GU J Sci, Part B, 8(4): 709-719 (2020)

Gazi University

Journal of Science

PART B: ART, HUMANITIES, DESIGN AND PLANNING

http://dergipark.gov.tr/gujsb

USE OF EYE TRACKING TECHNOLOGY IN EVALUATING PRODUCT IMAGES AND OPTIMAL PROCESS DECISIONS

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Article Info

Received: 09/10/2020
Accepted: 23/11/2020

Keywords

Eye-tracking, Optimal Image Display Decision, Image Evaluation

Abstract

Evaluation of visual elements constitutes a significantly important input in the field of design as well as in numerous other fields. We are on the verge of a transformation where users generally meet the product on a screen, also with the influence of changing lifestyle habits. Within this scope, the time users spend with visual elements and collection of information about the said process constitute an important topic of research. This study focused on the evaluation of images via eye-tracking technology. Variables such as the repetition, number, order, and layout of the elements that form an image are known to affect the use of images. This experimental study was conducted in 3 different steps with the users and the obtained results were provided here. In this context, application recommendations were provided concerning the order of visual pages, properties of transition between images, the time factor, and content layout.

1. INTRODUCTION

Evaluation of products by users is a topic that attracts the attention of designers. While such evaluations sometimes take place when users have a direct encounter with and experience the product, some users provide comments about a product via digital platforms. In today's circumstances, remote product evaluation has become increasingly important, considering most experiences take place in an online or remote environment. In this context, it appears to be important that users can obtain information from product visuals in the product evaluation process. It is asserted that product visual designs provided an idea about the product for the consumer [1]. The way of using the visual design constitutes importance for users to form a judgement about a product or in order to pass a judgement to the user. These inputs would help designers make better design decisions and have new product design possibilities. The significance of eye-tracking outputs has been underlined in determining both the important features while selecting a product and the noticeable or unnoticed changes on the product [1]. Another study, on the other hand, focused on interpreting and guiding the user's interest in computer graphics, image and object perception, and visual search applications [2].

Such studies provide vital input about the properties of information provided by the use of technology via eye-tracking. While the utilization of technology provides data input for design, it also leads to shorter design processes and affects product-related decisions. Studies demonstrating that people perceive 90% of the information coming from the external world with their eyes suggest that eye-tracking technology, that has been increasingly popular in recent years, could contribute to the studies and provide new methods for the designer [3, 4].

In the present study, the pursuit of an evaluation practice associated with design processes was addressed as the main source of motivation. Here, developing the opportunities provided via information, appreciation, and cognitive factors by the use of technology and the methods that would contribute to the provision of inputs were considered essential.

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2.AIM AND SCOPE OF THE STUDY

The main purpose of this study was to provide information about the optimal methods of using eye-tracking technology in order to contribute to the design process. In this context, ways of obtaining information by the researcher using eye-tracking technology were investigated with a product example. Here, the first stage involved answering the question "how will the visual elements that will eventually be the end product meet the user?". In the study, it was first aimed to question the ideal variation, order, sequence, and time in the screen display via generic pattern images, before proceeding to a product example. Therefore, the goal of the study was to focus on the components of a discussion that questions the optimum number of images and the optimum way of placing the images on the screen and interprets the same in association with eye-tracking technology. Attempts were made to provide the designer with a road map on how blank pages between images and repeated display of the images should be via gaze metrics.

Answers to the following questions were sought within the scope of research:
- What should be the optimal number of products that can be simultaneously evaluated by the user?
- How should the products be positioned on the screen?
- Should the time provided for image evaluation be limited or unlimited?
- How should be the order of displaying images in a repeated, sequential, and consecutive manner?

Experimental studies have been conducted using eye-tracking technology via pattern images in order to answer the research questions. The following display criteria were determined for the images:
- Number; single (1) or multiple (9)
- Page layout; horizontal or vertical
- Duration of image evaluation
- Repeated display
- Order of display
- Properties of transition between images

and the experimental studies were conducted within this framework.

