a mandatory condition before proceeding to comparative analysis and hypothesis testing because hypothesis testing can be carried out on normally distributed datasets. Additionally, the comparative analysis can predict a number of data insights statistically that are interpreted and elaborated in accordance with the underlying mechanism and processes of visual attention and visual perception. The analyzed outcomes and existing relationships among the variables in terms of numeric quantities

and statistical indicators are resilient facts that reflect the undergoing phenomena of human cognition and visual perceptions. By mentioning these values and interpreting their meanings through data interpretations, we can establish a consolidated pitch for our research findings.

The schematic diagram of eye movements system and present research study plan as processes that are involved during eye movements experimentation, are represented in Figure 1.

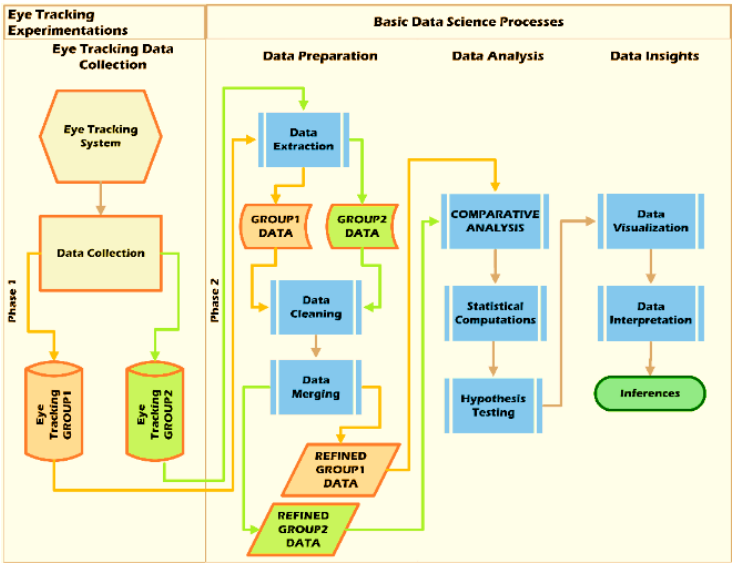

Figure 1. Present research study processes.

3. Experimental setup and procedure

At first, we selected an artistic scenery, Green Hills, for our experimentation. The reason to choose this artistic scenery was having numerous cognitively built in human emotions and feelings that were our utmost agenda to trace or record these cognitively generated human activities during eye movements of the Subjects, i.e. participants.

The experimental setup consisted of eye movements system that was used for recording of eye movements. In eye movements system, the system illuminated infrared light for movements the eye movements. The camera, connected to the system, captured the location of viewer's eyes in terms of movements during experimentation time. As the viewer moved his/her eyes to look a new location of the scene, the camera recorded new movements also. This process of recording continued subsequently. The system-generated eye movements trails and heat maps using the captured data that was utilized for further analysis.

The schematic diagram of eye movements system and basic processes involved during eye movements experimentation was represented in Figure 2.

Figure 2. Operational processes of eye movements system.

In our experiments, we studied track of eye movements as the sequenced gazing of viewer's eye movements, which was generated by the system, during scene viewing. These were the dynamic shifts of eye gaze in scene viewing. By these eye fixations, movements pattern was generated by eye movements system that records the human eye movements.

4. Method and data collection

We selected 40 participants (20 for each ethical group) from a number of fields randomly, aging from 19 years to 45 years. Further, we assigned these participants (Subjects) to view selected famous artistic scenery (Object).

Their eye movements were closely monitored as they viewed 32 bits full-color artistic scenes. The Objects, the scenes were displayed on a computer monitor. We have shown the scenery at a resolution of 1280 × 1024 pixels and subtended 15 degree horizontally by 10 degree vertically at a viewing distance of 75 centimeter. Eye position was sampled from an Eye Tech Digital Systems TM3 16 mm Eye Tracker, and movements data was parsed into sequenced gazing with circles of concentration.

