

“The eyes are the windows to the brain”: pupillometry and eye fixation patterns in smartphone product communications*

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Abstract

Monitoring eye movement has been proven crucial for understanding consumer behaviour, and pupillometry can indicate whether the stimuli cause much confusion in the brain. This research examined the impact that smartphone promotional messages have on the brain's cognitive demands and analysed the visual attention that those received. In the realm of neuromarketing, this study explored the smartphone industry and its advertising impact on Greek consumers, as well as its effect on their mental workload levels measured through pupil dilation. An eye tracking device with a comparative questionnaire were used to investigate these topics, with their results from a final sample of 31 people (17 female and 14 male) agreeing with a large body of the pre-existing literature, which suggests that, although men and women might have slightly different approaches to this product category, they mostly have similar biometric results. The stimuli included 10 images containing promotional content from five brands (Sony, Apple, Realme, Xiaomi, Samsung). After the detailed analysis of the eye

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tracking results that included fixation and pupil metrics and their comparison with the correlated literature, the study concluded that the appearance of the smartphone is the element that attracts the customers' visual attention the most and that the tested material generally did not demand considerably high amounts of mental workload to be processed. Ultimately, it highlighted the importance of implementing a combination of implicit and explicit research methods to gain a comprehensive understanding of the impact of product advertising on visual attention and mental effort, having additional academic and practical implications.

Keywords: *product advertising, eye tracking, mental effort, visual attention, pupil dilation*

JEL classification: *M31, M37, D12, D87*

1. Introduction

To provide a comprehensive foundation for the study, this introductory chapter outlines the broader context in which the research is situated and clarifies the key industry dynamics and methodological considerations that shape the analysis presented in the subsequent sections.

1.1. Smartphone industry and challenges

In Greece, there are more than 14 million mobile connections (corresponding to 135% of its population) (Kemp, 2021), but there are no known studies that have investigated consumer behaviour in the smartphone industry using neuromarketing methods. Within this extremely competitive field, companies are investing significant amounts of money in promotion to gain an advantage over their competitors (Jae, 2011). Hence, there is certainly a necessity for more extensive investigation into consumer behaviour, and the advertising impact on their decision-making using implicit methods, as high-tech brands have to compete in a precarious market (Msaed et al., 2017; Yang & Gabrielsson, 2017). The key question in this study was how smartphone brands can gain knowledge about attention and their ads by using eye-tracking methods.

1.2. Eye-tracking method and research query

Based on the review of current literature, it appears that this is one of the first studies to attempt the testing of promotional messages and images coming from brands of the smartphone industry in the Greek market, by using an eye tracking device; that is to say that it attempted something similar to what Bang and Wojdyski (2016) examined in their research, where they tested the product category of coffee shops and their venture of marketing in form of online banner ads, in which they observed, and recorded with an eye tracker, customers' division of attention and their reactions to the tasks of personalised versus non personalised ads and of different demands of

mental effort. In more detail, for the needs of this paper five of the most powerful technological brands (i.e., Apple, Realme, Samsung, Sony and Xiaomi) and certain of their latest smartphone models were examined, to investigate a form of their commercial efforts, in terms of the interest they gained and of the participant's brain response with the levels of mental workload that those evoked.

The eye-tracking method is preferred over other neuromarketing tools due to device mobility and its ability to provide a wide range of accurate data about visual attention. After all, people's eyesight is what captures the vast majority of the information coming from their surroundings and the extraneous sources (Hahn et al., 2016). Adding to that, another important reason is that it can profoundly detect biometric data that were completely inaccessible with traditional marketing (Mansor & Mohd Isa, 2018), especially about pupil dilation (a metric generally known as pupillometry) which is corroborated to be a reliable indicator of people's magnitude of mental efforts and of their implicit cognitive procedures (Diede & Bugg, 2017; Hahn et al., 2016; Sirois & Brisson, 2014).

In detail, the research query was divided into 4 different sub-questions as follows:

- RQ1: Do smartphone ads implicitly demand significant levels of mental effort provoking big amounts of cognitive load?
- RQ2: Which of the smartphone's elements are attracting important interest and attention?
- RQ3: Are there any differences in these results between men and women, and if yes, to what extent?
- RQ4: Do the implicit results of the eye tracker differ and/or contrast with the self-reported answers?

These four research questions were carefully developed to align with the study's overarching objectives: (1) to identify which ad elements most effectively attract attention among Generation Z consumers, and (2) to explore how smartphone advertisements engage cognitive resources through implicit neuromarketing metrics. By combining biometric data (eye-tracking and pupillometry) with self-reported responses, the study aims to provide a comprehensive understanding of both unconscious and conscious consumer reactions to smartphone advertising.

