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RESEARCH ARTICLE

Visual attention to nicotine product packaging: Evidence from an eye-tracking study among university students

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Abstract

Background: Nicotine product packaging conveys both branding and health information, yet marketing elements may visually compete with warning labels and weaken risk communication, particularly for novel nicotine products.

Objective: This study aims to assess how visual attention is distributed across key packaging features of conventional cigarettes, heated tobacco, e-cigarettes, and nicotine pouches among young adult nicotine users.

Methods: We conducted an experimental eye-tracking study with 45 Czech university students, all of whom had used nicotine products in the previous two weeks. Participants physically handled and inspected the packaging of four product types: conventional cigarettes, heated tobacco, e-cigarettes, and nicotine pouches. Visual attention was analyzed across five predefined areas of interest, including warning labels, branding, and product composition. Two eye-tracking indicators were assessed: fixation duration and dwell time within each area of interest. Repeated-measures analysis of variance and post hoc tests were used to determine statistically significant differences both within and across product types.

Results: Branding and product composition consistently received more attention than warning labels or general text. Warning labels attracted the most attention, only for conventional cigarettes. In cross-product comparisons, branding was significantly more engaging for e-cigarettes and nicotine pouches, while attention to health warnings remained low. Fixation data supported these trends, suggesting more intensive processing of branding than of health-related information.

Conclusion: Warning labels on conventional cigarettes attracted substantially more visual attention than those on novel nicotine products, where branding and composition dominated instead. This suggests that current packaging requirements for e-cigarettes, heated tobacco, and nicotine pouches may not achieve comparable

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warning salience. Extending established cigarette packaging standards to these categories, alongside clearer communication of relative product risk, could improve consumer engagement with health information.

Keywords: Eye-tracking; Tobacco packaging; Warning labels; Public health policy

1. Introduction

Packaging of nicotine products plays a crucial role in shaping consumer perceptions and guiding visual attention. In the absence of direct health counseling, packaging can become the primary source of information.[1] The World Health Organization emphasizes that warnings on packaging aim to raise awareness of health risks, reduce product appeal, and influence behavior.[2] However, these goals are frequently undermined by competing visual stimuli such as branding and design.[3]

Recent European studies confirm that warning label effectiveness varies across population groups. Kahnert *et al.*[4] showed that warning salience improved after the European Union Tobacco Products Directive, but behavioral responses were more pronounced among women, participants with higher education levels, and less dependent smokers. Graphic warnings were rated more effective than text-only formats among Greek adolescents[5], and Hitchman *et al.*[6] found their impact varied by country and socioeconomic status.

These limitations in warning effectiveness are particularly consequential, given the widespread misunderstanding of relative product harm. A significant body of research documents consumers' difficulty in comparing the relative harm of nicotine products. Tan *et al.*[7] found that adults in the United States often failed to see Food and Drug Administration-authorized modified-risk products as less harmful than cigarettes. Snell *et al.*[8] reported that many low-income older adults viewed e-cigarettes as equally harmful or more harmful, limiting harm-reduction efforts. O'Brien *et al.*[9] and Czoli *et al.*[10] further showed widespread misunderstanding of risks tied to smokeless tobacco and alternative nicotine delivery products. Consistent with these findings, a large survey of Polish adolescents showed that less popular products such as water pipes and smokeless tobacco were often perceived as more harmful than regular cigarettes, highlighting a generally insufficient and sometimes misleading understanding of the relative harmfulness of nicotine products, alongside gaps in public health education.[11] Furthermore, research suggests that cigarette smoking may be sustained not only by risk perceptions but also by perceived benefits such as relaxation or greater social comfort, which are associated with heavier smoking and more negative attitudes toward quitting.[12]

In Czechia, the prevalence of nicotine use among young adults remains high. According to Csémy *et al.*[13], 24.9% of individuals aged 15–24 reported smoking combustible tobacco products in the past 30 days, with 9.1% smoking almost daily or daily. In the same age group, 16.6% reported past-30-day e-cigarette use (4.3% daily), 11.4% reported heated tobacco use (3.9% daily), and 3.4% reported nicotine pouch use (0.9% daily). Overall prevalence has slightly declined, but patterns of use have shifted toward e-cigarettes and heated tobacco. These trends highlight that Czech university students (a central focus of our study) are situated in a population segment with both high nicotine use and rapid adoption of novel products.

Visual attention is a key condition for processing health messages. Peters *et al.*[14] describe attention as the first step in message effectiveness. Sillero-Rejon *et al.*[15] demonstrated that pictorial warnings engage viewers more than text-only versions, especially among smokers not planning to quit. These findings align with evidence that visual, loss-framed content evokes stronger responses.[16]

Design characteristics such as warning size and location are also important determinants of warning effectiveness. Increasing warning coverage from 30% to 70% increased visual attention and reduced focus on branding,[17] particularly under standardized packaging and among non-smokers. Similarly, White *et al.*[18] found greater awareness of smoking harms among Australian adolescents after larger front-of-pack warnings were introduced.

Nevertheless, awareness does not always translate into behavioral change. Taylor *et al.*[19] noted that while recall improved after the introduction of nicotine addiction warnings in England, concern and behavioral responses remained unchanged. Trofor *et al.*[20] found that although smokers across six European countries were aware of common risks, they lacked knowledge of lesser-known harms. In both studies, higher health literacy was associated with a stronger warning impact.

Packaging design also shapes how warnings are perceived. King *et al.*[21] showed that contrast and

simplified shapes in e-cigarette advertisements improved both attention and comprehension. Eye-tracking, as emphasized by Strasser *et al.*,[22] is increasingly used to objectively evaluate which packaging elements attract gaze and attention. Placement matters: upper-pack warnings receive more fixations than bottom-positioned warnings.[17] Johnson *et al.*[23] found that pictorial warnings in cigarette ads attracted early and frequent attention via heatmapping. Sidhu *et al.*[24] showed that emotionally charged "high-avoidance" warnings sustained visual attention longer than milder ones. However, in non-standardized packaging, warnings still compete poorly with branding. Liu *et al.*[25] found that IQOS advertisements in the United States drew more attention to flavor descriptors and logos than warnings. Similarly, Chen-Sankey *et al.*[26] observed that visual design elements in e-cigarette ads outperformed textual warnings in grabbing attention, and this translated into more favorable product perceptions.