The Subjects' heads were held steady in advance prior to experimentation. Prior to the first trial, Subjects completed a procedure to calibrate the output of the eye tracker against spatial positions on the display screen. This procedure was repeated regularly throughout the experiment to maintain high level of accuracy. Subjects were initiated to view the scenes freely.

The scenery was presented to the Subjects in very comfortable mode. During the time span, the Subjects viewed the scenes with their normal eyes and focused attention on the Object, i.e. the scenery.

After the phase of data collection for both ethical groups' participants, we started the process of data preparation that involved tediously longest phase of this study. This process of data preparation consisted of data extraction, data cleansing, and data merging. At first, the data was extracted and transferred from the various sources of the eye movements system. Next, a mapped transformation of data was loaded by the data analysis system. In our case, we utilized the data analysis system equipped with R environment. In the next step, the eye movements data were cleaned for all kinds of ambiguity, defect, and inconsistency by using a set of approaches to refine and tidy the eye movements data. Finally, the data were combined and merged as a complete set of all samples to go ahead for data analysis phase for both ethical groups.

5. Data analysis and data interpretation

During this phase of analysis, we analyzed statistically the eye movements data for estimation and evaluation of existing variables of the data population in terms of numerous data samples of both ethical groups. Later, we proceeded through the process of hypothesis testing.

Although we conducted and carried out a number of statistical analysis for this eye movements data, yet we presented those results that seemed to be appealing for conclusive remarks and did viable evidences within our statistical population.

We computed and analyzed all of our data generated by eye movements system using R statistical programming and RStudio environment for both ethical groups [36-44].

We started with the computation of the statistical summary of the collected eye movements data that turned out to be as shown in Table 1 and Table 2 for both ethical groups respectively.

The variables of eye movements data intended such as,

1. the eye tracking time in millisecond (Time[msec]),
2. ticking time during eye movements (Time[Ticks]),
3. gaze X and Y coordinates (GazeX, GazeY),
4. the diameter of eye movements focused circle(Diameter),
5. the left and right calibrations of the eye movements device in terms of left and right eyes
6. (LCalib, RCalib)
7. the left and right cross-sectional positions in terms of left and right eyes (LFound, RFound)

8. the left eye's X coordinate, Y coordinate, and diameter of focused circle (LX, LY, LD)
9. the right eye's X coordinate, Y coordinate, and diameter of focused circle (RX, RY, RD)
10. the positional accuracy of eye gaze in terms of logical; FALSE or TRUE (Lost), can be considered as categorical variable

Table 1. The statistical summary of the collected eye movements data for Group1

Time[msec]	Time[Ticks]	GazeX	GazeY	Diameter
Min. : 15.62	Min. :6.342e+17	Min. : 0.0	Min. : 3.0	Min. :1.600
1st Qu.: 6796.88	1st Qu.:6.342e+17	1st Qu.: 380.0	1st Qu.:477.0	1st Qu.:2.500
Median : 14187.50	Median :6.343e+17	Median : 665.0	Median :579.0	Median :2.800
Mean : 23626.50	Mean :6.342e+17	Mean : 653.1	Mean :589.4	Mean :2.738
3rd Qu.: 29863.28	3rd Qu.:6.343e+17	3rd Qu.: 894.0	3rd Qu.:691.0	3rd Qu.:2.800
Max. :101390.62	Max. :6.343e+17	Max. :1279.0	Max. :959.0	Max. :4.000

LCalib	LFound	LX	LY	LD	RCalib
Min. :1	Min. :1	Min. : -24.0	Min. : -14.0	Min. :1.600	Min. :1
1st Qu.:1	1st Qu.:1	1st Qu.: 381.0	1st Qu.: 471.0	1st Qu.:2.800	1st Qu.:1
Median :1	Median :1	Median : 667.0	Median : 577.0	Median :2.800	Median :1
Mean :1	Mean :1	Mean : 656.2	Mean : 596.1	Mean :2.692	Mean :1
3rd Qu.:1	3rd Qu.:1	3rd Qu.: 893.0	3rd Qu.: 687.0	3rd Qu.:2.800	3rd Qu.:1
Max. :1	Max. :1	Max. :1716.0	Max. :2272.0	Max. :4.000	Max. :1