2. Literature review

Neuromarketing is an emerging field of research that combines experimental setups with neuroscientific methods in order to understand consumer behaviour, untangle their emotions and unconscious motivators of the decision-making (Özbeyaz, 2021;

Nyoni & Bonga, 2017). The brain is connected with every vital function of the human body, and it is where any thought, emotion, feeling and attitude is generated, hence it is the main focus of neuromarketing and generally the most significant tool for uncovering and understanding the human behaviour (Davis et al., 2017).

More specifically, it is considered to be suitable for advertising or marketing research, as it provides unique biometric information and results (Rawnaque et al., 2020). Neuromarketing studies utilise tools and devices such as the functional magnetic resonance imaging (fMRI) a technique that measures brain activity by detecting changes in blood flow, the electroencephalography (EEG), the Magnetoencephalography (MeG), Galvanic Skin Response (GSR), eye-tracking devices and others to get real-time answers about the decision-making issues (Nyoni & Bonga, 2017). Its main purpose is not to replace the traditional marketing techniques (e.g., surveys), but to expand the knowledge of the consumers' buying decision with insights about their emotional and psychological state, using biometric data that traditionally were obscure under the self-reported answers (Aldayel et al., 2020; Hakim & Levy, 2018; Kumar et al., 2019; Tomkova et al., 2020; Venkatraman et al., 2015; Yadava et al., 2017); and thus Fortunato et al. (2014) claim that neuromarketing's significance is highlighted by its ability to fulfil that purpose to *fill the gaps left by traditional marketing research*.

2.1. Smartphone industry characteristics

In the smartphone industry, it is easy to assume that customers do not have to choose based solely on sensory preferences, such as taste or appearance, they must consider their needs more thoughtfully to find the most suitable high-tech product for themselves (Chen et al., 2016; Hie et al., 2017). As a result, brands are providing new smartphone models in a short period of time from each other, whilst they are trying to increase their market share in a very competitive marketplace (Wong et al., 2019). Consumers are attracted by specifications such as the speed of the processor, the camera's quality, or the battery's capacity (Rajasekaran et al., 2018), but in different regions and cultures, such factors that affect the brand-switching behaviour of smartphones users can vary in significance (Ling et al., 2018; Satriawan & Setiawan, 2020). Other researchers suggest that the appearance of the smartphone has a notable influence on creating customers' attitude towards it and on their overall satisfaction, but there are still some more complex motivators that form their buying decision (Kim et al., 2016; Wong et al., 2019). Accordingly, Yeh et al. (2016, p. 253) tried to uncover the factors that lead to brand loyalty for smartphone users and found that functional, emotional and social value are positively related with it, but Wong et al. (2019, p. 237) later supported that the functional value is less effective on preventing brand switching behaviours. Other papers claim that the convenience of use, the social communication and self-expression capabilities (including the device's look and its attractiveness) are features which can be very

significant for luring customers of high-tech products (Al-Kwafi, 2016; Lau et al., 2016; Lee et al., 2011).

Furthermore, the price of the smartphone is a determinant of the perceived quality and, thus, it is a decisive attribute of the customer's intention to buy (Bharat, 2021; Satriawan & Setiawan, 2020; Zahid & Dastane, 2016). Simultaneously, the electronic word of mouth (eWOM) contributes significantly on the decision-making in favour of a smartphone purchase (Alrwashdeh et al., 2019). Contrariwise, there are studies that found eWOM to have no impact on the customer buying decision and then studies that although recognized eWOM as a positive contributor at the time of the purchase decision, they distinguished it from viral advertising which was considered to be much more important for enhancing the purchase intention (Sawaftah et al., 2020).

Consequently, with the continuous need for discovering and distinguishing the functions that really matter for the consumer (Kim, 2016), the question of how a marketing campaign can be effective and provoke the right emotions to the customer elicits (Baraybar-Fernández et al., 2017; Kun et al., 2017; Vallejo et al., 2019); whilst it is also known that companies spend great amounts of resources for promotion and advertisements (Golnar-Nik et al., 2019; Kumar et al., 2019; Yadava et al., 2017; Zahid & Dastane, 2016).

2.2. Research gaps and perceptual differences between males and females

Most of the existing literature about advertising in general is mainly based on the answers that customers give on self-reporting forms, in which they express their feelings and decisions in their own words; but eventually, many of their decisions are being taken unconsciously, and sometimes it is even difficult for them to understand and describe the exact emotion they are experiencing at any moment (Baraybar-Fernández et al., 2017). Thus, the smartphone market should be investigated in greater depth regarding advertising and its impact on the decision-making, in order to achieve and produce the best marketing mix possible (Zahid & Dastane, 2016).