In the scope of this study, first of all, generic pattern examples were designed in a manner to enable visual and multiple examinations. Eye-tracking metrics were recorded for all participants, while they watched and focused on the two-dimensional images of products on the screen, using eye-tracking technology that would provide data input for design. The output of the study showed how the product presentations and displays should be in accordance with the results obtained from user behavior.

3.THEORETICAL BACKGROUND

The designer needs to understand the user in order to design the proper product for users. A designer can only improve his/her works by an accurate interpretation of the relationship between the product and the user. Sensory evaluations are important in the interaction between the user and the product. A model was developed relating to product design communication [5]. The said model focuses on the transfer of a message from the designer to the person for whom the product is intended via a channel. In this model, the designer conveys messages to the user with product design. The mentioned model was improved in another study [6]. As shown in Figure 1, the producer and consumer meet for the first time, when users perceive a product with their senses. The concept of consumption relates to the channel that encompasses the geometry, size, texture, material, color, graphics, and details of a product and sense of the same by users through seeing, touching, tasting, smelling, and hearing as well as to the cognitive, emotional and behavioral reactions of the consumer. The product is the carrier of the message and users receive such messages from the product via their senses. Therefore, users are the receivers of the message.

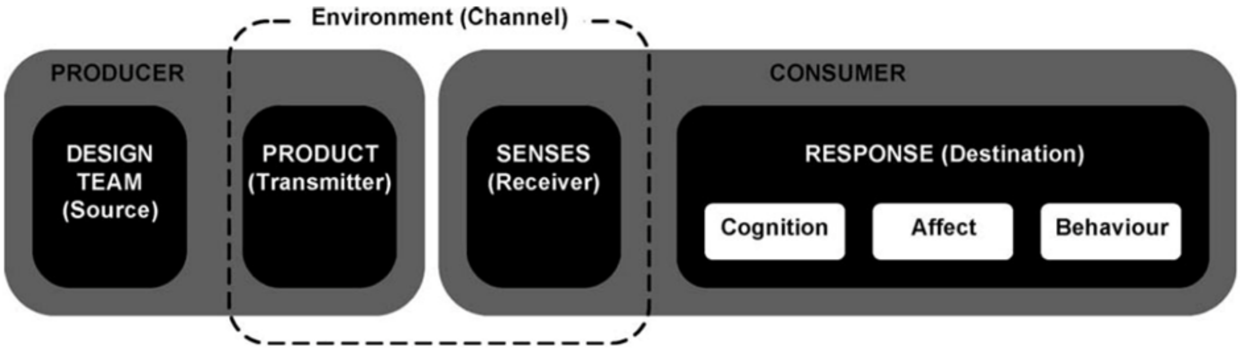

Figure 1. Model of design as a process of communication [6]

The advancement of technology affects the design processes for industrial products, thereby leading to radical changes in user-product interactions and ways of transmitting the messages [7]. Technologies (such as artificial intelligence, virtual & augmented reality, eye-tracking) that have an impact on product design directly determine the way a designer handles and the improvement process of a product as well as how a product becomes the end product. It is stated that technological innovations taking place in the 21st century have a considerably high potential of altering the industrial design practice significantly. Worldwide access to the internet has expanded the communication network of designers, digital technologies have created new opportunities and digital design tools have shortened the distance between the designer and user, all of which will affect the future studies of industrial designers [8]. These opportunities have a role in the improvement of design by technology in a manner that generates information, assists the practice of design and affects product decisions. For instance, artificial intelligence technology provides information processing and information input to solve the design problem since it is important to understand the user's mindset about how to use the product and to simulate the behaviors [9]. Products with artificial intelligence, which have characteristics such as human emotion, thought, behavior and intuition, turn machines into intelligent and thinking devices. It has been a big step to understand and feel people in order to develop better products [10].

