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Determining the Perception Created by Health Warnings on Plain Cigarette Packs with Visual Attention: Eye-Tracking Technique

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Abstract: This study examines the effects of the plain packaging policy implemented in Türkiye, analyzing how different demographic groups perceive health warnings on cigarette packaging. Employing advanced eye-tracking technology, the research identifies distinct visual attention patterns between smokers and non-smokers when exposed to 'Anxiety' and 'Disturbing' visual cues. Detailed metrics, including fixation counts, durations, and saccade amplitudes, are used to measure and analyze the responses of these groups to the health warnings. The findings reveal that non-smokers significantly focus more on textual warnings, suggesting that text-based elements are more impactful for this group. Conversely, smokers tend to either avoid or become desensitized to disturbing imagery. Additionally, the study finds that female participants exhibit higher saccade amplitudes compared to males, indicating a more thorough examination of the packaging. This gender-specific difference is especially pronounced in their responses to 'Disturbing' images, where females show greater engagement, pointing to an increased sensitivity to such stimuli. These insights not only advance our understanding of effective health communication but also underscore the importance of designing public health interventions that cater to the unique responses of different demographic groups. This research significantly enriches the field of tobacco control, providing evidence-based strategies to enhance the effectiveness of visual warnings, thereby supporting targeted smoking cessation efforts.

Keywords: visual attention; plain cigarette packs; anxiety; disturbing; eye-tracking

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1. Introduction

According to the data announced by the World Health Organization, eight million people died from tobacco use in 2022 [1]. Of these deaths, 7 million were direct smokers, while about 1.2 million were recorded as passive participants who were exposed to participants who smoke. Among passive participants who smoke, 65.000 children die from cigarette smoke-related diseases annually. All forms of tobacco are harmful, and there is no safe form of exposure to tobacco.

Pictorial warnings on cigarette packs are an essential tobacco control strategy globally due to high exposure, universal access, and low cost. WHO encourages the implementation of the 2003 FCTC, which emphasizes the effectiveness of pictorial warnings over text messages to reduce the number of smokers worldwide [2]. By 2015, graphic warning policies had been implemented in 77 countries and jurisdictions that host approximately 50% of the world's population [3,4]. As of October 2020, 17 countries, including Australia, Saudi Arabia, Singapore, Türkiye, Canada, France, and the United Kingdom, have adopted plain packaging laws for tobacco products [5].

Cigarette packs have been an effective communication tool for tobacco companies, allowing them to communicate their brand and marketing messages to consumers [6,7], and research has shown that they can be practical tools for communicating the health risks of smoking [8,9]. A one-pack-a-day smoker could potentially see around 7300 packs of cigarettes per year (20 views/day × 365 days/year). Cigarette pack messages reach a larger audience than other anti-tobacco efforts, like mass media campaigns, because of their continuous exposure and direct consumer interaction [10].

When the studies are examined, it is seen that the harmful effects of tobacco use, especially visual stimuli, increase the adverse effects and accordingly change the attitudes, intentions, and behaviors toward cigarettes [4,8]. However, some smoke participants may have defensive reactions to these images or be unconcerned with their emotional content [11–13].

Over the years, numerous public health interventions and policies have been implemented to reduce smoking prevalence, such as graphic health warnings (GHWs) and plain packs for cigarette packs [4,8]. The effectiveness of these measures is closely linked to how individuals perceive and process the visual information presented on cigarette packs [14]. Understanding the differences in visual attention and eye movement patterns between participants who smoke and participants who do not smoke and male and female participants is crucial to designing more effective interventions.

The eye-tracker can directly measure attention, an essential precursor to information processing, recall, memory, and other important determinants of basic sciences [15,16]. Processing the information in health alert cues in an image is complex. The first step in making the method practical is to obtain the person's attention. Thus, observers will focus on understanding, remembering, and using the information in health decision-making [17]. With eye tracking, neurological measurements given by individuals to stimuli such as fixation and saccades are obtained as quantitative values. Thanks to these data, the cognitive state analysis helps to give more accurate information about the observation.

When the WHO's 2020 data on current tobacco use trends in people aged 15 and over in Türkiye were analyzed, it showed 38.1% for men, 12.9% for women, and 25.1% for both genders. About 15,760,600 people are estimated to smoke [18]. When the statistics of the Ministry of Health of the Republic of Türkiye were examined, the cigarette and tobacco use statistics of 40.1% of men over the age of 15, 13.3% of women, and an average of 26.5% in 2016 were similar to those of the WHO [19]. To reduce smoking in Türkiye, the flat pack application was started on 5 December 2019, and its application was created on 5 January 2020. With the flat pack application, all cigarette pack designs were made into a single color and pattern with Article 24 of Law No. 7151 dated 15 November 2018. Warning pictures and writings were added to eighty-five percent of the surface of the cigarette packs. In this way, the advertising factor in cigarette packages was eliminated, and the demand and interest were minimized.

This study aims to assess the effectiveness of integrating health warnings into the plain packaging design of cigarette packs. It specifically examines the psychological and behavioral responses of smokers and non-smokers to two categorized health warnings: "Anxiety" and "Disturbing". The research employs a comparative analysis across different participant groups categorized by smoking status and gender. The originality of this study stems from its evaluation of Türkiye's plain packaging policy through a broad participant base, utilizing visual attention measurement techniques. Eye-tracking technology is employed to measure participants' attention to health warnings objectively, and these data are used to understand the impact of warning design on smoking behaviors. This work offers valuable insights for enhancing the effectiveness of different health warnings in smoking cessation campaigns, suggesting tailored approaches to maximize public health outcomes.

2. Related Work

The exploration of how visual cues and messaging influence tobacco consumption has become a pivotal area of research within public health disciplines. A growing body of literature employing advanced methodologies such as eye-tracking and virtual reality (VR) provides nuanced insights into the cognitive and behavioral responses of smokers and non-smokers to various anti-smoking strategies. This section synthesizes seminal studies that investigate the efficacy of health warnings, the impact of advertisement design, and the potential of innovative technological tools in modifying smoking behaviors. By examining these diverse approaches, we aim to identify effective strategies for tobacco control that can be adapted to different demographic and psychological profiles.