Adding to that, at the present time there is still a general absence of understanding and reporting on the overall consumer behaviour as regards to the smartphone industry (Bharat, 2021), and notably most of the studies about it ignore the impact of advertising on their buying behaviour (Chine et al., 2019). For that reason, there have been some studies which call for further research about other reasons that could lead customers to switch their smartphones (Oh & Park, 2020), except from contributors such as convenience, brand name and social influence that can influence the customer's purchase intention (Golnar-Nik et al., 2019; Kaushal & Kumar, 2016).

As regards the gender variable, according to Boscolo et al. (2020, p. 301), there have been many studies which have proven that between the two genders (males and females) there are variations both in the evaluation process of advertising and in the attitudes towards them. He et al. (2021, p. 1541) also highlighted that men and women show different preference in products and advertisements, which are often created separately from brands in order to address the needs of each gender respectively.

Duan et al. (2021, p. 5) did find some differences in the cognitive fluency between the two genders. Similarly, other studies mentioned variations between male and female results (Aymerich-Franch, 2014; Boscolo et al., 2020; Vecchiato et al., 2014), but at the same time there is need for more extensive research for advertising effects on the two genders (Aymerich-Franch, 2014; Baraybar-Fernández et al., 2017; Cartocci et al., 2016; Sawaftah et al., 2020; Stefko et al., 2021), especially with using and implementing neuromarketing approaches to capture their response to the marketing stimuli (Boscolo et al., 2020; Goodrich, 2014).

3. Methodology

This paper employed a methodology that transformed raw eye-tracking metrics into original interpretations, offering a fresh perspective on the field of studies about high-tech products and smartphone advertisements. This approach is sufficient to classify it as qualitative research (Sandelowski, 1995). With purposive sampling, it is expected that the selected sample will provide singular and plentiful individual information (Etikan et al., 2016). The nature of the study required participants with specific characteristics, and by using the number of subjects suggested in the literature, the results could be replicated and transferred to the typical population with similar traits (Gheondea-Eladi, 2014).

More specifically, smartphones are one of the most appealing high-tech products for the younger generations (Golnar-Nik et al., 2019), and especially for smartphone brands it is the Generation Z (people born from 1997 and after), which is associated with the use of social media since its born, that has an extreme importance as a consumer category (Mohammed, 2018). According to the academia, part of the Gen Z is considered to be people who were born after 1997, and who in fact are people very familiar with technology and social media usage, as they were born or grew inside a period of massive technological and web advancements (Cilliers, 2017; Prakash Yadav & Rai, 2017; Turner, 2015); thus, all the participants were adults born from 1997 to 2004.

A total of 35 participants voluntarily took part in the research, comprising 20 women and 15 men. However, due to corrupted data, only 31 recordings were used in the analysis. All 31 participants reported having normal or corrected-to-normal

vision, and they were all fluent in Greek. The group consisted of 17 females and 14 males, all aged between 18 and 25 years old.

3.1. Experimental setup and data processing

Before the experiment, each participant completed a standard 9-point calibration sequence using the Tobii Pro Studio software to ensure high spatial accuracy across the display area. During the main session, each stimulus was presented for 8 seconds, followed by a 2-second neutral gray screen to minimize carry-over effects between exposures. Participants were seated approximately 60–65 cm from the monitor, with the device operating at a 30 Hz sampling rate. The room lighting was kept constant to avoid external luminance effects on pupil diameter.

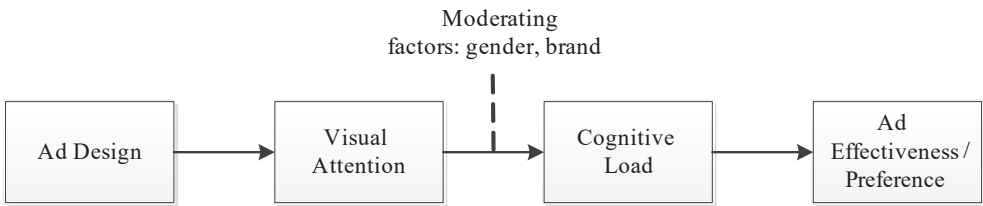
Raw gaze data were inspected and cleaned according to standard neuromarketing practice. Blinks and signal losses shorter than 100 milliseconds were interpolated, and any fixation lasting less than 80 milliseconds was removed. Approximately 4 % of the total data points were excluded due to blinks or calibration drift. Final metrics for analysis included Time to First Fixation (TTFF), Total Fixation Duration (TFD), Fixation Count (FC), and average pupil dilation per Area of Interest (AOI). These procedures ensured the reliability and replicability of the measurements across participants.

