



Analysis of Fixation Parameters during Visual Search

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Abstract—

The path traversed by eye movements is called as scanpath. The event of scanpath majorly consists of two components that include saccades and fixations. While saccades represent random movements of eyes, the fixations are related to viewing visual scene regions for a constant period of time. Fixations have been an important scanpath component that could reveal behavioral characteristics of individuals during various real life domains. One of the important domains of eye movement analysis is visual search where a target object has to be found among a group of distracters. Analysis of fixations during visual search could reveal vital information about search pattern of individuals. Many interactive and diagnostic applications could be developed based on information about search pattern of individuals.

There are various parameters related to fixation components of eye movements. Fixations have been generally analyzed in terms of fixation parameters. In this paper two important fixation parameters that include maximum fixation duration and total fixation duration has been analyzed during two experiments of visual search. The results suggest complexity of image during visual search impacts identified parameters of fixation.

Keywords-Fixations; visual search; maximum fixation duration; total fixation duration.

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I. INTRODUCTION

Eye movement analysis has been an important area of research. Eyes are the vital facial features that could reveal information about underlying cognitive inclination and processing. The analysis of eye movement data could potentially present an insight about human behavioral pattern and objects of interest [1, 2]. Eye movement analysis has been a part of many research domains that include medical, marketing, gaming, psychology, advertisements, scene viewing and visual search [3, 4]. Various sophisticated head mounted devices and remote equipments have been employed for detection of eye movements. The recorded data has been analyzed using different data processing software [5]. The path traversed by eye movements in presence of any visual scenario is termed as scanpath [6]. The important components of scanpath are fixations and saccades. Fixations are defined as the constant looking of eyes at a particular object or scene. Saccades are categorized as corrective eye movements that do not reveal much information about human behavioral tendencies. However, fixation analysis represents one of the methods of understanding human cognitive and behavioral patterns [7, 8]. Fixations have been generally understood in terms of parameters associated with

fixations. The two most common fixation parameters are maximum fixation duration and total fixation duration [8-10]. In this paper the parameters have been analyzed on data of visual search experimentation. The domain of visual search is a prominent area of research where the impact of distractions in finding the actual target object is observed. The distraction can be in the form of increased number of heterogeneous objects, high color similarity between foreground and background objects and high similarity between target and non target objects [11, 12]. In the present work two experiments of visual search have been discussed. In the first experiment a total of ten subjects search for objects in two images. The experiment showed inconclusive results for the parameter 'total fixation duration'. Therefore the experiment has been repeated further on thirty one subjects for better understanding of impact of visual search on parameters of fixations. The method of detection and analysis of recorded eye movement data has already been reported in the previous work [13]. The next section discusses about the related work on the parameters of scanpath in the domain of visual search.

II. RELATED WORK

The research in the domain of visual search suggests a relationship between fixations and scene complexity.



The complexity of scene is directly proportional to the presence of distracters during visual search [14, 15]. Presence of complexity in a scene impacts movement of eyes. One of the methods for analysis of impact of scene complexity on eye movements is through quantification of values for parameters related to fixations. The parameter 'maximum fixation duration' is the longest time consumed during a particular fixation among all the fixations. The parameter of 'maximum fixation duration' is computed during all the experiments of visual search for every individual. Another parameter of fixation 'total fixation duration' indicates the cumulative sum of time duration for all the fixations during visual search scenario by an individual. Many researchers suggest that longer fixation duration during a visual search in comparison to another visual search may indicate former being more complex than the latter [16, 17]. Also higher fixation duration can be an indication of visual scene being interesting and relevant [18, 19]. An increase in fixation duration has been observed during visual search where target visibility is less [18, 20]. Some authors also suggest that complexity of scene might not impact total fixation duration and maximum fixation duration [21]. In the previous work presented by the authors [13], it has been found that parameter of 'total fixation duration' remained inconclusive. The parameter of 'maximum fixation duration' has been higher for image with higher number of heterogeneous objects than image with low chromatic variation. Since the result of 'total fixation duration remained inconclusive, in the present work the number of subjects have been increased to thirty one. In the present work a

comparative analysis between previous experiment of visual search and the current experiment of visual search has been put forth. The analytical results have been derived for the two identified parameters of fixations. The results suggest that scene complexity has a definite impact on movement of eyes as will be discussed in section IV. Section III presents a discussion on the methodology implemented for analysis of fixation parameters during visual search.

