Cognitive Impact of Eye Movements in Picture Viewing

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Abstract

We compared and analyzed eye tracking experiments to test the hypothesis that the patterns generated during picture viewing were mainly determined by eye movement generated links. Eye movement data were collected from participants who viewed photographs of artistic portraits during an active viewing. The links as determined by a popular evolutionary computational model, based on Genetic Algorithm, did not anticipate saccade sequences of eye movements. The optimized Genetic Algorithm (GA)-generated graphs differed considerably from the graphs generated by eye tracking. The existing evidence is consistent with the hypothesis that cognitive and, in turn, metacognitive factors take part in active gazing of eyes. The pattern generated by eye movements can only be substantiated with cognitive processes.

Keywords: *Eye Movements, Cognitive Process, Picture Viewing*

1. Introduction and background

Eyes are strongly connected with human brain, which is the domicile of all cognitive processes of human intelligence. Study of eye movements is significant not only to understand working of human mind but to understand cognitive processes inside human mind also [1], [2].

Each eye structure contributes in a particular way to the visual process and the process of cognition, and jointly they bring about a wide scope of visual functions, from the perception of an object's shape, size, and color to the perception of distance [2], [3]. Further, these cognitive processes and metacognitive processes can be influenced by human behavior, intuitive feelings, and human emotion [4], [16], [17].

Eye gaze accomplishes a number of essential tasks in interaction. Besides being an essential basis of information during social dealings, gaze is associated to verbal and non-verbal actions [5], [6]. Our 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 [7]. The saccadic eye movements are significant during picture viewing. They consist of two temporal phases: fixations and saccades. Fixations are stops or periods of time when the point of gaze or significant look is relatively still. The average fixation duration varies. Fixation duration varies according to the activity we are involved in [8], [9], [10].

The hops between stopping points are called saccades. During saccades, the eyes move at a relatively speedy rate to change the focus or direction of the point of vision from one spatial position to another. It is during fixations that we get hold of valuable information, whereas our vision is blocked out and we are basically sightless during saccades [8], [11], [12].

By the use of sophisticated methods of measuring the position of the eyes at any moment, it becomes immediately apparent that the eyes are never motionless for more than a fraction of a second; the movements are of three types: (1) irregular movements of high frequency (30–70 per second) and small excursions of about 20 seconds of arc; (2) flicks, or saccades, of several minutes of arc occurring at regular intervals of about one second; and between these saccades there occur (3) slow irregular drifts extending up to six minutes of arc [2], [6], [13].

Saccades are often information-seeking in nature, directed to particular objects or regions by the requirements of ongoing behavior. This indication brings to light the existence of cognitive processes of eye movements in picture viewing. Although this point seems obvious to eye movement researchers, it is often overlooked in the visual perception and visual cognition literatures. While understanding what is initially apprehended from a picture is an important theoretical topic, it is not the whole story;

vision naturally unfolds over time and multiple fixations. Any complete theory of visual cognition, therefore, requires understanding of how ongoing visual and cognitive processes control the direction of the eyes in real time, and how vision and cognition are affected by where the eyes are pointed at any given moment in time [2], [3], [6].

During artistic picture 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 data 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. This process provides ongoing activities of cognition, and metacognition of our human brain.

The main motive of this study in artistic picture viewing was to identify and illustrate the cognitive and metacognitive processes that are observed by the shifts of gaze during the eye movements. These shifts, the eye tracks, are observed in terms of important links which is considerably different or nonexistent in graphs generated by an optimized algorithm, Genetic Algorithm.

2. Eye tracking system

In eye tracking system, the infrared rays come from the system to eye for tracing the eye movements. These infrared rays are reflected to the system from eye to record the data of eye movements. The eye, itself is like a sensor can sense and is controlled by human brain where cognitive processes are produced.