This study was conducted using eye-tracking technology (Tobii Pro X2-30). Participants viewed two online photos per brand, one with the actual device with hardware specifications, and one containing promotional messages. In total, the participants viewed 10 online photos each. Areas of Interest (AOIs) were selected for all 10 photos that included the smartphone model, technical specifications, customer reviews and promotional texts. The visuals were sourced directly from official promotional content and online listings of each smartphone brand. The first image for each brand showcased the product with a focus on its physical attributes—device shape, screen design, and hardware specifications—presented on a clean, neutral background. The second image for each brand was designed to simulate a promotional ad, including product-centred marketing phrases, logo placement, and design elements such as vibrant colours or stylized fonts. The content aimed to reflect realistic brand communication strategies found on social media, websites, or digital ads. All stimuli were static (non-animated) and presented in high resolution to maintain visual clarity and enable precise gaze tracking.

To clarify the theoretical foundations, we present a simplified conceptual model linking ad design, visual attention, and cognitive load (Figure 1). Based on the limited capacity model of motivated mediated message processing (Lang, 2000) and dual-process perspectives (Petty & Cacioppo, 2012), we propose that specific design aspects of an ad (e.g., layout balance, colour contrast, and imagery complexity) can determine the flow of visual attention. Attentional amplification, or

concentrated attention, in turn, modulates cognitive load, and, therefore the speed at which viewers process and retain message information. These relationships summarize the expected paths as represented in Figure 1 for the core variables investigated in this study.

Figure 1: Conceptual model of relationships between ad design, visual attention, and cognitive load



Source: Author’s construction

3.2. Metrics and interpretation

The metrics analysed for each AOI were: time to first fixation (TTFF), meaning how fast participants fixated on an AOI (Bebko et al., 2014); total fixation duration (TFD), meaning how long participants fixated on a specific area (Tsai et al., 2012; Zhang & Yuan, 2018) combined with fixations count (FC) measuring how many times participants fixated on an AOI (Pfiffelmann et al., 2020); pupil dilation which measures changes in the size of the eye’s pupil as it is widely accepted that the pupil of the eye dilates when a task demands more mental effort to be decoded (Alnaes et al., 2014;; Hosseini et al., 2017; Palinko & Kun, 2011). The five brands included in this study were: Apple, Samsung, Xiaomi, Sony and Realme. The brands were pretested to determine their level of popularity. All participants viewed the 10 photos in a randomized order. At the end of the test, they were asked for their explicit opinions about the stimuli, with the purpose of gaining comparative results between eye-tracking and the questionnaire.

4. Empirical data and analysis

This chapter presents the empirical findings derived from the eye-tracking and pupillometry measurements, together with the corresponding self-reported questionnaire responses. The following subsections systematically outline the results related to mental effort, visual attention, and cross-method comparisons, offering an integrated view of how participants processed and evaluated the smartphone advertisements.

4.1. Results of mental effort

When it comes to pupil dilation, all of the brands did a great job in making their promotional efforts understandable and somehow efficient without exaggerated and complex content. Participants’ pupil dilation attested that they did not have to apply an increased amount of mental effort to decode and comprehend the stimuli (Table 1). It is noteworthy that there were no significant variations between male and female participants (Table 2), which somewhat contradicts previous, and stereotypical, evidence from similar studies about high-tech products (Kotzé et al., 2016).

Table 1: Overall results of pupil dilation

AOI	Mean of dilation times per participant	Occasions of pupil dilation
Specifications	1.323	41
Promotional texts	0.677	21

Source: Author’s calculations

Table 2: Gender results on pupil dilation

Gender	Mean of dilation times per participant	Occasions of pupil dilation	Average % change
Female	1.029	35	2.426 %
Male	0.964	27	2.371 %

Source: Author’s calculations

In fact, it is in agreement with the notion that over the last century the gender gap on the positivity of attitudes towards technology is becoming more and more marginally distinguishable (Cai et al., 2017).

4.2. Results of visual attention

The element that attracted significantly more attention, based on the TTFF (Table 3), TFD and FC (Table 4) metrics, was the appearance of the smartphone (the actual device). In this regard, the study refutes what Mao et al. (2020, p. 16) claimed in their article, where they supported that the smartphone’s design has started decreasing in importance for the customer. As a matter of fact, it supports the allegations that the appearance is very important in the creating process of the customers’ impressions and for their general psychological gratification (Kim, 2016; Wong et al., 2019).