III. METHODOLOGY

In this section experimental structure of the present work has been discussed. An overview of the setup, subjects and images used for experimentation has been presented.

A. The Setup

A digital camera with a resolution of (4592x3056) with 1.42 megapixels has been used that captures eye movements. The camera with a frame rate of 25fps has been placed on a tripod. The subjects have been seated at a distance of 50cm (l_1) from the camera. The face of subjects has been rested on a chin rest. The distance between camera and screen has been kept as 200cm (l_2). The dimensions of the screen has been 158x252 cm² ($l_3 * h_1$). Fig. 1 presents a general overview about the experimental setup that has been employed for detection of eye movements. The placement of screen, subjects and camera has been set in a way to ensure proper detection of eye movements while subjects perform experimentation of visual search. A description about the images used for the present experimentation has been put forth in next sub section.

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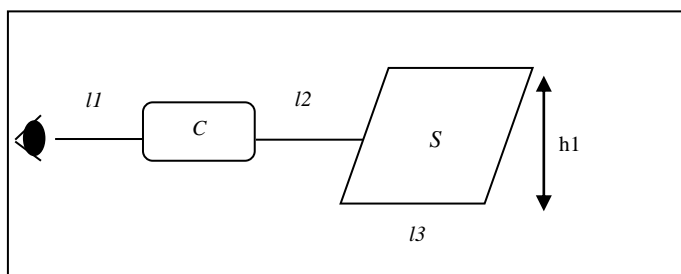


Figure 1. Experimental setup for eye movement detection. $l_1=50cm$, $l_2=200cm$, $l_3=252 cm$, $h_1=158 cm$.

B. Images of Visual Search

A total of two images have been displayed before the subjects, one after another. In the first image a board with 'Thank You' written has to be found (@Wegmans on twitter via Business Insider). The image is a representation of heterogenic content. Once the subjects find the board, the subjects have been directed to close their eyes to mark the end of one visual search

scenario. In the next image the subjects have been directed to find parrot in an all green background (www.artwolfe.com via cogtography.wordpress.com). The image represents less chromatic variation between foreground and background. Fig.2 presents the images shown one after the other with objects to be found encircled.



Figure 2. Images (a) and (c) are the images shown to subjects. Images c) and (d) encircle objects that have to be found in the respective images.

C. Subjects and Analysis System

A total of 41 subjects have been analyzed during the experimentation. In the first experiment a total of ten subjects perform visual search on the presented images (Fig. 2). In the second experiment a total of thirty one subjects perform visual search on the two images presented (Fig. 2). The subjects aged between 21 to 45 years have been made to sit for the experimentation. The analysis system for the experimentation comprises of different algorithms and techniques. Separate technique has been implemented for eye detection, iris detection and tracking. Algorithms have been implemented for isolation of fixations and associated parameters. The detection and analysis system has already been explained in previous research paper [13].

In the next section a discussion on results obtained for the two identified parameters of fixations has been put forth.

IV. RESULTS AND DISCUSSION

During experiment one, the results of parameter 'maximum fixation duration', and 'total fixation duration' for ten subjects have been calculated. The results have been presented in Table 1. The results indicate that parameter of 'maximum fixation duration' has generally been high during image 1 than image 2 visual search. A total of three subjects i.e. subject 3, subject 7 and subject 9 show results otherwise. For the parameter of 'total fixation duration' nothing conclusive can be inferred as the difference of obtained values is very less and many of the subjects exhibit almost similar duration of total fixations. Also none of the two visual scenario show higher values for total duration of fixations consistently.