RFound	RX	RY	RD	Lost
Min. :1	Min. : 13.0	Min. : 21.0	Min. :1.600	Mode :logical
1st Qu.:1	1st Qu.: 379.0	1st Qu.: 475.0	1st Qu.:2.800	FALSE:14380
Median :1	Median : 664.0	Median : 584.0	Median :2.800	
Mean :1	Mean : 650.9	Mean : 600.7	Mean :2.784	
3rd Qu.:1	3rd Qu.: 895.0	3rd Qu.: 692.0	3rd Qu.:2.800	
Max. :1	Max. :1603.0	Max. :2685.0	Max. :4.000	

Table 2. The statistical summary of the collected eye movements data for Group2

Time[msec]	Time[Ticks]	GazeX	GazeY	Diameter
Min. : 15.62	Min. :6.343e+17	Min. : 0.0	Min. :156.0	Min. :1.900
1st Qu.: 4195.31	1st Qu.:6.343e+17	1st Qu.: 290.0	1st Qu.:433.0	1st Qu.:2.200
Median : 8890.62	Median :6.343e+17	Median : 529.0	Median :522.0	Median :2.800
Mean : 9958.36	Mean :6.343e+17	Mean : 583.6	Mean :526.7	Mean :2.861
3rd Qu.:14523.44	3rd Qu.:6.343e+17	3rd Qu.: 851.0	3rd Qu.:633.0	3rd Qu.:3.100
Max. :27984.38	Max. :6.343e+17	Max. :1279.0	Max. :959.0	Max. :4.900

LCalib	LFound	LX	LY	LD	RCalib
Min. :1	Min. :1	Min. :-336.0	Min. : 154.0	Min. :1.600	Min. :1
1st Qu.:1	1st Qu.:1	1st Qu.: 287.0	1st Qu.: 449.0	1st Qu.:2.200	1st Qu.:1
Median :1	Median :1	Median : 521.0	Median : 538.0	Median :2.800	Median :1
Mean :1	Mean :1	Mean : 582.2	Mean : 547.8	Mean :2.896	Mean :1
3rd Qu.:1	3rd Qu.:1	3rd Qu.: 858.0	3rd Qu.: 650.0	3rd Qu.:2.800	3rd Qu.:1
Max. :1	Max. :1	Max. :1495.0	Max. :1591.0	Max. :5.200	Max. :1

RFound	RX	RY	RD	Lost
Min. :1	Min. : 5.0	Min. : 122.0	Min. :1.600	Mode :logical
1st Qu.:1	1st Qu.: 302.0	1st Qu.: 412.0	1st Qu.:2.200	FALSE:4427
Median :1	Median : 543.0	Median : 503.0	Median :2.800	
Mean :1	Mean : 596.6	Mean : 517.1	Mean :2.827	
3rd Qu.:1	3rd Qu.: 849.0	3rd Qu.: 611.0	3rd Qu.:2.800	
Max. :1	Max. :2217.0	Max. :1591.0	Max. :4.600	

For both ethical groups, the statistical summaries of the collected eye movements data, the data population for eye movements data indicated normal tendency. All the variables of eye movements data had no irregularity. Further, the variable, Time [Ticks], had exponential factor in its measurements. Moreover, all the variables of eye movements data had numeric data quantities except for the variable, Lost, that had nonnumeric data quantities, Boolean or logical data.

Next, we started the process of normality test (normal distribution) by analyzing the data for all variables sequentially. Each analysis of QQ-plot involved with two corresponding variables of both ethical groups respectively.

The significant outcomes that were of prime interest to us had shown as below in figure 3 sequentially.

