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TESTING EYE TRACKING METRICS IN SPECTACLE FRAMES' CUSTOMER PREFERENCES

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Abstract: *Eye-tracking is becoming increasingly popular in all fields of activity, helping companies to understand customers' visual attention, to create valuable products and services, according to their customers' needs and desires. Nevertheless, this unconventional research method is still in the early development stage in the neuromarketing domain. For many practitioners, it's many metrics that are confusing, and each of them is debatable in their reliability to adequately analyse customer preferences. This paper aims to analyse whether eye-tracking represents a reliable source of information in understanding customers' preferences in spectacle frames, namely, to test through statistical analysis the most appreciated eye-tracking metrics and to determine which one is suited for customer preference assessment.*

Keywords: *Eye-tracking, eyeglass frames, customer preferences, statistical analysis, fixation duration*

1. INTRODUCTION

Nowadays, businesses operate in an increasingly competitive environment [1], a crucial element for their survival is to offer products or services that attract the user's attention and create positive emotion for them. The eyes provide approximately 80% of the information possessed by a person, so the product evaluation is particularly influenced by the visual impression [2]. Managing customer satisfaction with specific products or service attributes has been widely acknowledged as relevant to the success of the final offer [3]. Converting impressions, emotions and desires, about selected range of products or services; to realise new design solutions and specific technical parameters [4][5], verbal and non-verbal measurement methods can be used [2]. The face-to-face survey, telephone interview and online survey are part of the verbal methods category [2]. Non-verbal measurement methods include electroencephalography (EEG), electromyography (EMG) and eye tracking [6]. The study presented in this paper is based on testing eye-tracking metrics. Through the experimental eye-tracking method, eye movements and gaze localisation are recorded, relative to time and task. This technology has developed over time, evolving from cumbersome and expensive technologies to those that are accessible and friendly to both the participant and the researcher [7]. The visual analyser, through its complex structure, focuses light on the anterior and posterior sections of the eye through the lens. Back of the eye contains receptor cells (cones and rods), located on the retina, which allow us to have day and night vision. The fovea centralis represents the area located on the retina with the highest visual acuity. High visual acuity across the entire visual field is achieved simply and effectively through eye movement. The eye movement is triggered automatically and is performed rapidly. The movement occurs to focus the interest zone on the fovea. Eyes move both voluntarily and involuntarily, and eye-tracking devices detect these types of movements [8]. Eye movements are processed in numerous metrics, with fixation duration and dwell time being the most important parameters [9]. The most utilized eye following parameter is fixation duration

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(duration of average fixation). A longer fixation duration means the more time participants spend interpreting the image [10]. The long duration of fixation, for the interpretation of the image, denotes a problematic perception of the fixed object [11]. This parameter indicates the grade of difficulty or ease in information extraction. Duration of the first fixation on an area of interest (AOI) represents the time during which the participant identifies and recognises the stimulus image, being a fast process [12]. Dwell time metric refers to fixing the look on an area of interest for some time [13]. In the case of selecting, the dwell time metric indicates the person's attention, more precisely, he looks at and fixes the object to be selected for some time [14].

In recent years, the field of eyeglass frames has received very little consideration in the specialised literature, as not many individual eye-tracking studies have been performed. The present study analysed the options of clientele from the Western region of Romania, regarding eyeglass frames. This study complements research conducted using grounded theory, which analysed customer preferences around the world, through information from the online environment. Therefore, in this paper, the outcome obtained in the preceding study will be tested using the eye-tracking method. The case study is a preliminary one, involving 25 people, eyeglass wearers, who form a heterogeneous group.

The paper is structured in eight chapters. The first chapter is an introductory one, presenting general information regarding the study conducted, for a better understanding of the following chapters. The second chapter contains the theoretical background of the paper. In this section, theoretical elements regarding the eye tracking method are presented: basic notions of anatomy and movement of the eye; parameters resulting from the eye-tracking procedure. Chapter three includes the methodology for performing the eye-tracking experiment. The next chapter includes the results obtained from the experiment and its statistical processing and interpretation. Final chapters, discussions and conclusions, includes an overview of the significant aspects of the paper, also presenting possible future research directions.

