

Exploring the effects of attachment dimensions on nicotine-induced attentional bias: an eye-tracking observational study in young people who smoke

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Abstract

Introduction: Tobacco use disorder (TUD) is shaped by pharmacological and neuropsychological mechanisms, with growing evidence implicating attachment strategies and emotion regulation in its onset and maintenance. A hallmark of TUD is attentional bias (AB), in which smoking-related cues disproportionately capture attention, indicating alterations in cognitive control processes. However, research on AB in TUD has largely overlooked the role of attachment strategies.

Methods: In this observational case-control study, 110 healthy Italian university students (62 people who smoke, 48 participants who do not smoke) completed the Fagerström Test for Nicotine Dependence and the Attachment Style Questionnaire and performed an eye-tracking task. Each trial presented a prime image (neutral or threatening), followed by a choice between smoking- and care-related images displayed side by side. AB indices included relative fixation time, fixation count, and gaze points.

Results: People who smoke exhibited reduced AB toward care cues regardless of emotional priming, with no prime-related changes in gaze behavior. AB indices for care- and smoking-related images were determined by smoking status rather than the preceding image. Regression analyses showed that avoidant and dismissing attachment styles significantly predicted AB indices, along with group status. Among people who smoke, nicotine dependence predicted relative fixation time only.

Conclusions: AB toward smoking cues is influenced not only by smoking status but also by individual attachment patterns. These findings support evidence that attention and choice can dissociate: primes may affect decisions without altering gaze. The results highlight the importance of integrating socio-affective factors into research on drug-related AB.

Implications: This study introduces a novel eye-tracking paradigm that contrasts smoking-related cues with care related (rather than neutral) stimuli, offering a more ecologically valid approach to investigating attentional bias in people who smoke. By priming participants with emotionally valenced images and analyzing gaze patterns across competing salient stimuli, we demonstrate that attentional bias is modulated not only by nicotine dependence but also by individual differences in attachment-related constructs. These findings underscore the relevance of socio-affective factors in addiction research and support the utility of emotion- and attachment-sensitive protocols for uncovering the complex mechanisms underlying cue reactivity in addiction.

Keywords nicotine dependence, attachment theory, emotion regulation, eye, tracking

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Introduction

Tobacco use disorder (TUD) is a complex condition that, beyond nicotine's (NIC's) addictive properties,¹ involves neuropsychological, socio-affective, and environmental factors, contributing to the initiation and maintenance of smoking behavior.^{2,3} Among the cognitive mechanisms implicated in this process, attentional bias (AB; the preferential allocation of attentional resources to substance-related stimuli among individuals with a history of substance use), plays a critical role.⁴ Exposure to smoking-related cues triggers self-reported craving, as well as physiological and neurocognitive changes in people who smoke,^{5,6} with the magnitude of these responses linked to the severity of TUD.^{7,8} Notably, in individuals who smoke AB and substance craving exhibit a bidirectional relationship, heightened craving enhances AB toward substance-related cues, while greater AB, in turn, intensifies craving.⁷ From this perspective, elucidating the dynamics of AB toward smoking-related cues may offer valuable insights for developing more effective cessation interventions, particularly for young people who smoke with limited smoking experience.^{5,9}

Attachment theory provides a useful framework to understand information processing and attentional biases. In particular, research has demonstrated a robust association between attachment patterns and substance use disorders, whereby heightened attachment-related distress may increase the salience of drug cues and bias attention toward them for emotion regulation and perceived security.^{10,11} In adulthood, individuals often rely not only on physical closeness but also on internalized, symbolic representations of trusted attachment figures to maintain emotional equilibrium. Under stress or in the absence of secure attachment, this regulatory strategy may be replaced by substance use as a maladaptive means of recreating an inner sense of comfort and security.^{10,12} Previous studies have shown a relationship between insecure attachment styles and increased risk of substance use and addiction, possibly as a maladaptive strategy to regulate intense emotions or unmet attachment needs.^{13,14} Longitudinal and meta-analytic evidence further demonstrate that insecure attachment often precedes substance abuse, while substance use may further impair attachment security.^{11,12}

Attachment styles develop through caregivers' availability, responsiveness, and support, which shape internal models of self and others. When attachment figures are available and responsive in times of need, they support the optimal functioning of the attachment system, fostering internal working models of self and others that are positively oriented.^{15,16} Conversely, when attachment figures are unavailable or unsupportive, children often develop defensive secondary attachment strategies, typically expressed as either hyperactivation or deactivation of the attachment system.¹⁷ Individuals high in attachment anxiety often employ hyperactivating strategies, showing heightened vigilance toward attachment figures and persistent efforts to elicit care. While these behaviors may temporarily secure attention, they often reinforce anxiety and dependency. In contrast, individuals with high attachment avoidance use deactivating strategies, minimizing attachment needs and avoiding intimacy through emotional, cognitive, and physical distancing, a process Bowlby¹⁶ termed "defensive exclusion." Research shows that anxious individuals focus attention on attachment-related stimuli, whereas avoidant individuals divert attention from such cues.¹⁸ Bailey¹⁹ demonstrated that anxious attachment is associated

with longer response latency to threatening words in the emotional Stroop task, suggesting greater difficulty disengaging from threatening information compared to individuals with low attachment anxiety.²⁰ This provides further evidence of AB toward threatening stimuli in anxious attachment.²¹ By contrast, strong evidence supports the use of deactivation strategies among avoidantly attached individuals. Edelstein and Gillath²² found that avoidant attachment was negatively associated with attention to attachment-related words, and subsequent studies have reported an inverse relationship between avoidant attachment and AB toward threatening attachment-related words.²³