The strong relationship between products and senses and the fact that technology is advancing to generate information for design constitute a field of study that will guide the designers. Moreover, since 90% of the information reaching the brain is visual and 65% of people are visual learners, the eye and sense of sight are considered the most important sensory elements in the field of design, which supports the studies that focus on the said elements [4, 11]. It is underlined the importance of eyesight for designers and suggested analyzing gaze in order to understand its effect on the design process and provide data for design education [12]. A designer focusing on the sense of sight in order to understand the psychology of users and their approach to a product in addition to interpreting the visual attractiveness of product design would be reaching the most important mediator in the user-product relationship. The esthetic experience begins by visually examining a product. A multilayered communication that consists of bottom-up and top-to-bottom transitions between the senses is used to discover eye movement behavior [13, 14]. While designers use visual information to solve a problem, make a decision, and create a concept, consumers use the same to make a judgement about appearance, value, and product preference.

In recent years, eye-tracking technology has been widely used in design processes, particularly in a testing website and packaging designs. These images can be shown to users in order to analyze data collected simultaneously on where users look and focus on. Besides, static two-dimensional product images are utilized most of the time to evaluate the design of three-dimensional products from the esthetic aspect [15]. In the last century, visual stimuli have significantly evolved from analog and static towards digital and interactive. Since digital activities constitute a major part of modern life (for instance, looking at an image on the screen and magnifying and zooming in to analyze the image), eye-tracking technology has also been intensively used on dynamic stimuli. However, it is difficult to accurately determine eye-tracking data for dynamic stimuli [16]. Studies on psychology and perception revealed that people focused on static visual stimuli (location, color, the shape of the object etc.) for longer periods, therefore seeing the details by more careful and repeated gazes [17]. Consequently, showing a static image to the user was considered a suitable solution when a detailed evaluation of an object was required. The demonstrated eye-tracking metrics contain data such as fixation duration/count/percentage, visit count/duration, pupil diameter, time until the first fixation, duration of the first fixation, number of blinks, etc.

It is asserted that eye-tracking technology was a suitable method to understand, design, and evaluate user experience. Visual hierarchy maps directly reveal where a person is looking at and in what order as well as the areas that are fixated on [18]. These evaluations of visual analytics can be undoubtfully obtained digitally by using eye-tracking technology [19].

It was reported that the lack of recorded and quantitative results was the limitation of relevant studies [20]. Eye-tracking studies can reveal how the design elements on a product such as color, details, and balance could affect the total esthetic perception of an image. Therefore, designers can eliminate problems such as people forgetting, ignoring, or not noticing where they looked at with eye-trackers employed in user research [21].

4.METHODOLOGY

The study that aimed to utilize an eye-tracking technology as an evaluation and data acquisition tool in the field of design was conducted with the Tobii X2-60 mobile eye tracker and the unportable eye tracker, i.e. Tobii T120, located at the human-computer interaction (HCI) laboratory of METU. Within this scope, the experiments were conducted with a total of 22 participants (10 females and 12 males) aged between 20-45 who were studying at or graduated from the department of industrial design. Participants were included in the study if they did not have any eyesight problems.

4.1 Preparation of images

According to the examples in the literature, eye-tracking studies were conducted by showing products and images to the user, while displaying a different number of products on the same screen. In some studies, only the product that was fixated on was centered on the screen, whereas other studies employed paired comparison groups or layouts that involved a simultaneous display of multiple products (the number of images fixated on, e.g. five, six, eight, ten) to the user [22, 23]. In the present study, generic patterns were used instead of products in order to eliminate the effects of product-participant interaction. At the stage that involved the order and layout of contents to be displayed to the participants, different pattern samples were evaluated, and possibly suitable 15 available pattern images were selected (Figure 2).