From a regulatory perspective, Czechia follows the European Union Tobacco Products Directive, which requires combined text-and-picture health warnings covering 65% of cigarette packs. National legislation has gradually extended mandatory labeling and health warning requirements to all nicotine products, including e-cigarettes, heated tobacco, and nicotine pouches. Since April 2024, these categories have also been subject to excise stamps and related labeling obligations, although some novel products remain only partially regulated.

To our knowledge, this study is the first to combine an eye-tracking experiment with side-by-side exposure to four major nicotine product types—conventional cigarettes, heated tobacco, e-cigarettes, and nicotine pouches—under controlled conditions. Existing eye-tracking research has predominantly focused on conventional cigarette packaging, with only limited attention given to alternative nicotine products that have been examined in isolation. No prior study has directly compared visual attention patterns across all four major product categories simultaneously. This gap is important because as the market shifts toward novel products with distinct packaging formats, regulatory frameworks based on evidence from cigarette packaging alone may not adequately capture how consumers process information across the broader product landscape. This design therefore provides unique comparative insights into how visual attention is distributed when multiple packaging formats compete for consumers' attention, a scenario common in real-world retail environments.

2. Materials and methods

2.1. Study design and participants

A controlled, cross-sectional eye-tracking experiment was conducted in May 2024 at the Laboratories of Behavioral Studies of the Jan Evangelista Purkyně University in Ústí nad Labem, Czech Republic, involving 45 students from the same university. Participants were recruited through the ORSEE database—an official database of registered participants, through which invitations and information about ongoing or planned behavioral experiments were distributed. The inclusion criteria for participation required that the respondent had consumed any nicotine product at least once during the last two weeks.

Before the start of the experiment, the participants signed an informed consent confirming their participation. Each participant received fixed compensation of CZK 300 (approximately EUR 12), and the session lasted approximately 15–20 min.

Participants were invited to a secluded room individually and fitted with mobile eye-tracking glasses (Tobii Glasses 2.0, Tobii, Sweden). They were then shown four nicotine products representing the main categories available on the Czech market: (i) a pack of conventional cigarettes, (ii) a heated tobacco product pack, (iii) an e-cigarette refill package containing watermelon ice flavor, and (iv) a nicotine pouch package containing peppermint storm flavor (Figure 1). The same four products were used for all participants to ensure comparability across product types.

As shown in Figure 1, these products were selected to capture the main product categories and reflect real-world market conditions. Within each category, a widely available brand and standard retail variant were chosen, with limited editions or promotional packaging excluded. All products displayed the legally mandated Czech health warnings in accordance with the European Union Tobacco Products Directive. While the specific warning texts and imagery differed across the categories, these differences were retained to reflect the actual consumer environment, where warnings compete with branding.

Products were physically presented to the participants in a randomized order. All four products were available simultaneously, and participants were instructed to handle and inspect them freely during the eye-tracking session. To ensure that each package was examined carefully, participants were subsequently asked to rank the four products from the most to the least harmful based on their impressions. Although this ranking task provided an incentive for attentive viewing, it may also have directed participants' focus toward health warnings and other informational elements more than would occur in a purely naturalistic setting.

After completing the eye-tracking task, participants filled out a short post-experimental questionnaire



Figure 1. Examined nicotine products

collecting basic demographic information (e.g., gender, age, and education level), self-reported nicotine use, and health literacy. Health literacy was assessed using the standardized HLS-Q16 instrument, a 16-item scale evaluating the ability to access, understand, appraise, and apply health information.

2.2. Statistical analysis

Eye-tracking data were analyzed through predefined areas of interest (AOIs), which allowed for statistical comparison of participants' visual attention across packaging features. Heat maps were generated as descriptive visualizations to illustrate aggregate gaze patterns. AOIs were defined as follows:

(i) AOI 1 (warning labels): Pictorial and textual health warnings required by law.
(ii) AOI 2 (product composition and ingredient information): Quantitative statements (e.g., nicotine strength, number of sticks/pouches, ingredient list).
(iii) AOI 3 (brand logo and marketing elements): Brand names, logos, and design features intended to promote product appeal (e.g., color schemes and flavor

descriptors such as "Watermelon Ice" or "Peppermint Storm").

(iv) AOI 4 (other textual or visual elements): Neutral or functional information not directly linked to marketing, such as barcodes, recycling symbols, manufacturer details, or general layout graphics.

(v) AOI 5 (cessation support link): A standardized "quit webpage" reference, present only on conventional cigarette packaging.

Marketing elements (AOI 3) were distinguished from other textual/visual elements (AOI 4) based on their primary communicative function: persuasive branding and appeal versus neutral informational or regulatory content.

While AOIs were defined consistently across all four product types based on their communicative function, their physical implementation necessarily varied across product packages. Differences in package shape, surface area, and visual layout meant that AOIs were not spatially identical across products. Additionally, warning label formats differed across product types in accordance with applicable regulations: conventional cigarette packaging featured a combined pictorial-and-text warning, while warnings on alternative products were primarily text-based. Both factors reflect the real-world consumer environment, but should be considered when interpreting cross-product comparisons.

Two key eye-tracking indicators were examined:

(i) Time spent per AOI (dwell time, mean per participant per AOI): The total amount of time each participant spent looking at a given AOI group, including multiple fixations and refixations. This metric captures the overall sustained attention dedicated to packaging elements during the viewing session.

(ii) Fixation duration (mean per fixation): The mean length of a single fixation on a given AOI, measured in seconds. This metric provides an index of the depth of cognitive processing associated with individual fixations. While dwell time reflects how much overall attention an element received, fixation duration captures how intensively it was processed when attended to.

These measures were selected because they provide complementary information: one on sustained attention across the entire viewing period, and the other on the intensity of processing during each fixation. Measures such as time to first fixation were not included, as our AOIs represent grouped packaging features (e.g., all warning elements, all brand elements) rather than discrete, spatially isolated objects.