Aims and hypotheses

In a previous study,²⁴ we demonstrated the presence of a cognitive bias among young individuals who smoke, evidenced by their significantly greater selection of smoking-related stimuli compared to participants who do not smoke, accompanied by slower reaction times, irrespective of the emotional cues presented. Additionally, emotion dysregulation and attachment style were found to be significantly associated with response choice, although neither variable was related to response latency. Following up on these findings, the present study is focused on the relationship between attachment-related constructs and attentional processes.

AB in people who smoke has been investigated using various methods, including eye-tracking (ET), which has proven effective in detecting AB across multiple forms of addiction.^{25,26} Using ET, studies have shown that people who smoke exhibit longer fixation durations on smoking-related cues compared to people who do not smoke.⁶ It is important to note that most studies presented drug-related cues alongside neutral cues to determine whether the former acted as an attentional sink. However, TUD is also shaped by other factors, including emotional processes and psychological constructs.^{27,28} As these variables can impact participants' responses independently of their direct association with the drug, it is essential to account for their potential effects.^{29,30} To our knowledge, no other studies have investigated the AB to smoke-related cues in people who smoke and people who do not smoke using only non-neutral stimuli. To address this gap, in this study, we leveraged a basic psychological construct (the prioritization of care-seeking under negative emotional conditions), to evaluate its modulation in individuals who smoke when only a drug-related cue was available. According to the attachment theory, the attachment system is activated under conditions of perceived threat or distress, motivating regulatory strategies aimed at restoring psychological security.¹⁶ Exposure to threatening images may therefore indirectly activate attachment-related processes insofar as such stimuli elicit negative affect and threat appraisal, subsequently shaping AB toward cues associated with comfort or regulation.^{31,32}

Participants were primed using images of varying emotional valence (neutral or threatening) and then given the option to choose between two side-by-side images depicting smoking-related and care-related cues. ET was used to record gaze characteristics on each image, which were analyzed alongside pen-and-paper measures of attachment behavior. In this study, we aimed to focus specifically on the relationship between attachment-related constructs and attentional processes, as behavioral responses have already been examined in our previous related studies,²⁴ where young people who smoke showed a

cognitive bias, selecting smoking-related stimuli more frequently and responding more slowly than participants who do not smoke, independent of emotional cues. In the present study, we ask: Does AB emerge when individuals who smoke are presented with two highly salient images, one depicting care and the other smoking, after exposure to a neutral or threatening prime? Is AB consistently directed toward the substance, or can exposure to a caring stimulus mitigate this effect via attachment-related regulatory mechanisms? If so, how do attachment-related constructs influence AB in both people who smoke and people who do not smoke?

Given that the presence/absence of TUD differentiates the two populations under study, we expect that people who smoke (despite the moderate NIC addiction levels) will generally exhibit greater AB to smoking-related cues than participants who do not smoke and that this bias will be associated with NIC dependency. Further, we hypothesize that differences in attachment dimensions will predict AB to smoking-related cues above NIC dependency.

Methods

Study characteristics

Observational case-control study. Questionnaire scoring and ET data analysis were conducted by staff who were blinded to the participants' experimental group.

Sample recruitment

One hundred and ten healthy volunteers were recruited from the local university population and assigned to either the people who smoke (PWS) or people who do not smoke (PWDNS) group based on their self-reported smoking status. Participants in the PWS group had a baseline expired CO greater than 6 ppm (iCOquit breath test CO monitor) and were asked not to make any changes to their smoking habits.³³ Participants in the PWDNS group reported that they had never engaged in smoking. None of the participants had a history of, or current symptoms of, neurological or psychiatric disorders, nor did they report recent or current use of psychoactive drugs or electronic cigarettes. Participants were native Italian speakers with normal or corrected-to-normal vision. No form of payment was given. An informed written consent was obtained prior to study entry. All experimental procedures were approved by the ethics committee (UniCa, ID n. 0062572) and conducted in accordance with the Declaration of Helsinki.

Psychological measures

Fagerström Test for Nicotine Dependence, Italian version

NIC dependence related to cigarette smoking was evaluated using the Fagerström Test for Nicotine Dependence, Italian version (FTND).³⁴ This self-administered, seven-item questionnaire is designed to provide an ordinal measure of NIC dependence related to tobacco smoking. FTND score ranges from 0 to 10 points and encompasses five categories: very low dependence (0–2); low (3–4); mid-high (5–6); high (7–8); and very high (9–10).

