Analysis of Consumer Visual Attention to Retail Design Elements Using Eye-Tracking Technology

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Abstract This study analyses consumer visual responses to store design elements using eye-tracking technology, focusing on identifying behavioural patterns across different age and gender groups. The primary goal was to assess how consumers respond to various aspects of the retail environment, such as price tags, promotional banners, and checkout zones. Statistical tests (Mann-Whitney U, ANOVA, and T-test) indicated no statistically significant differences between the groups observed, suggesting a need for an expanded sample size for more precise analysis and a deeper understanding of these interactions.

Keywords eye-tracking, consumer behaviour, visual attention, retail environment.

JEL M31, M37, L81, L96

1. Introduction

Analysing consumer behaviour in the sales environment is a key factor for optimising store design and increasing sales efficiency, especially in a visually stimulating environment where consumers are faced with a multitude of stimuli on a daily basis. [1] In the current literature, it is often highlighted that retail design elements such as price tags, advertising banners, product layouts or the design of the checkout area itself can significantly influence customer decision making. Price tags with clear, large print or colourful banners highlighting promotions and discounts have the potential to attract attention and encourage impulse purchases. Conversely, a cluttered or chaotic layout of the sales area can confuse and discourage consumers from buying. [2,3] Given this fact, the use of advanced technologies such as eye-tracking is becoming an increasingly common method in consumer behaviour research. [4]

The eye-tracking technology enables detailed tracking of consumers' eye movements and fixation points, providing accurate data on their visual preferences. [5] Tracking fixation points, saccades, and other aspects of visual attention enables the identification of which elements of the sales environment consumers register and respond to most intensely, which is useful for better understanding their buying behaviour. [5,6]

Based on previous studies, it appears that the impact of the sales environment may vary by demographic factors such as age and gender, supporting the need for a comprehensive analysis of differences between consumer groups. Therefore, [4,6,7] the aim of this research is to gain insight into the visual responses of different demographic groups to store design elements and to investigate whether there are statistically significant differences between gender and age groups. Thus, this research will provide new insights into how design elements can be optimized for different types of consumers. The Mann-Whitney U test, ANOVA and T-test were used to statistically evaluate the data collected, allowing for a thorough assessment of the differences between groups. This research extends the existing knowledge on consumer behaviour in retail environments and offers potential benefits for the design of effective marketing strategies in the retail industry. [8,9]

2. Methodology

The research uses eye-tracking technology to investigate in-store consumer behaviour, focusing on the analysis of visual attention of different demographic groups. Eye-tracking technology enables detailed tracking of eye movements and provides both quantitative and qualitative data that are essential for understanding which elements of the in-store environment attract consumers' attention and what factors influence their visual interaction with products and store design. [10]

The five-user rule, first proposed by Jakob Nielsen in his 2000 article "Why You Only Need to Test with 5 Users", argues that eye-tracking testing with five users can detect up to 85% of usability problems. This rule of thumb is based on a model where a single user reveals 31% of problems on average, and is applicable to qualitative testing of homogeneous focus groups. However, as Nielsen points out, when testing

DOI: 10.26552/tac.C.2024.2.4

heterogeneous user groups or when testing quantitatively, the number of respondents needs to be increased. Research, such as a study by Laura Faulkner of AWS, has shown that groups of five users can detect only 55% to 85% of problems, while groups of ten users have detected up to 95%. [11]

In selecting the sample size, we took an approach that mitigates these limitations and included 21 respondents who were selected on the basis of age and gender. The age categories were divided as follows:

- **15-18 years** (8 respondents). This age group includes young consumers who are accustomed to modern technology and often follow current retail trends.
- **19-25 years** (12 respondents). The largest group of respondents, representing young adults who have already established some consumer habits.
- **26-50 years** (1 respondent). Older consumers who prefer the stability and simplicity of the retail environment.

In terms of gender, 9 males and 12 females were included in the sample, which allowed a comparison of gender differences in visual attention. Although the sample of respondents was relatively small, it provided a basis for initial analysis and the formulation of further recommendations.

