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Review

Chronic Tobacco Smoking and Emotional Processing Abilities: A Systematic Review

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Abstract

Introduction: Tobacco use disorder (TUD) remains highly prevalent and is associated with widespread cognitive impairments, particularly in attentional functions. Conversely, the understanding of emotional deficits related to TUD remains limited, despite its potential impact on mood regulation.

Methods: We conducted the first systematic review on emotional processing in TUD, based on a well-established model of emotion distinguishing three processes (emotional identification, emotional response, and emotional regulation), to which we added emotional attention as a fourth component. Capitalizing on a preregistered approach and following PRISMA guidelines, we synthesized existing literature on emotional processing impairments in TUD, identifying 14 relevant studies.

Results: Findings indicate large-scale impairments encompassing all emotional components in TUD, demonstrating that emotional processing constitutes a crucial dimension of TUD.

Conclusion: Emotional processing emerges as a key aspect of TUD but, in view of the currently limited quantity and quality of research in this area, we offer guidelines for more comprehensive and theory-grounded investigations, to advance theoretical knowledge and pave the way for efficient interventions.

Implications

This systematic review shows that tobacco use disorder (TUD) is associated, beyond the already documented cognitive deficits, with emotional impairments encompassing emotional identification, response, regulation and attention. Such widespread modifications of emotional processing might be involved in the emergence and persistence of TUD, and hence constitute new targets for researchers and clinical practitioners.

Introduction

Tobacco use disorder (TUD) is characterized by a lack of control over smoking leading to clinically significant impairments, such as withdrawal symptoms (eg, insomnia, restlessness, irritability, anxiety) or distress.[1] The main psychoactive component in smoked tobacco is nicotine,[2] and its effects depend on its dose and administration mode.[3] The continued and uncontrolled use of nicotine-containing products characterizes TUD, which is the major preventable cause of death worldwide.[4,5] Beyond its physiological consequences on most organs of the body,[3] TUD, as all addictive states, implies the learning of the associations between the contextual cues that predict tobacco availability and the rewarding effects of tobacco.[6] Tobacco constitutes a positive emotional prime because it enhances the salience of rewards and reinforcers, and thus decreases negative affect, including stress and anxiety.[7] Furthermore, it modulates sensory, psychomotor, attentional, and executive functions and, ultimately, learning and memory processes.[3,6,8] Tobacco effects on cognition have been extensively studied: while acute administration (ie, the immediate effect of nicotine on the brain and body following smoking, including a short-term increase in dopamine transmission) seems to be performance-enhancing and to improve cognition, especially attention and memory functions,[8,9] TUD, namely the chronic use of tobacco (ie, the repeated and long-term use, progressively reducing dopamine activity through neuroadaptation) appears associated with cognitive impairments.[9] Chronic TUD has even been proposed as a potential risk factor for cognitive deterioration and dementia in later adulthood.[9,10]

In striking contrast with these well-established cognitive correlates, the association between TUD and emotions has been far less explored. Emotional intelligence has a key role in mental and physical well-being and plays a protective role against mental illnesses and addictions.[11] Specifically, people with high levels of adaptive emotional regulation

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(ie, the ability to use a diverse repertoire of regulatory strategies, flexibly adapting them to the context and situation)[12] are less prone to using and abusing substances.[11,13,14] Conversely, dysfunctional emotional regulation[13–15] and emotional expression are involved in addiction onset and maintenance.[13] The inability to cope and manage one's own emotion, which may lead to anxiety and depression,[13,16] is correlated with substance abuse onset.[11,17] Thus, tobacco abuse can be conceptualized as a "self-medication attempt," where people use drug when unable to regulate their pervasive, intense negative feelings.[16,18,19] The influence of altered emotional regulation abilities in the onset of addiction has been largely established, but drug consumption itself might in return affect one's emotional regulation abilities on subclinical and clinical populations with addictive disorder.[18,20,21] Nevertheless, the extent of emotion research is less straightforward in TUD. So far, impairments related to emotional processing in TUD have been investigated in some studies targeting emotional processes, mostly by focusing on emotion regulation abilities, thus neglecting the importance of other emotional processes (eg, emotional appraisal/identification and emotional response). Additionally, these studies often explored TUD effects in populations that present polyconsumption or with an already existing psychiatric/neurologic condition.[14,18] This may lead to contradictory conclusions that limit our understanding of the field.

