

# Eye Movements Look for Analogical Patterns during Scene Viewing

Gufran Ahmad

**Abstract**—Research studies of eye movements for comprehending underlying mechanism of visual attention and perception have been inspiring. These studies are mandatory to have knowledge of humans' cognitive dynamics. We conducted and analyzed eye tracking experiments to test the hypothesis that the patterns generated during scene viewing were primarily determined by analogical aspect of cognitive processes. Eye movement data, in terms of heat maps, were collected from participants who viewed artistic portraits during active viewing. The patterns produced from eye tracking system during scene viewing traced a sequence of similar elements of the scene. This scientific investigation proved the hypothesis that eye movements looked for analogical patterns during scene viewing.

**Index Terms**—Eye movements, analogical patterns, cognitive processes, scene viewing.

## I. INTRODUCTION AND BACKGROUND

Eye tracking is one of the promising interdisciplinary fields to bring substantial knowledge related to many areas of study. Many people are dedicating in this active topic not only for scientific and social purposes but for economic and business purposes also. Our previous work contributed notable amount of assets to the scientific and social communities as well [1].

Eyes are one of the indispensable senses of human body. Being associated with human brain, eyes are prominent to human attentions and cognitive processes. Henceforth, eyes involve in each and every processes; initiating from vision to perception and further, cognition, including metacognition [2]-[4].

Most of the times, eyes take part in the verbal and nonverbal communications and convey the desirable information among the participants of communication. Eyes also dynamically participate in the processing of data for information and the visualization of information which are common practices among professionals and individuals, including artists and scientists [2], [4]-[6].

During eye movements, eyes move to fetch a specific fraction of the visible region in viewing because of having tendency to perceive the degree of detail visible in the central direction of gaze. In the movements, they pass through two temporal phases: fixations (the stops or periods of time when the point of gaze or significant look is relatively slow) and saccades (the hops between stopping points). Saccades are

often information-seeking and directed to specific objects or regions by the requirements of ongoing behavior. This also concludes the existence of cognitive processes of eye movements in viewing [1], [5]-[9].

Art is characteristically human way of cognitive activity that is aimed at influencing the minds of viewers. Being constructivist in nature, it aims at the deliberate refinement and elaboration of worldviews. Most of the arts are metacognitive in its role as it engages in self-reflection, both individually and socially. The varieties and modes of art are technology-driven. Art is always aimed at realizing the cognitive consequence [10]-[12].

Analogy is basically similarity in which the same relations or likeness hold between different domains or systems. Analogy is significant in cognitive processes and is key mechanism in creativity which is also a part of the subject, like Visual Art. The main focus of analogical research is on the mapping process by which people understand one state or pattern in terms of another. Mapping is basically process of aligning the representational structures of the two cases and projecting inferences [13]-[16].

In analogical mapping, a familiar condition is used as a model for making inferences about an unfamiliar condition. The mapping process includes a structural alignment between two represented conditions and the projection of inferences from one to the other. The alignment must be structurally consistent, i.e. there must be a one-to-one correspondence between the mapped elements in the base and target, and the arguments of corresponding predicates must also correspond [13]-[16].

During artistic portrait observation, we move our eyes rapidly in irregular manner to change focus from one fixation to another fixation. This process, saccade, is one of the most common behavior of eyes. Pattern is obtained only during the periods of relative gaze constancy, known as fixations. The process of directing the eyes to view picture in real time is known as gazing of eyes [6]-[9], [17]-[19].

The main motive of this study in artistic scene viewing is to identify and illustrate the idea of analogy and the generated patterns based on this core idea which is evolved by the cognitive and metacognitive processes that are observed by the shifts of gaze during the eye movements.

## II. EYE TRACKING SYSTEM

In eye tracking system, the system illuminates infrared light for tracking the eye movements. The camera, connected to the system, captures the location of viewer's eyes in terms of fixation during experimentation time. As the viewer moves his/her eyes to look a new location of the scene, the

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Gufran Ahmad is with the College of Computer Sciences and Information Systems, Jazan University, Jazan, Kingdom of Saudi Arabia (e-mail: gufran.researcher@gmail.com).

camera records new fixation also. This process of recording continues subsequently. The system generates eye tracks and heat maps using the captured data which is utilized for further analysis.