TABLE I. RESULT OF FIXATION PARAMETER DURING IMAGE 1 AND IMAGE 2 VISUAL SEARCH. M- MAXIMUM FIXATION DURATION. T- TOTAL FIXATION DURATION. TIME DURATION OF M IS IN MILLISECONDS AND T IN SECONDS.

| Subjects | Image 1 | | Image 2 | |
|------------|-------------|------|-------------|------|
| | M (ms) | T(s) | M(ms) | T(s) |
| Subject1 | 1520 | 13 | 1000 | 15 |
| Subject 2 | 2320 | 05 | 1960 | 04 |
| Subject 3 | 2160 | 05 | 2920 | 07 |
| Subject 4 | 2320 | 04 | 1120 | 04 |
| Subject 5 | 1120 | 06 | 760 | 04 |
| Subject 6 | 4520 | 06 | 560 | 02 |
| Subject 7 | 800 | 07 | 1480 | 10 |
| Subject 8 | 1760 | 06 | 1360 | 05 |
| Subject 9 | 560 | 03 | 800 | 03 |
| Subject 10 | 1000 | 03 | 960 | 05 |

The average results of the two parameters show that parameter of ‘maximum fixation duration’ on an average has been higher during image 1 visual search than image 2 visual search. The average results of parameter ‘total fixation duration’ show almost no difference of values (Fig.3).

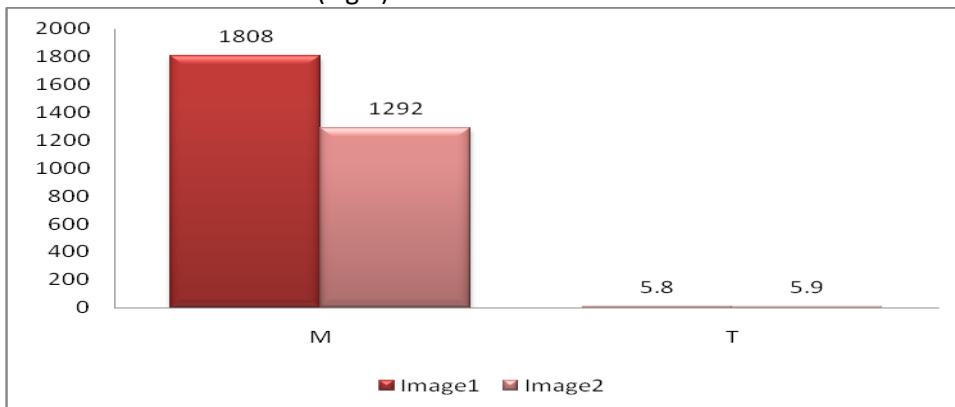


Figure 3. Average values of fixation parameters for image 1 and image 2

Based on the obtained values it has been observed that no definite conclusion could be given out based on the available data. since out of two one parameter is inconclusive. The parameter of ‘maximum fixation duration’ although show higher values during image 1 visual search, but one cannot designate image 1 being more complex than image 2. Many of the reserachers suggest presence of higher ‘maximum fixation duration’ for complex visual search tasks and many suggest vice versa. So the authors conducted experiment second. In

the second experiment thirty one subjects have performed the experiment of visual search. It has been found that around twenty subjects exhibited higher values for ‘maximum fixation duration’ during image 1 visual search than image 2 visual search. A total of eleven subjects show higher values of ‘maximum fixation duration’ for image 2 visual search. Fig.4 presents the values generated during visual search task on image 1 and image 2.