To evaluate differences in attention across packaging elements, we conducted repeated-measures analysis of variance (ANOVA) tests separately for each product type (conventional cigarettes, heated tobacco, e-cigarettes, and nicotine pouches). Assumptions of normality were assessed using the Shapiro–Wilk test. Several dependent variables showed significant departures from normality and positive skewness (see Appendix), a pattern commonly observed in eye-tracking measures such as dwell time and fixation duration. Given the within-subject design, sample size (n = 45), and the documented robustness of repeated-measures ANOVA to moderate violations of normality, parametric analyses were retained.

Violations of sphericity were corrected using Greenhouse–Geisser or Huynh–Feldt adjustments (based on Mauchly's sphericity test and subsequent Greenhouse–Geisser ε and Huynh–Feldt ε coefficients). Following a significant repeated-measures ANOVA, pairwise comparisons between factor levels were conducted using estimated marginal means. p-values were adjusted for multiple comparisons using Tukey's post hoc test. The sign of the reported mean differences (MD) reflects the order of conditions in the statistical software output. Positive and negative values therefore indicate only the direction of the contrast, while substantive interpretation is provided in the Results section.

In an additional exploratory analysis, we tested whether attention to specific AOIs followed consistent patterns across products. This was done using a two-way repeated-measures ANOVA with AOI and product type as within-subject factors. This allowed us to assess whether certain types of packaging elements (e.g., branding or warnings) systematically attracted more or less attention across product categories. In a further exploratory analysis, associations between health literacy and visual attention measures were examined using Pearson correlation coefficients. Correlations were calculated separately for each AOI and for both eye-tracking indicators (time spent per AOI and fixation duration). Statistical significance was assessed at the 5% level.

All statistical analyses were conducted using jamovi (version 2.6.26.0, The jamovi project, Australia).

2.3. Ethical considerations

This study was reviewed and assessed by the Research Ethics Committee of Anglo-American University in Prague (approval date: April 25, 2024), which determined that the research methodology and the nature and sensitivity of the planned data collection were appropriate and did not require further detailed ethical review. Informed consent was obtained from all participants prior to participation.

3. Results

Among the participants, 60% were women, the average age was 23.5 years (standard deviation = 4.05), the average health literacy score was 11.44 (standard deviation = 2.73), and 53.3% were undergraduate students. Table 1 shows the prevalence of different nicotine products among participants.

3.1. Within-product comparison of visual attention

3.1.1. Time spent per area of interest

A repeated-measures ANOVA, adjusted for sphericity violations, showed a statistically significant effect of AOI on time spent per AOI across all four product categories: nicotine pouches ($F[1.39] = 16.7$, $p < 0.001$), e-cigarettes ($F[2.64] = 8.27$, $p < 0.001$), conventional cigarettes ($F[1.83] = 48.1$, $p < 0.001$), and heated tobacco ($F[2.15] = 5.98$, $p = 0.003$).

As shown in Figure 2, for nicotine pouches, participants showed the longest dwell time on product composition (AOI 2), significantly more than for warning labels (AOI 1; MD = −2.503 [AOI 1−AOI 2], $t(44) = -4.65$, $p < 0.001$) and general text (AOI 4; MD = 2.764, $t(44) = 4.81$, $p < 0.001$). Branding elements (AOI 3) were also viewed more than general text (MD = 1.521, $t(44) = 7.35$, $p < 0.001$), while warning labels received less attention than both product composition and branding (both $p < 0.001$) and did not differ from general text ($p = 0.567$).

In the case of e-cigarettes, participants again focused significantly more on branding and composition than on general text elements (MD = 2.825, $t(44) = 6.560$, $p < 0.001$ for branding; MD = 1.471, $t(44) = 2.697$, $p = 0.047$ for product composition). Although warning labels were also viewed longer than general text (MD = 1.652, $t(44) = 3.502$, $p = 0.006$), no significant differences emerged between the three main AOIs (warning labels, branding, and composition), suggesting comparable levels of attention across these elements.

For conventional cigarettes, warning labels clearly dominated visual attention, receiving significantly longer dwell time than all other AOIs, including branding (MD = 2.925, $t(44) = 6.271$, $p < 0.001$), composition (MD = 3.948, $t(44) = 8.770$, $p < 0.001$), general text (MD = 3.142, $t(44) = 7.306$, $p < 0.001$), and cessation support links (MD = 3.688, $t(44) = 8.317$, $p < 0.001$). Product composition, by contrast, was viewed the least, whereas branding attracted more attention than the cessation link (MD = 0.764, $t(44) = 3.252$, $p = 0.018$).

Finally, for heated tobacco, warning labels drew more attention than branding (MD = 1.186, $t(44) = 3.306$, $p = 0.010$) and general text (MD = 1.111, $t(44) = 4.119$, $p < 0.001$), while composition also received slightly more attention than general text (MD = 0.756, $t(44) = 2.637$, $p = 0.054$). No significant differences were observed between the remaining AOI pairs.

3.1.2. Average fixation duration

A repeated-measures ANOVA showed a statistically significant effect of AOI on fixation duration for nicotine pouches ($F[3] = 6.05$, $p < 0.001$), e-cigarettes ($F[2.74] = 3.51$, $p = 0.020$), and conventional cigarettes ($F[3.65] = 10.4$, $p < 0.001$), but not for heated tobacco ($F[1.9] = 1.80$, $p = 0.173$).

As shown in Figure 3, for nicotine pouches, participants showed the longest fixation durations on product composition (AOI 2), significantly more than on warning labels (AOI 1; MD = −0.175 [AOI 1−AOI 2], $t(44) = -2.983$, $p = 0.023$) and general text (AOI 4; MD = 0.205, $t(44) = 3.237$, $p = 0.012$). Branding (AOI 3) also showed longer fixation durations than general text (MD = 0.137, $t(44) = 2.723$, $p = 0.044$), while differences between AOI 2 and AOI 3 were not significant.

For e-cigarettes, fixations were significantly shorter on product composition than on branding (MD = −0.122, $t(44) = -2.952$, $p = 0.025$), with no other paired differences reaching significance.

