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Associative Relevance Based Stimulus Shifts Focus in Eye Movements

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Abstract

Recent studies on eye movements have been moving around business demands tremendously. Business scenarios where study of eye movements can boost business prospects, have adapted this promising arena. Equally, tracking eye movements can express the underlying mechanism of visual perception and dynamics of humans' cognition that are of prime concerns for business transactions. In this study, we conducted a series of eye tracking experiments to validate our hypothesis that associated contexts of portrait's elements stimulated shift in focus of eye movements during artistic portrait viewing. We collected the eye movement data of participants who regarded artistic portraits during active viewing. The maps produced from eye tracking system during portrait viewing traced focal links in eye movements on contextual basis. These experimental facts confirmed the hypothesis that associative relevance based stimulus shifts focus in eye movements.

Keywords: associative relevance, business, cognition, eye movements, visual focus

1. Introduction

1.1 Problem Introduction and Significance

Demanding research studies on eye movements have surpassed and commenced the interdisciplinary domains, newfound views, sophisticated technologies, and wide-ranging applications rapidly. Tracking of eye movements can provide intriguing and meaningful comprehensions of human thoughts and intentions that constitute human behavior and interaction that is indeed necessity not only for research intents but also for business goals. Recently, numerous businesses trading for online sales and shopping, marketing, advertising, and designing are heavily investing and seriously paying attentions for consumer's eye movements because of the purpose to know about consumer's trends and tendencies. By knowing the consumer's minds, the businesses can response their efforts accordingly and competently (Pan et al., 2004; Hermansen, 2015; Bojko, 2013).

Eye movements enable a human to see visible world by visual understanding of surrounding objects as there exist biological links between eyes and human brain. Human's visionary including eye movements for visual insight are neurocognitive mechanism underlying many phenomena. During viewing, the human mind stimulates and evolves cognitive processes include human's sensation, consciousness, visual attention, perception, metacognition, reasoning, analogical thoughts, information processing, and other pertinent processes (Bly & Rumelhart, 1999; Brown, 1999; Duchowski, 2003; Tommasi, Peterson, & Nadel, 2009; Wells, 2000; Ahmad, 2014).

During the process of eye movements, eyes change focuses to spot a specific portion of the visible region in viewing because of having tendency to perceive the degree of detail visible in the central direction of eye gaze or focus. In the movements, they pass through two temporal phases: Fixations (the stops or periods of time when point of focus 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 infers the existence of cognitive processes of eye movements in viewing as well (Stark & Ellis, 1981; Holsanova, 2008; Snowden, Thompson, & Troscianko, 2012; Rayner, 1992; Tsotsos, 2011; Ahmad, 2015).

1.2 Relevant Background and Corresponding Research Design

Studies on the establishment of coordinated rule between sequenced fixations of eye movement and human activities have moved towards a promising status. The study of relations of fixation sequences to the conduct of

usual human activities has its origin. In fact, intrinsic salience of objects is not accountable for focal shifts in eye movements, but by their relevance to the task or context in hand. In contradiction of free viewing, the eye movements and contextual actions are associative in nature and have a chain of linking. Contextual actions consist of a number of perspectives including an act of associativity within the contexts, elements, or intents (Henderson & Hollingworth, 1998; Hoffman, 1998; Gompel, Fischer, Murray, & Hill, 2007; Duchowski, 2003; Holsanova, 2008).

Moreover, a focused visual representation (spotlight metaphor) facilitates and forms focus of attention in eye movements during pictorial viewing. The locus of directed attention in visual space is supposed as having more illumination than areas to which attention is not directed or areas from which attention has been removed. The spotlight of attention turns off at one location and then on at other. Further, as human's competences for attention and processing for information has limitations cognitively, so it is rather problematic to think about focusing everything at a time. Cognitively, human concentrate attention on small parts, one at a time and similarly, human can focus on only small pieces of information at a time (Gompel, Fischer, Murray, & Hill, 2007; Henderson & Hollingworth, 1998; Hoffman, 1998; Rayner, 1992; Holsanova, 2008).