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

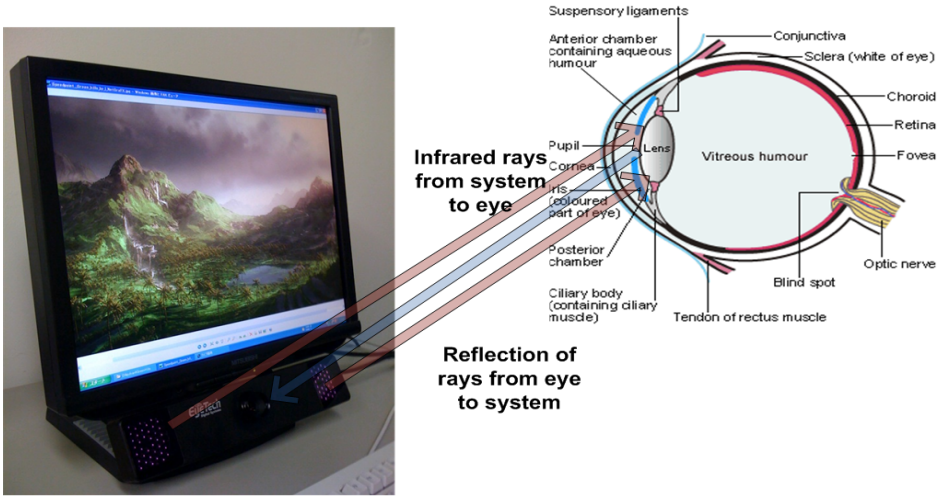

Figure 1. Eye tracking system with operational processes.

The traces of eye movements are captured in different formats as per user's convenience. 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.

In our experiments, we study the tracks of eyes drawn by the eye movements. This creates a number of saccades in terms of links that combine fixations during eye movements. Hence, we use the data tracked by eyes to plot the graph that consists of fixations as nodes and saccades as eye tracks or links.

3. Present study

We investigated the existence and impact of cognitive process during picture viewing and its relation to picture properties. Initially, eye movement data was collected from participants who viewed full-color pictures while engaged in a visual search task in which they are freely viewing different regions appeared in each picture. The data was utilized in generating graphs for both eye tracked links and Genetic Algorithm based links in the second stage. Finally, we compared and analyzed the fixation data graph against the graph generated from Genetic Algorithm [14], [15] graph. The interpretation is carried out with the help of cognitive and metacognitive process which are the only solutions in current scenarios. The links generated by eye movements are significant in interpreting exact motive behind the viewer's mind from cognitive point of view [16], [17].

4. Flow chart of study

The study on eye movements in picture viewing consists of planned processes that are represented as shown in the adjacent flow diagram (figure 2). This is a comparative study of two graphs that are generated from eye tracks and optimized Genetic Algorithm.

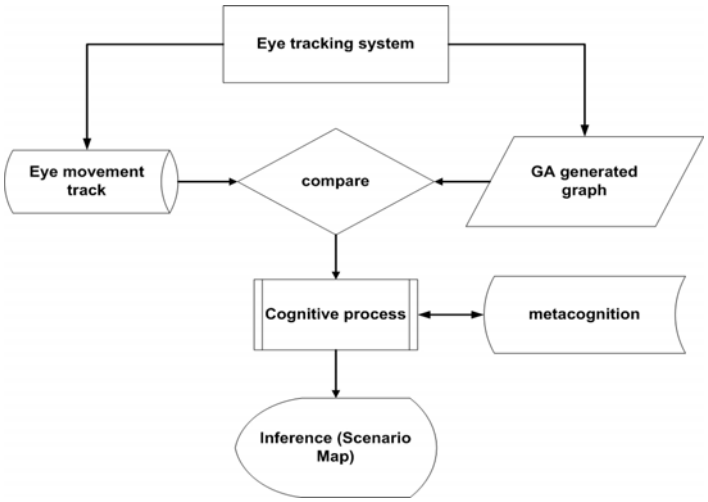

Figure 2. Flow chart of research study.

It begins with recording of eye movement tracks of Subject, a viewer on eye tracking system for an Object, artistic portrait. The data, gathered by recording this eye movement, is used to plot graph of eye tracks. Another graph is generated by our application interface, which is developed to generate a graph based on Genetic Algorithm. We used the same data that is gathered during eye movement recording. These two graphs are compared side by side to identify and illustrate the scenario map that arises.

During comparison stage, we utilize cognitive process, and metacognitive process to under-stand the hidden mechanism that creates resultant scenario maps. By analyzing these scenario maps, we come up with concluding remarks on evolving phenomena. Creation and analysis of scenario maps are important stages to understand and interpret the underlying cognitive processes that exist in human interactions, social networks, human's decision making systems, marketing area [18], [19].

5. Method

We selected two prominent participants from different fields, a Biologist and an Environmentalist. These Subjects, the participants were assigned as first Subject and second Subject respectively. Their eye movements were closely monitored as they viewed 32 bits full-color artistic pictures of Green Hill and Artist's Expression. The Objects, the pictures were displayed on a computer monitor.