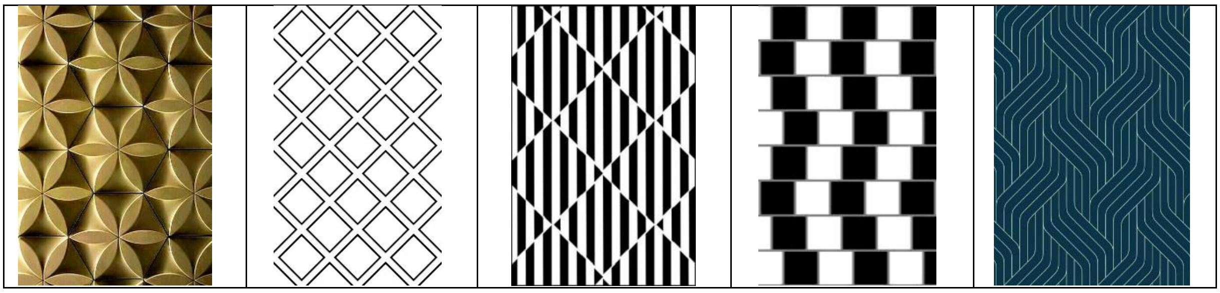

Figure 2. Examples of patterns used in the study

Each pattern sample was rendered ready to use in a manner enabling a different examination each and 18 alternative ways of the display were designed by placing a different number and layout of patterns on the screen (see Figures 4 and 5).

4.2 Experiments

The experiments were conducted in two stages. 12 participants used the Tobii X2-60, mobile eye-tracker, in Stage 1 and 10 participants used the Tobii T120 device at the HCI laboratory in Stage 2. Meanwhile, procedures concerning the use of these two different devices were conducted. In this two-layer process, each experiment lasted approximately 30 minutes with each participant, and a completely silent environment was provided while participants examined the different patterns so as not to distract them. This process is shown in detail in Figure 3.

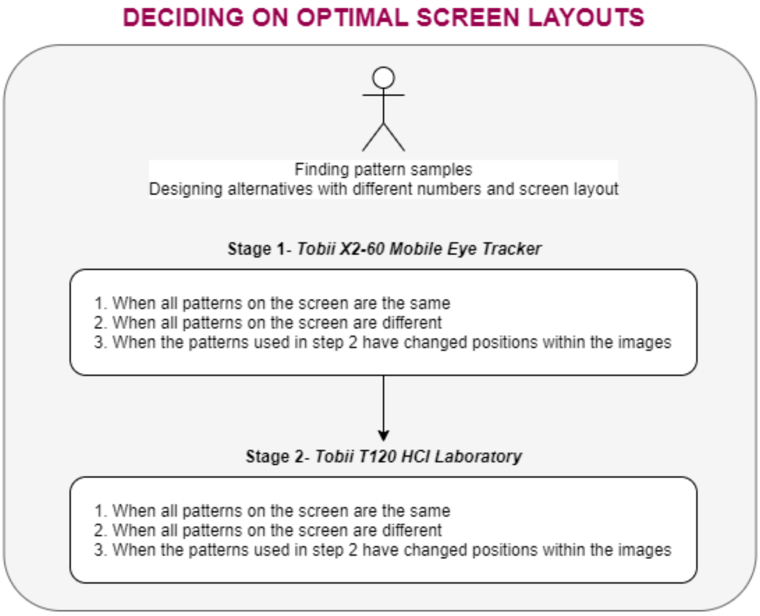

Figure 3. Process of the conducted experiments

Here, the main focus was the layout of images on the screen. Therefore, details of the visual interaction to be established with the participant were first investigated before conducting the studies on the product. At this stage, diversifications considering the variables such as the number of displayed products, i.e. single or multiple, vertical or horizontal layouts, and products aligned in a single line or multiple lines were found to be important.