Table 3: AOI rank in terms of TTFF seconds

AOI	TTFF in seconds	Occasions that it was the first thing noticed
1. Model 1 st display	2.712	56.744 %
2. Reviews	3.996	3.226 %
3. Specifications	4.256	40 %
4. Model 2 nd display	4.924	21.963 %
5. Logos	7.615	4.516 %

Source: Author’s calculations

Table 4: AOI rank in terms of TFD seconds and FC

AOI	TFD in seconds	Mean duration per participant in seconds	Fixations Count	Mean of total fixations per participant	Occasions with 0 fixations
1. Specifications	861.59	27.793	2,361	76	1.29 %
2. Models	425.064	13.712	1,663	54	11.29 %
3. Logos	97.974	3.161	366	12	37.419 %
4. Reviews	10.089	0.326	45	2	56.452 %

Source: Author’s calculations

4.3. Eye-tracking results compared with questionnaire

Interestingly, eye tracking results on this specific point agreed with those of the questionnaire, where the appearance also received the highest score. This outcome was somewhat expected due to the prolonged exposure time that the photos had, allowing people to have enough time to process all information in the stimuli. If exposure was set to only a few seconds, implicit and explicit results would probably differ substantially.

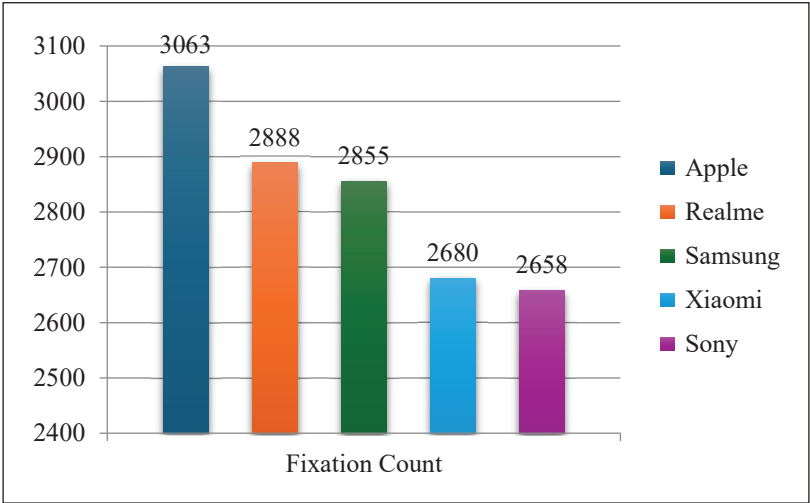
A deeper analysis of self-reported answers revealed that there were important differences compared to eye tracking. More specifically, Realme came last by a large margin in visual focus according to self-reporting results, while it had the third best performance, very closely following the first two brands, in TFD (Table 5) and the second best in FC (Figure 2). Another significant discrepancy was about promotional messages’ complexity, where Samsung was in first place and Apple was in last place in self-reporting, while the complete opposite positions were observed in eye tracking (Table 6).

Table 5: Brands’ smartphones rank on the questionnaire and on eye tracking

Questionnaire Rank on Interest	Questionnaire Score on Interest	Eye-tracking Rank (TFD)	TFD in seconds
1. Apple	3.94	1. Apple	863.58
2. Samsung	3.58	2. Samsung	827.87
3. Xiaomi	3.58	3. Realme	822.83
4. Sony	2.74	4. Xiaomi	772.28
5. Realme	2.52	5. Sony	734

Source: Author’s calculations

Figure 2: Fixation count of the 5 brands’ smartphones



Source: Author’s calculation

Table 6: Brands’ smartphones ranking on questionnaire and eye tracking

Questionnaire Rank on the Complexity of the ads	Questionnaire Score on Complexity	Eye-tracking Rank	Participants with dilated pupils (at least once)
1. Samsung	3.26	1. Apple	13
2. Sony	3.23	2. Sony	12
3. Xiaomi	3.06	3. Realme Xiaomi	11
4. Realme	3.03		
5. Apple	2.84	4. Samsung	9

Source: Author’s calculations

The final remark of this comparison was the difference between male and female responses on the questionnaire, and their results were captured on the eye tracker. More distinctively, females reported a mean score of 2.89 about the complexity of the ads, while males reported a mean score 3.33. However, the results presented in Table 7 indicated the exact opposite, even by a very small margin.

Table 7: Gender results on pupil dilation

Gender	Mean of dilation times per participant	Occasions of pupil dilation	Average % change
Female	1.029	35	2.426 %
Male	0.964	27	2.371 %

Source: Author’s calculations

Although this research used a relatively small sample to ensure the validity of the self-reported data, it is adequate enough for neuromarketing research and for the comparative section about self-reported versus biometric responses (Janić et al., 2022; Ćirović et al., 2022).