The pictures were shown at a resolution of 1280 × 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 and saccades.

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. Subjects saw Green Hills and Artist's Expression pictures.

The pictures were presented to the Subjects for maximum duration of 80 sec. During this time span, the Subjects viewed the pictures with their normal eyes and focused attention on the Object, the pictures.

5.1. Analysis 1: Comparing eye tracking graph to Genetic Algorithm generated graph for first Subject

Figure 3. Portrait tracked by eyes and GA-generated graph for first Subject respectively

In the above artistic portraits of figure 3, the left side portrait was recorded graph of eye movements for first Subject, the Biologist. The right side portrait was the graph generated by optimized Genetic Algorithm for the same Subject. In both sides, the dataset could be observed in terms of all the fixations. All fixations in both graphs lied exactly at the same positions in two dimensional coordinates because of the same dataset.

Figure 4. Comparison in links made by eyes and GA-generated graph for first Subject respectively

During the comparative analysis (figure 4), difference between eye tracked link and GA-generated link was observed. In extreme right of the right side graph, there was an important link missing between starting of water fall and ending of water fall, whereas in the left side graph, this prominent link exists.

The inquisitive mind of viewer began cognitive process during picture viewing. As Subject came across the right side of portrait, he gazed the top of water fall. During this process of cognition, he sensed and passed through the phases of perception and subsequently metacognition that brought

Subject towards the bottom of water fall. This sequential phenomenon was resemblance of cognitive process itself of human mind. This remarkable cognitive process was recorded as eye tracks, in terms of distinguished link. This link was not traced in Genetic Algorithm generated graph on right side portrait because of nonexistence of cognitive process. This ensured the Subject viewed this artistic portrait along with cognitive, and in turn, metacognitive processes. Hence, such scenario was clear evidence of cognitive parts in picture viewing.

Another remarkable difference was existence of horizontal scanned path in the left side of eye tracked artistic portrait. This horizontal scan path was the clear indication of cognitive and in turn, metacognitive process. The absence of these processes was quite obvious in the Genetic Algorithm generated graph in the right side because of nonexistence of cognitive and metacognitive processes. During horizontal scan path made by eye drawing was resemblance of scan path revisited due to cognitive influences. Though the scanned paths did not revisit completely, yet it revealed that the paths were affected by underneath cognitive and metacognitive processes which were inseparable part of eye movements.

However, later interview of Subject itself confirmed the same sequential process of cognition. As he stated that he was gazing the origin of waterfall and later got interest in sequential water fall that was flowing from upper portion of portrait to the lower portion of portrait. He was passing through cognitive and subsequently metacognitive state during the entire span of viewing time.

5.2. Analysis 2: Comparing eye tracking graph to Genetic Algorithm generated graph for second Subject

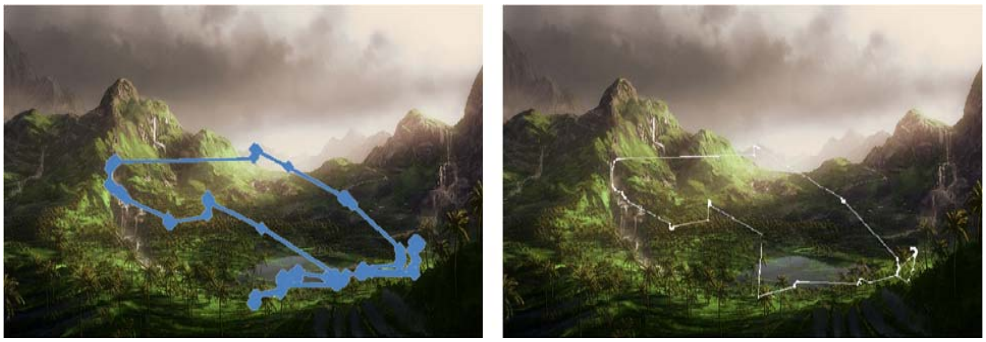

Figure 5. Portrait tracked by eyes and GA-generated graph for second Subject respectively

This artistic portrait, in figure 5, was viewed by the Environmentalist who observed this artistic portrait of Green Hill. During his observation, his eye movements created a closed loop in the left side portrait. Similar loop was created by the GA-generated graph in the right side portrait.