Attachment Style Questionnaire, Italian version

The Attachment Style Questionnaire, Italian version (ASQ) is a 40-item Likert-type self-report questionnaire³⁵ developed to assess five dimensions of adult attachment.^{36,37} The constructs measured by the ASQ are: "Confidence" (8 items), which refers to an attitude of trust toward the significant others (characteristics of a secure attachment); "Discomfort with Closeness" (10 items), reflecting the difficulty to trust others and to have them depend on self, and "Preoccupation with Relationships" (8 items), indicating the need of persistently being close to the significant other, correspond to Hazan and Shaver's³⁷ conceptualization of avoidant attachment and anxious/ambivalent attachment, respectively; "Need for Approval" (7 items), indicating the necessity for acceptance and confirmation from others, and "Relationships as Secondary" (7 items), reflecting a positive representation of self and complete distrust of others, are consistent with Bartholomew's³⁶ characterization of the fearful/preoccupied and dismissing attachment, respectively. Items are measured on a 6-point Likert scale, ranging from "1" (strongly disagree) to "6" (strongly agree). For sake of clarity, the ASQ subscales labels will be replaced with their corresponding attachment dimensions throughout the manuscript (eg, "Discomfort with Closeness" → "Avoidant").

Experimental procedure

Visual stimuli

One hundred and eighty images were selected from the following databases to serve as priming or target images. For emotional stimulation, the International Affective Picture System (IAPS) was utilized.³⁸ Forty IAPS pictures were selected to represent threatening (eg, accidents, human attacks) and neutral (eg, domestic objects) conditions (Appendix A). The 40 pictures had mean valence ratings of 2.52 (SD=0.64) for the threatening condition and 5.11 (SD=0.32) for the neutral condition, and mean arousal ratings of 6.62 (SD=0.41) and 2.91 (SD=0.68) for the threatening and neutral conditions, respectively. Valence and arousal ratings differed significantly between the two conditions, with $F(1, 38) = 264$ for valence and $F(1, 38) = 438$ for arousal.³⁸

Forty images from the Besançon Affective Picture Set-Adult (BAPS-Adult³⁹), depicting comfort-related scenarios involving care (eg, an adult comforts an infant in distress), were used (Appendix A). Two random sets of 20 images each were created: one for the threatening condition and one for the neutral condition. According to Szymanska et al.,³⁹ the mean ratings of perceived comfort, valence, and arousal were consistent across both sets. The two lists did not significantly differ in any dimension.

Forty images were selected from the SmoCuDa database⁴⁰ and included smoking paraphernalia (eg, cigarettes, ashtrays), as well as images depicting individuals who smoke, presented in approximately equal proportions (40% and 60%, respectively). No smoking-related images showing social interactions were selected. Selected pictures were randomly divided into two lists of 20 items: one for the neutral condition and one for the threatening condition (Appendix A). Content was consistently balanced for valence or arousal ratings. The two lists did not significantly differ in any dimension.

For the 20 filler trials, 60 neutral pictures (20 priming and 40 choices) were selected from the IAPS (Appendix A).

Eye-tracking

A portable, monocular ET headset (Pupil Labs GmbH) was used to capture gaze data, featuring a 200 Hz eye camera and a 120 Hz world camera for recording the visual scene.

Pupil Capture software (version 3.4, Pupil Labs GmbH) was used for calibration and recording. Pupil Player software (version 3.4, Pupil Labs GmbH) was employed to review ET recordings for quality assessment and to define surfaces for data extraction. Raw data from individual surfaces were processed using a custom Python 3 script.

Experimental task

Participants sat in a quiet, dimly lit room on a chair with a headrest, 70 cm from the screen, to minimize movement during recordings. Visual stimuli were presented using PsychoPy3 2024.2 software on a 17" LCD monitor (75-Hz refresh rate), with images occupying approximately 40° of the visual angle, both horizontally and vertically. Participants were instructed to focus their gaze on the centre of the screen, and before starting the experiment, they were given the following instructions (originally in Italian, translated here to English):

You will be presented with a series of images, some of which may evoke negative emotions. Following each image, you will be asked to choose between two options, selecting the one you believe would be most effective in helping you manage any negative feelings possibly elicited by the previous image.

To choose one of the probe images, participants used a response pad.

Participants completed 60 trials presented in random order: 20 with a threatening condition, 20 with a neutral condition, and 20 filler trials. Each trial presented four isoluminant images in sequence: first, a fixation cross at the center of the screen (500 ms), then a gray screen (300 ms), followed by a prime image (4 s), and concluding with two probe images shown side-by-side (Fig. 1). The relative position (left vs. right) of the probe pictures was counter-balanced within participants; probe images remained visible until a response was made. In both the neutral and threatening conditions, one of the probe images depicted a caring scenario (CARE) while the other depicted a smoking-related scenario (SMOKE). In the filler trials, all images had neutral content. After the experiment ended, the participants were asked a yes/no question asking if the stimuli presented elicited a negative emotion, as an experimental check.