2. THEORETICAL BACKGROUND

Focusing on a single stimulus, among those identified by our senses, for subsequent processing, results in the formation of medium and long-term memories, represented by the cognitive process called visual attention. It should be noted that attention, being a natural function, is difficult to measure using traditional methods, so for a more precise measurement, the eye-tracking measurement system will be used [15].

2.1 How does the eye work?

There is a close connection between eye-tracking and the human visual analyser anatomy. The eye's role is to capture, focus, and transmit light, just as a camera does through its aperture, lens and photosensitive region. The following figure shows the visual analyser and its main components [16].

In the process of eye tracking, an important role belongs to the cornea. The cornea houses the lens inside it, and in front of it is the pupil. Through the pupil, light enters the eye, and its diameter manages the quantity of light entering and the resulting image intensity. Cornea and lens role is to focus light entering the eye onto the retina. Retina, located at the back of the eye represents the place where the clear, inverted image is formed [16][17].

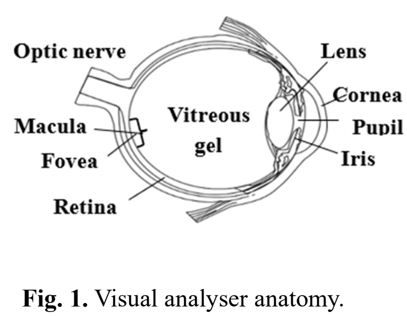

Fig. 1. Visual analyser anatomy.
Source: author's own research

One of the eye interest zones is the retina. Here is the fovea centralis, where the photoreceptor cells with rods and cones are concentrated, and it is also the area where any image that the eyes focus on is captured in detail [9][10]. Like other systems, the optical system of the eye has imperfections. More precisely, people are faced with the so-called vision defects. These occur when the image is formed in front of the retina (myopia) or when the visual rays meet behind the retina (hyperopia). Vision defects are increasingly widespread among the adult population in developed countries. They are treated by using glasses with corrective ophthalmic lenses or contact lenses. Thus, the large number of glasses wearers represents a point of interest for the present study.

2.2 Eye movements and eye tracking metrics

Eye movement is performed voluntarily and involuntarily. Regarding voluntary eye behaviours, three types of oculomotor behaviours are distinguished: gaze control, saccade and smooth pursuit. Saccades are very rapid and simultaneous movements of both eyes. Their occurrence is intermittent during sustained movements. In most cases, they occur two or three times per second. However, there are also people in whom the frequency is one saccade every second [18]. Thus, two types have been distinguished, long saccades and microsaccades. Long saccades are characterised by amplitudes of up to half a degree or more [19][20]. The factors that determine their occurrence are frequent head movements, the use of illuminated spaces to the detriment of dark ones and the use of instruments with a high noise level [19][21]. The following figure captures the basic movements of the eye.

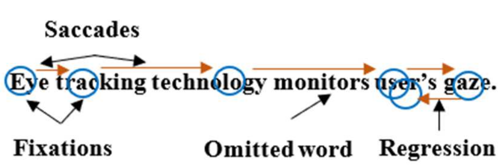

Fig. 2. Basic movements of the eye.
Source: author's own research.

Another type of eye movement is smooth pursuit. This appears when the eyes track a moving object. If an object is moving faster, smooth pursuit occurs at the same time as saccades [22]. There are also involuntary eye movements. In most cases, there are no notices by the viewer, but the eye tracker detects them. The three main types of movements are tremors, microsaccades and drift. Small, high-frequency, uncorrelated movements between the eyes, with a random direction, are called tremors. Uncorrelated low-speed movement causes the gaze to move away from the fixation point between the eyes and is named drift. Microsaccades have a shorter duration than saccades presented in voluntary movement. They are correlated between the eyes and have a frequency of occurrence of one to two per second [23]. Measuring people's eye movements to determine their level of attention and the area they are looking at is done using eye-tracking technology. Therefore, the eye-tracker records the eye movements described above and makes them available to researchers in the form of metrics. In addition to the metrics obtained, visual representations such as heat maps are generated after applying the eye-tracking technique. A heat map is represented in the following figure.