Moodie et al. [20] engaged approximately 1400 participants, including adolescents and adults in England, to explore the efficacy of pictorial warnings on cigarette packs. Their study revealed that while these warnings were generally ineffective at deterring established young smokers, they had a noticeable impact on those who had never smoked or were only experimental smokers. This differentiation in response underscores the potential for targeted health messages to influence non-smokers or new smokers more effectively than their habitual counterparts.

Expanding on this theme, Maródi [21] focused on a younger demographic, assessing the impact of health warning visuals on seventh-grade students in Hungary. Utilizing a sophisticated eye-tracking setup, the study highlighted that highly emotive or frightening imagery prompted greater attention to the accompanying textual warnings. However, when both the textual and visual elements lacked sufficient intensity, the health messages failed to engage the students effectively. This finding suggests a threshold of stimulus intensity below which health communication may not achieve its intended effect, highlighting the importance of strategic message design in health education efforts.

Further exploring the role of textual warnings, Lochbuehler et al. [22] examined the behavior of long-term smokers using eye-tracking technology to track their attention to risk corrective statements on cigarette packs. Their results indicated a predominant disregard for text-only warnings, suggesting that the absence of accompanying images might reduce the overall visibility and impact of these messages. This research points to the critical need for integrating compelling graphical elements that can capture and retain the viewer's attention, thereby enhancing the communicative value of health warnings.

Eye-tracking technology has elucidated how visual elements in advertising influence young adults' perceptions and behaviors toward tobacco and vaping products. Stevens et al. [23] conducted a study that revealed young adults' pronounced focus on human images in e-cigarette advertisements. This focus not only captured significant attention but also appeared to diminish perceptions of harm post-exposure, suggesting that human imagery in advertisements might reduce the perceived risks associated with vaping products. Such findings highlight the potential of visual content in advertisements to shape young adults' attitudes toward the safety and appeal of e-cigarettes, potentially undermining the effectiveness of health warnings.

Further insights from Liu et al. [24] demonstrated that promotional content in IQOS advertisements significantly overshadowed mandated health warnings. This study involved 164 college students and showed that the promotional content greatly attracted their attention, overpowering the impact of health warnings such as the Surgeon General's warning. Notably, participants with prior e-cigarette use displayed increased favorable attitudes and intentions toward IQOS when their focus was more on promotional content than on health warnings. These results suggest a critical need for regulatory measures to ensure that health warnings are effectively positioned to compete with promotional content in tobacco-related advertisements, particularly to prevent the transition from e-cigarettes to more harmful tobacco products among young adults. This synthesis of findings underscores the importance of enhancing the visibility and impact of health warnings to counteract the persuasive power of advertising within the tobacco industry, aligning with public health objectives to combat nicotine addiction among young populations.

Recent advancements in eye-tracking and virtual reality technologies have profoundly impacted research in tobacco control, revealing new dimensions of how visual cues and contextual settings influence smokers' behaviors and perceptions. Schröder and Mühlberger [25] demonstrated the innovative use of virtual reality to explore cognitive biases, employing VR-based anti-saccade tasks that placed smokers in varied contextual environments like park scenes. Their findings indicated that such environments could intensify attentional biases, underscoring VR's potential as a powerful tool not only for understanding but also for modifying addictive behaviors. This insight is crucial as it suggests that manipulating environmental cues in VR settings could be strategically used to alter habitual patterns in smokers, thereby offering a novel pathway for intervention strategies.

Adding to the discourse on visual attention, Sillero-Rejon et al. [26] investigated how the size and presentation of health warnings on cigarette packaging influence consumer behavior. Their research, conducted using eye-tracking and discrete choice experiments among Colombian smokers and non-smokers, demonstrated that larger, more conspicuous health warnings effectively diverted attention away from branding toward health messages. This was particularly effective among non-smokers and younger demographics, reducing their willingness to initiate smoking and altering their perceptions of the product's taste and harm. These findings highlight the importance of visual prominence in health communication and suggest that enhancing the visibility of health warnings could be a key factor in tobacco control policies, especially in preventing the initiation of smoking among vulnerable groups.

Similarly, Kim et al. [27] focused on the impact of the FDA logo's prominence within the "Every Try Counts" initiative. Their study revealed that increased visual fixation on the FDA logo significantly boosted the reception of the message and strengthened cessation intentions among adult smokers. This underscores the role of prominent health endorsements in public health messaging, illustrating how strategic placement of authoritative logos can amplify the effectiveness of cessation campaigns, thus providing a critical tool for enhancing the impact of public health interventions aimed at reducing smoking rates.

Moreover, Wilcockson et al. [28] delved into the complexities of cognitive responses among smokers by classifying them based on their dependency levels. Their analysis revealed that dependent smokers exhibited reduced inhibitory control and heightened attentional biases towards smoking-related stimuli, contrasting sharply with non-dependent smokers. These insights emphasize the nuanced nature of addiction and underscore the need for interventions tailored to individual dependency levels. By addressing these varying levels, tobacco control strategies can be more precisely targeted, potentially increasing their effectiveness in aiding cessation among different smoker categories.

Creswell and Skrzynski [29] explored the relationship between smoking motivation, attentional bias (AB), and smoking behavior in a controlled setting. Their study, involving ninety daily smokers under conditions of varying smoking motivation, revealed that while higher motivation levels increased craving and reduced the time to the first puff, they did not significantly alter the attentional biases towards smoking-related cues. Importantly, these biases did not predict actual smoking behavior, suggesting that while craving can be intensified by motivation, it does not necessarily translate into increased smoking, indicating a gap between craving-induced attentional bias and actual smoking actions. This finding prompts a reevaluation of intervention strategies that solely focus on reducing cravings without addressing the broader behavioral cues and contexts that trigger smoking.