Participants completed the questionnaires and underwent the ET recording in a counterbalanced way.⁴¹

Outcome measures

AB. Relative fixation times (RFT) of CARE and SMOKE target images were calculated for each trial. Aligned to the methods used by Rahmani et al.,²⁹ RFT is defined as the proportion of time the participant fixates on each probe image divided by the total fixation time. Accordingly, the RFT Attentional Bias Index was calculated by subtracting the CARE RFT from the SMOKE RFT:

$$RFT_{Prime} = \left(\frac{FixationTime_{SMOKE}}{TotalFixationTime_{Trial}} \right) - \left(\frac{FixationTime_{CARE}}{TotalFixationTime_{Trial}} \right)$$
 The RFT indices were calculated for both the Neutral and Threatening primed trials, which were then summed to compute the Overall RFT score: $RFT_{Overall} = (RFT_{NeutralPrime}) + (RFT_{ThreateningPrime})$. Thus, positive values indicate greater attentional allocation toward SMOKE images relative to CARE images, whereas negative values indicate greater attentional allocation toward CARE images relative to SMOKE images. Values close to zero indicate no clear attentional preference between the two image categories. Using the same procedure, we calculated the relative number of fixations (RNF) and the relative number of gaze points (RGP, the specific location identified by the eye tracker in its coordinate system) indices.

Statistical analyses

Analyses were performed using IBM SPSS v29.0.0.1 (IBM Corp, 2023), setting the statistical significance at the conventional threshold of 0.05. A priori power analysis revealed a required total $N = 84$ participants (effect size = 0.20, $\alpha = 0.05$, $1 - \beta = 0.95$) for ANOVA analysis, and a required total $N = 94$ participants (effect size = 0.20, $\alpha = 0.05$, $1 - \beta = 0.90$) for regression analysis.

Results

Sample characteristics

Our sample consisted of 62 PWS and 48 PWDNS ($N = 110$). The PWDNS group was composed of 32 female (66.7%) and 16 male (33.3%) participants, with a mean age of 24.5 years ($SD = 4.29$). The PWS group was composed of 29 female (46.8%) and 33 male (53.2%) participants, with a mean age of 24.6 years ($SD = 4.13$). Smoking habits lasted for an average of 7.7 years ($SD = 4.74$), and the average FTND score was 2.7 ($SD = 2.40$). Most PWS were classified as having a Mild (27.3%) or Strong (23.6%) level of NIC addiction; only six (5.5%) were categorized as Very Strong, and none were classified as having a low level of NIC addiction.

ASQ descriptive statistics, reliability, and group comparisons

The results showed a good reliability of all the ASQ scales (Secure: $\alpha = .802$, Avoidant: $\alpha = .787$, Dismissing: $\alpha = .778$, Fearful: $\alpha = .780$, Ambivalent: $\alpha = .692$). The descriptive statistics of the ASQ for the two groups and for the whole sample are presented in Table 1. Moreover, the Pearson correlation coefficients were computed between the ASQ subscales for the whole sample: all the correlations were statistically significant, with mild to moderate strengths (Table 2). A series of independent-samples t -tests showed no significant differences between groups.

Group and prime effects on AB indices

A repeated-measures ANOVA was performed to assess the effects of Prime (Threatening vs Neutral) and Group (PWS vs PWDNS) on the AB indices (RFT, RNF, RGP). In general, Table 3 shows that in all indices, the AB is more directed toward CARE. On the one hand, results showed no significant effect of Prime on RFT ($F = 1.56$; $df = 1, 108$; $P = .214$; $\eta_p^2 = .014$), RNF ($F = .80$; $df = 1, 108$; $P = .372$; $\eta_p^2 = .007$), and RGP ($F = .54$; $df = 1, 108$; $P = .465$;

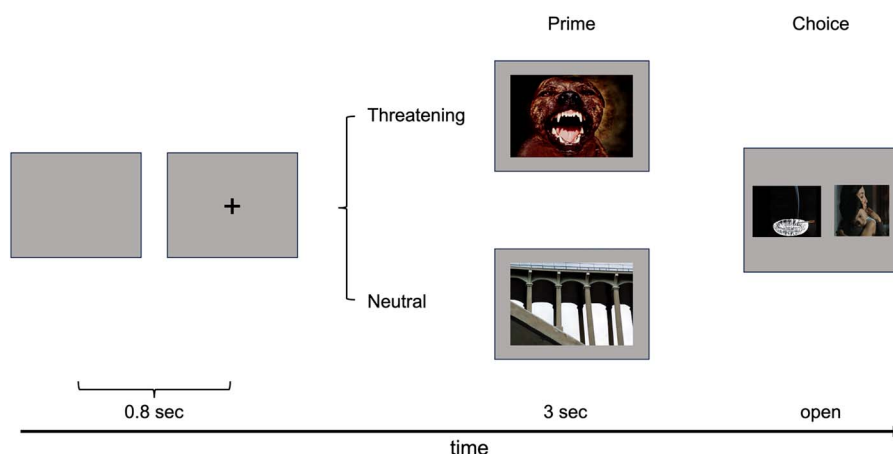


Figure 1 Schematic depiction of the experimental task used in the study, illustrating the temporal sequence and layout of the visual stimuli presented during each trial.

Table 1 Attachment Style Questionnaire (ASQ) subscales means and standard deviations (groups and whole-sample).