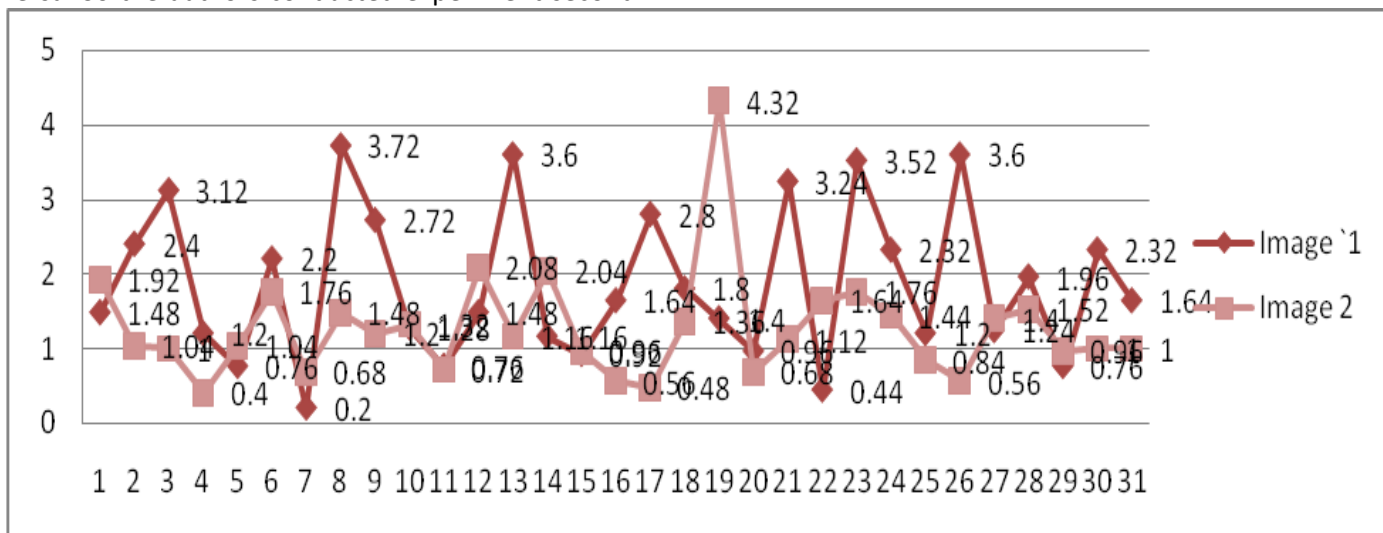


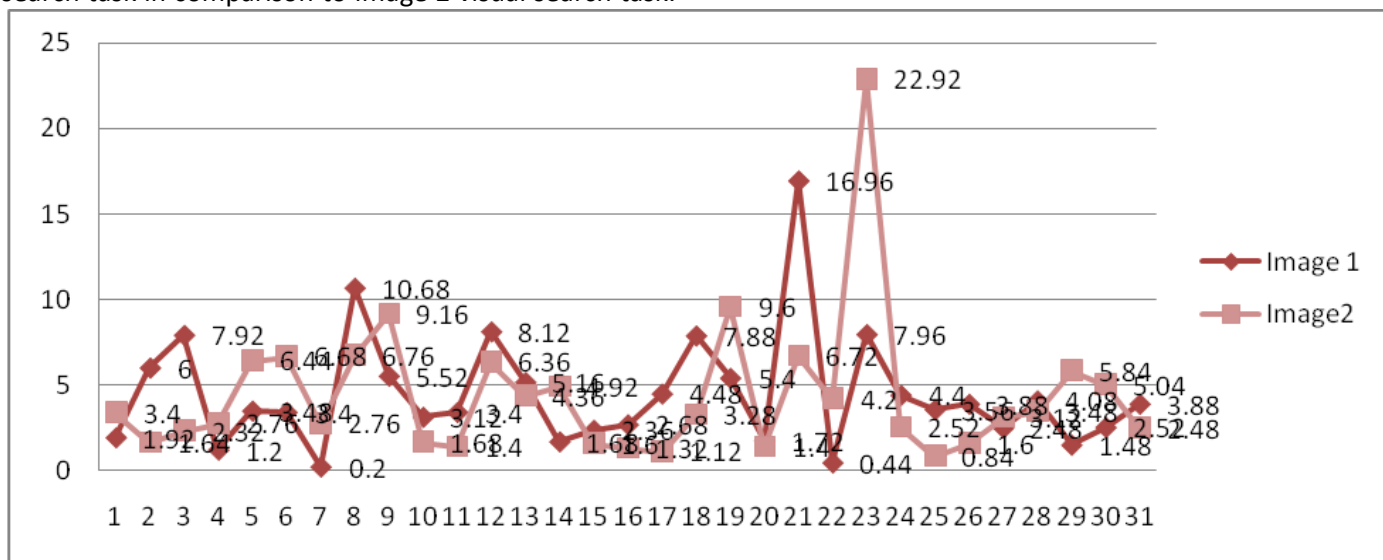
Figure 4. Result of ‘maximum fixation duration’ during visual search task on image 1 and image 2. Values of time duration is in seconds.