Keller-Hamilton et al. [30] assessed the impact of different types of warnings in e-cigarette advertisements, particularly comparing parody warnings against FDA-mandated warnings. Their research involving 73 young adults, all previous tobacco users, used eye-tracking to measure how long participants viewed each type of warning. The study found that participants spent significantly more time looking at parody warnings than the FDA-mandated ones, and the presence of a model's face notably reduced the attention paid to the mandated warnings. This study highlights the critical role of advertisement design in capturing consumer attention and suggests that regulatory measures need to

consider the visual appeal of health warnings to ensure they are effective in a competitive advertising landscape.

In a related vein, Hardardottir et al. [31] examined the effects of plain versus branded cigarette packaging on attention to graphic health warnings among smokers with different levels of illness sensitivity. Utilizing the EyeLink 1000 to track eye movements, the study demonstrated that plain packaging significantly increased visual engagement with health warnings, particularly among smokers characterized by low illness sensitivity. This suggests that plain packaging can be an effective tobacco control strategy by enhancing the visibility and impact of health warnings, potentially aiding in smoking cessation efforts, especially among individuals less proactive about their health.

Recent advancements in virtual reality (VR) and eye-tracking technologies are shaping the landscape of tobacco control research, providing innovative tools to understand and influence smokers' behaviors and perceptions. Liu et al. [32] introduced a novel VR paradigm designed to induce and measure nicotine craving among participants. This setup, which alternated between scenes containing nicotine and tobacco product cues and neutral scenes, was used to assess the direct effects of these cues on craving. The study's findings demonstrated that VR could effectively simulate environments that trigger nicotine craving, with significant increases in attentional bias and pupil diameter observed in active scenes. This underscores the potential of VR as a precise tool for studying addiction and developing targeted interventions based on how smokers physiologically respond to environmental cues.

Complementing this technological approach, Sillero-Rejon et al. [33] explored how different cigarette packaging features affect visual attention and behavioral responses. Conducted at the University of Bristol, this study utilized eye-tracking technology to examine how non-smokers, weekly smokers, and daily smokers reacted to health warnings of varying immediacy, framing, and severity. The findings highlighted that pictorial warnings placed on the upper half of the pack significantly increased visual attention and elicited stronger behavioral responses such as avoidance and reactance, particularly when compared to text-only warnings. This research suggests that the visual design of cigarette packaging can play a critical role in influencing consumer behavior, providing evidence that more prominent and visually engaging warnings might be more effective in preventing smoking.

Park et al. [34] further investigated how different types of graphic health warnings—specifically, health-related threats and social threats—affect smoking cessation intentions among smokers and non-smokers. By measuring attentional biases and assessing perceived unpleasantness using eye-tracking technology, the study found that both groups perceived health-related threats as more impactful, which led to stronger intentions to quit or continue abstaining from smoking. Interestingly, non-smokers found all graphic health warnings to be more unpleasant than smokers did, suggesting that non-smokers might be more sensitive to such warnings, which could influence their smoking-related decisions.

The studies reviewed herein collectively highlight the significant role of sensory engagement and contextual relevance in the effectiveness of health communication related to smoking cessation. The findings from eye-tracking research underscore the necessity for health warnings to not only capture attention but also to provoke a cognitive and emotional response that discourages smoking. Similarly, virtual reality emerges as a promising tool for simulating real-world environments that can trigger and potentially reshape smoking habits through immersive experiences. These technological advancements in research methodologies provide a foundation for developing more targeted and contextually appropriate interventions. As tobacco control policies evolve, integrating these insights will be crucial in designing health messages that are not only seen but are also impactful, ultimately guiding individuals toward making healthier lifestyle choices. The synthesis of these studies directs our ongoing research towards optimizing the visual and contextual components of anti-smoking campaigns to enhance their effectiveness across various population segments, thereby contributing to broader public health goals of reducing

smoking prevalence and its associated health burdens. By examining the "Anxiety" and "Disturbing" health warnings on plain cigarette packs, this research aims to deepen our understanding of how these warnings affect smokers and non-smokers across different demographics, particularly within the unique cultural and regulatory context of Türkiye. The insights gained from this study are expected to contribute significantly to the design of more effective health communication strategies, thereby enhancing the overall impact of public health interventions aimed at reducing smoking prevalence.

Research Hypothesiswe

H1. *Is there a significant difference in the AOI distributions in the images between the Smoker and Non-Smoker groups?*

H2. *Is there a significant difference between male and female groups in AOI distributions in plain cigarette pack images?*

H3. *Health stimuli perceived as "Anxiety" will attract participants' visual attention more than those perceived as "Disturbing"?*

3. Materials and Methods

3.1. Material and Experimental Design

This study used a mixed model design that included gender and smoking status (non-smoker and daily smoker) as between-subject factors. Eye-tracking devices were used to measure the number of eye movements for health warnings on cigarette packs. The study used 14 designs with pictures and texts for Türkiye's flat cigarette pack application [35].

Incorporating expert opinions into research methodologies greatly enhances the validity and reliability of findings, particularly in fields requiring deep knowledge and practical experience, such as public health and tobacco control. Experts ensure that theoretical constructs are robustly linked to practical clinical realities, thereby grounding the research in empirical evidence. As noted by Okoli and Pawlowski [36], utilizing expert panels adds rigor to research processes, especially in complex categorization tasks, by minimizing subjective biases and improving consistency. This method aligns with health communication best practices and is supported by Meuser and Nagel [37], who highlight the crucial role of expert interviews in qualitative research. In our study, we applied this rigorous approach to categorize the visual content and warning labels on cigarette packages in Türkiye. The images were systematically classified into two categories: 'Anxiety' and 'Disturbing,' based on the evaluations of a panel of five healthcare professionals, including doctors and nurses with expertise in the field. Figures 1 and 2 illustrate examples of plain cigarette packages categorized under the 'Anxiety' and 'Disturbing' labels, respectively, demonstrating how our expert panel's criteria were employed to guide this classification process. Such expert-driven categorization not only strengthens the empirical foundations of our study but also enhances its applicability and defensibility across diverse contexts.