4.4. Supplementary comparisons across gender and brand groups

To ensure that the observed effects were not affected by demographic or brand-specific factors, exploratory comparisons were performed using the existing eye-tracking and pupillometry metrics. Descriptive checks across gender (male vs. female) and brand conditions revealed no notable differences in fixation or pupil-dilation measures. This suggests that the neurophysiological patterns observed in the study primarily reflect ad-design characteristics rather than participant demographics or brand familiarity.

5. Results and discussion

First of all, it was found that throughout the participants’ interaction with the stimuli, the eye tracking device managed to detect dilated pupils for just about a few times per session. This practically implies that they did not have to put great amount of mental effort, in their attempt to decode and comprehend the promotional text of the smartphone and its characteristics. This evidence appears somewhat unanticipated, because previous research had definitely demonstrated that there are alterations in the consumer behaviour for familiar and unfamiliar brands, as regards to the attitudes towards the advertisement (Rhee & Jung, 2018), to the intensity of processing the analogous information (Martí-Parreño et al., 2017), and, finally,

to the brand itself under miscellaneous marketing channels (Junior Ladeira et al., 2022). The idea behind this observation was that Realme and Sony could be seen as unfamiliar brands for the Greek consumer, since their market share in Greece for 2021 had been below 10% cumulatively, and the others as familiar ones, inasmuch as they had conquered the majority of the Greek market (more than 60%) for the same timeline (Statcounter, 2022).

Furthermore, it can be concluded that the participants' brains, who are part of the Generation Z, did engage with the promotional messages from the smartphone brands, for the reason that for more than 80% the stimuli display did not evoke excessive amounts of cognitive load. In general, comprehensible advertising content lowers the demands of the customers' amounts of cognitive load that are disposable for such tasks, in a way that does not lead to their undesirable cognitive disengagement (Bang & Wojdyski, 2016; Jae, 2011; Wang & Duff, 2016). In its turn, customer's brain engagement with the ad is not just a simple proof of marketing's effectiveness, but it is actually one of its main purposes that can enhance brands' efforts to communicate their message to their audience (Wang, 2006), and thus to be able to allure their cognitive attention (Janić et al., 2022). Eventually, by having secured those, the brand with a better marketing communication is capable of inducing a greater feeling of connection to the customer with the product itself (Kim et al., 2017).

Finally, what this study uncovered for that specific matter, is equally useful for academics and practitioners. More accurately, it showed that the variable of brand familiarity might not be completely applicable to the smartphone industry and to young adults in Greece, regarding their unconscious brain and visual reactions towards their promotional messages. Simultaneously, it confirmed for managers that they were able to find the right balance on the difficulty and the amount of the information that they provided to the customer, acting as it was suggested for such high-tech brands in other regions (Msaed et al., 2017); whilst it filled some gaps left on the past in the smartphone consumer behavior, and extended the marketing analysis on this industry for the vital category of Gen Z audience (Aroean & Michaelidou, 2014; Mohammed, 2018).

Regarding the visual interest, the initial and most prominent finding was that the design of the smartphones was the element that attracted the participants' concentration for a very long period of time. Participants first noticed the smartphone model's design, faster than any other area of interest in the stimuli. This disclosure indicates that young adults are spending most of their available time gazing at the appearance of the smartphone before anything else during their interplay with a smartphone promotional message, no matter the brand. In alignment with past research on the topic, the smartphone's design manifested as one of its most significant and impressive parts for the customer (Ayodele & Ifeanyichukwu, 2016; Chen et al., 2016; Tan & Sie, 2014; Wong et al., 2019), but at the same time this came in complete

contradiction with evidence by consumers from another continent who put it in the last places of their preferences that contribute to their buying decision (Rajasekaran et al., 2018); and also with a more recent research which stated that the design has been falling behind in matter of its significance (Mao et al., 2020).

Additionally, the study can be used alongside others, as it was suggested, for the sake of comparisons among different countries and continents about the customer's incentives and behaviour in the smartphone market (Kim et al., 2016). Finally, the biometric results combined with those on paper claim that the design of the smartphone, and subsequently the camera features with battery capacity, are those that attracted the customer's concern and those that need to be projected the most. It is known that features of the smartphone are those that are of the utmost importance for the consumer's purchase decision (Lay-Yee et al., 2013). Hence, these results are also answering to the request for a deeper investigation on the marketing mix of smartphone brands in their attempt to understand and produce the most suitable one (Zahid & Dastane, 2016).