The heat map shows the zone where the eyes are focused the most, at different thermal intensities. The focus of the eyes on a particular stimulus is captured in the fovea centralis, and the fixation occurs. The fixations of multiple participants are represented on the heat map by a colour code. Red indicates the existence of a large number of long-lasting fixations. Yellow orange is used to highlight medium-lasting fixations, and green is used for a few short-lasting fixations [24].

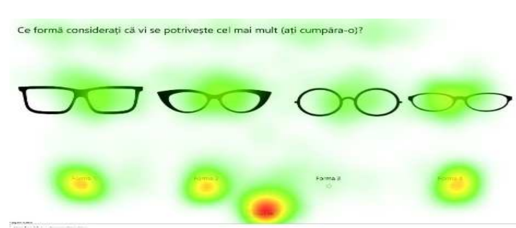

Fig. 3. Heatmap of eyeglass frame shape.
Source: iMotion software.

According to [25], the most significant metrics based on fixation are the probability of fixation, fixations number, fixation position, time to first fixation, first fixation duration and total fixation time. Also, in the specialised literature regarding the frequently reported attributes of consumers' visual attention, parameters such as fixation duration (duration of average fixation), first fixation duration and dwell time are analysed [26] [27].

An essential element in eye movement data analysis is the area of interest. This marks significant sections of the images, which will later be analysed separately [25]. The totality of almost stable discrete points, followed by the eye, is called fixations [28]. The parameters fixation duration (duration of average fixation), first fixation duration, and dwell time measure position duration, having a close connection with the measurement of the time during which the participant's gaze remains in position. The most important metric is fixation duration. This can be divided into several parameters such as fixation average time, first fixation duration and gaze duration. The fixation average time represents the total of all subjects' fixation durations, divided by their number [12]. Another important parameter is the first fixation duration, which represents the duration of the first fixation on an area of interest (AOI), not considering the number of subsequent fixations on the same area of interest [29]. The dwell time parameter, also known as gaze duration, represents the total time spent watching a particular area of interest [30].

3. METHODOLOGY

3.1.Participants

The participants are a heterogeneous group of 25 people from the Western part of Romania, both women and men, aged between 18 and 64, from different educational and work backgrounds, all wearing eyeglasses, who verbally expressed their consent to take part in the experiment. The study was performed during July and August 2024 in a university laboratory with soft light and no visual or audio distractions.

3.2.Product structure

To align the level of customer perception with the technical parameters of the product, it is necessary to have detailed knowledge of the product structure. Figure four shows, the basic components of the eyeglass frame. To these are added the temple of the frames, but they do not represent the subjects of the present study. Also, a major characteristic of the frames is that they can differ in shape, size and colour.

3.3 Apparatus, stimuli and procedure

The experiment was performed on a 15.6-inch laptop LCD and a screen-based Smart Eye AI-X eye tracker. Data analysis has been performed with the help of the iMotion software license. After a two-minute calibration, each participant, with good and excellent results, continued the experiment. The stimuli have been displayed in the centre of the screen, with a grey background. A pre-study has been performed to evaluate the accurate information and adequate understanding of tasks, as presented in figure five. The participants were presented with the stimuli in a pre-determined order.

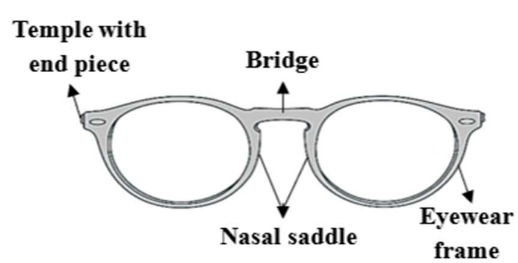

Fig. 4. Spectacle frame structure
Source: author's own research.