3.2. Working Group

It consists of participants who do not smoke (those who have never smoked more than 100 cigarettes in their lifetime and are currently participants who do not smoke) and daily participants who smoke (who smoke at least five cigarettes per day). All participants must have normal vision or have a structure that will not affect eye tracking. Accordingly, those with high astigmatism and strabismus, those with eyes too small to wear lenses, and those with eye disease, psychiatric disorders, and neurological diseases were excluded from the study. Participants filled out questionnaires about personal information forms (age and gender), smoking habits, and smoking history (age of first smoking, year of smoking, amount of daily smoking, and last smoking hour). Ethics committee approval with file number 2022-9- and file number 2022-143 was obtained from Bandirma Onyedi Eylül University Health Sciences Non-Interventional Research Ethics Committee for the

collection of eye-tracking data. All participants were informed before the experiment, and the Volunteering Form was filled out.



Figure 1. Sample plain cigarette pack images belonging to the "Anxiety" category. (Example Figure 1 image 2: Smoking slows blood flow and causes sexual impotence).



Figure 2. Sample plain cigarette pack images belonging to the "Disturbing" category. (Example Figure 2 image 2: Smoking causes throat cancer).

3.3. Data Collection

In an Istanbul University's Department of Informatics study, participants' eye movements were analyzed using the Tobii Pro X2-60 eye-tracker and Tobii Studio Pro Lab 1.145.28180 software. Before the eye-tracking test, each participant was positioned at a distance of 50 to 70 cm from the computer. The experiment focused on understanding participants' attitudes towards cigarette packs, using images 829 px wide and 1131 px high, centrally positioned on the monitor.

Participants began by completing a Personal Information Form with details like date of birth, gender, living situation, education level, and smoking status. Following this, they were seated in front of the eye-tracker for calibration, using a 9-point calibration method. Once calibration was successful, they received on-screen instructions and were allowed to ask questions before starting the experiment.

The experimental procedure involved displaying 14 images from cigarette packs, each for 5 s. To help maintain a fixed gaze position, a blank image was shown for 2 s between each cigarette pack image. This process was designed to be brief yet practical, lasting 5 to 10 min per participant.

3.4. Eye Tracking

Eye-tracking technology plays a pivotal role in our investigation, providing a window into how individuals process visual stimuli within a dynamic environment. This study employs advanced screen-based eye-tracking devices designed to assess the user's gaze on computer screens comprehensively. These devices utilize near-infrared light to illuminate the eyes, creating well-defined reflections on the pupil and cornea, which are captured by integrated camera sensors as seen in Figure 3. The data captured are processed using sophisticated image processing algorithms, which accurately determine the three-dimensional position and gaze direction of the user's eyes, facilitating precise identification of gaze points and focus durations on the screen [38]. This enables precise determination of the points on the screen where the user is focused and the duration of their focus.

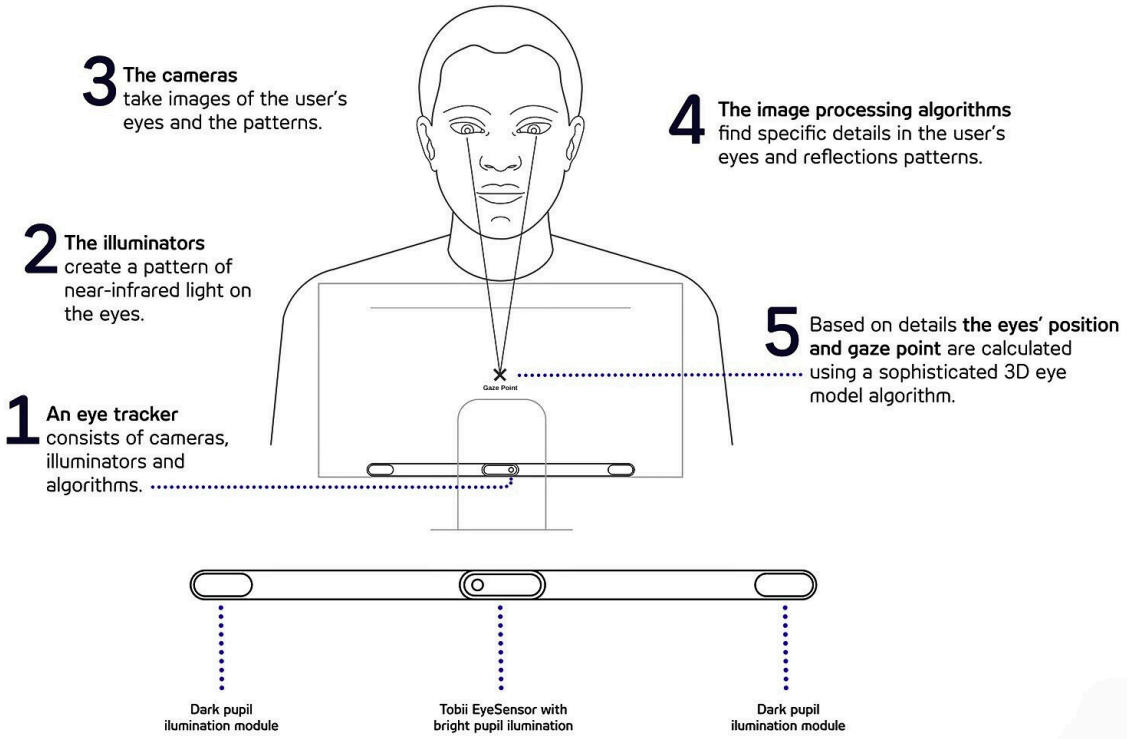


Figure 3. How screen-based eye-tracking devices work.

The methodology of eye tracking is grounded in its ability to provide valuable indicators of how individuals attend to and perceive various elements within a scene. We measure several key metrics to assess visual attention and cognitive engagement:

Fixations: These are periods when the eyes remain relatively stationary, focusing on a specific element of the visual field. Each fixation, lasting about 200–300 milliseconds, is indicative of concentrated attention, providing insights into the points of interest within the stimulus [39].

Saccades: These rapid eye movements between fixations facilitate the transition of gaze across different points of interest, typically lasting 20–40 milliseconds. Saccades are crucial for understanding how information is processed sequentially across the visual field. In the context of visual attention research, larger saccade amplitudes can often suggest a behavioral tendency to avoid disturbing visual stimuli [40–42].