Stage 1- Tobii X2-60 Mobile Eye Tracker

As a preliminary preparation for the experiments, the first applications were performed with the mobile Tobii X2-60 eye tracker. This device was employed by connecting to a laptop in the workplace of the participants. Since it is a mobile eye-tracker it can be connected to different-sized screens, but the recommended screen size is up to 25-inch computer screen. The eye-tracker was operated with a distance of 70 cm to the participant. Gaze data were recorded at 60 Hz data rate and 30-35 milliseconds of delay. The studies were carried out with previously prepared experimental models (alternative screen layouts) on the computer. A single image as well as two, three, four, five, six, and nine images were shown to the participants with different screen layouts. The study was completed in three steps.

1. When all patterns on the screen are the same: In step 1, the same patterns positioned with different vertical and horizontal layouts were shown to the participants with each screen layout containing one to nine images (Figure 4).

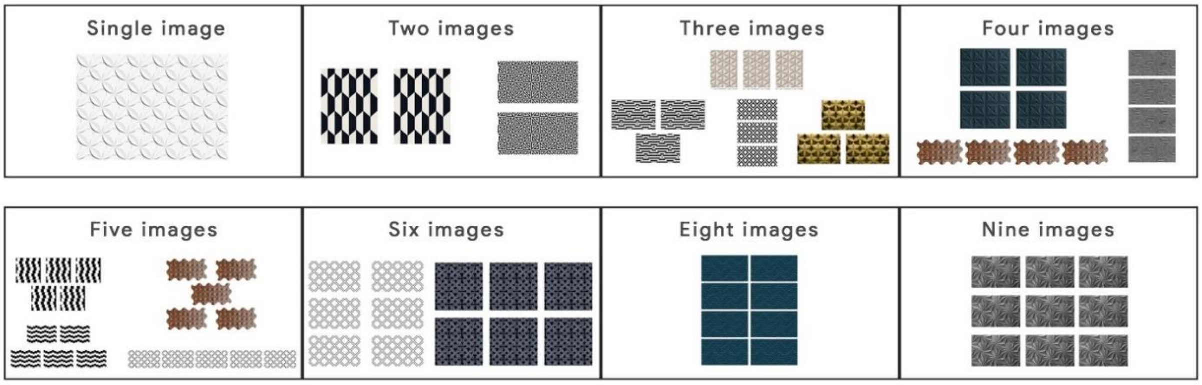

Figure 4. Pattern positioning examples depending on a different number of images

The duration of gazing at images was either limited (5 seconds, 10 seconds, 15 seconds) or unlimited (unlimited duration – proceeds by clicking the mouse). There were 12 participants in these experiments, wherein the participants were randomly assigned to four groups based on the said durations, and three participants in each group gazed at the images throughout the same period. The images were grouped depending on the number of patterns, i.e. one to nine, and shown to the participants consecutively or randomly.

2. When all patterns on the screen are different: In step 2, images containing a single pattern or multiple patterns were horizontally or vertically positioned on the screen as in step 1. The difference of this step as compared to step 1 was the use of different patterns in each of the images that contained multiple patterns (Figure 5). Similarly, the participants gazed at the patterns shown for 5, 10, and 15 seconds or an unlimited duration. As in step 1, the images were shown to the participants consecutively and randomly.

3. When the patterns used in step 2 have changed positions within the images: In step 3, i.e. the final step, an analysis was performed in accordance with the output obtained from step 2. The difference of this step compared to step 2 was that the same patterns used in step 2 were shown to the user at different positions on the screen. Again, the experiment was conducted with limited and unlimited time as well as in consecutive and random order as in step 2.