	ASQ Secure m (s.d.)	ASQ Avoidant m (s.d.)	ASQ Dismissing m (s.d.)	ASQ Fearful m (s.d.)	ASQ Ambivalent m (s.d.)
PWS	31.4 (6.75)	40.5 (8.80)	15.7 (5.18)	20.9 (6.72)	28.1 (6.76)
PWDNS	31.0 (6.20)	38.4 (7.27)	14.7 (6.18)	21.3 (7.13)	28.4 (5.87)
Whole sample	31.2 (6.49)	39.6 (8.20)	15.3 (5.64)	21.0 (6.87)	28.2 (6.36)

The original ASQ subscale labels were replaced with the corresponding attachment dimension, for sake of clarity. Abbreviations: PWS, people who smoke; PWDNS, people who do not smoke.

Table 2 Attachment Style Questionnaire (ASQ) subscales Pearson correlations (whole-sample).

	ASQ Secure	ASQ Avoidant	ASQ Dismissing	ASQ Fearful
ASQ Avoidant	−0.636**			
ASQ Dismissing	−0.406**	0.348**		
ASQ Fearful	−0.537**	0.264**	0.204*	
ASQ Ambivalent	−0.411**	0.352**	0.194*	0.466**

The original ASQ subscale labels were replaced with the corresponding attachment dimension, for sake of clarity. **Correlation is significant at the 0.01 level (two-tailed); *Correlation is significant at the 0.05 level (two-tailed).

$\eta_p^2 = .005$). On the other hand, the main effect of Group was significant on RFT ($F = 4.89$; $df = 1, 108$; $P = .029$; $\eta_p^2 = .043$), RNF ($F = 4.77$; $df = 1, 108$; $P = .031$; $\eta_p^2 = .042$), and RGP ($F = 4.33$; $df = 1, 108$; $P = .040$; $\eta_p^2 = .039$). Regardless of the prime, AB indices differed significantly between groups, with PWS showing lower bias scores toward CARE stimuli compared with PWDNS.

Since there was no statistically significant Prime effect on the AB indices, it was decided to discard the Neutral/Threatening distinction for the subsequent analyses, thus considering only the Overall AB indices in the regression models.

AB and attachment dimensions

A series of linear regression analyses were performed, setting the AB measures (RFT, RNF, RGP) as the dependent variables, while the Group (PWS/PWDNS) and the ASQ scales were set as predictors, using forced entry method. The collinearity assessment showed

that the variance inflation factor (VIF) and the tolerance of the predictors did not exceed the commonly used thresholds⁴² (≥ 10 and < 0.2 , respectively), with the highest VIF being 2.403 and the tolerance being 0.416 for the ASQ Secure predictor; thus, the multicollinearity between predictors could be excluded. The results (Table 4) showed that on the one hand the Group and the ASQ Avoidant and Dismissing subscales were significant predictors of all the AB indices (RFT, RNF, and RGP), while ASQ Secure attachment scores significantly predicted only the RNF and RGP. On the other hand, the β coefficients of the ASQ Ambivalent and ASQ Fearful subscales were not statistically significant. Although R^2 coefficients of the models were modest, the results suggested that the research hypothesis of AB indices being influenced not only by the smoking habit but also by the participants' attachment-related dimensions could not be rejected.

We also hypothesized that people who smoke' AB could be affected by their level of NIC dependence; thus, additional linear

Table 3 Attentional Bias indices means and standard deviations.

	RFT			RFN			RGP		
	Neutral m (s.d.)	Threat m (s.d.)	Overall m (s.d.)	Neutral m (s.d.)	Threat m (s.d.)	Overall m (s.d.)	Neutral m (s.d.)	Threat m (s.d.)	Overall m (s.d.)
PWS (<i>n</i> = 62)	−0.15 (0.156)	−0.17 (0.123)	−0.32 (0.252)	−0.14 (0.147)	−0.16 (0.119)	−0.30 (0.243)	−0.16 (0.155)	−0.17 (0.127)	−0.33 (0.257)
PWDNS (<i>n</i> = 48)	−0.21 (0.162)	−0.22 (0.130)	−0.43 (0.273)	−0.20 (0.143)	−0.20 (0.123)	−0.40 (0.250)	−0.22 (0.157)	−0.22 (0.138)	−0.44 (0.274)
Whole sample (<i>n</i> = 110)	−0.18 (0.161)	−0.19 (0.128)	−0.37 (0.266)	−0.17 (0.148)	−0.18 (0.123)	−0.34 (0.250)	−0.19 (0.158)	−0.19 (0.133)	−0.38 (0.268)

Abbreviations: RFT, relative fixation time (in milliseconds); RFN, relative number of fixations; RGP, relative number of gaze points. PWS, people who smoke; PWDNS, people who do not smoke. Negative values of the RFT, RFN and RGP coefficients reflect attentional bias toward CARE stimuli.

Table 4 Whole-sample regression models.