Areas of Interest (AOIs): These are predefined regions of the visual stimuli that are of particular importance to the study. AOIs are analyzed to determine the number and duration of fixations, which helps assess the cognitive load and the level of engagement with these elements. This analysis is vital for understanding which aspects of the stimuli draw more attention and are more engaging to the viewer [43].

In analyzing the data from these eye-tracking metrics—namely, the number of fixations, the duration of each fixation, the amplitude of saccades, and pupil size—we obtain a comprehensive understanding of the participant's visual and cognitive processing. These parameters are crucial as they relate directly to the amount of information the user is processing and how they are engaging with the visual elements presented [44–46]).

To elucidate the cognitive mechanisms underpinning the observed behaviors, we calculate the mean and standard deviation of fixation durations and saccade amplitudes within each AOI. This quantitative assessment helps us understand the intensity of visual attention and cognitive load across different conditions and participant groups. By analyzing these metrics, we can identify patterns of visual engagement and attentional shifts that are crucial for developing effective communication strategies [47,48]. Additionally, by focusing on areas of high semantic importance within the stimuli, we can explore how specific content areas influence cognitive processes and behavioral responses, providing insights essential for tailoring public health interventions [49].

3.5. Data Analysis

Neurological bare eye-tracking data such as fixation and saccade obtained with Tobii Pro Lab software were analyzed in the SPSS v18. The significance level of the obtained findings was accepted as $p = 0.05$. Descriptive statistics were used to characterize interest in picture and text stimuli by smoking and gender status. The widely used Kolmogorov–Smirnov and Shapiro–Wilk tests were used to determine whether the data showed a normal distribution [50]. The Kolmogorov–Smirnov (K-S) test, when the group size is greater than 50, and the Shapiro–Wilk test, if small, are the two tests used to examine the normality of the data [51]. In cases where the data were normally distributed, the independent groups *t*-test was used to examine the differences between the groups regarding the research questions. The Mann–Whitney U-Test was used for non-parametric tests.

3.6. Limitations

This study yields important insights into the effects of visual health warnings on cigarette packaging across various demographic groups. However, several limitations should be considered:

Cultural and Regulatory Context: The generalizability of our findings may be limited as the study was conducted within the specific cultural and regulatory framework of Türkiye. Responses to health warnings may vary significantly in different international contexts due to cultural and legal differences in the perception and regulation of tobacco products.

Participant Categorization: Our binary categorization of participants into smokers and non-smokers may not capture the full spectrum of smoking behaviors. A more detailed categorization, including occasional smokers and individuals in cessation programs, might provide a more nuanced understanding of the responses to health warnings.

Reliance on Self-Reported Data: The study's reliance on self-reported smoking status introduces potential biases such as social desirability and recall errors. These biases might lead participants to underreport or misreport their smoking behaviors, potentially affecting the study's outcomes.

Use of Static Images: The employment of static images in our study does not capture the dynamic nature of how individuals interact with cigarette packaging in real life. Future studies could benefit from incorporating dynamic or interactive packaging simulations to yield findings that more closely reflect real-world conditions.

Interpretation of Eye-Tracking Data: Although eye-tracking provides precise measurements of visual attention, it does not elucidate the psychological or emotional reasons behind these gaze patterns. Integrating qualitative methods such as think-aloud protocols or in-depth interviews could provide deeper insights into the cognitive and emotional processes influencing attention.

Measurement of Psychological Constructs: Our study proposes psychological mechanisms such as cognitive avoidance and heightened sensitivity without direct measurement. Future research incorporating psychophysiological tools or neuroimaging techniques could offer a more direct assessment of the cognitive and emotional responses elicited by health warnings.

Subjective Categorization of Warnings: The categorization of health warnings into 'Anxiety' and 'Disturbing' was based on expert opinions, which might introduce subjectivity. Employing a more empirically grounded methodology for categorizing warning types could improve the consistency and reliability of our results.

Addressing these limitations in subsequent research will refine our methodologies and broaden the applicability of our findings, thereby enhancing the design and effectiveness of public health interventions aimed at reducing smoking prevalence.

4. Results

Findings and comments in line with the hypotheses obtained in the research are presented under the following subheadings.

H1. *Is there a significant difference in the AOI distributions in the images between the Smoker and Non-Smoker groups?*

Table 1 presents an in-depth analysis of eye-tracking data that underscores significant differences in how smokers and non-smokers engage with health warnings on cigarette packs. This table includes data on the number of fixations and total amplitude of saccades, providing insights into the visual attention and processing behaviors of the two groups when exposed to cigarette packaging labeled with "Disturbing" and "Anxiety" themes.

The fixation data show that non-smokers tend to focus more on textual elements of the health warnings than smokers. Specifically, non-smokers recorded a higher number of fixations on text (mean = 10.39, SD = 2.82) compared to smokers (mean = 8.20, SD = 3.39), with a statistically significant difference (t = 1.38, $p = 0.004$). This suggests that textual warnings are more effective in capturing the attention of non-smokers, potentially due to their higher sensitivity to health-related information. In contrast, the number of fixations on images did not significantly differ between the groups, indicating that pictorial warnings alone may not be sufficient to distinguish attentional responses between smokers and non-smokers.

Table 1. *t*-test results and Mann–Whitney U-Test results for AOI of plain cigarette packs of participants who smoke and participants who are in the no smoke groups.