One of the main variables of this paper, and the only that was responsible for the participants split in two smaller groups, was the gender variable. Generally, it is proven that this variable is of great significance for such brain studies (Palmiero & Piccardi, 2017), as it has been categorically reported that females and males do have various reactions in many categories when shown the same product or ad (He et al., 2021; Janić et al., 2022). This concept is crucial and needs to be kept monitored (Stefko et al., 2021), and on a first interpretation, it can be said that the results only added to the debate of already disunited written works and opinions on this aspect.

In consonance with a major part of past research (Baraybar-Fernández et al., 2017; Boscolo et al., 2020; Kim, 2016;), either with or without deploying neuroscientific methodology, the outcome of pupillometry and the rest of the eye tracking metrics indicate that there are no noteworthy differences for men and women. More specifically, the slight dissimilarities in their perceptual ability, and the dispersion of their visual attention, are simply appended to the view that in the technological context those are mostly a stereotypical issue of concern (Kim, 2016). In fact, both male and female participants showed similar implicit attitudes toward the five brands and their respective advertisements. There were only a few minor statistical variances, which is consistent with findings from other neuromarketing studies. (Baraybar-Fernández et al., 2017; Boscolo et al., 2020). These variations may be attributed to the sample including three more women than men. On the contrary, the inquiry fundamentally disagrees with the literature that employs traditional methodological approaches, which suggest conclusions different from what has just been described (Aymerich-Franch, 2014; Cai et al., 2017). Additionally, it further objects to neuroscientific ones that examined participants' reactions to some TV commercials based on their gender (Vecchiato et al., 2014), but also to other non-

neuro studies that had tested the gender influence on products or advertisements under the scope of the online and technological environment and mentioned differences among them (Kotzé et al., 2016).

Nevertheless, this research provides some practical insights for professionals aiming to stay competent in the Greek smartphone market, while also addressing some gaps in academic literature. First, it can be concluded that the results of the smartphone advertisement tested here were largely similar for both males and females in terms of perceptual fluency. Secondly, it can be noted that females showed slightly more interest in the design of the smartphone model than males, as indicated by the average duration and number of fixations. Thirdly, it addresses the need for further exploration of how advertising affects both genders, particularly through neuroscientific methods (Cartocci et al., 2016; Goodrich, 2014); and ultimately, it delves deeper into the human cognitive system separated by gender, in which there are huge promises and opportunities for enlarging the quality and the quantity of the literature about the consumer behaviour topic (Meyers-Levy & Loken, 2015).

For the scope of this study, the questionnaire employed here was indeed effective in contributing to the discussion regarding the traditional qualitative or quantitative methods compared to the neuromarketing approach. In any respect, it is well acknowledged that questionnaires alongside with focus groups and interviews are almost costless, but the ideal questionnaire with zero imperfections is practically impossible and in many cases the bias in direct communication is unavoidable (Aldayel et al., 2020; Fortunato et al., 2014; Gountas et al., 2019; Hakim & Levy, 2018; Hakim et al., 2021); thus, the questionnaire was meant to be used as supplementary proof or comparative evidence on the eye tracking results.

The comparison revealed that, in many cases, the eye tracking results did not align with participants' responses on the questionnaire, particularly regarding questions assessing the perceived difficulty of each brand's advertising messages. The brand that was reported to have the most complex ad (i.e., Samsung) was actually the one that had provoked pupil dilation to the fewest number of participants, added to some serious deviations of their declared interest on the smartphone models from the division of their visual interest in those (e.g., the Realme model was by far last at participants' interest on paper but one of the best in eye tracking).

Accordingly, this paper accomplished to confirm the notion that respondents' answers in a questionnaire, as well as in traditional research tools, may not always be driven by rationality. Instead, they are often influenced by the respondents' subjective beliefs and preferences (Tomkova et al., 2020). Additionally, it reinforced the notion that traditional methodologies often fail to detect the unconscious attitudes of the customer, which in turn will result in deteriorated information, especially about advertising effects (Agarwal & Dutta, 2015; Kumar et al., 2019).

More importantly, it provides concrete evidence of how eye-tracking systems can be utilized and the opportunities they offer marketers within the broader context of neuromarketing's theoretical framework (Mansor & Mohd Isa, 2018).

6. Conclusions

To recapitulate, this study addresses theoretical gaps in understanding online promotion within the smartphone market. It highlighted the significance of utilizing neuromarketing methods to assess the effectiveness of advertising and marketing efforts. The research involved testing promotional messages and images from the smartphone industry using an eye-tracking device. At the same time, defining the content and elements of an ad that connects the brand message with the smartphone's specifications and their functional usefulness for consumers is challenging. (Al-Kwafi, 2016; Msaed et al., 2017). What the data analysis of the participants' eye tracking sessions revealed about this issue, in assistance with their questionnaire answers, is summarised as follows: The design of the smartphone model was found to be the most significant visual point of interest, as participants had large duration and big numbers of eye fixations on the area that had actual images of the smartphone's appearance. The specific type of promotional messages that were examined did not provoke significant cognitive load, as indicated by changes in pupil size. Hence, the smartphone brands communicated their message in a smooth way that did not confuse the participants with excessively complex content, which in turn did not encourage them to disengage with the ads.