The technological core of the research was the Screen Based Eye Tracker, which enables accurate recording of respondents' eye movements through infrared sensors and high-frequency cameras. This device was complemented by SMI's BeGaze software, which processes and visualizes the data collected by the eye-tracker. The combination of hardware and software provided a robust platform for analysing consumers' visual attention, while enabling the following metrics to be tracked and evaluated:

- **Fixations** - the number of fixations on specific elements of the sales environment. This metric reflects which elements most captured respondents' attention.
- **Fixation length** - the amount of time respondents spent on each element. A higher fixation length indicates a more intense interest in a particular element.
- **Saccades** - rapid eye movements between fixation points that show how efficiently respondents scan the sales environment and what elements they skip.
- **Dwell time** - the total time spent looking at a particular element, giving a picture of its attractiveness and ability to hold attention.

Respondents were presented with visual stimuli in the form of photographs of different parts of the stores. These photographs contained three main types of design elements that were targeted to test visual attention:

- **Price tags** - the photographs included different types of price tags with different placement (eye level, near the floor), text size, and colour design. The goal was to determine which placement and visual form of price tags most captured consumers' attention.
- **Advertising banners** - banners with different colours, graphic design and text content were tested to determine which visual features most appeal to consumers.
- **Checkout Zones** - respondents were presented with two types of checkout zones, those with a clear layout and those with lots of visual cues.

Photographs were prepared to allow A/B testing, where responses to two different design variations of the same element were compared. For example, for the checkout zone, it was analysed whether customers pay more attention to products in a zone with a clear minimalist design or, on the contrary, in a zone with a lot of visual stimuli.

Four hypotheses were defined in this research, which focused on the analysis of differences in consumer visual behaviour according to gender, age and the influence of the design of the sales environment. The hypotheses were formulated to provide answers to key questions regarding visual attention and consumer behaviour in stores. Individual hypotheses were tested using advanced statistical methods (Mann-Whitney U test, ANOVA, T-test) to test their validity.

Hypothesis 1: Difference in fixation length between men and women

(H0): There is no difference in the length of fixation on the product between men and women.

(H1): There is a difference in the length of fixation on the product between men and women.

Hypothesis 2: Difference in average fixation by age group

(H0): There is no difference in average fixation between different age groups (15-18; 19-25).

(H1): There is a difference in average fixation between different age groups (15-18; 19-25).

Hypothesis 3: The difference in the number of saccades between men and women

(H0): There is no difference in the number of saccades between men and women.

(H1): There is a difference in the number of saccades between men and women.

Hypothesis 4: Effect of checkout zone design on fixation on products

(H0): The design of the checkout zone does not affect the length of fixation on products.

(H1): The design of the checkout area has an impact on the length of fixation on products.

3. Results

This study provides initial insights into consumer visual attention within retail environments. Practical recommendations include designing clear and visually appealing price tags, simplifying checkout zone layouts, and using vibrant promotional banners to draw attention. While no statistically significant differences were found across demographic groups, these findings highlight the importance of thoughtful visual design to enhance customer experience and streamline purchasing decisions. Future research with larger sample sizes and additional demographic variables could further refine these insights and offer more targeted recommendations for retail professionals. The main objective was to test whether there are statistically significant differences between

different demographic groups (men vs. women, different age categories) and how visual cues, such as checkout area design, influence consumer behaviour. Different statistical methods were used to evaluate each hypothesis, providing quantitative data for detailed comparison. Although not all differences proved to be statistically significant, the research revealed useful insights into consumer interaction with in-store design elements.

Each hypothesis was tested under the assumption of the null hypothesis (H0), which asserted that there was no statistically significant difference between the groups or design variations analysed. The alternative hypothesis (H1) assumed the opposite. The results of the testing provided a picture of whether the hypothesised differences were confirmed or rejected.

Hypothesis 1: Difference in fixation length between men and women.

To calculate the Mann-Whitney U test, we have identified 2 areas that represent the gender of the respondents, and these are male and female. The total number of respondents is 21, which is less than 30. Based on this, we have chosen an appropriate method of calculation namely Mann-Whitney U test. The values for testing the hypothesis are given in the table. Microsoft Excel software was used to calculate the values. For the calculation we have chosen 2 sexes where we have also determined the order of the elements see groups T_1 and T_2.