Table 1. Self-reported frequency of consumption of each nicotine-product category

Self-reported nicotine product use status	Tobacco products	Heated tobacco products	E-cigarettes	Other smokeless nicotine products	Nicotine pouches
Yes, daily	7	4	10	2	5
Yes, occasionally	22	6	24	5	5
No, former user	11	9	4	5	6
No, never	5	26	7	33	29
Total	45	45	45	45	45

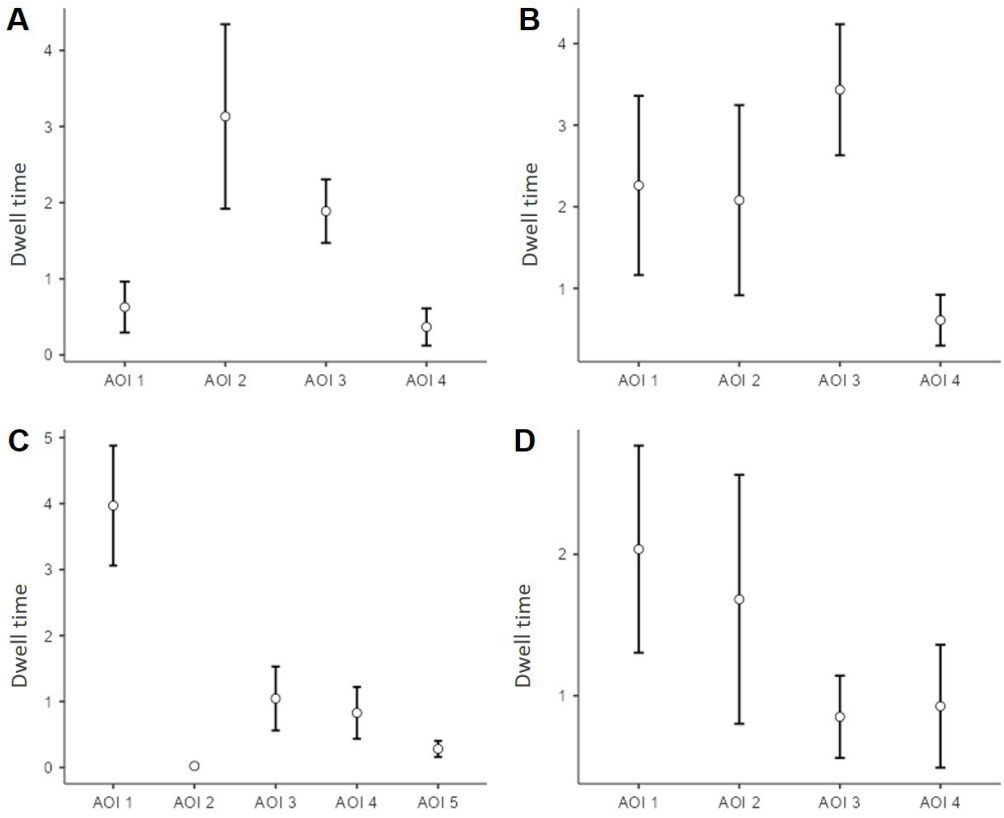


Figure 2. Average dwell time per area of interest (AOI) by product type (seconds). (A) Nicotine pouches. (B) E-cigarettes. (C) Conventional cigarettes. (D) Heated tobacco.
Notes: AOI 1: Warning labels; AOI 2: Product composition and ingredient information; AOI 3: Brand logo and marketing elements; AOI 4: Other textual or visual elements; AOI 5: Cessation support link.

For conventional cigarettes, warning labels had the longest fixations, significantly more than product composition (MD = 0.247, $t(44) = 7.561$, $p < 0.001$), branding (MD = 0.130, $t(44) = 4.559$, $p < 0.001$), and cessation links (MD = 0.150, $t(44) = 4.333$, $p < 0.001$). The difference between warning labels and general text was not significant ($p = 0.221$).

3.2. Cross-product comparison of visual attention

To assess whether specific packaging elements consistently attract more or less attention across different nicotine product types, a follow-up repeated-measures ANOVA was conducted with product type as a within-subject factor for each AOI.

3.2.1. Time spent per area of interest

For time spent per AOI, significant differences were observed across product types for all four AOIs: warning labels (AOI 1; $F[2.56] = 19.8$, $p < 0.001$), composition (AOI 2; $F[3] = 12.2$, $p < 0.001$), branding (AOI 3; $F[2.02] = 23.7$, $p < 0.001$), and general text (AOI 4; $F[3] = 3.10$, $p = 0.029$).

As shown in Figure 4, post hoc tests showed that warning labels (AOI 1) on conventional cigarettes attracted significantly more attention than on nicotine pouches (MD = −3.342, $t(44) = -8.034$, $p < 0.001$), heated tobacco (MD = 1.934, $t(44) = 4.887$, $p < 0.001$), and e-cigarettes (MD = −1.709, $t(44) = -3.058$, $p = 0.019$). Additionally, participants spent more time on warning labels for heated tobacco compared to nicotine pouches (MD = −1.408, $t(44) = -4.546$, $p < 0.001$).

Product composition (AOI 2) on conventional cigarettes received significantly less visual attention than on nicotine pouches (MD = 3.109, $t(44) = 5.231$, $p < 0.001$), e-cigarettes (MD = 2.057, $t(44) = 3.559$, $p = 0.005$), and heated tobacco (MD = −1.659, $t(44) = -3.802$, $p = 0.002$). Additionally, participants spent more time on composition information on nicotine pouches compared to heated tobacco (MD = 1.450, $t(44) = 2.937$, $p = 0.026$).