		Group	*n*	$\overline{X}$	S	sd	t	*p*
Number of Fixations	Picture	participants who smoke	34	5.84	2.87	70	3.97	0.780
		participants who do not smoke	38	6.01	2.10			
	Text	participants who smoke	34	8.20	3.39	70	1.38	0.004
		participants who do not smoke	38	10.39	2.82			
Total Amplitude of Saccades		participants who smoke	34	54.47	16.09	70	−4.18	0.000
		participants who do not smoke	38	70.97	17.37			

Table 1. *Cont.*

		Group	*n*	Mean Rank	Sum of Ranks	U	*p*
Average Duration of Fixations	Picture	participants who smoke	34	42.25	1436.50	450.50	0.027
		participants who do not smoke	38	31.36	1191.50		
	Text	participants who smoke	34	37.18	1264.00	623.00	0.795
		participants who do not smoke	38	35.89	1364.00		
Duration of First Fixation	Picture	participants who smoke	34	41.57	1413.50	473.50	0.052
		participants who do not smoke	38	31.96	1214.50		
	Text	participants who smoke	34	37.00	1258.00	629.00	0.848
		participants who do not smoke	38	36.05	1370.00		

The total amplitude of saccades reveals a broader range of eye movements in non-smokers compared to smokers, with non-smokers showing a higher amplitude (mean = 70.97, SD = 17.37) versus smokers (mean = 54.47, SD = 16.09). This finding, which is statistically significant (t = −4.18, p = 0.000), indicates that non-smokers engage in more extensive visual scanning of the cigarette packs. However, this behavior may also reflect an avoidance mechanism, particularly in response to the aversive content depicted in the "Disturbing" and "Anxiety" images. Non-smokers may quickly scan these disturbing elements to avoid prolonged exposure to unpleasant stimuli, suggesting a protective visual behavior.

These patterns of visual engagement have critical implications for the design of public health messages on cigarette packaging. The effectiveness of textual versus pictorial warnings in engaging different groups underscores the need for tailored approaches in health communication. For non-smokers, ensuring that textual warnings are engaging and informative could enhance the preventive impact of these messages. For smokers, overcoming habituation to graphic images might require integrating novel visual strategies or rotating warning themes to recapture their attention.

H2. *Is there a significant difference between male and female groups in AOI distributions in plain cigarette pack images?*

Table 2 provides a detailed statistical analysis of the differences in how male and female participants engage with plain cigarette packs, focusing particularly on the areas of interest (AOIs) that include pictorial and textual elements. The results reveal that females exhibit a significantly higher number of fixations on pictorial content compared to males (females mean = 6.59, SD = 2.52; males mean = 5.40, SD = 2.34), with a t-value of 2.074 and a p-value of 0.044. This suggests a deeper or more sustained visual engagement with these elements by females, perhaps indicating a greater alertness to or interest in the visual stimuli provided.

The Total Amplitude of Saccades, which measures the breadth of eye movements across the visual field, showed significant gender differences. Females demonstrated a broader range of eye movements (mean = 70.22, SD = 18.79) compared to males (mean = 57.55, SD = 16.64), with a t-value of 3.033 and a p-value of 0.003. This greater amplitude could suggest a more comprehensive scanning behavior by females, potentially indicating a more thorough processing of information. However, an alternative interpretation might

consider this behavior as indicative of avoidance, particularly in response to disturbing or anxiety-inducing images within the "Disturbing" and "Anxiety" themes. Such avoidance behavior could manifest as quicker scans across unsettling images to minimize emotional discomfort, suggesting a defensive visual strategy employed by females.

Table 2. *t*-test and Mann–Whitney U-test results for AOI of plain cigarette packs of male and female groups.

		Group	***n***	$\overline{\mathbf{X}}$	**S**	**sd**	***t***	***p***
Number of Fixations	Picture	Female Male	32 40	6.59 5.40	2.52 2.34	70	2.074	0.044
	Text	Female Male	32 40	9.26 9.43	3.32 3.27	70	−0.218	0.829
Total Amplitude of Saccades		Female Male	32 40	70.22 57.55	18.79 16.64	70	3.033	0.003
		Group	***n***	**Mean Rank**	**Sum of Ranks**		**U**	***p***
Average Duration of Fixations	Picture	Female Male	32 40	42.25 31.36	1436.50 1191.50		450.50	0.027
	Text	Female Male	32 40	37.18 35.89	1264.00 1364.00		623.00	0.795
Duration of First Fixation	Picture	Female Male	32 40	34.67 37.96	1109.50 1518.50		581.50	0.507
	Text	Female Male	32 40	30.00 41.70	960.00 1668.00		432.00	0.018

Moreover, the Mann–Whitney U Test results complement these findings by showing significant differences in the average duration of fixations on pictures, with females exhibiting longer durations (mean rank = 42.25) compared to males (mean rank = 31.36; U = 450.50, $p = 0.027$). This indicates not only more frequent but also more prolonged engagements with pictorial warnings by females. Additionally, the quicker initial engagement with text by females, as demonstrated by the shorter duration of the first fixation (U = 432.00, $p = 0.018$), might imply a rapid processing of textual information, which could be critical in contexts where immediate comprehension of health warnings is necessary.

These insights are essential for designing effective tobacco control measures. The distinct patterns of visual attention and processing exhibited by females and males, particularly regarding pictorial elements and the extent of visual exploration, suggest that gender-specific approaches might enhance the effectiveness of public health messages on cigarette packaging. By understanding these behavioral nuances, health communicators and policymakers can tailor their strategies to maximize the impact of smoking cessation campaigns, thereby potentially reducing smoking prevalence more effectively.

H3. *Will health stimuli perceived as "Anxiety" attract participants' visual attention more than those perceived as "Disturbing"?*

Table 3 offers a detailed examination of how smokers and non-smokers respond to "Anxiety" and "Disturbing" stimuli on cigarette packs, utilizing eye-tracking metrics to assess visual attention differences. This analysis is pivotal in understanding how emotional content in health warnings influences viewer engagement and processing.

The *t*-test results illustrate significant differences in how participants interact with these emotionally charged stimuli. Notably, the number of fixations on "Disturbing" stimuli was significantly lower for smokers (mean = 6.72, SD = 1.43) compared to non-smokers (mean = 7.95, SD = 0.96), with a *t*-value of −4.304 and a *p*-value of 0.000, suggesting that smokers may avoid or disengage from particularly unsettling content. In contrast,

for "Anxiety" stimuli, both groups demonstrated varied engagement, but smokers still showed restricted eye movement, with a mean amplitude of saccades significantly lower (mean = 56.38, SD = 17.84) than non-smokers (mean = 72.36, SD = 17.87), indicating a more confined visual exploration which might suggest a form of cognitive avoidance or desensitization to the stimulus.

Table 3. *t*-test results for plain cigarette packs of smoker and non-smoker groups.