However, there exist a number of influential factors, which bring flow of thoughts and cognitive mechanisms during the eye movements. We look in a location of portrait that is partly determined by the portrait's constraints and region's informative description, partly by the task, intent, context, or interest. Observers can arrange different visual paths through the same portrait, since they extract information from those parts of the portrait to describe particularly. Therefore, the evolved flow of thoughts cognitively, stimulates the conscious focus of attention to move to the next contextual part of the portrait. This indicates that the underlying stimulus shifts the visual focus of eye movements during portrait viewing according to those influential factors (Henderson & Hollingworth, 1999; Hoffman, 1998; Liversedge, Gilchrist, & Everling, 2011; Stark & Ellis, 1981; Griffin, 2004; Holsanova, 2008).

As we look at a piece of artwork, an enthralling sequence of neurological, perceptual, and cognitive phenomena arises. These phenomena lead us towards our understandability and intellectual capacity about the piece of artwork instantly. In addition, as science is laying its foundation to comprehend our experience about art, in similar manner, the art gives us a view of mind that understands the art. Certainly, we identify that all types of art are one of the most splendid expressions in our lives. It can relax our heart and energize our feelings. Further, artistic understandings arouse deep thoughts as well as all types of emotions. Moreover, an art is a productive activity that focuses on the thoughtful alteration and exaggeration of worldviews. As a rule, all known pieces of art are creative, constructive, and metacognitive as per their roles because of being explicable and self-explanatory. The types and styles of art are technology-driven as innovative technologies bring renaissance to the artworks. The most essential part of an art is its goal or motive to turn out to be conscious and sentient about the art itself, and concurrently, showering sequential cognitive processes in human mind, so that a new-fangled inspiration or perspective may be sensed by adaptive minds of admirers (Solso, 1994; Viegas & Wattenberg, 2007; Turner, 2006; Solso, 2003).

Eye movements process and develop a series of flowing thoughts sequentially to extract information about the portrait or object of interest. These flows of thoughts mostly emanate the opinion of analogy. Though there are a number of perspectives about analogy, yet analogical sense is always available in visual perceptions. Based on available literatures, it gives the impression that the perspective of mapping and the perspective of higher level of perception are two different aspects of the same thing, i.e., analogy (Holsanova, 2008; Gentner, Rattermann, & Forbus, 1993; Gentner, 1983; Gentner & Markman, 1997; Gentner & Medina, 1998; Hofstadter & Sander, 2013).

Associative relevance is evolutionary and cohesive notion, which emanates from thoughts of analogy. Associative relevance is noteworthy phenomenon within cognitive processes. It is an underlying mechanism for creativity and annihilation of complexity during information processing and extraction of information for better understanding of the object of interests. It is an associative chain that links contexts, intents, portions, elements, colors, contrasts, or relations based on similarity or sameness. Further, associative relevance manipulates and generates a stimulus cognitively to associate relative visual contexts. The process of associative relevance originates in the middle of focal shifts during eye movements after the establishments of analogical objects or portions of interest in the active viewing (Gentner, Rattermann, & Forbus, 1993; Bly & Rumelhart, 1999; Gentner & Markman, 1997; Gompel, Fischer, Murray, & Hill, 2007; Ahmad, 2014).

2. Method

During artistic portrait observation, we move our eyes freely in unsupervised manner. The viewer's eyes can change focus from one fixation to another fixation liberally. By recording viewer's eye movements, we obtain a pattern of eye tracks consisting of saccades and fixations or eye focuses. The main motive of this study in artistic portrait viewing is to identify associative relevance and to visualize the associative eye movement patterns.

We investigate the focusing of eye movements from cognitive perspective, including the associative nature of focal shifts, during scene viewing and analyze the patterns of sequenced focusing of eyes to visualize the information. Here, tracking of eye movements, comparing, and visualization of sequenced focusing patterns to extract information for interpretations are essential steps of this study.

Initially, eye movements, in terms of sequenced focuses, are collected from participants who view full-color scenes while engaging in a visual search task in which they are freely viewing different fields of each scene. Finally, we compare and analyze the sequenced focusing against the artistic scene. The underlying inherent associative relevance notions interpret the existing analogical thoughts cognitively in current research.