The schematic diagram of eye tracking system and basic processes involved during eye tracking experimentation is represented in Fig. 1.

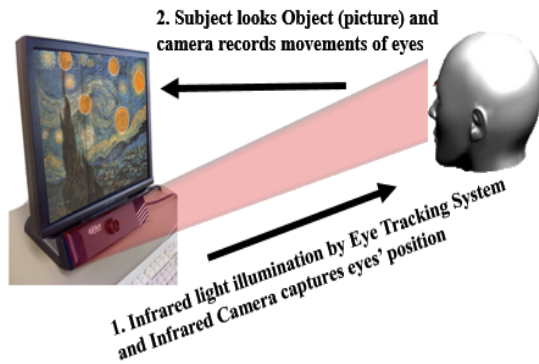


Fig. 1. Eye tracking system with operational processes.

The traces of eye movements are taken in diverse layouts as per analyst's suitability. Among them, there are two most common formats are Heat Map and Sequenced Gazing with circle of concentration. In Heat Map, the track of eye is recorded as illumination and intensity of infrared light rays. This is based on Energy Therapy Technique (ETT). In Sequenced Gazing, the eye tracks are entered as numbered circles with their areas indicating the time duration of eye's gazing in those areas respectively [3], [5].

In our experiments, we study the heat maps of viewer's eye movements, which is generated by the system, during scene viewing. These are assured evidences of eye movements.

### III. PRESENT STUDY

We investigate the eye movements from cognitive perspective during scene viewing and analyze the patterns of heat map to visualize the information. Here, visualization of heat map patterns to extract information for interpretation are essential involvements of this study.

Initially, eye movement heat map was collected from participants who viewed full-color scenes while engaged in a visual search task in which they are freely viewing different regions appeared in each picture. Finally, we compared and analyzed the heat map against the artistic portrait. The interpretation is carried out with the help of cognitive and metacognitive processes in current research.

### IV. FLOW CHART OF STUDY

The study on eye movements during scene viewing consists of a number of steps to be performed. These steps are represented as shown in the adjacent flow diagram (Fig. 2). This is a comparative study of two items; one item is artistic portrait and other item is the heat map of the same portrait, which generated from eye tracking system.

It begins with recording of heat map of eye movements for a Subject; a viewer on eye tracking system for an Object; artistic portrait. The generated heat map of the same artistic

portrait is comparable to the original artistic portrait. This comparative analysis brings visualization and interpretation of the outcome. So, these two items gets compared side by side.

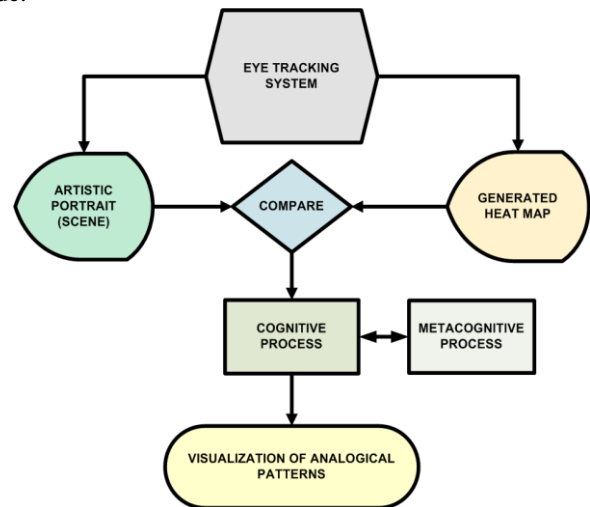


Fig. 2. Flow chart of research study.

During comparison stage, we utilize cognitive process, and metacognitive process, in addition to analogical perspective, to understand the hidden mechanism that creates resultant maps. By analyzing, we come up with concluding remarks on evolving phenomena.

### V. METHOD

We selected 38 participants from a number of fields within university, aging from 22 years to 32 years. These Subjects, the participants were assigned to view 3 randomly selected famous artistic portraits as shown below in Fig. 3.