As recently suggested,[14] there is a need for an isolated exploration of emotion-related deficit per substance of abuse. We have hence decided to focus the current review on TUD. Therefore, the present paper offers a thorough review of the literature, which aims at clarifying the current state of this field and identifying ways to move it forward, by organizing the literature according to a well-validated theoretical model of emotional processing. An asset of the present review is thus its theory-grounded approach, as it categorizes evidence using the theoretical framework proposed by Phillips and collaborators.[22,23] This model, which delineates distinct emotional processes, offers a robust structure for interpreting findings. Moreover, it has been successfully applied to organize evidence related to emotional processing deficits in binge drinking and in other contexts,[24–26] highlighting its relevance and versatility across different domains. It proposes three stages of emotional processing:

1. *Emotional appraisal/identification*, which involves the detection and processing of the emotional significance of a stimulus, that can be either internal (eg, self-emotional states) or external (eg, situation or other individuals' emotional expressions). In human research, this process has been investigated by self-report questionnaires or by paradigms assessing the ability to identify emotionally salient stimuli.
2. *Emotional response*, which involves the production of a specific affective state in response to the emotional stimulus/situation. This subcomponent includes cognitive, physiological, and behavioral correlates, as well as conscious emotional feelings. In human research, this process has been investigated by paradigms inducing affective states (eg, mood induction, fear conditioning) and measuring the emotional response elicited by the participant.
3. *Emotional regulation*, which involves the control of the affective state and emotional behavior. It encompasses the modulation or inhibition of the emotional appraisal and/or response. In human research, emotional regulation has been investigated through self-reported questionnaires and paradigms designed to assess the ability to control or modulate responses to emotional stimuli.

In addition to these three categories, we added a fourth category that groups studies exploring *emotional attention*. Some cognitive aspects, such as emotional attention, are fundamental for the enactment of several aspects related to emotional processing abilities.[27] In fact, there is some evidence showing that emotional attention plays a role at the three levels of emotional processing, simultaneously influencing emotional identification,[28] emotional response,[29] and emotional regulation.[30] We thus incorporated here the Situation by Trait Adaptive Response (STAR) model's[31] broader framework,[32] which suggests that both situational factors (eg, context, mood states) and trait-level characteristics (eg, anhedonia, executive functioning) can influence reward and attentional processes involved in nicotine dependence. According to Gilbert's STAR model,[31] nicotine's rewarding effects involve mechanisms such as enhanced goal achievement, cognitive and attentional biases toward rewarding cues, and alterations in reward sensitivity. These effects can help to explain why individuals with TUD may rely on nicotine in low-reward situations or under cognitive strain, where nicotine's performance-enhancing effects are most noticeable. Additionally, the negative reinforcement model[33] complements this framework by showing how individuals with TUD may engage in tobacco use to manage negative emotions, which creates maladaptive patterns of emotional response and regulation. This negative reinforcement cycle highlights how TUD both reflects and perpetuates challenges in regulating distress and avoiding emotional discomfort. This integrated model hence provides a thorough approach to understanding emotional processing deficits in TUD and suggests research avenues to further explore these interconnected processes.

Methods

This systematic review follows the guidelines of Preferred Reporting items for Systematic Reviews and Meta-Analyses (PRISMA).[34] We consulted two databases (July 20, 2023): PubMed and Scopus. We preregistered the complete protocol at PROSPERO (registration number CRD42022330348). The following key terms were used: "tobacco use disorder," "nicotine consumption," "nicotine/tobacco smoking," together with "emotional appraisal," "emotional identification," "emotional response," "emotional regulation," "emotional processing," and "emotions." Two authors (E.M. and M.G.), working independently, selected the articles at each stage of the review (identification, screening, eligibility, and inclusion) by using Rayyan systematic review software. Authors resolved disagreements through discussion and consensus. Among the 867 papers identified, the authors selected 1 publication. Apart for the paper from Nesbitt[35] that we included in the current review, not a lot of research focused on this research topic before 2000. Therefore, we decided to consider studies published in English since 2000 (January 1, 2000 to July 20, 2023). Following the PRISMA guidelines, two authors (E.M. and M.G.) extracted data in tables independently. In order to determine papers' inclusion criteria, we referred to the PICOS

procedure (Population, Intervention, Comparator, Outcome, Setting)[36] as follows:

1. Regarding the *Population*, only studies on human samples were considered.
2. Regarding the *Intervention*, studies were considered if they included a validated measure of tobacco consumption, as determined through standardized diagnosis tools[37](eg, Fagerström Test of Nicotine Dependence).[38,39] Additionally, this measure had to be included as a main variable in the analyses. However, not all the studies included a formal diagnosis of TUD.
3. Regarding the *Comparator*, studies were considered if they offered a direct comparison between an experimental group of smokers and a matched control group of nonsmokers. This deliberate exclusion of studies comparing smokers with abstinent smokers and ex-smokers was motivated by our aim to isolate smoking-related impairments without considering potential long-term effects of smoking. Consequently, studies comparing different states of smoking satiety were included only if they provided a direct comparison with a group of never-smokers.
4. Regarding the *Outcome*, studies were included if they explored the relationship between TUD and emotional processing abilities as a dependent variable. When the effects of other substance use are included, the study design must allow to isolate the specific effects of tobacco smoking.
5. Regarding the *Setting*, studies were included when proposing comparisons between groups or experimental conditions (ie, interventional, observational, cross-sectional), thus excluding single-case studies and studies without experimental data.

Table 1 presents a detailed explanation of the inclusion criteria.

Results

Selection Process

We identified 867 articles through database searches. We exported the articles to Rayyan to eliminate duplicates (N = 112). Screening of titles and abstracts led to the identification of 31 articles fulfilling our inclusion criteria. The main reasons for exclusion at the phase of "title/abstract reading" was the investigation of other topics (ie, no emotional processing measured) (N = 400), the absence of a valid measure of tobacco smoking (N = 159), or the absence of original data (N = 114). After the "full text reading" phase, 14 articles were found to meet the inclusion criteria, and 17 studies were excluded (Figure 1).

Table 1. Inclusion Criteria for the Studies

1. Articles must be written in English or French.
2. Articles must be empirical studies (ie, comprising original data).
3. Articles must be human studies.
4. Participants must be tobacco smokers. If they consume other substances, tobacco must be the main substance of use.
5. Articles must explore the relationship between tobacco smoking and emotional processing abilities.
6. Articles must include a sample of smokers compared to a matched group of nonsmokers.
7. Articles must mainly examine the effects of tobacco on emotional abilities or, when other substance use groups are included, their experimental design must allow to isolate the specific effects of tobacco smoking.

Characteristics of the Studies

Among the studies considered, 50% were published after 2010 and, of these, 43% were published after 2020. The proportion of studies conducted in different parts of the world were as follows: North America 64%, Europe 29%, and Asia 7%. The main characteristics of each study are summarized in Supplementary Table 1.

Quality Assessment

As underlined in papers reviewing methodological quality assessment scales,[40,41] there is currently no gold-standard tool for assessing cross-sectional studies. Therefore, we have decided to evaluate the methodological quality of each reviewed study using an adapted version of the quality assessment tool for observational cohort and cross-sectional studies, developed by the National Heart, Lung and Blood Institute.[42] As most studies included in the present paper are cross-sectional, this scale appears as the most appropriate for our purpose. Additionally, it has been recently used in systematic reviews on similar topics.[43,44] In order to properly evaluate the studies included in the current paper, four items (items 3, 6, 7, and 13) of the original scale have been removed from the evaluation scale. The final assessment scale thus comprised 10 items with a binary answer (Yes/No), leading to a raw rating between 0 and 10. For each study, we computed a score (ie, percentage of items with a "Yes" answer), leading to a global quality rating that allowed papers' classification as "poor" for scores below 50%, "fair" for scores between 50% and 69%, "good" for scores between 70% and 79%, and "strong" for scores of 80% and beyond. According to our rating (Table 2), most of the studies were rated as "good" (36%), 28.5% as "fair," 28.5 % as "poor," and 7% as "strong." The mean rating of the studies included in the current paper is "fair." It should be noted that, as the original scale was adapted in order to fulfill the needs of the current paper, our methodological quality assessment was based on the selected information reported in each paper. Therefore, it could be considered as partly evaluating the quality of methodological description rather than the methodological quality of the paper per se.