2.1 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 eyes to look a new location of the scene, the camera records new fixation also. This process of recording continues subsequently. The system generates eye movement tracks and heat maps using the captured data. We utilize these data for further analysis.

Figure 1 shows the schematic diagram of eye tracking system and basic processes involved during eye tracking experimentation.

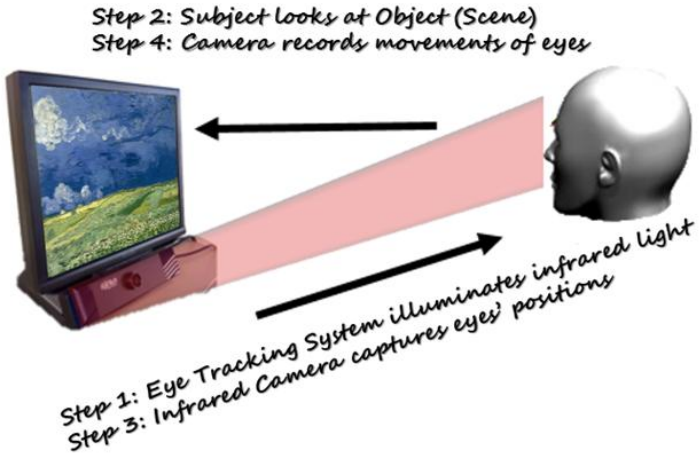

Figure 1. Eye tracking system with operational processes

We take the traces of eye movements in diverse layouts as per analyst's suitability. Among them, there are two most common formats are Heat Map and Sequenced Gazing (focus) with circle of concentration. In Heat Map, we record the track of eye as illumination and intensity of infrared light rays. This is Energy Therapy Technique (ETT) based process. In Sequenced Gazing, the system assigns the eye tracks as numbered circles with their areas indicating the time duration of eye gazing in those areas respectively.

In our experiments, we study the sequenced focusing of viewer's eye movements. The system generates sequenced focusing of viewer's eye movements during scene viewing. These focal shifts are associative relevance based stimuli that propagate during scene viewing.

2.2 Flow Chart of Study

The study on eye movements during scene viewing consists of a number of steps. We perform these steps one after the other to complete our study. The flow chart in the below Figure (Figure 2) shows these steps. This is a comparative study of two items; one item is artistic portrait and other item is the eye movement tracks of the same portrait generated from eye tracking system.

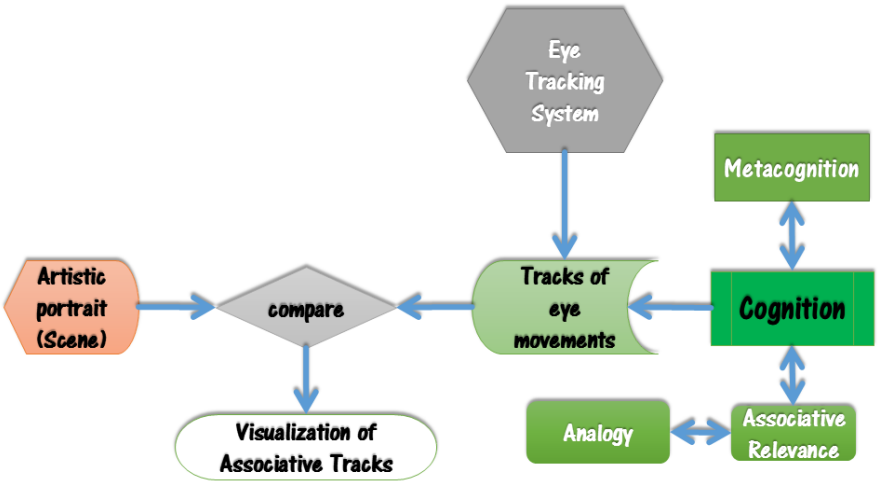

Figure 2. Flow chart of research study

It begins with recording of eye movement tracks for a Subject; a viewer on eye tracking system for an Object; artistic portrait. The generated tracks of eye movement of the same artistic portrait are comparable to the original artistic portrait. This comparative analysis infers visualization and interpretation of the outcome. Therefore, these two items gets a comparison side by side.