Men and women did not show significant differences that would pinpoint the gender variable as a notable factor. However, using more representative or larger samples could provide different insights. The responses to the questionnaire partially failed to align with the actual intuitive eye-movement results of the eye tracking system, indicating obvious contradictions in participants' visual attention and interest.

Despite the disagreements observed in both the self-reported questionnaires and participants' eye-tracking data, it is worth pinpointing those explicit self-reported answers, whether in questionnaire form or through other traditional qualitative and quantitative methods, are irreplaceable. They offer a more comprehensive understanding of a subject.

In summary, this study addressed theoretical gaps in the smartphone industry and highlighted the need for effective advertising and marketing efforts. It also extended previous works and reported its findings by using the eye-tracking methodology. The eye-tracking method combined with a more traditional self-reporting questionnaire achieved the study's main objective to a satisfactory level, which was to uncover participants' visual interest and attention in smartphone ads and the potential mental demand that those ads impose. In conclusion, this research has

accomplished some valuable insights for practitioners and managers of smartphone brands in the Greek market. It also examined some underexplored theoretical areas of consumer behaviour in this industry. Additionally, the study provided some distinct directions and suggestions for further research in these areas for academics to pursue in the future.

When considering the limitations of this study, several points should be highlighted. Firstly, the sample size was relatively small and focused solely on young adults in Greece, which means the findings may not fully represent broader or more diverse populations. However, it is worth noting that the sample size is in line with established norms in neuroscience and neuromarketing research, where the use of biometric tools often involves smaller, highly controlled groups. While including more participants in future studies could enhance generalizability, the current sample was sufficient to yield meaningful and reliable insights. Secondly, cultural influences, such as local attitudes toward advertising and brand familiarity, may also have subtly shaped participants’ responses. Additionally, we relied solely on static images, without incorporating dynamic formats like video ads, which are increasingly relevant in real-world digital marketing. Exposure time to each stimulus was brief, and we did not assess behavioural follow-up, such as purchase intent or engagement. These are all valuable paths for future research, which could expand on this work with more diverse samples, immersive ad formats, and real-world behavioural measures to deepen our understanding of how attention and mental effort influence consumer decisions.

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„Oči su prozori mozga“: pupilometrija i obrasci fiksacije oka u komunikaciji putem pametnih telefona

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Sažetak

Praćenje pokreta očiju pokazalo se ključnim za razumijevanje ponašanja potrošača, a pupilometrija može ukazati uzrokoju li podražaji veliku zbunjenost u mozgu. Ovim istraživanjem ispitao se utjecaj promotivnih poruka putem pametnih telefona na kognitivne zahtjeve mozga i analizirala vizualna pozornost korisnika. U području neuromarketinga, ovaj rad istražuje industriju pametnih telefona i njezin utjecaj oglašavanja na grčke potrošače, kao i njezin utjecaj na razinu mentalnog opterećenja mjenjenog širenjem zjenica. Za ovo istraživanje, uz komparativni upitnik, koristio se uređaj za praćenje oka, a rezultati konačnog uzorka od 31 osobe (17 žena i 14 muškaraca) u skladu su s velikim dijelom postojeće literature, što sugerira da, iako muškarci i žene mogu imati neznatno drugačiji pristup ovoj kategoriji proizvoda, u većini slučajeva imaju slične biometrijske rezultate. Podražaji su uključivali 10 slika s promotivnim sadržajem 5 brendova (Sony, Apple, Realme, Xiaomi, Samsung). Nakon detaljne analize rezultata praćenja očiju koja je uključivala fiksaciju i metriku zjenica te njihove usporedbe s povezanom literaturom, u radu se dolazi do zaključka da je izgled pametnog telefona element koji najviše privlači vizualnu pažnju korisnika te da općenito, testirani materijal nije zahtijevao veliko mentalno opterećenje korisnika za procesuiranje. Konačno, istaknuta je važnost primjene kombinacije implicitnih i eksplicitnih istraživačkih metoda kako bi se dobilo sveobuhvatno razumijevanje utjecaja oglašavanja proizvoda na vizualnu pažnju i mentalni napor, što ima dodatne akademske i praktične implikacije.

Ključne riječi: oglašavanje proizvoda, praćenje pogleda oka, mentalni napor, vizualna pažnja, širenje zjenica

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