Fig. 5. Eye tracking experiment process.
Source: author's own research.

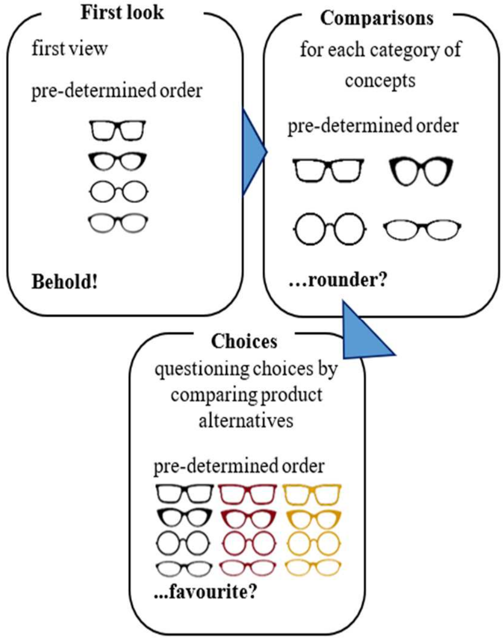

Fig. 6. Eye-tracking experiment phases.
Source: author's own research.

They all visualised four eyeglass frame shapes: rectangle, round, cat-eye and oval, the ones determined from the customer feedback analysis and were requested to choose one of them, the most probable to purchase. The experiment was then repeated to determine the size and colour of the spectacle frame with the highest probability of purchase. The whole process, including the calibration, lasted for approximately 4 minutes.

4. RESULTS

In the previous study, the grounded theory was used to identify customer preferences for eyeglass frame shape, size, and colour. Analysing customer reviews led to the identification of four shapes and three colours preferred by people around the world [31]. Since the heatmap does not provide conclusive information regarding customers' choice, a statistical analysis of the three most important metrics based on fixation was carried out [32].

Statistical analysis consists of applying the statistical tests (Paired T.test [33], Bartlett's test [34], Levene [35] and Fligner-Killen [36] test and normality tests: Shapiro-Wilk test [37], Kruskal-Wallis's test [38]), and has a twofold purpose, to determine the most appreciated shape of the frame by customers and to establish the most important metric, out of the three analysed.

4.1 Spectacle frame shape preferences

Table 1 shows the statistical results collected after applying the paired T-test and Bartlett's test [32][34] for the three chosen metrics. Paired T-test show the result of the mean difference between two correlated measurements. The Bartlett's test results show that the p-value is at the limit or below 0.05, signifying that there is no homogeneity. By applying the homogeneity tests [35][36] and normality classical tests [37][38], limitations were observed, relative to normality and homogeneity (Table 1).

The results obtained after performing the previous tests show that for the fixation duration and first fixation duration metrics, the p-value is too small to support the hypothesis of homogeneity between the four groups. It results that the dwell time metric is not precise and useful (Table 2).

Table 1

Results for the paired T-test and Bartlett's test.

Paired T-test				
Metrics	**Area of interest**	**AOI1**	**AOI2**	**AOI3**
Fixation duration	AOI2	0.417	-	-
	AOI3	0.322	0.761	-
	AOI4	0.322	0.088	0.081
First fixation duration	AOI2	0.901	-	-
	AOI3	0.547	0.547	-
	AOI4	0.043	0.043	0.011
Dwell time	AOI2	0.97	-	-
	AOI3	0.61	0.61	-
	AOI4	0.97	0.97	0.61

Bartlett's test			
Metrics	**K-squared**	**df**	**p-value**
Fixation duration	7.7629	3	0.05117
First fixation duration	21.045	3	0.0001031
Dwell time	8.6833	3	0.03381

Table 2

Results for homogeneity and normality tests.