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

2.3 Experimental Procedure

We selected 47 participants from a number of fields within university, aging from 20 years to 37 years. These Subjects, the participants watched three randomly selected famous artistic portraits as shown below in Figure 3.

The artistic portraits were “Wheatfield with Cypresses” “Starry Night over the Rhone” and “Wheatfield under Thunderclouds” by Van Gogh.

Figure 3. Selected Artistic Portraits for research study

We closely monitored Subjects’ eye movements as they viewed 32 bits full-color artistic sceneries. A computer monitor displayed the Objects, i.e., the artistic portraits. The shown portraits were at a resolution of 1280 × 1024 pixels, subtended 15 deg. horizontally by 10 deg. vertically. Further, the viewers gazed at the artistic portraits 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 (circles with focused time-period in areas) and saccades (sequenced focuses with linear edges).

Furthermore, we held the Subject’s head steady in advance prior to experimentations. Prior to the first trial, Subjects completed a procedure to calibrate the output of the eye tracker against spatial positions on the display screen. We repeated this procedure regularly throughout the experiment to maintain high level of accuracy.

Subjects looked at the artistic portraits freely and generously.

Subjects saw the artistic portrait for a short duration of 25 seconds to limit perceivable attentiveness. During this time span, the Subjects viewed the portraits with their normal eyes and focused attention on the Object, i.e., the artistic portrait.

3. Analysis

In this phase of analysis, we analyzed all three portraits respectively with the intention to elaborate our findings in the most common and generalized perspective.

3.1 Study of Artistic Portrait 'Wheatfield with Cypresses'

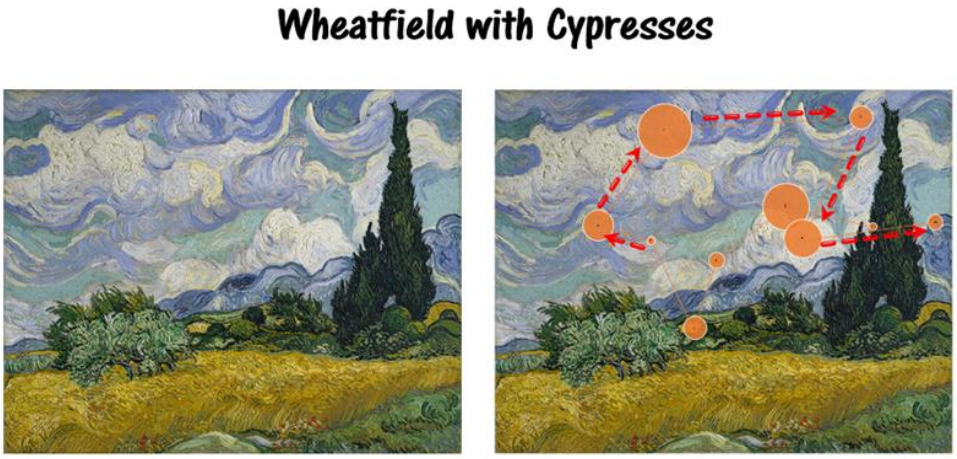

Figure 4. Portrait of 'Wheatfield with Cypresses' and sequenced focuses of the same portrait

In these eye-tracking experiments of Figure 4, the Subject attentively looked at artistic portrait of "Wheatfield with Cypresses" having widely extended Wheatfield along with green trees and bushes, and glossy and whirled clouds, etc. In the beginning, the Subject's sensation brought forward human consciousness to direct them gradually towards visual attention over the glossy and whirled cloud. At this stage, the Subjects perceived knowledge about the field of the portrait, which helped them to move to the next step.

However, the Subject looked at greenery of trees and central hut in the next visual relocation because of existence of cognitive dissonance based on irrelevant flows of cognitive thoughts. This brought the temporal pause in attention due to origin of novel flow of thought in the middle of earlier flow of thought for glossy and whirled cloud. Anyway, previous flow of thought for glossy and whirled cloud dominated again and recovered during the next visual focus of attention in eye movements (Solso, 2003; Turner, 2006; Liversedge, Gilchrist, & Everling, 2011; Solso, 1994).