The artistic portraits are “Starry Night; a famous portrait by Van Gogh during exile time”, “Last Supper of Jesus with his companions by Leonardo Da Vinci”, “Mona Lisa by Leonardo Da Vinci”.



Fig. 3. Selected artistic portraits for research study.

Their eye movements were closely monitored as they viewed 32 bits full-color artistic pictures. The Objects, the pictures were displayed on a computer monitor. The pictures were shown at a resolution of  $1280 \times 1024$  pixels and subtended 15 deg. horizontally by 10 deg. vertically at a viewing distance of 75 cm. Eye position was sampled from an Eye Tech Digital Systems TM3 16 mm Eye Tracker, and eye tracking data was parsed into fixations within heat maps.

The Subject's head was 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 pictures freely.

The pictures were presented to the Subjects for maximum duration of 100 sec. During this time span, the Subjects viewed the pictures with their normal eyes and focused attention on the Object, the portrait.

Here, we analyzed all 3 portraits respectively with the intention to elaborate our findings in the most common and generalized perspective.

#### A. Analysis 1: Study of Starry Night Artistic Portrait



Fig. 4. Portrait and generated heat map of the same portrait.

In the above artistic portrait of Fig. 4, the left side portrait is the original portrait. The right side portrait is the heat map generated by eye tracking system during the scene viewing by the Subject.

As the Subject started to view the portrait, he viewed at different regions of the portrait. As he came across the region of star; the whirled round shape, he fell into the process of perception. Gradually, he moved to adjacent region of the star because of the cognitive processes [6]-[9], [17], [18]. So, the attention of the Subject shifted to another similar region of the portrait because of the associated influential thought of analogy that came into play in the middle of the initiated cognitive process. These cognitive and metacognitive processes led to the Subject towards the idea of analogy.

With these thoughts and processes, the Subject got motivated to move subsequently to other similar regions of the portrait, which is obvious from the heat map of the portrait. This sequential phenomenon was resemblance of cognitive process itself of human mind. Moreover, it is analogical thought which is central to this experimentation and led to the visualization of analogical patterns which were generated by the eye movements of the Subject. These processes continued repeatedly during the entire span of viewing time.

Further, later interview of Subject confirmed the same sequential process of cognition and analogical thoughts. As he stated that he was gazing at the whirled round star and later got interest in similar region consisting of whirled round star that was adjacent to the current portion of portrait.

#### B. Analysis 2: Study of Last Supper Artistic Portrait

In this artistic portrait, Jesus, sitting in the center, was having dinner with his companions at a common table. Suddenly, he spoke, "One of you will betray me". Thereafter, the scene reflected beautifully the reactions of the all the 11 companions and Jesus himself.

During the eye tracking experiment, the Subject started to look over a region of the portrait with his interest and gradually after a moment because of the influential factor

associated with the core processes, he moved to other region of the portrait. He gazed heavily within three regions of the portrait subsequently. The underlying cognitive and metacognitive processes along with analogical thought are quite obvious in this case.

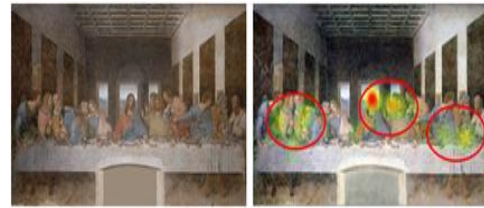


Fig. 5. Portrait and generated heat map of the same portrait.

The generated heat map showed these three strongly emphasized regions of the portrait. These regions were filled with a number of gestures; hands, eyes, facial expressions, directed flow of motion to express the emotions and feelings of the companions as well as Jesus himself with facial expressions and gesture [4], [6], [8], [9], [17], [18]. The influential factors; gestures and expressions that compelled the viewer to shift from one region to other region are analogical in nature. Therefore, this analogical patterns generated by the eye tracking system were mainly based on gestures.

In successive interview, the concerned Subject revealed that he was strongly influenced by the gestures and facial expressions during scene viewing. Mostly, he was interested to understand the communicative gestures of analogical nature.