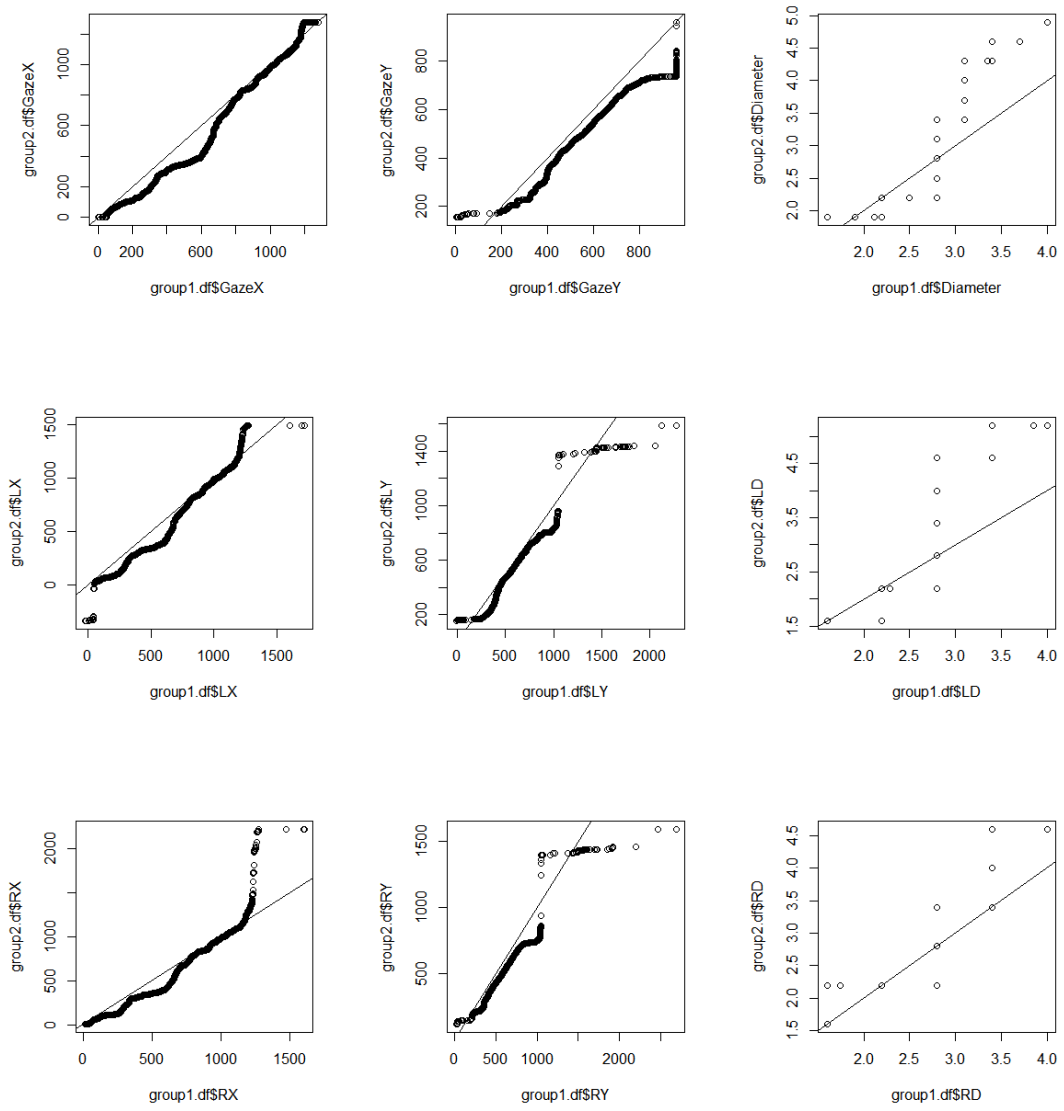

Figure 3. Quantile-Quantile Plots for the two datasets of two groups (Group1 and Group2).