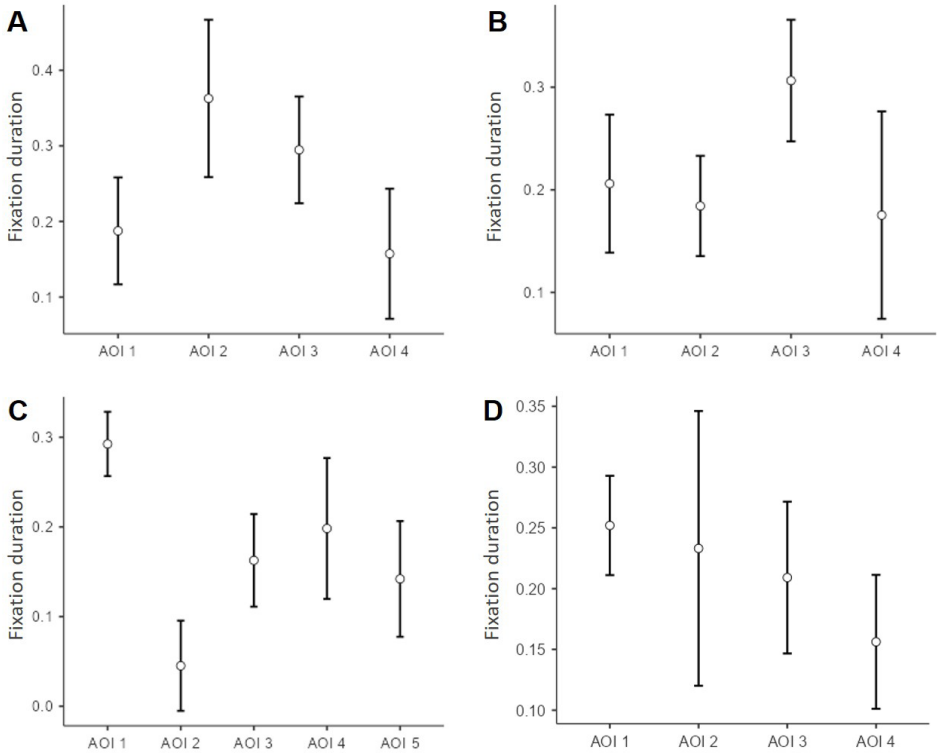


Figure 3. Average fixation duration per area of interest (AOI) by product type (seconds). (A) Nicotine pouches. (B) E-cigarettes. (C) Conventional cigarettes. (D) Heated tobacco.
Notes: AOI 1: Warning labels; AOI 2: Product composition and ingredient information; AOI 3: Brand logo and marketing elements; AOI 4: Other textual or visual elements; AOI 5: Cessation support link.

Branding and marketing elements (AOI 3) received significantly more visual attention on e-cigarettes, significantly more than on nicotine pouches (MD = −1.546, $t(44) = -4.829$, $p < 0.001$), conventional cigarettes (MD = 2.388, $t(44) = 5.140$, $p < 0.001$), and heated tobacco (MD = 2.583, $t(44) = 6.802$, $p < 0.001$). Additionally, participants spent more time on branding for nicotine pouches compared to heated tobacco (MD = 1.038, $t(44) = 5.106$, $p < 0.001$).

General text (AOI 4) attracted significantly more visual attention on conventional cigarettes than on nicotine pouches (MD = −0.461, $t(44) = -2.704$, $p = 0.046$). A marginal difference was also found between heated tobacco and nicotine pouches (MD = −0.559, $t(44) = -2.665$, $p < 0.051$), with pouches receiving more attention.

3.2.2. Average fixation duration

For fixation duration, significant differences across products were also observed for AOI 1 ($F[2.38] = 3.72$, $p = 0.021$), AOI 2 ($F[2.49] = 12.0$, $p < 0.001$), and AOI 3 ($F[2.8] = 6.71$, $p < 0.001$), but not for AOI 4 ($p = 0.759$).

As shown in Figure 5, post hoc tests showed that average fixation duration was significantly longer on warning labels (AOI 1) for conventional cigarettes compared to nicotine pouches (MD = −0.105, $t(44) = -2.850$, $p = 0.032$).

For product composition (AOI 2), fixation duration was significantly longer on nicotine pouches compared to conventional cigarettes (MD = 0.318, $t(44) = 5.688$, $p < 0.001$) and e-cigarettes (MD = 0.178, $t(44) = 3.183$, $p < 0.014$). Participants also showed longer fixation durations for conventional cigarettes than for heated tobacco (MD = −0.188, $t(44) = -2.947$, $p = 0.025$).

For branding and marketing elements (AOI 3), participants had shorter average fixations for conventional cigarettes compared to e-cigarettes (MD = 0.144, $t(44) = 4.321$, $p < 0.001$) and nicotine pouches (MD = 0.132, $t(44) = 3.063$, $p < 0.019$). Branding on e-cigarettes also received significantly longer fixations than on heated tobacco (MD = 0.097, $t(44) = 3.268$, $p < 0.011$).

The heat map illustrates overall visual attention patterns across all nicotine products (Figure 6). Branding elements