Levene test				
Metrics	**Group Residuals**	**df**	**F-value**	**Pr(>F)**
Fixation duration	G	3	1.8623	0.1422
	R	84	-	-
First fixation duration	G	3	2.0303	0.1158
	R	84	-	-
Dwell time	G	3	0.5659	0.1639
	R	84	-	-

Fligner-Killeen test			
Metrics	**chi-squared**	**df**	**p-value**
Fixation duration	5.2216	3	0.1563
First fixation duration	4.978	3	0.1734
Dwell time	1.6414	3	0.65

Shapiro-Wilk test		
Metrics	**W**	**p-value**
Fixation duration	0.95823	0.006333
First fixation duration	0.8384	2.208e-08
Dwell time	0.82627	8.863e-09

Kruskal-Wallis's test			
Metrics	**chi-squared**	**df**	**p-value**
Fixation duration	5.8865	3	0.1173
First fixation duration	8.9887	3	0.02944
Dwell time	52.2875	3	0.5149

Table 3

Paired T-test and Bartlett's test results

Paired T-test			
Metrics	**Area of interest**	**AOI1**	**AOI2**
Fixation duration	AOI2	0.93	-
	AOI3	0.73	0.73
First fixation duration	AOI2	0.52	-
	AOI3	0.15	0.28
Dwell time	AOI2	0.35	-
	AOI3	0.96	0.35

Bartlett's test			
Metrics	**K-squared**	**df**	**p-value**
Fixation duration	3.6124	2	0.1643
First fixation duration	6.4938	2	0.0389
Dwell time	7.6576	2	0.02174

4.2 Spectacle frame dimension preferences

By applying statistical tests to compare groups based on mean and variance, a series of results were obtained, which are presented in Table 3. After performing the paired t-test, the highest probabilities are for pairs AOI1-AOI3 (dwell time metric) and AOI1-AOI2 (fixation duration and first fixation duration metrics). Bartlett test shows that the resulting values cannot support the existence of homogeneity. Table 4 shows the results of the homogeneity and normality tests.

The homogeneity and normality tests show that only one parameter, fixation duration, registers a higher p-value, meaning that the hypotheses of homogeneity and normality cannot be rejected.

Table 4

Homogeneity and normality test results

Levene test				
Metrics	**Group Residuals**	**df**	**F-value**	**Pr(>F)**
Fixation duration	G	2	0.1521	0.8592
	R	63	-	-
First fixation duration	G	2	1.4383	0.245
	R	63	-	-
Dwell time	G	2	0.9826	0.38
	R	63	-	-

Fligner-Killeen test			
Metrics	**chi-squared**	**df**	**p-value**
Fixation duration	0.052173	2	0.9743
First fixation duration	3.4469	2	0.1784
Dwell time	3.4629	2	0.177

Shapiro-Wilk test		
Metrics	**W**	**p-value**
Fixation duration	0.91016	0.0001572
First fixation duration	0.88296	1.488e-05
Dwell time	0.82627	1.573e-09

Kruskal-Wallis's test			
Metrics	**chi-squared**	**df**	**p-value**
Fixation duration	0.71074	2	0.7009
First fixation duration	3.446	2	0.1785
Dwell time	1.8359	2	0.3993

4.3 Eyewear colour preferences

Table 5 contains the results obtained after applying the tests that compare the groups according to the mean and variance. In the colour preference case, high probabilities are found for AOI1-AOI3 and AOI1-AOI2 pairs, as well as in the case of size preference. Bartlett test shows absence of homogeneity. Table 6 contains the results of the homogeneity and normality tests.

Table 5

Bartlett's and paired t-test results

Paired t-test			
Metrics	**Area of interest**	**AOI1**	**AOI2**
Fixation duration	AOI2	0.985	-
	AOI3	0.43	0.43
First fixation duration	AOI2	0.60	-
	AOI3	0.30	0.39
Dwell time	AOI2	0.41	-
	AOI3	0.72	0.42
Bartlett's test			
Metrics	**K-squared**	**df**	**p-value**
Fixation duration	30.899	2	1.951e-07
First Fixation duration	6.9074	2	0.03163
Dwell time	6.9606	2	0.0308