		Group	***n***	$\overline{\mathbf{X}}$	**S**	**sd**	***t***	***p***
Number of Fixations	Disturbing	participants who smoke	34	6.72	1.43	70	−4.304	0.000
		participants who do not smoke	38	7.95	0.96			
Total Amplitude of Saccades	Anxiety	participants who smoke	34	56.38	17.84	70	−3.790	0.000
		participants who do not smoke	38	72.36	17.87			
	Disturbing	participants who smoke	34	51.93	14.74	70	−4.446	0.000
		participants who do not smoke	38	69.13	17.73			
		Group	***n***	**Mean Rank**	**Sum of Ranks**	**U**		***p***
Number of Fixations	Anxiety	participants who smoke	34	28.19	958.50	363.50		0.001
		participants who do not smoke	38	43.93	1669.50			
Average Duration of Fixations	Anxiety	participants who smoke	34	43.68	1485.00	402.00		0.006
		participants who do not smoke	38	30.08	1143.00			
	Disturbing	participants who smoke	34	40.82	1388.00	499.00		0.097
		participants who do not smoke	38	32.63	1240.00			
Duration of First Fixation	Anxiety	participants who smoke	34	40.68	1383.00	504.00		0.109
		participants who do not smoke	38	32.76	1245.00			
	Disturbing	participants who smoke	34	38.07	1294.50	592.50		0.546
		participants who do not smoke	38	35.09	1333.50			

Further depth is added by the Mann–Whitney U test outcomes, which highlight differences in the distribution of ranks between smokers and non-smokers. Smokers exhibited a significantly lower mean rank in the number of fixations on "Anxiety" stimuli (U = 363.50, $p = 0.001$), underscoring a reduced visual engagement. This trend continues with the average duration of fixations, where smokers also showed longer durations on "Anxiety" stimuli (U = 402.00, $p = 0.006$), potentially indicating a deeper processing or contemplation when they do focus on these images. However, no significant differences were observed in the duration of the first fixation for either type of stimuli, suggesting that initial reactions to the stimuli are similar across groups, with differences emerging only in sustained attention.

These findings are critical for tailoring public health messages on cigarette packaging. The apparent avoidance of disturbing content by smokers, particularly, highlights the need for strategies that can effectively engage this group without triggering avoidance behaviors. Understanding that non-smokers are more receptive to these warnings suggests that different approaches might be necessary to captivate and educate smokers and non-smokers effectively.

Table 4 offers a critical examination of how male and female participants respond differently to "Anxiety" and "Disturbing" stimuli on plain cigarette packs, using eye-tracking technology to capture detailed metrics of visual engagement. The analysis focuses on the number of fixations and the total amplitude of saccades, revealing nuanced patterns in how genders process these emotionally charged visuals.

Table 4. *t*-test results for plain cigarette packs of male and female groups.

		Group	**n**	$\overline{X}$	**S**	**sd**	***t***	***p***
Number of Fixations	Disturbing	Female Male	32 40	7.69 7.11	1.18 1.43	70	1.822	0.073
Total Amplitude of Saccades	Anxiety	Female	32	72.72	19.12	70	3.287	0.002
		Male	40	58.49	17.52			
	Disturbing	Female Male	32 40	66.90 56.29	19.16 16.59	70	2.516	0.014
		Group	***n***	**Mean Rank**	**Sum of Ranks**		**U**	***p***
Number of Fixations	Anxiety	Female Male	32 40	39.36 34.21	1259.50 1368.50		548.50	0.300
Average Duration of Fixations	Anxiety	Female Male	32 40	33.52 38.89	1072.50 1555.50		544.50	0.279
	Disturbing	Female Male	32 40	30.91 40.98	989.00 1639.00		461.00	0.043
Duration of First Fixation	Anxiety	Female Male	32 40	29.81 41.85	954.00 1674.00		426.00	0.015
	Disturbing	Female Male	32 40	32.86 39.41	1051.50 1576.50		523.50	0.187

Disturbing Stimuli: The data indicate that females tended to fixate slightly more on disturbing stimuli (mean = 7.69, SD = 1.18) than males (mean = 7.11, SD = 1.43). Although the difference was not statistically significant (t = 1.822, p = 0.073), it suggests a trend where females may engage more intensely with such stimuli. This could imply greater responsiveness or sensitivity to visual elements intended to elicit strong emotional reactions.

Anxiety Stimuli: When examining anxiety-inducing stimuli, no significant differences were found in the number of fixations between genders (U = 548.50, p = 0.300), indicating that both males and females initially engage with these stimuli to a similar extent.

This metric, reflecting the range of eye movements, showed significant differences for both types of stimuli. Females exhibited a broader range of eye movements compared to males, with values notably higher for anxiety-inducing (mean = 72.72, SD = 19.12) and disturbing stimuli (mean = 66.90, SD = 19.16). These findings (t = 3.287, p = 0.002 for anxiety; t = 2.516, p = 0.014 for disturbing) suggest that females engage in more extensive visual exploration, which could indicate a deeper or more comprehensive processing of the content presented.

The observed differences in visual attention patterns underscore the importance of considering gender when designing and implementing public health warnings on cigarette packaging. The increased amplitude of saccades in females suggests that health warnings might need to be particularly compelling or visually arresting to effectively capture and hold their attention. Conversely, the similarity in initial fixations for anxiety-inducing

stimuli across genders suggests that these types of warnings initially draw attention equally from both males and females, highlighting their potential effectiveness in capturing viewer interest.

These insights are vital for public health officials and policymakers aiming to craft effective anti-smoking messages that resonate with diverse audiences. By tailoring the design and content of health warnings to align with the specific visual processing styles of different genders, public health campaigns can enhance the impact and retention of critical health information, potentially leading to more effective smoking cessation outcomes.

5. Discussion

This investigation delves into the nuanced ways in which different demographic groups—specifically smokers versus non-smokers and males versus females—respond to visual stimuli on cigarette packaging featuring "Anxiety" and "Disturbing" design motifs. The findings enrich our understanding of how visual attention and eye-tracking metrics differ among these groups, offering critical insights for the design of public health interventions tailored to these distinctions.