	RFT ($R^2 = 0.162$)			RFN ($R^2 = 0.173$)			RGP ($R^2 = 0.173$)		
	b (s.e.)	std. β	<i>P</i> -value	b (s.e.)	std. β	<i>P</i> -value	b (s.e.)	std. β	<i>P</i> -value
Group (PWS vs PWDNS)	−0.13 (0.049)	−0.24*	.011	−0.12 (0.046)	−0.24*	.010	−0.12 (0.049)	−0.23*	.013
ASQ Secure	−0.01 (0.006)	−0.26	.066	−0.01 (0.005)	−0.29*	.039	−0.01 (0.006)	−0.29*	.039
ASQ Avoidant	−0.01 (0.004)	−0.33*	.009	−0.01 (0.004)	−0.35*	.005	−0.01 (0.004)	−0.36*	.004
ASQ Dismissing	0.01 (0.005)	0.20*	.049	0.01 (0.004)	0.21*	.038	0.01 (0.005)	0.20*	.047
ASQ Fearful	0.00 (0.004)	−0.09	.433	0.00 (0.004)	−0.09	.433	0.00 (0.004)	−0.12	.276
ASQ Ambivalent	0.01 (0.004)	0.17	.109	0.01 (0.004)	0.16	.135	0.01 (0.004)	0.20	.067

For sake of clarity, the original ASQ subscale labels were replaced with the corresponding attachment dimension. Dependent variables: RFT, relative fixation time; RFN, relative number of fixations; RGP, relative number of gaze points. Negative values of the RFT, RFN, and RGP coefficients reflect attentional bias toward CARE stimuli. PWS, people who smoke; PWDNS, people who do not smoke. * $P < .05$; ** $P < .001$.

regression analyses were performed on the PWS group only ($n = 60$; two participants were excluded due to incomplete data), setting the AB indices as the dependent variables, while the level of dependence, as measured with the FTND, and the ASQ subscales were set as the predictors, using the forced entry method. Results (Table 5) indicated that, of all the attachment measures, the ASQ Avoidant and Dismissing subscales were statistically significant AB predictors (as with the whole sample), while the Dependence Level was only for the RFT. As such, the results showed that at least some of the attachment-related constructs steered the attention of participants in the PWS group, along with their NIC addiction level (which, however, had a smaller effect overall). It should be noted that the ASQ Secure subscale no longer was a significant predictor of the AB indices of the PWS group, as it was within the whole sample.

Discussion

In this study, we investigated the impact of attachment dimensions on AB toward smoking cues in a group of young people with light smoking habits, compared to participants who do not smoke. To achieve this, we primed participants using images with either neutral or threatening emotional valence and used ET to measure gaze characteristics over two salient images, one representing care and the other representing smoking, presented side-by-side afterward. We found that the care images show a greater AB in all indices, with differences between individuals who smoke and participants who do not smoke. Prime quality

(Threatening vs. Neutral) did not affect our measures, whereas the main effect of the group (PWS vs. PWDNS) was significant, with people who smoke' AB indices indicating a lower bias toward care-related stimuli. Further, regression analyses conducted on the whole sample indicated that Group and the ASQ Secure, Avoidant, and Dismissing subscales significantly predicted the AB indices. In the PWS group, however, secure attachment was no longer a significant predictor, while NIC dependence level exhibited a smaller yet significant effect, limited to RFT.

The present investigation stems from a previous study that used a similar experimental paradigm²⁴ and revealed the presence of a cognitive bias in young people with light smoking habits, shown by their significantly greater selection of smoking-related stimuli. In this study we focused our investigation on the dynamics of attentive processes (as indexed by gaze behavior), regardless of the image chosen. We found that no alterations of gaze behavior emerged in relation to the prime. Priming typically occurs unconsciously, functioning through associative memory networks in which activating one concept (prime) increases the accessibility of related concepts (targets).^{43,44} Thus, if we describe it as the participants' tendency to make a choice to counteract the negative emotions evoked by the threatening image (as by task instructions), then the presence of a prime effect can be considered confirmed.²⁴ Our present results can be explained in terms of the known dissociation between the dynamics of attentive processes and the final behavior. In fact, relevant research indicates that while attention can influence the information we process, it does not always translate directly

Table 5 People who smoke group regression models.

	RFT ($R^2 = 0.435$)			RFN ($R^2 = 0.425$)			RGP ($R^2 = 0.427$)		
	b (s.e.)	std. β	P-value	b (s.e.)	std. β	P-value	b (s.e.)	std. β	P-value
Dependence level	0.10 (0.045)	0.27*	.024	0.07 (0.044)	0.19	.112	0.08 (0.046)	0.21	.077
ASQ Secure	−0.01 (0.006)	−0.19	.254	−0.01 (0.006)	−0.25	.132	−0.01 (0.006)	−0.27	.115
ASQ Avoidant	−0.02 (0.004)	−0.56**	.000	−0.02 (0.004)	−0.55**	.000	−0.02 (0.004)	−0.57**	.000
ASQ Dismissing	0.03 (0.006)	0.55**	.000	0.03 (0.006)	0.59**	.000	0.03 (0.007)	0.57**	.000
ASQ Fearful	0.00 (0.005)	−0.08	.518	0.00 (0.005)	−0.11	.377	−0.01 (0.005)	−0.14	.268
ASQ Ambivalent	0.00 (0.005)	0.10	.402	0.00 (0.004)	0.04	.725	0.00 (0.005)	0.07	.561