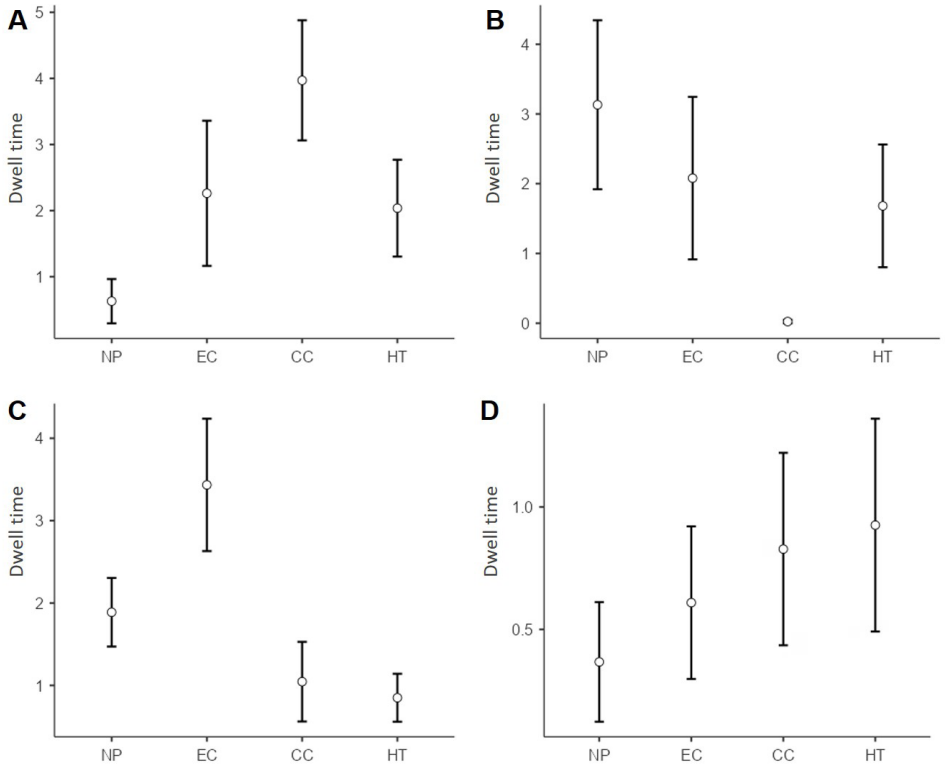


Figure 4. Average dwell time for each AOI across products (seconds). (A) AOI 1, (B) AOI 2, (C) AOI 3, and (D) AOI 4.
Abbreviations: AOI: Area of interest; CC: Conventional cigarettes; EC: E-cigarettes; HT: Heated tobacco; NP: Nicotine pouches.

such as logos and flavor descriptors attracted the strongest attention, while health warnings and detailed text received substantially less visual attention. These visual trends are consistent with the AOI-based statistical findings.

3.2.3. Relationship between health literacy and visual attention

Exploratory correlation analyses were conducted to examine associations between health literacy and eye-tracking measures across all AOIs and product categories. Only three significant correlations were observed. For dwell time, health literacy was negatively correlated with attention to other textual or visual elements on e-cigarette packaging (EC_AOI_4; Pearson's $r(43) = -0.314$, $p = 0.036$). For fixation duration, health literacy was also negatively correlated with attention to warning labels on e-cigarettes (EC_AOI_1; Pearson's $r(43) = -0.326$, $p = 0.029$) and other textual or visual elements (EC_AOI_4; Pearson's $r(43) = -0.363$, $p = 0.014$) on e-cigarette packaging. No other statistically significant correlations were identified.

4. Discussion

This study provides evidence that warning labels on novel nicotine products (heated tobacco, e-cigarettes, and nicotine pouches) attract substantially less visual attention than those on conventional cigarettes, where warnings consistently dominated attention across both dwell time and fixation duration. This cross-product disparity represents the study's most robust finding and carries direct implications for the packaging regulation of novel nicotine products.

For conventional cigarettes, warning labels outperformed all other packaging elements, suggesting that the current regulatory framework (combining pictorial warnings with 65% pack coverage) achieves meaningful visual prominence. This pattern was less consistent for alternative products. For e-cigarettes and nicotine pouches, branding and product composition attracted attention comparable to or greater than that attracted by health warnings, suggesting that current packaging requirements for these categories may not achieve the

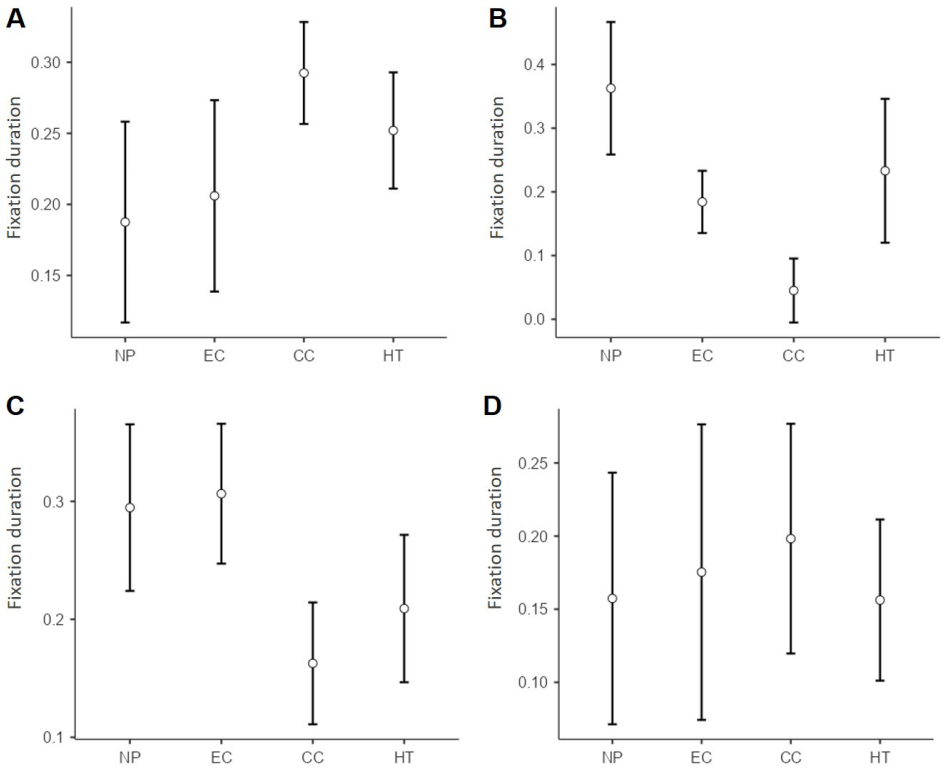


Figure 5. Average fixation duration for each AOI across products (seconds). (A) AOI 1, (B) AOI 2, (C) AOI 3, and (D) AOI 4. Abbreviations: AOI: Area of interest; CC: Conventional cigarettes; EC: E-cigarettes; HT: Heated tobacco; NP: Nicotine pouches.

same level of warning salience. This is consistent with earlier eye-tracking and experimental studies showing that health warnings lose salience in branded or cluttered visual environments,[3,26,27] and with evidence that alternative products often feature colorful, brand-heavy designs that compete effectively with regulatory content. Whether the disparity observed here reflects differences in warning size, format, placement, or overall packaging complexity cannot be determined from the present data, and causal attribution to specific design features would exceed what this design permits.

It is also worth noting that the higher warning salience observed for conventional cigarettes is consistent with prior evidence that pictorial warnings attract greater attention than text-only formats.[15] However, given that warning format co-varies with packaging size, placement, and overall visual complexity across product types, the present data do not permit isolating the contribution of pictorial versus text-only formats to the observed cross-product differences.