The Subject's motivation is unexplainable from the perspective of GA-generated graph (figure 6) whereas it was convenient to understand the eye tracked graph with underlying cognitive process.

Figure 6. Comparison in tracks of eyes and GA-generated graph for second Subject respectively

During the picture viewing, the eye movements of the Subject came across an outer virtual ellipse created by the picture intensity. Hence, it started to follow along the path. After a short while, due to metacognitive process, the Subject came across an inner ellipse created by the dark region and surrounded by the central lake. The Subject visualized about the dark portions of portrait and begins to think about the dark region of the portrait. Finally, Subject came across the central lower lake surrounded by mountains. Such phenomenon can be explained only by cognitive and metacognitive processes of Subject's mind.

Successive interview, conducted for the concerned Subject, revealed that he was at first strongly influenced by the bright region of portrait during viewing it. Later he observed the dark side of portrait to look into it. The central lake was his prime interest of viewing because of its nice cooling effect during summer and magnificent constituent as per the perspective of healthy environment. These comments make known the existence of cognitive and metacognitive processes during picture viewing of Subject.

5.3. Analysis 3: Comparing Eye Tracking Graph to Genetic Algorithm generated graph for first Subject

Figure 7. Portrait tracked by eyes and GA-generated algorithm for first Subject respectively

This artistic expression portrait, in figure 7, was about human interaction and human behavior in common lives of all usual humans. This portrait was viewed by the first Subject, the Biologist. The method and condition were exactly same as mentioned earlier during these experimentations.

The links in the left side portrait were generated by Subject's eye movements, whereas the right side of portrait showed the Genetic Algorithm generated graph of the same data of eye movements.

During the analysis phase, we recognized that the Subject's eye movements scanned the entire picture horizontally which was quite essential to understand the human behavior. The human behavior was represented by certain expressions of visual creatures in the portrait. This cognitive process was missing in the algorithm generated graph.

The Subject emphasized on an existing character, the animal that was dancing with joy as well. This gave a glimpse of common behavior of human, the happiness and enjoyment which can be observed in animals as well. This reflected the usual cognitive behaviors can pass through the animals also.

Subsequent interview of concerned Subject, the Biologist, confirmed the same findings. He stated that he was actively looking the picture by gazing horizontally the entire picture to find the common expressions of all characters. Also, he thought longer for the dancing animal and considered capabilities of animal.

5.4. Analysis 4: Comparing Eye Tracking Graph to Genetic Algorithm generated graph for Second Subject

Figure 8. Comparison in tracks of eyes and GA-generated graph for second Subject respectively

In this portrait of figure 8, the Subject's eye movements during active picture viewing were on the left side whereas the right side portrait was the graph created by Genetic Algorithm. This portrait was viewed by the second Subject, the Environmentalist.

The Subject concentrated on the left side of portrait where there were common human's activities like dancing, enjoying and playing are happening. These activities brought him towards the consideration of emotional attitudes of humans and animals. This brought him to sense the moment of happiness as well.

The following interview of the Subject did confirm the cognitive activities of the Subject. As he stated that he felt happiness and pleasure during the picture viewing. He felt all the good emotional attributes and excitements during picture viewing as well.

These eye movements can be explained with cognitive and metacognitive processes of human minds. The cognitive processes brings Subject to the state of happiness that in turn, inspire hope and enhance fruitful activities. The metacognitive process in between cognitive processes leads viewer to mental relaxation, distraction and decreases mental distress.

6. Discussion

In this study, the artistic portraits gain their influence from the fact that the artists are visualizing this realistic world in different perspective, humanitarian perspective. These emotional perspectives are rather too complex to understand from visual analytics and analytical reasoning. These cognitive perspectives are reflected by eye movements during picture viewing.

During the final stage of experiments, the creations of scenario maps are an essential and integral part of entire process. The scenario maps are indeed open viewpoints of each and every analyst who examine them for the specific purposes. This brings a number of interlinks between the gaps created by different viewpoints of analysts. Though the creation of such scenario maps is available in the literature [6], [13], [18], [19], yet its existence and interpretation varies drastically. In this regard, the scenario maps strengthen again the existence of cognitive and metacognitive processes intrinsic in these maps.