Afterward, as the focus of attention shifted due to the nature of eye movements for information retrieval, the visual attention focused on glossy and whirled clouds. At this position, the Subject came across cognitively generated stimuli that evolved flows of analogical thoughts. These thoughts derived a sense of associativity among the focused clouds in subsequent movements of eyes. These types of associative chaining among relevant elements, i.e. the glossy and whirled clouds in the artistic portrait arose from cognitively induced factor and analogical thoughts. The glossy color of the clouds had brightness contrast types of associative relevance that cognitively influenced the movements of eyes. As the portion of the portrait was comparatively brighter than the remaining portions of the portrait, the contextual biasing of the visual field of the portrait caused this eye focusing phenomena. Further, whirled shape of the clouds grew stimuli based on associative relevance in their shapes, which propagated the flow of analogical thoughts to move forward in the focus of attention during eye movements.

Later interviews of the Subjects suggested that the visual fields of brightness contrast were the subject of interest to the Subjects. Further, related fields of similarity compelled them to shift their eye focuses dynamically. Moreover, whirled shaped clouds established the portions of interest in the portrait, where these shapes had similarity or sameness. Hence, the conclusion came from undergoing cognitive processes of Subjects' minds in portrait viewing that the associative relevance based stimulus shifts visual focus in eye movements.

3.2 Study of Artistic Portrait 'Starry Night over the Rhone'

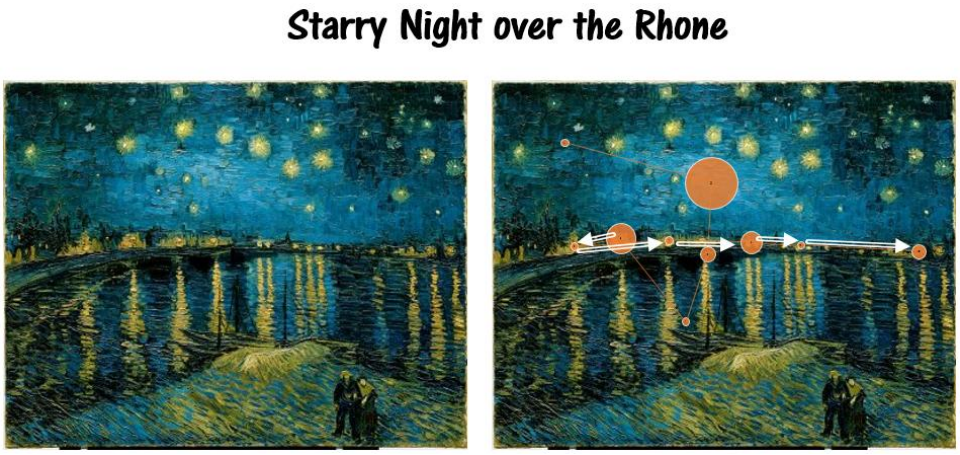

Figure 5. Portrait of 'Starry Night over the Rhone river' and sequenced focuses of the same portrait

In these eye-tracking experiments of Figure 5, we presented an artistic portrait "Starry Night over the Rhone River" which was an artistic expression of a view over Rhone River in a night when the stars were twinkling. In the beginning, the consciousness of the Subject developed visual attention and the Subject started focusing at central brighter field of illuminated sky and persisted there longer for processing information to perceive and retrieve the knowledge. Next, due to top to down scan path consideration, the focus of visual attention moved downwards in the portrait. Here, cognitive dissonance affected the eye movements and diverted from the previous flow of thought related to illuminated sky to newly developed and irrelevant flow of thought (Solso, 2003; Turner, 2006; Solso, 1994; Liversedge, Gilchrist, & Everling, 2011).

However, the temporal pause in previous flow of thought due to cognitive dissonance passed through a recovery phase and retrieved the flow of thought. Subsequently, Subject's visual focus of attention moved to the illuminated source across the river due to the influence of brightness contrast biasing in the visual fields of the portrait. This brings visual perception to the Subjects for the knowledge of context and relevant fields. The existing cognitive process in the human minds enlightened the other coexisting processes, i.e., the process of analogical considerations and the process of linking visual elements of portrait based on associative relevance.