However, it is also possible that the elevated attention to product composition does not necessarily reflect higher visual appeal but rather participants' efforts to locate information that was missing or inconsistently presented. In particular, some nicotine pouch and e-cigarette packages provided incomplete or unclear data on nicotine content, which may have led participants to spend more time visually searching these areas. This interpretation points to the importance of standardized and clearly accessible product information to avoid misleading consumers.

The associations between health literacy and visual attention were also investigated; however, meaningful correlations emerged only for e-cigarette packaging. Higher health literacy was associated with shorter fixation duration on warning labels and on neutral textual elements, as well as with less time spent viewing neutral textual elements overall. This pattern may suggest that participants with higher health literacy processed e-cigarette packaging more efficiently, requiring less visual effort to extract relevant information, though the absence of similar associations for other product types and for branding or composition elements limits the generalizability of this interpretation. Given the exploratory nature of this analysis and the small

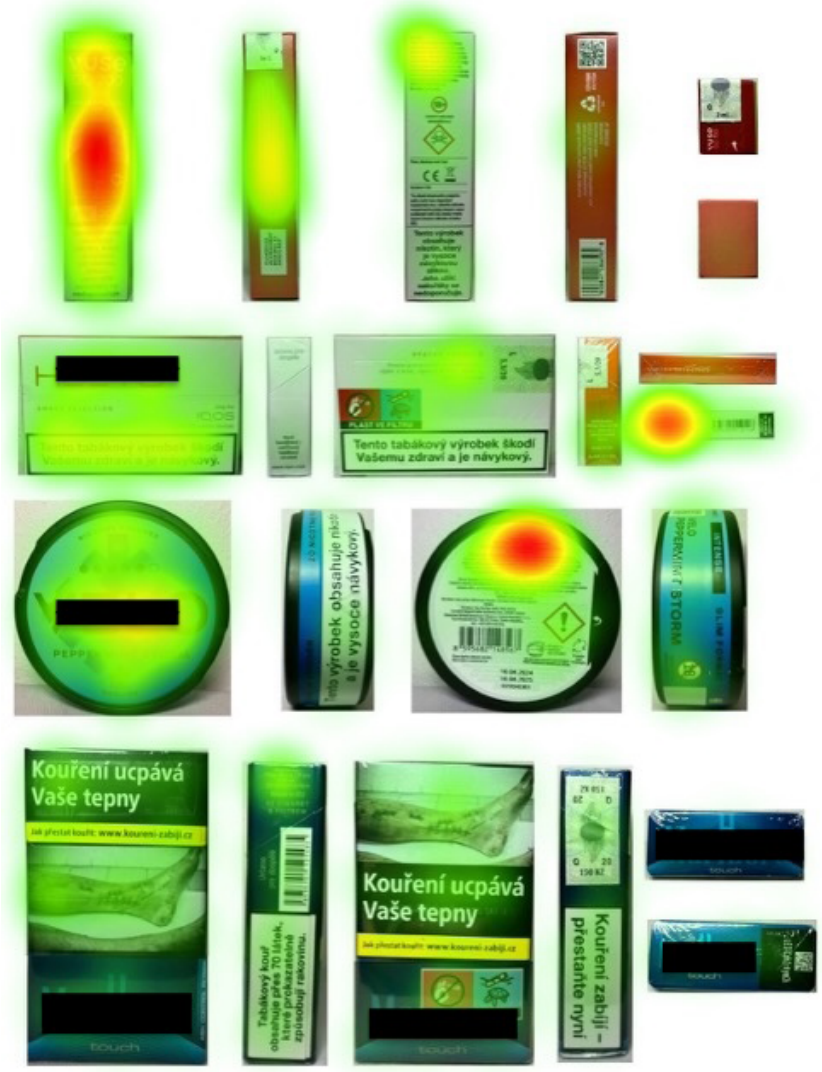


Figure 6. Heatmap illustrating overall visual attention patterns across all nicotine products
Note: Warmer colors indicate areas receiving greater visual attention across participants.

number of significant correlations relative to the number of comparisons tested, these findings should be interpreted with caution.

Taken together, our results support two key policy directions. First, the design and placement of health warnings on alternative nicotine products warrant regulatory attention. The disparity in warning salience between conventional cigarettes and novel products suggests that extending existing cigarette packaging requirements (in terms of warning size, placement, and pictorial content) to these categories could meaningfully improve consumer engagement with health information. Standardized packaging, which reduces the visual prominence of branding elements while prioritizing clear warnings, has been shown to improve attention to health messages, reduce product appeal, and support more accurate risk perceptions.[28–30] Second, packaging regulations alone may be insufficient. Broader communication strategies should focus on conveying relative product risks in a format that is comprehensible, visually accessible, and contextually relevant to consumers navigating an increasingly diverse product landscape.[7,10] This is particularly pertinent for younger consumers, among whom adoption of novel products is accelerating, and risk misperceptions remain prevalent.[7,8,10,11]

However, this study has several limitations. The sample included only university students from one Czech institution, limiting generalizability, and the modest sample size (n = 45), reduces statistical power. Several eye-tracking variables exhibited non-normal distributions and positive skewness; although repeated-measures ANOVA is generally considered robust to such violations in balanced within-subject designs, results should nevertheless be interpreted with appropriate caution. Considerable variation in product-specific nicotine use across participants (from daily users to never-users) may have further influenced attention patterns in ways that the design does not permit us to examine systematically. AOI comparability across products was constrained by differences in package shape, surface area, and warning label formats: conventional cigarettes featured pictorial warnings while alternative products carried primarily text-based warnings, reflecting regulatory differences that may have contributed to observed disparities in warning salience. These real-world formatting differences were retained deliberately to preserve ecological validity. Exploratory correlations between health literacy and visual attention were limited to a small number of significant associations confined to e-cigarette packaging and should be interpreted as preliminary, given the number of comparisons tested. Finally, the experimental setting may have influenced participant behavior, limiting ecological validity more broadly.