For sake of clarity, the original ASQ subscale labels were replaced with the corresponding attachment dimension. Dependent variables: RFT, relative fixation time; RFN, relative number of fixations; RGP, relative number of gaze points. Negative values of the RFT, RFN, and RGP coefficients reflect attentional bias toward CARE stimuli. * $P < .05$; ** $P < .001$.

into our choices, indicating the presence of a complex interplay between sensory input, cognitive processes, and decision outcomes.^{41,45} While the prime effect intended to modulate emotional responses appears to shape the ultimate decision, it does not necessarily influence the way visual attention is allocated to the stimuli. Congruently, our results suggest that the time spent viewing care- or smoking-related images was influenced not by the prime but by the participants' status as people who smoke or people who do not smoke. Nevertheless, our results did not reveal a significant relationship between attention (as indexed by our ET measures) and decision-making processes. Likewise, no significant association emerged between the emotional priming manipulation and the ET measures. These findings may be interpreted as consistent with a possible dissociation between AB and decision-making; however, this interpretation remains tentative. Future studies are required to directly test this possibility through experimental manipulation of affective cues, AB, and decision-making processes.

In agreement with the literature, we found that individuals who smoke were less biased toward care-related cues compared to individuals who do not smoke.⁴⁶ However, with respect to the available literature, our results show a smaller effect size that may depend on the characteristics of our experimental paradigm. In fact, contrasting to most of the prior studies that associated smoking-related cues with neutral stimuli, in this study, smoking-related cues were always paired with meaningful (care) stimuli competing for attention.^{25,46,47} When multiple stimuli compete for an individual's limited attentional resources, a bias toward emotional stimuli facilitates quick detection and preparation for adaptive responses.^{48,49} In our paradigm, care-related images possess a distinct positive valence that can be understood through attachment theory,^{48,49} while the valence of smoking-related images is likely to differ substantially between the two experimental groups. People who smoke may associate these cues with positive valence due to the rewarding effects of smoking, while people who do not smoke might view them negatively, possibly influenced by anti-smoking campaigns that often leverage emotional graphic warnings to stress the dangers of TUD.^{50,51} Our findings support the suitability of this experimental paradigm, which may contribute a novel perspective to research on AB. By not pairing a drug-related image with a neutral one, participants were compelled to focus on two meaningful images, each relevant for different reasons. Our findings highlight that in

AB studies, especially those examining complex phenomena like addiction, stimulus selection is critical, as factors beyond drug dependency can influence observed patterns.

In early childhood, seeking physical closeness helps regulate emotions, but in adulthood, this often shifts to relying on mental representations of another's symbolic presence.⁵² Thus, avoidant individuals may turn to attachment substitutes and maladaptive coping strategies, including those linked to addiction.⁵² Our study examined whether AB indices could be explained by attachment-related constructs measured by the ASQ. Regression analyses showed that, alongside smoking habits, the ASQ Secure, Avoidant, and Dismissing subscales significantly predicted AB indices. The differential contribution of avoidant and dismissing attachment dimensions to AB toward smoking cues is a key finding of the present study. Although both reflect deactivating strategies within the attachment system, they represent distinct regulatory profiles. The results indicate that individuals who defensively minimize attachment needs may differentially allocate attentional resources toward smoking-related cues, consistent with the possibility that smoking functions as an alternative regulatory mechanism. Notably, these associations emerged only among people who smoke, suggesting that attachment-related processes interact with established substance use behaviors rather than reflecting a general attentional style. Furthermore, attachment dimensions predicted AB more consistently than NIC dependence severity, highlighting the potential relevance of relational regulatory systems in shaping cue salience in young people who smoke. Previous studies have identified several cognitive mechanisms through which attachment styles shape care-seeking versus alternative reward pursuit. Avoidant individuals consistently exhibit attentional biases away from care-related stimuli.⁴¹ According to dual-process models of avoidant defenses,⁵³ this pattern may reflect two-stage attentional dynamics: care-related or threatening stimuli are initially registered and automatically engaged but are subsequently disengaged from once controlled regulatory processes are recruited. Furthermore, motivational processes highlight differences in approach-avoidance tendencies across attachment styles, with avoidant individuals showing avoidance motivation toward care-related cues, perceiving comfort-related stimuli as threatening⁴¹ and reporting discomfort with closeness and interdependence.³² On the one hand, these results suggest that attentional processing of salient stimuli is shaped by both lifestyle behaviors and internalized interpersonal models,

highlighting the value of integrating attachment theory into models of attentional processing to explain individual differences in sensitivity to emotionally salient cues. On the other hand, the specific mechanisms activated and their relative importance vary substantially across different contexts and measurement approaches, requiring careful interpretation of when and how each mechanism operates.