Outcome: Emotional Processing Impairments

We organized the selected studies within the three emotional processing subcomponents of our reference model.[22,23] Additionally, we grouped four relevant studies exploring emotional attention impairments in a fourth subcomponent.

Emotional Appraisal/Identification

Description of the Results.

Emotional appraisal/identification refers to the ability to detect and process the emotional significance of the stimulus.[22,23] A total of three studies with three different tasks evaluated emotional appraisal/identification. The first one[52] assessed emotional appraisal/identification through the Test of Emotional Intelligence by the Fundación Botín for adolescents

(TIEBDA),[58] which measures four dimensions: emotional perception, emotional facilitation, emotional understanding, and emotional regulation. It reported that the probability of TUD is higher among adolescents with less ability to understand and perceive emotions than those with higher skills. The second[45] used a morphing task, in which participants had to identify emotional expressions (ie, neutral, happiness, anger, fear). Participants with TUD were significantly slower than nonsmokers in recognizing angry facial expressions; no differences among groups were found for happiness and fear. In addition, the third study[55] used a Facial Emotion Perception Task (FEPT) to assess participants' ability to categorize facial expressions into one of four possibilities: happiness, sadness, fear, and anger. In their study, a sample of people with major depressive disorder (MDD) was included. They found that participants with TUD, compared to nonsmokers, had significantly poorer overall performance to detect emotions displayed by faces, in particular related to happy and sad faces. Additionally, their study provides evidence for distinctive, nonoverlapping cognitive and affective decrements in MDD and TUD: while MDD appears to be mostly associated with cognitive decrements, emotional processing decrements seem to be associated with a positive TUD history.

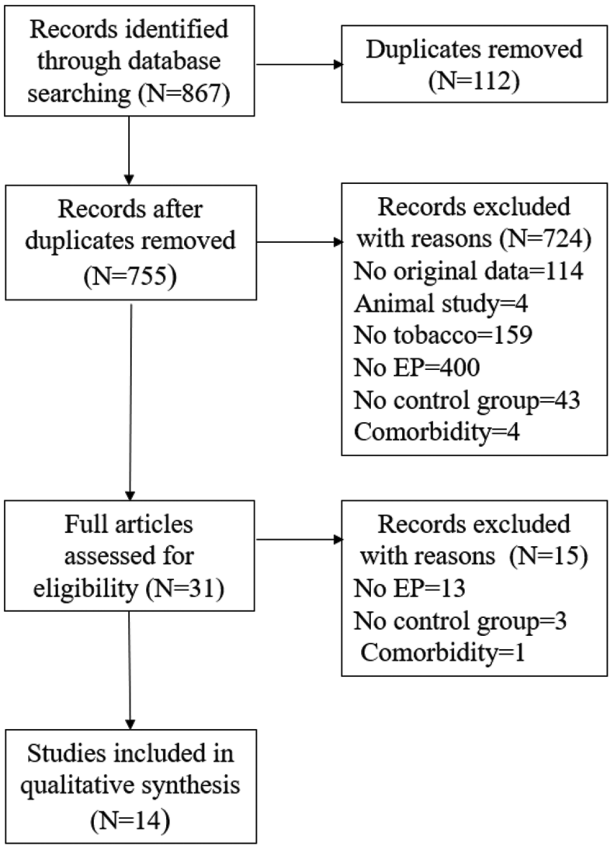

Figure 1. PRISMA flow diagram describing the selection and review process of the papers included. EP = emotional processing.

Impact of Age, Gender, Psychopathology, and Sample Size.

All the three studies reported in this section did not find any relevant difference in performance related to gender. Participants' age range is different across studies, as two studies[52,45] included a sample of adolescents while one[55] included a sample of older adults, and a sample of MDD patients. Eventually, sample sizes are considerably different across the three studies (from less than 100 participants[45,55] to 799)[52] as well as the inclusion criteria for participants with TUD. These differences may explain some of the discrepancies observed in the results.

Conclusion.