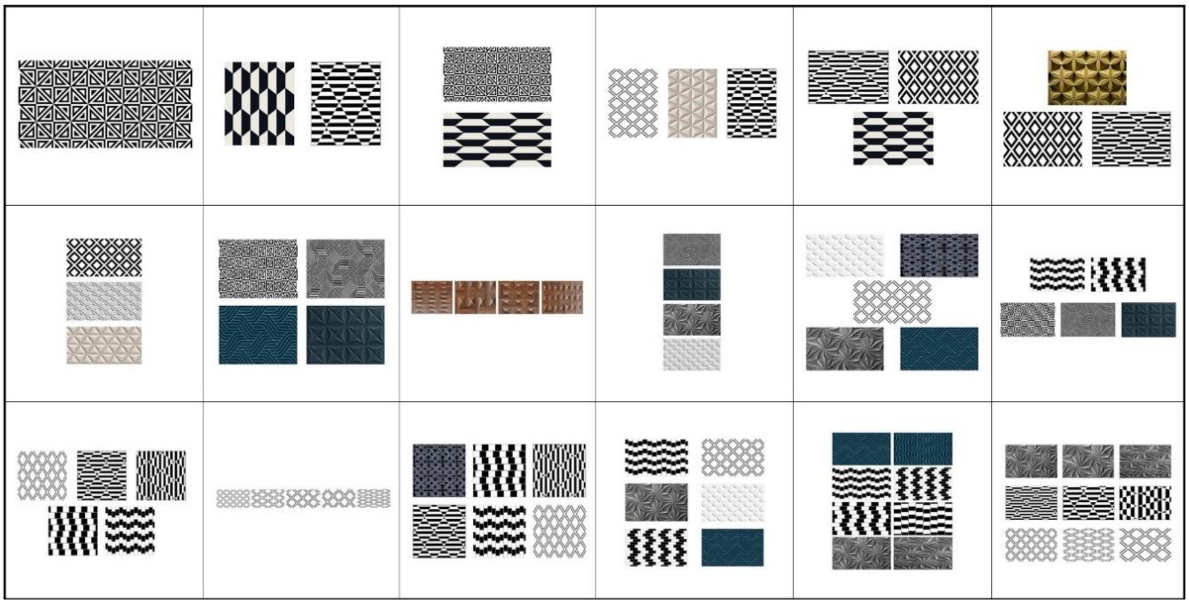

Figure 5. Different numbers and layouts of the patterns used in step 1

The data collected were classified and analyzed according to the order (consecutive or random display of images) and duration (images stayed on the screen for 5-10-15 seconds or for an unlimited time) variables and criteria were determined for laboratory studies.

Stage 2- Tobii T120 HCI Laboratory

Stage 2 was initiated with the data collected in Stage 1 and the details of this stage are presented below. This stage, which was conducted to verify the studies conducted in the previous stage and obtain quantitative analyses from the results, was performed with 10 new participants who used the unportable Tobii T120 device at the METU HCI laboratory.

Before conducting studies at the laboratory, the experimental sets were installed on the computer, and the Tobii software and eye tracker were rendered ready to use. The participants were seated at 70 cm distance to the 17-inch computer screen with 1280*1024 pixel resolution. A five-point calibration was performed for smooth data collection and experimentation. With this purpose, the participants were asked to follow a moving point on the screen with their eyes, and the experiments were initiated after the eye movement recordings were confirmed to be valid and clean at the beginning of each experiment. Gaze data were recorded at 120 Hz sampling rate (higher than Tobii X2-60) with 0.5° margin of error and 30-35 milliseconds of delay, and data with a 70% gaze ratio were analyzed.

1. When all patterns on the screen are the same: Eye movements of the participants did not yield a significant pattern when all pattern images were the same in Stage 1. Therefore, it was concluded that the patterns displayed on the screen should not be the same. Accordingly, this step was not carried out in Stage 2 as per the decision made considering the results of the same step in Stage 1.

2. When all patterns on the screen are different: In conducting this step at the HCI laboratory, durations were revised according to the results obtained previously. Gaze data obtained from the group with 15 seconds gaze duration was not very effective. It was understood that 15 seconds was a long time for comparative gazing at the same pattern images, which led to participant distraction. Therefore, the said duration was fixed at 10 seconds. The number and layout of the images were the same as those used previously (Figure 5).