Our research confirms that non-smokers are particularly attentive to textual warnings on cigarette packages, a finding that aligns with Maynard et al. [52] and Klein et al. [15], who observed that non-smokers are generally more receptive to health communications. This heightened receptivity to textual information presents a strategic advantage in designing effective smoking cessation messages. Additionally, our analysis also noted that smokers often exhibit defensive or dismissive reactions to graphic imagery, especially those categorized as 'Disturbing'. This behavior, which aligns with findings by Glock & Kneer [11] and Stothart et al. [13], suggests a tendency among smokers to engage in cognitive avoidance, potentially diminishing the effectiveness of fear-based health warnings. These insights underline the necessity of tailoring health warnings to accommodate the distinct psychological profiles of smokers and non-smokers. By strategically enhancing the clarity and salience of textual warnings for non-smokers and addressing cognitive avoidance in smokers, public health campaigns can be optimized to increase their overall impact on smoking cessation efforts.

Gender differences in visual processing are markedly evident in our study, where female participants demonstrated greater saccade amplitudes, indicating a more intensive and thorough engagement with visual information. This observation supports findings by Harrison et al. [53] and Orquin et al. [54], who documented inherent differences in how genders process risk-related visuals, influenced by variations in empathy and risk perception. The enhanced emotional reactivity and empathy typically associated with women [55] further elucidate their heightened response to emotive content in health warnings. Additionally, our results show that female participants exhibit shorter fixation durations on 'Anxiety' themed warnings, aligning with Kreuter et al. [56], who emphasized the importance of immediate cognitive engagement with health messages. Such rapid engagements are critical for initiating cognitive and emotional processes that can catalyze behavioral change, underscoring the significance of the initial impact of visual cues on health behavior modification. These findings underscore the necessity of designing gender-specific public health interventions, suggesting that tailoring health warnings to evoke strong emotional responses from females could be particularly effective. By leveraging the deeper cognitive processing responses of women to emotionally charged content, public health messages can optimize engagement and facilitate impactful behavior change, thereby enhancing the efficacy of smoking cessation campaigns.

Integrating these insights with the broader discourse in tobacco control, particularly the growing emphasis on demographic-specific interventions [4,57], this study extends the current understanding of optimal design strategies for health warnings on cigarette packs. It suggests that public health strategies could significantly benefit from leveraging these differential cognitive and visual engagements to enhance the impact of smoking cessation campaigns.

The unique responses to "Anxiety" and "Disturbing" themes also offer a deeper understanding of the emotional and cognitive engagements elicited by different warning types. In conclusion, this research not only maps out how distinct demographic groups interact with and process health warnings but also provides a template for the customization of public health messages. By tailoring interventions to fit the specific visual and cognitive engagement patterns identified through sophisticated eye-tracking metrics, health communicators and policymakers can craft more effective anti-smoking campaigns, potentially increasing their efficacy across diverse populations.

6. Conclusions and Future Work

This study's implications are extensive, providing critical guidance for future public health policies and interventions. The pronounced responsiveness of non-smokers to health warnings underscores the potential of increasing the visibility and prominence of these warnings to further deter smoking initiation. Longitudinal investigations of these interventions could yield deeper insights into their long-term effectiveness.

In conclusion, our findings reveal significant gender differences in responses to visual health warnings on cigarette packaging, highlighting the necessity of designing public health interventions that are tailored to these distinct visual attention patterns. As we move forward, it is essential to broaden these strategies to encompass a wider range of demographic variables, such as age and cultural backgrounds. Integrating these diverse demographic insights will refine the specificity and effectiveness of health communication strategies, facilitating the development of more universally applicable tobacco control measures. By adopting such a comprehensive and inclusive approach, we can align public health interventions more closely with the varied needs of a global population, thereby significantly enhancing the outcomes of smoking cessation campaigns worldwide.

Furthermore, the advanced use of eye-tracking technology in this study underscores its potential to evaluate real-time responses to public health messaging, paving the way for more dynamic and responsive health communication strategies. Looking ahead, integrating these findings into the broader context of digital health communications could significantly expand the reach and impact of health warnings. Additionally, exploring the psychological mechanisms that underpin visual attention to health warnings will enrich our understanding of consumer behavior within health contexts, potentially leading to the development of more effective health communication tools.

This study's detailed analysis of the differential impacts of health warning designs on various demographic groups provides new insights that can directly inform the design of more effective tobacco control policies. Unlike previous works, this research offers tailored insights that are vital for developing targeted interventions, thereby contributing significantly to the field of public health.

This research elucidates the significant impact of visual health warnings on cigarette packaging and their profound influence on smoking behavior. By integrating advanced methodologies such as eye-tracking combined with think-aloud protocols, our study delves deeper into the cognitive and emotional dynamics elicited by these warnings. Additionally, the use of Implicit Association Tests (IAT) could uncover the unconscious biases and attitudes toward smoking that significantly influence both visual and cognitive engagement with these warnings.

The adoption of these sophisticated methods is set to transform our understanding of health communication. We advocate for a comprehensive approach that integrates quantitative data with qualitative insights, utilizing methodologies like longitudinal studies and facial expression analysis. This integrated strategy will not only validate and refine the psychological constructs associated with our findings but also facilitate the creation of more effective public health messages tailored to meet the diverse needs of global audiences. Such efforts are essential for enhancing the efficacy of smoking cessation campaigns and improving public health outcomes.

Moreover, this research significantly advances our understanding of how visual elements on cigarette packaging influence public health behaviors across diverse demographic groups. By revealing distinct differences in how smokers and non-smokers, as well as males and females, process visual health warnings, our study provides crucial insights for designing more effective anti-smoking campaigns tailored to the unique needs and sensitivities of these groups. Furthermore, the integration of objective measures, such as cotinine levels in saliva or carbon monoxide levels in breath, in future research could further refine these strategies, ensuring they are based on accurate and reliable assessments of smoking status. Moving forward, effectively incorporating these findings and methodologies into the development of global health strategies will be pivotal in reducing smoking rates and enhancing public health outcomes worldwide.

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