Overall, it seems that TUD is correlated with emotional appraisal/identification impairments. However, evidence is scarce and partially contradictory. An overall impairment in emotional appraisal/identification abilities can be observed in TUD.[52,55] Moreover, happiness and sadness are the worst recognized emotions.[55] Some contradictory results exist,[45] reporting no differences between TUD and healthy participants in identifying happiness and fear and proposing that, for

Table 2. Quality Assessment Scores of the Included Studies According to the Adapted NHLBI Quality Assessment Tool for Observational Cohort and Cross-sectional Studies

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Quality rating
Bernstein et al. (2014)[45]	Yes	Yes	No	No	No	No	No	Yes	NR	No	3/10
Chae et al. (2008)[46]	Yes	No	NR	No	No	Yes	No	Yes	NR	No	3/10
Engelmann et al. (2011)[47]	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NR	No	7/10
Faulkner et al. (2020)[48]	Yes	Yes	Yes	No	No	Yes	Yes	Yes	NR	Yes	7/10
Faulkner et al. (2022)[49]	Yes	Yes	Yes	Yes	No	Yes	No	Yes	NR	Yes	7/10
García-Moya et al. (2017)[50]	Yes	Yes	Yes	No	Yes	No	No	Yes	NA	Yes	6/10
Gilbert et al. (2008)[51]	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	8/10
González-Yubero et al. (2020)[52]	Yes	Yes	Yes	No	Yes	No	No	Yes	NA	Yes	6/10
Grillon et al. (2007)[53]	Yes	No	NR	No	Yes	Yes	No	Yes	NR	No	4/10
Klein and Knäuper (2009)[54]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	7/10
Meyers et al. (2015)[55]	Yes	No	No	No	No	No	No	Yes	NR	Yes	3/10
Nesbitt (1973)[35]	Yes							Yes	NR	No	7/10
Piper and Curtin (2006)[56]	No	Yes	No	Yes	No	Yes	No	Yes	NR	Yes	5/10
Waters and Li (2008)[57]	No	Yes	No	No	No	Yes	Yes	Yes	NR	Yes	5/10

Abbreviations: NA, not applicable; NR, not reported.

anger, smokers had lower response times but not worse recognition rates. Therefore, the nature and extent of impairments in emotional appraisal/identification in TUD is not clear yet.

Emotional Response

Description of the Results.

Emotional response refers to the production of a specific affective state in response to the emotional stimulus/situation.[22,23] Emotional response has been evaluated in five studies, through three different tasks. Three studies[46,47,56] delivered participants with affective and tobacco-related pictures. The first[46] measured autonomic responses (ie, pupil size) after pictures presentation, and asked participants to fill in the Self-Assessment Manikin.[59] They found that valence, arousal, and dominance ratings for neutral, pleasant, unpleasant, and tobacco-related pictures were not significantly different between participants with TUD and nonsmokers. However, participants with TUD had significantly higher autonomic responses to tobacco-related pictures, compared to nonsmokers. The second[47] found differences in ratings of pleasantness, but not arousal, of tobacco-related pictures between participants with TUD, abstinent TUD participants, and nonsmokers: TUD participants and abstinent TUD participants rated tobacco-related pictures as more pleasant and arousing than neutral ones, while nonsmokers rated the tobacco-related pictures as less pleasant but more arousing than neutral pictures. Additionally, they measured the startle eyeblink reflex (ie, a rapid defensive response to a sudden, intense stimulus, characterized by an eyeblink reflex, which serves to protect the organism from a potential impact to the head)[60,61] and found that smokers, compared to nonsmokers and abstinent smokers, did not show robust fear-potentiated startle responses (ie, an objective measure of affective reactivity, which tests the increase in startle magnitude during states of negative affectivity or anxiety) to unpleasant pictures, compared to neutral ones. The third study[56] reported normal emotional response (ie, startle magnitude) intensities during tobacco withdrawal. These results suggest that self-reported measures of emotional response do not show differences between TUD participants, abstinent TUD participants, and nonsmokers. Moreover, another study[53] measured emotional response through a threat experiment (ie, a fear conditioning experimental procedure) and found that abstinent and non-abstinent TUD participants had greater sustained potentiated startle reflex than nonsmokers during the unpredictable condition (ie, one of the conditions of the threat experiment, during which the threat cue is not always paired with the fear-inducing stimulation), while only acutely abstinent TUD participants had greater cue-potentiated startle than nonsmokers. In general, this effect was more pronounced in females. Globally, participants with TUD displayed greater reactivity to fearful stimuli compared to nonsmokers. Finally, an older study[35] measured emotional response by delivering electrical shocks and asking participants to rate the intensity of the electrical shocks they received. They observed that participants with TUD, as compared to nonsmokers, could tolerate a higher amount of electrical shocks when smoking a cigarette but a lower amount of shocks when not smoking. Additionally, they found that cigarettes with higher nicotine content were more effective at reducing emotionality in TUD. These findings suggest that nicotine may contribute to the alleviation of fear and, more broadly, enhance the regulation of emotional experiences.