In each case, the decisive line indicated the existence of high level of normality among the variables of both ethical groups' datasets because most of the data points did not fall on the lines. Therefore, the normal distribution of both ethical groups' datasets verified successfully.

In addition to these, the proposed hypothesis was tested using t-test for 2 samples which is used to determine if the 2 samples are different from each other. In our case, the samples are the data sets from the both ethical groups.

The Welch two sample t-tests for the respective variables of both ethical groups (Group1 and Group2) were summarized in the Table 3 as shown below sequentially.

Table 3. t-Tests for the two datasets of two groups (Group1 and Group2).

```
Welch Two Sample t-test

data:  group1.df$GazeX and group2.df$GazeX
t = 11.309, df = 6726.6, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
57.42180 81.50387
sample estimates:
mean of x mean of y
653.1111  583.6483
```

```
Welch Two Sample t-test

data:  group1.df$GazeY and group2.df$GazeY
t = 24.689, df = 8072.5, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
57.69825 67.65082
sample estimates:
mean of x mean of y
589.3545  526.6799
```

```
Welch Two Sample t-test

data:  group1.df$Diameter and group2.df$Diameter
t = -10.756, df = 5008, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
-0.1458538 -0.1008813
sample estimates:
mean of x mean of y
2.737893  2.861260
```

```
Welch Two Sample t-test

data:  group1.df$LX and group2.df$LX
t = 11.806, df = 6601.5, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
61.72056 86.29791
sample estimates:
mean of x mean of y
656.1796  582.1703
```

```
Welch Two Sample t-test

data:  group1.df$LY and group2.df$LY
t = 15.251, df = 7649.9, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
42.14317 54.57430
sample estimates:
mean of x mean of y
596.1417  547.7829
```

```
Welch Two Sample t-test

data:  group1.df$LD and group2.df$LD
t = -15.872, df = 4842.1, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
-0.2292364 -0.1788317
sample estimates:
mean of x mean of y
2.691516  2.895550
```

```
Welch Two Sample t-test

data:  group1.df$RX and group2.df$RX
t = 8.3252, df = 6424.5, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
41.53274 67.11639
sample estimates:
mean of x mean of y
650.9058  596.5812
```

```
Welch Two Sample t-test

data:  group1.df$RY and group2.df$RY
t = 27.65, df = 8237.4, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
77.65666 89.50782
sample estimates:
mean of x mean of y
600.6663  517.0840
```

```
Welch Two Sample t-test

data:  group1.df$RD and group2.df$RD
t = -4.0405, df = 5499.1, p-value = 5.405e-05
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
-0.06341878 -0.02198330
sample estimates:
mean of x mean of y
2.784270  2.826971
```

As shown above, the results of t-tests surfaced the respective t values as well as the very low p-values (the probability) with significantly high level of confidence (95%) that implied the two independent datasets of both ethnic groups different from one another.

Hence, we rejected the null hypothesis that the differences in the means of both ethical groups were equal to zero for all cases quantitatively. Further, our proposed hypothesis turned out to be true as the differences in the means of both ethical groups were not equal to zero (nonzero quantity or value) for all the cases.

6. Conclusion

The comparative analysis and hypothesis testing indicated that there were noteworthy differences in the means of both ethical groups data sets with a considerably high level of confidence. Therefore, it driven out that there were substantial differences in the eye movements of these ethical groups.

The reason behind such substantial differences in the eye movements of these ethical groups relies on their drastically different inherent cognitive processes. Moreover, the dynamics of human cognition and underlying mechanism of visual perception are intensely influenced by the human ethics.

The ethical manners, work cultures, behaviors, attitudes of humans are related to humans' mindsets, beliefs, social customs, traditions, rituals, habits, social and moral societies, environmental backgrounds, civilizations. Therefore, these ethical activities and actions are reflected in terms of the eye movements of these ethical groups who participated in experimentations of eye movements.

Consequently, we confirmed and supported our proposed hypothesis that the eye movements of individuals related to dissimilar ethical groups were of different nature quantitatively.

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