3. When the patterns used in step 2 have changed positions within the images: The images used in the third step of Stage 1 were shown to the participants in the same manner, wherein half of the participants were provided with a gaze duration of 10 seconds and the other half had an unlimited gaze duration. Moreover, images were displayed consecutively to half of the participants and randomly to the other half.

5. ANALYSIS AND RESULTS

The results obtained at this stage of the study were used as a basis for the continued studies to be conducted with the products. Therefore, the data obtained here was used as a systematic roadmap concerning the display decisions for the designer.

As a result of these studies, heatmaps were prepared based on the first image gazed at among the comparative patterns displayed on the screen, the first and total fixation duration, the order of gazing at different clusters, and the effects of layout on gaze. Figure 6 shows some examples containing gaze data.

Figure 6. Heatmap, order of gaze, clusters, and gaze opacity examples for the same pattern

Heatmap examples provided in Figure 7 were obtained when the same patterns with the same count in the second and third steps of the experiment were positioned differently. Here, the heatmap obtained from gaze densities showed that all of the images that contained five horizontally-aligned patterns could be examined regardless of how the images were when patterns changed position within the image.

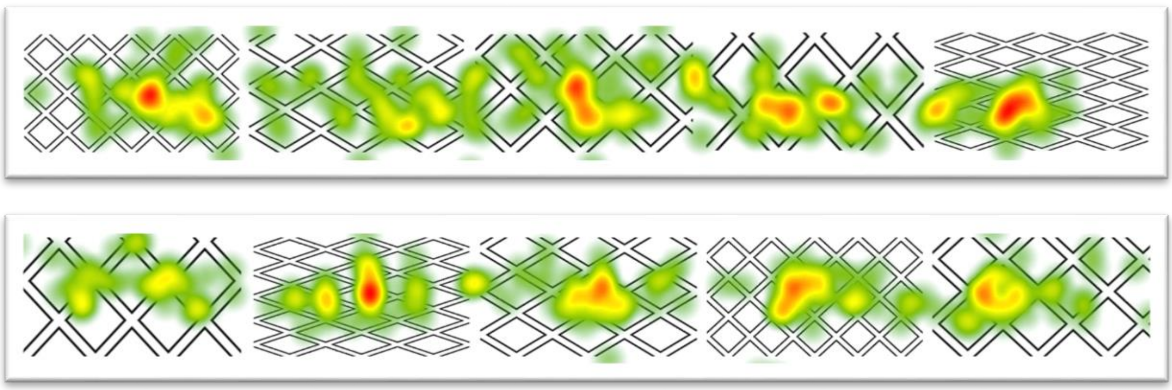

Figure 7. Above- Image that contained five patterns that were horizontally aligned in the second step; Below- Image that contained five patterns that were horizontally aligned with an altered screen layout in the third step

Considering that the products are very diverse in their forms, the patterns were also chosen and designed in various ways in terms of their colors, gaps between each shapes, angles of lines, horizontal or vertical alignments, outer borders, and shadows. These properties were deliberately kept different to measure participants' interest. Distinct or more complicated alternatives attracted the gaze of the participants in a shorter time. Moreover, when the color or the angle of the lines was different on the screen, gaze fixation numbers were higher and fixation durations were longer on that pattern for the first time. However, evaluation of the same image in the next step showed that the participants did not exhibit the same levels of attention, wherein different gaze densities and durations were also observed. In other words, longer and multiple examinations in the second step were transformed into a shorter and lower number of examinations in the third step, which showed that the participants were familiar with repeated images and felt less desire to examine the same.