#### C. Analysis 3: Study of Mona Lisa Artistic Portrait



Fig. 6. Portrait and generated heat map of the same portrait.

In this eye tracking experiment, the Subject was mostly gazing at the background of the portrait subsequently. Though in the beginning the Subject was gazing at the face of the lady, yet later, it got second thought and started to gaze at backgrounds of the portrait [4], [6]-[9], [17], [18].

Later interview of the Subject concluded that he was interested in facial expression and the Mona Lisa smile earlier, but shifted his thought later as was keen to know about the backgrounds. The background were of similar types like mountains, roads, bridges. So, they became matter of interest to the Subject. Henceforth, this evidence directed to the analogical patterns based on analogical thought.

## VI. DISCUSSION

In this study, the artistic portraits broaden their impact from the fact that the artists are visualizing this pragmatic world in different standpoint, i.e. humanitarian standpoint.

These emotional viewpoints are rather too complicated to comprehend from visual analytics and analytical reasoning. These cognitive perspectives and intrinsic analogical thoughts are revealed by eye movements during scene viewing.

During the last stage of experiments, the visualization of analogical patterns is a crucial and central part of whole activity. The visualization of analogical patterns are undeniably astonished perspectives of each and every analyst who inspect them for the definite intents. This, in turn, brings a number of analogies in scene viewing by various perspectives of analysts. Though the existence of analogical thought is available in the literature [11]-[16], yet its presence and explanation varies drastically. In this regard, the analogical patterns reinforce again the existence of analogical thoughts in between the inherent cognitive and metacognitive processes.

Shifting (saccades) and gazing during scene viewing are decisive factor for suitable achievement of task-relevant visual information [6], [9], [17]-[19]. In this study, we observed that the generated heat maps by eye movements are significant and are primary evidences to prove the analogical thoughts and associated cognitive processes in eye movements. These analogical thoughts are able to express human's cognitive aspects in terms of illumination and intensity observed in the heat maps. Without taking the account of analogical thought into consideration, it is impossible to understand the underlying sequential cognitive and metacognitive aspects as well.

Our final remark summarizes that the experimental evidence of analogical thoughts and generated analogical patterns during active scene viewing supports our hypothesis for which we conducted a series of experimentations. The hypothesis that eye movements look for analogical patterns during scene viewing, is the only and obvious testimony related to eye movements research study.

## VII. CONCLUSION

Our findings suggested the existence of analogical thoughts of the human mind in the middle of cognitive and metacognitive processes which were continuously happening during active scene viewing. These analogical thoughts led to the creation of analogical patterns of scene's elements.

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**Gufran Ahmad** has experience in teaching, research and industrial domains for national and international communities. He is ardent thinker and passionate knowledge sharer for cultivating intelligence among Scholars and Learners. He is dedicating his exertion on Visualization, Intelligent Information Processing, Predictive Modeling, and Decision Making which are hot talking points of KDD, AI, Cognitive Science, and HCI, not only from research perspective but from industrial perspective also. He holds Master of Engineering in computer software and theory from Harbin Engineering University, China, Postgraduate Diploma in Computer Applications from Jamia Millia Islamia, India, Master of Science in theoretical physics from Jamia Millia Islamia, India, Bachelor of Science in physics from Jamia Millia Islamia, India. He is currently a Faculty and Researcher for College of Computer Sciences and Information Systems, Jazan University. Earlier, he devoted his endeavor as Researcher and TF in The University of Tokyo, Faculty in Al-Falah Engineering College, Lecturer in Institute of Technology, Researcher and Teaching Assistant in Mie University, Japan, and IT Professional in Fintech Compu Systems Limited & Micro Computer Services & Solutions companies. He collaborated and wrote national and international articles, publications, teaching and technical notes that can demonstrate his writing intents. These creativities were appended as valued assets by organizations and corporates. Mr. Ahmad has been a committed member of Physics Association, National Computer Software Society, AICIT, and National Literacy Mission. He received numerous awards, including Best Employee of Corporate, Certificate of Merit, Best Author, and Young Researcher.