The result of parameter ‘total fixation duration’ indicate a total of eighteen out of thirty one subject exhibit higher values during image 1 visual search task. A total of thirteen subjects have higher value of ‘total fixation duration’ during image 2 visual search. Fig. 5 presents the resultant values of ‘total fixation duration’ during image 1 and image 2 visual search task. Fig. 6 presents a cumulative values for parameters of ‘total fixation duration’ and ‘maximum fixation duration’ during image

1 visual search and image 2 visual search. The results of ‘total fixation duration’ and ‘maximum fixation duration’ during visual search on image 1 and image 2 indicate towards higher values during image 1 image one visual search in comparison to image 2 visual search. The results indicate towards the images with higher heterogeneic content might be difficult to process for individuals than images with less chromatic variation. However the difference of values generated is very low,

Also the difference of subjects with higher values of fixation parameters is low. Many subjects out of thirty one subjects suggest higher fixation parameter values during image 2 visual search. The cumulative results do indicate higher values for during image 1 visual search than image 2 visual search. However the difference between generated values is low. The results indicate that image 1 might have been difficult to process during search task in comparison to image 2 visual search task.

However the low difference of resultant values suggest that the visual scenes with high heterogenic content and low chromatic variation might impact eye movements almost on the same level. To fully understand the impact on fixation parameters of eye movements, the authors suggest increase in number of images to be show to subjects. The images need to be of varied content with high target distracter similarity.



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Figure 5. Result of 'total fixation duration' during visual search task on image 1 and image 2. Values of time duration is in seconds.

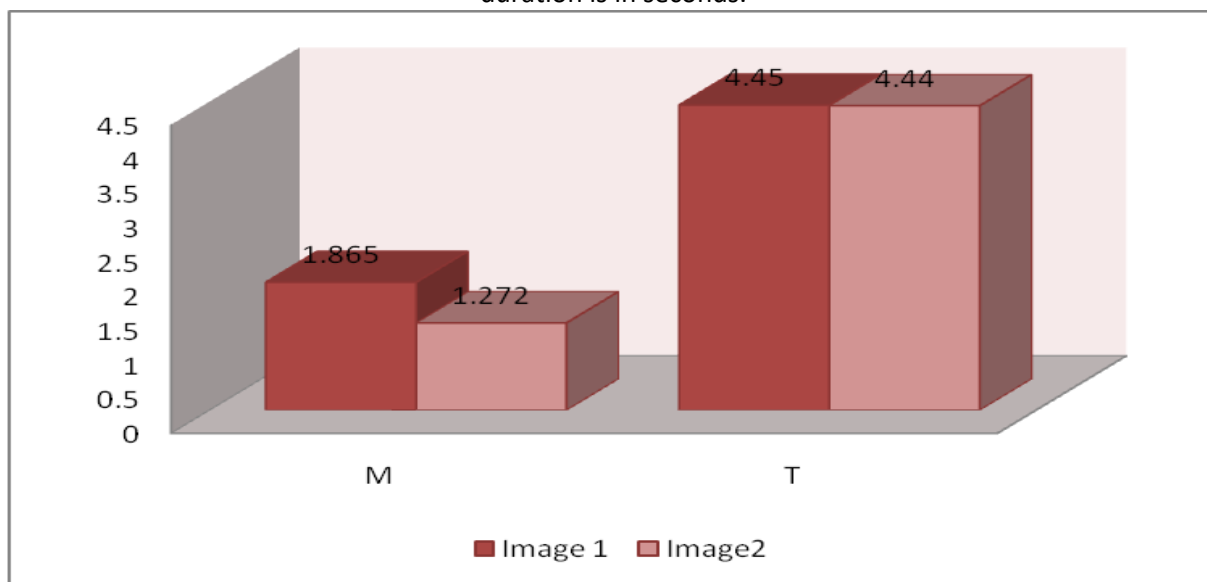


Figure 6. Average result of 'maximum fixation duration' (M) and 'total fixation duration' (T) during visual search task on image 1 and image 2. Values of time duration is in seconds.

Figure 7.

V. CONCLUSION

In this paper two parameters of fixations have been analyzed. The analysis has been undertaken during two experiments of visual search. Two images of different content has been shown to subjects. The subjects have been directed to spot specified objects in the two

presented images. The results indicate towards heterogenic content being difficult to process for subjects than low chromatic variation content. However the difference of generated results indicate low difference of impact on fixation parameters. Also the difference in number of subjects with higher values for



fixation parameters between the two visual search scenarios has been less. The authors suggest increase in the number of images. The images should have varied content with high target distracter similarity.

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