Despite these limitations, the study provides novel evidence by systematically comparing visual attention across multiple nicotine product types using standardized eye-tracking methods in a within-subjects framework.

5. Conclusion

This study provides evidence that warning labels on novel nicotine products attract substantially less visual attention than those on conventional cigarettes, for which current packaging requirements appear to support warning salience.

While conventional cigarette warnings still captured substantial attention, newer products such as e-cigarettes and nicotine pouches failed to achieve similar salience. These findings highlight a regulatory gap in attracting consumer attention to intended information and confirm that packaging design may undermine public health communication goals. Eye-tracking offers a valuable tool to evaluate and redesign these strategies. Future research should further explore how packaging layout and visual design shape attention and risk perception across different populations.

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Conflict of interest

The authors declare no conflicts of interest.

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Ethics approval and consent to participate

This study was reviewed and assessed by the Research Ethics Committee of the Anglo-American University in Prague (approval date: April 25, 2024), which determined that the research methodology and the nature and sensitivity of the planned data collection were appropriate and did not require further detailed ethical review. Informed consent was obtained from all participants prior to participation.

Consent for publication

Informed consent was obtained from all participants prior to their participation in the study. Each participant signed a written informed consent form confirming voluntary participation, awareness of the study's purpose, and agreement to the collection and processing of eye-tracking and questionnaire data. Participants were also informed that anonymized data may be used for research and publication purposes. No identifiable personal data or images of participants are included in this manuscript.

Availability of data

The datasets generated and analyzed during the current study are not publicly available due to participant privacy considerations but are available from the corresponding author upon reasonable request.

Further disclosure

During the preparation of this manuscript, the authors used Claude (Anthropic, Claude Sonnet 4) for language editing and improving readability of selected passages. AI was not involved in study design, data collection, data analysis, interpretation, or drawing conclusions. All AI-assisted content was reviewed and verified manually by the authors.

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Appendix

Table A1. Descriptive statistics of dwell time

AOI	*n*	Mean	Median	Standard deviation	Skewness	Standard error of skewness	Shapiro–Wilk *W*	*p*
NP_AOI_1	45	0.6287	0.1800	1.1143	2.842	0.354	0.618	<0.001
NP_AOI_2	45	3.1316	1.4100	4.0321	2.174	0.354	0.742	<0.001
NP_AOI_3	45	1.8882	2.0200	1.3863	0.336	0.354	0.932	0.011
NP_AOI_4	45	0.3671	0.0000	0.8130	3.406	0.354	0.521	<0.001
EC_AOI_1	45	2.2613	0.7100	3.6553	2.318	0.354	0.662	<0.001
EC_AOI_2	45	2.0800	0.5400	3.8793	2.938	0.354	0.588	<0.001
EC_AOI_3	45	3.4338	3.0600	2.6739	1.515	0.354	0.875	<0.001
EC_AOI_4	45	0.6091	0.0000	1.0371	2.091	0.354	0.658	<0.001
CC_AOI_1	45	3.9704	3.2900	3.0244	1.497	0.354	0.874	<0.001
CC_AOI_2	45	0.0229	0.0000	0.0823	3.886	0.354	0.312	<0.001
CC_AOI_3	45	1.0456	0.4700	1.6092	3.383	0.354	0.633	<0.001
CC_AOI_4	45	0.8280	0.1100	1.3084	2.177	0.354	0.667	<0.001
CC_AOI_5	45	0.2820	0.0600	0.4065	1.494	0.354	0.737	<0.001
HT_AOI_1	45	2.0364	1.3700	2.4392	2.444	0.354	0.737	<0.001
HT_AOI_2	45	1.6820	0.2000	2.9304	2.381	0.354	0.637	<0.001
HT_AOI_3	45	0.8504	0.4700	0.9684	1.434	0.354	0.830	<0.001
HT_AOI_4	45	0.9258	0.2500	1.4467	1.809	0.354	0.693	<0.001

Abbreviations: AOI: Area of interest; EC: E-cigarettes; HT: Heated tobacco; NP: Nicotine pouches.

Table A2. Descriptive statistics of fixation duration

AOI	*n*	Mean	Median	Standard deviation	Skewness	Standard error of skewness	Shapiro–Wilk *W*	*p*
NP_AOI_1	45	0.1876	0.1200	0.235	1.380	0.354	0.788	<0.001
NP_AOI_2	45	0.3627	0.2300	0.346	2.123	0.354	0.732	<0.001
NP_AOI_3	45	0.2947	0.2500	0.235	1.228	0.354	0.890	<0.001
NP_AOI_4	45	0.1573	0.0000	0.286	2.183	0.354	0.627	<0.001
EC_AOI_1	45	0.2060	0.1400	0.224	2.147	0.354	0.786	<0.001
EC_AOI_2	45	0.1842	0.1700	0.163	0.653	0.354	0.912	0.002
EC_AOI_3	45	0.3064	0.2400	0.197	2.743	0.354	0.696	<0.001
EC_AOI_4	45	0.1753	0.0000	0.336	3.637	0.354	0.546	<0.001
CC_AOI_1	45	0.2924	0.2900	0.119	0.690	0.354	0.950	0.051
CC_AOI_2	45	0.0451	0.0000	0.167	4.791	0.354	0.305	<0.001
CC_AOI_3	45	0.1627	0.1300	0.172	1.463	0.354	0.845	<0.001
CC_AOI_4	45	0.1982	0.1100	0.261	1.830	0.354	0.772	<0.001
CC_AOI_5	45	0.1420	0.0600	0.215	2.712	0.354	0.684	<0.001
HT_AOI_1	45	0.2520	0.2300	0.136	0.427	0.354	0.968	0.250
HT_AOI_2	45	0.2331	0.1400	0.376	2.886	0.354	0.654	<0.001
HT_AOI_3	45	0.2091	0.1800	0.208	1.790	0.354	0.832	<0.001
HT_AOI_4	45	0.1562	0.1500	0.183	1.594	0.354	0.804	<0.001

Abbreviations: AOI: Area of interest; CC: Conventional cigarettes; EC: E-cigarettes; HT: Heated tobacco; NP: Nicotine pouches.