Table 6

Results of homogeneity and normality tests

Levene test				
Metrics	**Group Residuals**	**df**	**F-value**	**Pr(>F)**
Fixation duration	**G**	2	2.7411	0.0722
	R	63	-	-
First fixation duration	**G**	2	0.1998	0.8194
	R	63	-	-
Dwell time	**G**	2	3.077	0.05309
	R	63	-	-

Fligner-Killeen test			
Metrics	**chi-squared**	**df**	**p-value**
Fixation duration	2.889	2	0.2359
First fixation duration	1.6989	2	0.4276
Dwell time	5.2643	2	0.07193
Shapiro-Wilk test			
Metrics	**W**		**p-value**
Fixation duration	0.71341		4.758e-10
First fixation duration	0.81311		1.047e-07
Dwell time	0.90861		0.0001362
Kruskal-Wallis's test			
Metrics	**chi-squared**	**df**	**p-value**
Fixation duration	2.781	2	0.2489
First fixation duration	2.2755	2	0.3205
Dwell time	0.88908	2	0.6411

The results of the applied tests show that the hypothesis of equality between groups cannot be rejected.

5. DISCUSSION

By applying an eye-tracking experiment, the preferences regarding spectacle frames of a group of people from the Western part of Romania were tested.

Regarding the frame shape preferences, statistical tests showed that the most important metric is fixation duration, and based on its results, it turns out that the oval shape of the spectacle frame is the most appreciated by customers.

From statistical tests applied to data obtained from expressing preferences regarding frame size, it was found that the most important metric is fixation duration, and customers appreciate medium-sized eyeglass frames. In the end, statistical tests were applied to the results obtained from colour preferences. Thus, it was found that in this case al three metrics have the same level of importance, and the colour appreciated by customers is burgundy.

Therefore, based on the results obtained, it was found that the participants in the experiment prefer medium-sized frames, with an oval shape and burgundy colour. Among metrics, the most important is fixation duration.

6. CONCLUSIONS

The paper aim was to test clientele preferences on spectacle frames through an eye-tracking experiment on eyeglass wearers from the Western part of Romania. The statistical analysis consisted of applying six statistical tests, based on which comparisons were made between mean and variance. Based on the statistical analysis, the existence or rejection of the hypotheses of normality and homogeneity was demonstrated. Also, the analysis was conducted on the main categories of preferences: shape, dimension and colour of the spectacle frames.

Based on the tests performed, the three metrics have the same level of importance, and customers appreciate medium-sized, oval-shaped, and burgundy-coloured spectacle frames. The study limitations were that the eye-tracking experiment was applied to a small group of people, under 50, resulting in less precise statistical results. Also, the experiment was conducted on people from the same geographical area, the Western part of Romania, which influenced the experiment and the statistical results. The findings of this paper can be used by manufacturing companies for the development of spectacle frames according to the preferences of customers from a certain geographical area. Resellers can use these findings to simplify the decision on spectacle frame acquisition. In the future, the study will be carried out on a larger number of respondents, and several shapes, sizes and colours of frames will be tested.

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Testarea indicatorilor de urmărire a ochilor pe baza preferințelor clienților cu privire la ramele de ochelari

Urmărirea ochilor devine din ce în ce mai populară în toate domeniile de activitate, ajutând companiile să înțeleagă atenția vizuală a clienților, creând produse și servicii valoroase, în funcție de nevoile și dorințele clienților lor. Cu toate acestea, această metodă de cercetare neconvențională este încă în stadiul incipient de dezvoltare în domeniul neuromarketingului, pentru mulți practicieni, numeroasele sale valori fiind confuze și fiecare dintre ele discutabilă în ceea ce privește fiabilitatea lor de a analiza în mod adecvat preferințele clienților. Această lucrare își propune să analizeze dacă urmărirea ochilor reprezintă o sursă fiabilă de informații în înțelegerea preferințelor clienților, în ceea ce privește ramele de ochelari și anume, să testeze prin analiză statistică cele mai utilizate metrici obținute în urma experimentului de urmărire a ochilor și să determine care dintre ele este potrivită pentru evaluarea preferințelor clienților.

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