The function =RANK.AVG (values;1) was used to determine the order. The number of elements in group A is n_1=12 (number of elements of the first group) and B n_2=9 (number of elements of the second group). To calculate U (expected value), we plug the values into the formula U_1 and then U_2. We then use U_{min} (the smaller of U_1 and U_2). U_{crit} (tabulated value based on the number of elements from the Mann-Whitney table, alpha=0.05 for a two-tailed test)

Table 1 Results of the Mann-Whitney U test

1.	$U_1 = n_1 \cdot n_2 + \frac{n_1 \cdot (n_1+1)}{2} - T_1 = 12 \cdot 9 + \frac{12 \cdot (12+1)}{2} - 160 = 26$
2.	$U_2 = n_1 \cdot n_2 + \frac{n_2 \cdot (n_2+1)}{2} - T_2 = 12 \cdot 9 + \frac{9 \cdot (9+1)}{2} - 71 = 82$
3.	$U_1 = \min(U_1;U_2) = U_{min}\ (26\ ;\ 82) = 26$
4.	For large samples, the normal distribution of the U-value can be used as an approximation, then calculate the μ_U proportional U-value and the Z-value.
5.	Therefore, for a set with less than 30 elements in each group, the exact values that can be read from the table are used. U_{crit} in our sample example, the U_{crit} = 26. If $U_{min} \leq U_{crit}$; $26 \leq 26$

From the result, we can conclude that U_{min} 26 ≤ U_{crit} 26 and this implies that we accept H0 and reject hypothesis H1: There is no difference in the length of fixation on the product between males and females.

Hypothesis 2: Difference in average fixation by age group.

The hypothesis aims to investigate whether there is a statistically significant difference in the average length of fixation on products between different age groups (15-18 years, 19-25 years, 26-50 years). The 26-50 age group was excluded from the measurement as this age group had only one representative, which is an unrepresentative sample. Thus, two age groups will be examined, namely the 15-18 age group and the 19-25 age group. To test the hypothesis, we used the statistical method of ANOVA. The following table shows a summary of the basic data before calculating the ANOVA.

Table 2 Basic data for the ANOVA calculation

Groups	**15-18**	**19-25**
Number	8	12
Sum	266	414,7142857
Average	33,25	34,55952381
Variance	17,0947522	29,6640383

In this example, the alpha value was 0.05. This means that when the P-value ≤ 0.05, we reject the null hypothesis and accept the alternative hypothesis.

Table 3 ANOVA results

Source of variation	Between Groups	Within Groups	Total
SS	8,23129252	445,967687	454,19898
df	1	18	19
MS	8,231292517	24,77598262	
F	0,3322287		
P-value	0,571487606		
F crit	4,413873419		

Since the F-value (0.3322) is less than F_{crit} (4.4139) and the P-value (0.5715) is greater than 0.05, we do not have enough evidence to reject the null hypothesis. That is, the difference in mean fixation length between the 15-18 and 19-25 age groups is not statistically significant. Based on this analysis, we can conclude that the average length of fixation on products is not statistically significantly different between the 15-18 and 19-25 age groups. Therefore, there is

DOI: 10.26552/tac.C.2024.2.4

insufficient evidence to support the alternative hypothesis that there is a significant difference between these age groups.

Hypothesis 3: Difference in the number of saccades between men and women.

Since the calculation procedure is the same as for Hypothesis 1, we present only the result of the hypothesis evaluation. Since the value of U_{stat}=40 is higher than the critical value of $U_{scritical}$=26, we accept the null hypothesis H0. That is, there is no statistically significant difference in the number of saccades between males and females.

Hypothesis 4: Effect of checkout zone design on product fixation.

To test the hypothesis, we used the statistical method T-test. To calculate the two-sample T-test between two independent samples left checkout zone ĽO7 and right checkout zone PO7, we use the following formula:

$$t = \frac{\overline{X_1} - \overline{\overline{X_2}}}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where:

- $\overline{X_1}$ and $\overline{X_2}$ are the averages of the two groups (cash zone ĽO7 and cash zone PO7),
- s_1^2 and s_2^2 are the variations of the two groups,
- n_1 and n_2 are the group sizes.