The Subject's visual focus moved towards next contextually biased visual field of the portrait, which was a field of brightness contrast. The process of analogical considerations guided the Subject's visual focus to think about the associative context of visual fields in the portrait, i.e., illuminated sources across the river. Such associative relevance under the basis of brightness contrast originated cognitively generated stimuli that exerted drive to assist visual focus to proceed further in the direction of associatively relevant elements of the portrait. Further, the focal shifts in eye movements reflected this associative relevance based chaining under the influential cognitive processes.

Later interviews of the Subjects realized these facts as well. They narrated that they were actively looking at similar bright regions of the scene because they were excited to know about these immensely lightened fields and the field in the middle of intense light. This inferred the presence of associative relevance based stimuli that shifted the visual focus of eye movements within the artistic portrait.

3.3 Study of Artistic Portrait 'Wheatfield under Thunderclouds'

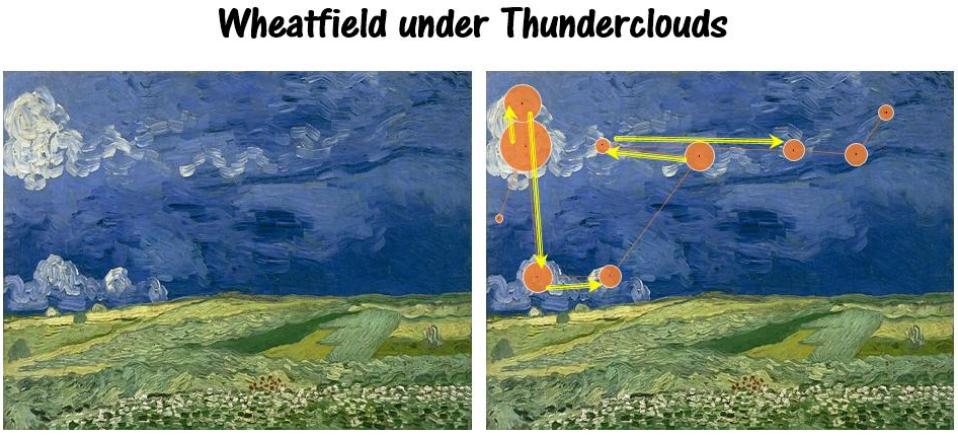

Figure 6. Artistic portrait of 'Wheatfield under Thunderclouds' and the sequenced focuses of the same portrait

In these eye-tracking experiments of Figure 6, we portrayed an artistic portrait "Wheatfield under thundercloud" in which there was a very large filed of harvested wheat crop along with the thundering clouds. In the beginning, Subject's consciousness brought visual attention on dense thundering cloud of relatively more illuminated. The Subject moved the focus of attention towards this cloud due to brightness contrast biasing. At this point, the Subject cognitively initiated information retrieval from the visual field of the portrait. Hence, the Subject came across the phase of visual perception from the element of the portrait and successfully perceived. Next, the Subject changed the visual focus to the adjacent cloud of the same level of brightness contrast. The contextual elements of the portrait revealed consideration of analogy and underlying mechanism of linking based on associative relevance among these elements of the portrait. Such associatively relevant elements of the portrait instigated cognitively structured stimuli that applied impetus over the focus of visual attention to shift towards the next field of relevant interest. Consequently, the visual focus of eye shifted to next illuminated cloud (Solso, 1994; Turner, 2006; Solso, 2003).

Subsequently, by the process of associative relevance based elemental searches within the visual fields of the portrait, the Subjects shifted focuses in sequence to the visual field of related contexts. The process continued and moved towards upper portions of the portrait. Thus, associative relevance based stimulus shifted the visual focus in eye movements during artistic portrait viewing.

Later interviews of the Subjects confirmed their interest in looking for illuminated and thundering clouds. Though they missed in the middle of active seek, yet they were keen to have. The thundering bright clouds were the portions of interest in the artistic portrait. Hence, we observed that these cognitive processes brought a conclusive outcome from the portrait with associative relevance notion over visual fields contextually.