Lastly, in-depth analysis of the PWS group was performed to test the effects of the addiction severity, and the results showed that the NIC dependence level exerted a smaller effect than expected and only on the RFTs, while the ASQ Avoidant and Dismissing subscales resulted the strongest predictors of all the AB indices. These results are consistent with previous research, which suggested that some attachment-related dimensions could be associated with TUD, with people who smoke showing more attachment anxiety and feelings of loneliness than participants who do not smoke.⁵⁴ However, it should be noted that, given the multifaceted nature of TUD, our observations provide just one perspective on the potential links between personality characteristics and tobacco use. In this regard, it is important to note that the present study relies exclusively on explicit self-report measures. However, Serra et al.⁵⁵ found that implicit insecure attachment (rather than explicit attachment) was associated with greater tobacco and cannabis use and with polydrug use in college students, highlighting the potential role of implicit attachment processes in addictive behaviors. Thus, we advocate that the relationships between the attachment-related dimensions and the cognitive processes require further investigation, to better understand whether attachment security could have a protective or moderating effect on substance use.

In conclusion, this study is, to our knowledge, the first to examine AB toward smoking-related cues contrasted with care-related stimuli rather than neutral ones. Across primes, AB indices differed significantly between groups: PWS showed lower bias toward care-related stimuli than PWDNS, though this bias was only marginally linked to NIC dependency. Additionally, attention deployment was significantly influenced by individual attachment style, affecting the degree to which participants were drawn to or resisted affective cues.

Limitations of the study

Our study focused on young people who smoke with moderate TUD and brief smoking histories. According to incentive-sensitization theory, heavier, long-term use leads to greater impairment of motivation and reward systems, so a more severe sample might have yielded different results. While the accumulated evidence reveals a consistent pattern where avoidant attachment is characterized by systematic avoidance of care-seeking cues through multiple reinforcing mechanisms, both the mechanisms engaged and their relative contributions vary across contexts and assessment approaches. It should be noted that the ASQ subscales are moderately intercorrelated, which may introduce multicollinearity or suppressor effects in the regression models; therefore, the effects of the Avoidant and Dismissing subscales should be interpreted with caution. Further, our results suggest that while ET provides an objective measure of AB, its outcomes warrant careful interpretation, as gaze patterns may be influenced by multiple contextual factors. This pattern suggests that during conscious decision-making, metacognitive

beliefs and addiction-related habits may exert stronger effects than automatic attentional processes. These observations await independent confirmation. Although the affective valence of the items used in the task was rated in a previous study,²⁰ only an experimental check was acquired from the participants after the experiment asking them if the stimuli elicited negative emotion. Future studies may want to add a more formal rating of the affective valence of the stimuli to be used in formal analyses. Lastly, since difficulties in emotion regulation can change over the lifespan, our results may not be fully generalizable to the wider age range of people who smoke.

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Declaration of interests

All authors declare no competing financial interests or personal relationships that could have influenced the work reported in this paper.

Author contributions

Beniamina Mercante (Conceptualization [equal], Data curation [equal], Investigation [equal], Methodology [equal], Writing—original draft [lead], Writing—review & editing [equal]), Federico Zorzi (Conceptualization [equal], Formal analysis [lead], Investigation [equal], Writing—review & editing [equal]), Arcangelo Francesco Uccula (Formal analysis [equal], Methodology [equal], Writing—review & editing [equal]), Carla Meloni (Formal analysis [equal], Writing—review & editing [equal]), Sahba Besharati (Methodology [equal], Writing—review & editing [equal]), and Paolo Enrico (Conceptualization [lead], Project administration [lead], Supervision [equal], Writing—review & editing [equal])

Data availability

All datasets are stored at the Department of Biomedical Sciences, University of Sassari, Sassari, Italy, under the responsibility of Paolo Enrico. Data will be made available upon reasonable request.

Appendix A: Images selected to serve as priming or target images

IAPS

1034; 1036; 1043; 1047; 1050; 1051; 1053; 1055; 1056; 1058; 1057; 1060; 1108; 1113; 1120; 1128; 1129; 1145; 1152; 1153; 1154; 1155; 1156; 1249; 1245; 1250; 1300; 1304; 3010; 3064; 3100; 1130; 1131; 1132; 1146; 3230; 3500; 3530; 6250; 6312; 6313; 6315; 6350; 6540; 6550; 6560; 6570; 7002; 7001; 7004; 7004; 7006; 7009; 7010; 7018; 7019; 7025; 7026; 7032; 7040; 7042; 7053; 7055; 7056; 7058; 7059; 7061; 7062; 7080; 7081; 7090; 7095; 7136; 7150; 7170; 7175; 7179;

7185; 7205; 7211; 7217; 7020; 7041; 7042; 7050; 7179; 7224; 7233; 7235; 7236; 7705; 9414; 9635.

BAPS-Adult

1; 2; 3; 4; 8; 9; 11; 12; 14; 15; 16; 19; 20; 22; 23; 24; 25; 26; 27; 28; 29; 30; 32; 34; 35; 40; 41; 42; 46; 47; 48; 49; 50; 51; 52; 55; 56; 57; 59; 64.

SmoCuDa

007; 008; 009; 010; 029; 033; 038; 039; 047; 048; 053; 058; 072; 075; 078; 079; 082; 085; 087; 098; 102; 115; 123; 136; 155; 161; 170; 176; 201; 204; 216; 117; 185; 208; 197; 206; 219; 225; 229; 243.

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