Calculation:

$$t = \frac{42{,}68 - 43{,}87}{\sqrt{\frac{108{,}33}{21} + \frac{157{,}47}{21}}} = \frac{-1{,}19}{\sqrt{5{,}16 + 7{,}50}} = \frac{-1{,}19}{3{,}15} = -0{,}553$$

The p-value is the probability of obtaining such or a more extreme t-value, assuming the null hypothesis (H_0) is true. The t-value, degrees of freedom, and type of t-test (one-sided or two-sided) are used to calculate the p-value for a t-test. The calculation involves several steps:

Determination of T-value and degrees of freedom:

T-value: t=-0.583

We calculate the degrees of freedom df as:

$$df = n_1 + n_2 - 2$$

Where:

- n_1 is the number of observations in the first group,
- n_2 is the number of observations in the second group.

In this case we have $n_1 = 21$ and $n_2 = 21$, so:

$$df = 21 + 21 - 2 = 40$$

We converted the t-value to a P-value using an online calculator available at www.graphpad.com, where we entered values for $t = -0.553$ and for $df = 40$. The result of the calculation, the value is 0.583. This means that the probability that we would obtain this or a more extreme t-value in random sampling, assuming no difference between the means (the null hypothesis is true), is 58.3%. Since the p-value is greater than 0.05, we do not reject the null hypothesis, meaning that there is no statistically significant difference between the groups being compared.

Using statistical methods, Mann-Whitney U test, ANOVA and T-test, we tested four stated hypotheses focusing on different aspects of consumers' visual attention. The results indicated that there were some differences in behaviour between the groups, but not all differences were statistically significant.

Hypothesis 1: Difference in fixation length between men and women.

Accepted hypothesis: (H0) There is no difference in the length of fixation on the product between men and women.

Hypothesis 2: Difference in average fixation by age group

Accepted hypothesis: (H0) There is no difference in average fixation between different age groups (15-18; 19-25).

Hypothesis 3: Difference in the number of saccades between men and women

Accepted hypothesis: (H0) - The number of saccades between men and women is the same.

Hypothesis 4: Effect of checkout zone design on fixation on products

Accepted hypothesis: (H0) - The design of the checkout zone does not affect the length of fixation on products.

Although we hypothesized that there was a difference in fixation duration between males and females, statistical analysis did not confirm this difference. Similarly, when comparing age groups, we did not find significant differences in the average length of fixation on products. On the other hand, experiments with checkout area design provided useful data on how design affects consumers' visual attention, although no statistically significant variation was found.

5. Conclusions

Based on the statistical analysis of the research, it was found that there were no statistically significant differences in consumer behaviour based on gender or age in terms of fixation length and number of saccades. These results may be influenced by the sample size, which highlights the limitations of the study and the need to include a larger sample of respondents in future research. Moreover, differences in checkout area design did not affect respondents' visual attention, suggesting that an effective sales environment does not depend solely on visual design, but also on other factors such as customer movement through the space or pricing.

The research has provided insights into consumer behaviour and their interaction with the retail environment. For retail design professionals, these findings present an opportunity to optimize store elements such as price tags, banner ads and checkout areas to increase customer engagement. Although no significant differences were found between

genders and age groups, the data highlight the importance of a clean and visually appealing layout of the sales space and the use of elements that can capture customers' attention.

The findings suggest that future research should focus on a larger sample of respondents and analyse other variables. Exploring other demographic and psychological factors could contribute to a deeper understanding of the complexity of consumer decision-making and the creation of more effective store designs that improve the customer experience and optimize the shopping environment.

Practical recommendations can be formulated in the light of these findings. Visual elements of stores, such as price tags, should be prominent, with legible fonts, contrasting colours and strategically placed at eye level. Advertising banners should be eye-catching, contain concise and clear calls to action, and be placed in high visibility zones. Checkout zones should be minimalist, uncluttered and complemented by impulse products that naturally catch the attention of customers. Technologies such as eye-tracking should be used regularly to analyse the effectiveness of design changes. In this way, it is possible to create store designs that better reflect customer needs and encourage positive buying behaviour.

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