An important output was obtained about the count and order as a result of showing the patterns to the users. It was found that the display of images that contained one to nine patterns did not have an impact on ignorance or otherwise of an image or the length or number of gazes, when varying pattern numbers or layouts, i.e. horizontal and vertical, were used. It was also found that the participants gazed at all images regardless of the layout and number of images and this outcome did not change when all images were displayed at varying repetitions with similar changes in position. That is to say, there was no loss concerning gaze when images containing a single pattern or multiple patterns were displayed with different layouts/order. Therefore, it was deemed possible to display multiple pattern images in the continued study to be conducted with products.

Evaluations for the Following Studies

Consequently, the optimal presentation decisions and ideal display variations were classified under the groups provided below:

The number of patterns: Eye-tracking metrics revealed that the participants glanced at all patterns, regardless of the number of patterns included in an image (single visual and multiple visuals). However, the users' grip on the images was decreased with a considerably higher number of patterns (9 patterns on the screen at the same time). It was concluded that the comparative groups should contain at most 4 products in order to enable decision making, selection, or evaluation concerning a product.

Page layout: It was found that the participants looked at all images, regardless of the layout (horizontal or vertical alignment on the screen).

Duration of evaluation: Providing the participants with limited (5-10-15 seconds) or unlimited time for image evaluation did not lead to a significant difference in terms of gaze order and fixation. However, it was decided to continue with a single-type experiment design instead of using different durations, which made the analyses and evaluations more complicated. Providing the participants with unlimited time for focusing on the differences and forming more opinions about the product was found to yield more realistic gaze data with complete examination and evaluation by the participants.

Repeated display: The fixation points on images vary depending on the participant. While a participant was fixated on a pattern, another gazed longer at another pattern. The outputs from eye-tracking metrics showed that the users tended to look for the differences. Similar elements in comparative presentations began to attract less attention. Similar to the results of a study, the participants paid less attention to the images they were familiar with, leading to shorter duration and lower count of gaze [24]. Therefore, it was planned to consider the fact that users pay more attention to an image at the first gaze while showing a product repeatedly.

Order of display: It was found that gaze density was decreased as the participants got tired of the final images when images were shown to the user in order from one to nine patterns. Therefore, it was deemed appropriate to show images randomly to the participants in order to ensure the balance of evaluation for all images in future studies.

Properties of transition between images: While showing the images to the participants, the experiment was designed with a plus sign placed at the center of a blank screen between images, which made the eyes focus at the center, and the participants started looking at the next image from the center. This was also observed in various existing studies [25, 26]. Such blanks were found to be necessary to eliminate the effect of the previous gaze on the eye.

6. CONCLUSION

In the present study, analyses were so far conducted with different variations with the aid of eye-tracking technology using generic pattern samples, without making an evaluation using the products. The eye movements of the participants on the screen were determined. In light of this visual information, the designer can be provided with a new and systematic roadmap by applying for the same order on the products, when optimum and ideal variations are revealed.

Within this scope, the main goal of using eye-tracking technology in this study was to determine where eye movements started or stopped, at what stage pupils were dilated or constricted, as well as the reasons thereof. Investigation of eye movements was found to be essential in order to understand the ideal number, order, duration, and layout of products to be shown irrespective of personal opinions, test the consistency of verbal expression with gaze, and determine which design changes are noticeable. In other words, this study has shown how the alterations made on the same images affected eye movement via measurable data such as how they changed the duration of gaze at the product, where people looked at first, and how pupils changed. Therefore, recording gaze data of the user enabled the designer to analyze with tangible and objective data.

Besides, the creation of a method for testing product designs with eye-tracking technology was initiated with this study. It is required to investigate the circumstances in which the applied method is valid and prove the same with examples to be able to use the collected results as design recommendations or data input for the designer. Creating an extensive basis for product formations to be developed as a result of experimental processes questioning multiple variables for a product group is considered an important quest for future studies.

Acknowledgements

Ethics committee approval was obtained for the study. We would like to thank all participants of the experiments and the METU HCI laboratory and its team for providing the suitability of the experimental setting and eye trackers.

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