4. Discussion

In this study, the artistic portraits cover their reflection with the main objective of artistic artworks in the shape of human cognitive mechanisms in viewing these artistic sceneries. These creative pieces of art manifest inherent human interactions to perceive information and interpretation of realistic world in human mind for understanding. These cognitively shaped emotional outlooks are too problematic to apprehend from data computing and machine based analytics. Consequently, eye movements determine and discover these cognitive perspectives and human thoughts for associative relevance notion in scene viewing (Viegas & Wattenberg, 2007; Tsotsos, 2011; Gompel, Fischer, Murray, & Hill, 2007; Henderson & Hollingworth, 1998).

The shifts in visual focus during artistic portrait viewing are profound steps for proper retrieval of task-relevant visual information, which are the requirements for visualization of final maps generated by eye tracking system. In this study, we notice that the generated eye movement tracks of sequenced focuses are remarkably associative in nature. These are major evidences to verify an association of analogical mapping based on contexts. Further, even a short-term failure of these associative mapping processes of analogical contexts as in the above-mentioned analysis due to cognitive dissonance caused by two irrelevant cognitions within a moment, conveys a completely different outcome for that moment. As a result, without taking account of associative

relevance of analogical mapping, it is impossible to link the entire scenario of human cognition in the sequential eye focusing of eye movement tracks. Further, the origin of associative relevance based stimulus is inseparable entity that has shown its evidence in the experimentations for eye movements.

Choosing an art as an aid to understand underlying mechanism of human cognition is a matter of discussion as well. As a human mind operates to mediate between the environment and the needs of the organism, an artistic creation comes into action to increase consciousness of human mind. Further, various enhanced states of consciousness might be achieved in the future through art, as some experimental means have already undertaken to do. As per available literatures, it is very sure that viewing an artwork can raise human consciousness significantly (Turner, 2006; Solso, 1994; Solso, 2003; Viegas & Wattenberg, 2007).

Furthermore, the reclamation of associative mapping from its deviated scan path stage due to temporary loss of sight or visual color based cognitive effects in addition to cognitive dissonance thoughts during eye movements for visual focal shifts is remarkable from the perspective of its proficiency. This proficiency of repossession is a convinced sign of coherent and consistent associative mapping founded in between the relevant visual fields of the artistic portrait passing through human cognitive processes. These repossessions of associative relevance are efficient of acquiring irreplaceable and unaffected overall outcomes despite unexpected interference during artistic portrait viewing (Griffin, 2004; Stark & Ellis, 1981; Snowden, Thompson, & Troscianko, 2012; Bly & Rumelhart, 1999).

During last stages of experimentations, the visualization of associative relevance of visual contexts in terms of associative eye movement tracks is a strategic and conclusive part of unabridged accomplishments. The visualization of associative eye movement tracks, in terms of associatively relevant visual contexts found in eye movements is unarguably innovative point of view for the specialists who study them for specific intents. Even though the existence of analogical concept and associativity in relevant visual contexts or intents are available in the concerned literatures, yet its manifestation and elucidation contrasts considerably as being different aspects of the same thing. In this regard, the visualization of associative eye movement tracks reveals once more the existence of associative relevance in visual contexts or visual elements of artistic portrait during scene viewing.

Furthermore, the experimental evidence of associative relevance during active portrait viewing holds our hypothesis for which we conducted a series of experimentations. The hypothesis that associative relevance based stimulus shifts visual focus in eye movements is credible, convincing, and innovative creativity related to eye movements study.

5. Limitation and Further Research

Although our findings suggested the existence of stimulus based on associative relevance and further, the ability of the stimulus to shift the visual focus of attention during eye movements, yet there were limitations for a detailed model of human visual attention and perception based on analogical thought and associative relevance based notion.

In future, we concentrate our research in the direction of a generalized model for human visual attention and perception based on the influential factors like, associative relevance based stimulus, analogical thinking, and other essential factors. In addition, we converge our experimentations for better scenarios, so that we may understand the detailed illustration of cognitively generated dynamics of human visual perception and inherent processes during eye movements.

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