Gazing during picture viewing is critical for appropriate advantage of task-relevant visual information. In this study, we observed that the links generated by eye movements are significant and are drastically different from GA-generated links because of the associated cognitive processes in eye movements. We found that GA-generated graphs, although are the best optimized evolutionary computational model to represent eye track up to certain extent, yet these graphs are lacking in expressing human cognitive aspects in terms of missing links among fixations, nodes. GA-generated graphs also fail to interpret fixation sequences. These missing links are bottleneck in understanding the underlying sequential cognitive and metacognitive aspects as well.

Our conclusion is that the evidence supporting the GA-generated graphs are weak supportive tools and that the existing evidence is consistent with the hypothesis that cognitive factors play the dominant role in gazing of eyes during active picture viewing.

7. Conclusion

The Evolutionary model based graphs such as GA-generated graph cannot explain the gazing of eyes during picture viewing. Our findings suggest that the cognitive factor is a critical and dominant determinant of eye movements in the active viewing of pictures.

8. References

[1] Brown, Tom. *The Science and Art of Tracking.* NY: Berkley Books, 1999.
[2] Rogers, Kara. *The Eye: The Physiology of Human Perception.* NY: Britannica Educational Publishing, 2010.
[3] Viegas, Fernanda B., and Martin Wattenberg. "Artistic Data Virtualization: Beyond Visual Analytics." *Online Communities and Social Computing, Second International Conference.* Beijing: Springer, 2007. 182-191.
[4] Wells, Adrian. *Emotional Disorders and Metacognition: Innovative Cognitive Therapy.* West Sussex: John Wiley & Sons, 2000.
[5] Duchowski, Andrew T. *Eye Tracking Methodology: Theory and Practice.* London: Springer Verlag, 2003.
[6] Holsanova, Jana. *Discourse, Vision, and Cognition.* John Benjamins Publishing Company, 2008.
[7] Griffin, Z. M. "Why look? Reasons for eye movements related to language production." In *The integration of language, vision, and action: Eye movements and the visual world*, by Henderson and Ferreira, 213-247. New York: Psychology Press, 2004.
[8] Henderson, J. M., and A. Hollingworth. "High Level Scene Perception." *Annual Review of Psychology 50*, 1999: 243-271.
[9] Rayner, K. *Eye movements and visual cognition: scene perception and reading.* New York: Springer Verlag, 1992.
[10] Solso, R. L. *Cognition and Visual Arts.* Massachusetts London: MIT Press, 1994.
[11] Henderson, J. M., and A. Hollingworth. "Eye movements during Scene Viewing. An Overview." In *Eye Guidance in Reading and Scene Perception*, by G. W. Underwood, 269-293. Oxford: Elsevier, 1998.
[12] Hoffman, J. E. "Visual Attention and Eye Movements." In *Attention*, by H. Pashler, 119-153. London: Psychology Press, 1998.
[13] Stark, Lawrence, and Stephen R. Ellis. "Scanpaths Revisited: Cognitive Models Direct Active Looking." In *Eye Movements: Cognition and Visual Perception*, by Dennis F. Fisher, Richard A. Monty and John W. Senders, 193-226. Hillsdale: Lawrence Erlbaum Associates, 1981.
[14] Akashi, Takuya, Yuji Wakasa, and Kanya Tanaka. "Using Genetic Algorithm for Eye Detection and Tracking in Video Sequence." *Systemics, Cybernetics and Informatics* 5, no. 2 (2007): 72-78.
[15] Cremene, Marcel, Ovidiu Sabou, Denis Pallez, and Thierry Baccino. "Eye Tracking Data Exploration within Interactive Genetic Algorithms." *Knowledge Engineering, Principles and Techniques.* Cluj-Napoca (Romania): HAL, 2009. 25-32.
[16] Ohsawa, Yukio, and Yusuke Maeda. "Eyes Draw Auxiliary Lines in Interpreting Images." *Journal of Computers* (Academy Publisher) 4, no. 10 (October 2009): 1012-1021.
[17] Ohsawa, Yukio, Yusuke Maeda, and Takahisa Yoshida. "Eyes Draw Auxiliary lines before Insight Moment." *IEEE International Conference on Systems, Man and Cybernetics.* Montreal: IEEE, 2007. 3499-3504.
[18] Ohsawa, Yukio. "Scenario maps on situational model, applied to blood test data for hepatitis C patients" *Studies in Computational Intelligence* (IEEE), 2006: 69-81.
[19] Horie, Kenichi, and Yukio Ohsawa. "Extracting high quality scenario for consensus on specifications of new product." *Studies in Computational Intelligence* (Springer), 2006: 273-285.