Impact of Age, Gender, Psychopathology, and Sample Size.

Some minor gender differences were observed, with females having a greater fear-potentiated startle than males in a fear conditioning experimental procedure.[53] Conversely, some studies[47,56] found no significant result related to gender, while others[35,46] did not address this question. In general, it appears that males and females display the same outcomes in the five studies. Regarding psychopathological states, only one study[53] reported that participants with TUD appear to be more reactive to anxiety than nonsmokers. Globally, the studies grouped in this section recruited participants that fall in a similar age range, composed by adolescents and young adults. Sample sizes are similar as well (from 19 to 30 participants). However, not all the studies apply the same inclusion criteria for TUD participants and this may account for some of the discrepancies observed in the results.

Conclusion.

It is difficult to draw conclusions from these studies, due to the variety of tasks used. According to self-reported measures, no differences were observed between participants with TUD and nonsmokers regarding emotional response.[46,56] However, at the physiological level, participants with TUD presented higher autonomic responses to smoking-related pictures than nonsmokers.[46] Regarding unpleasant stimuli, participants with TUD do not show robust fear-potentiated startle responses compared to nonsmokers,[47] but they do display greater potentiated startle than nonsmokers related to unpredictability.[53] Finally, at the behavioral level, participants with TUD, compared to nonsmokers, display greater avoidance responses if deprived from nicotine and lower avoidance responses when under its effect.[35] Overall, these studies suggest that people with TUD display blunted emotional responses at physiological and behavioral levels, heightened sensitivity to uncertainty and fear, and that nicotine appears to mitigate these effects, but the nature and extent of these impairment remain unclear.

Emotional Regulation

Description of the Results.

Emotional regulation refers to the ability to regulate affective states and emotional behaviors. It has been evaluated by five studies, through three different tasks. Three studies delivered participants with questionnaires measuring their emotion regulation capacities.[48,50,58] The first one[48] delivered participants with the Difficulties in Emotion Regulation Scale (DERS)[62] and observed that participants with TUD, compared to nonsmokers, report having more difficulties in emotion regulation, specifically lower levels in the emotional clarity scale of the DERS. These findings align with those of the other two studies that administered questionnaires.[50,52] Using two Spanish questionnaires—the TIEBDA[58] and the international Health Behaviour in School-aged Children (HBSC) survey (M. Gaspar de Matos et al., unpublished data, 2009)—they examined various emotional abilities. Depressive symptoms, coupled with lower emotion regulation abilities, were identified as strong predictors of substance use in adolescents, particularly TUD. Moreover, another study[49] delivered participants with an emotion regulation task (ie, participants were first instructed about how to use appraisal to regulate negative emotions and were then requested to

respond to negative and neutral pictures presented in 1st and 3rd person) and a self-reported questionnaire of emotion regulation, the DERS.[62] Their results confirmed that participants with TUD have more difficulties in regulating their emotions, and thus report higher emotion regulation difficulties than nonsmokers. Finally, another approach[56] was to deliver participants with a picture-viewing task followed by a voluntary emotion regulation task (ie, participants were presented with unpleasant or neutral images and instructed to "enhance," "suppress," or "maintain" the emotional response evoked by the picture) and found intact emotion regulation abilities during tobacco withdrawal. In fact, both abstinent and non-abstinent participants with TUD displayedno difficulty to voluntarily regulate their emotional response to external, punctual stressors.

Impact of Age, Gender, Psychopathology, and Sample Size.

All of the five studies included in this section had a sample of adolescents/young adults, except for one,[49] with a sample aged 18–63 years old. However, they did not report any effect related to age. Moreover, no significant results related to gender were reported in any of the five studies. Regarding psychopathology, just one study[50] found that depressive symptoms positively impact tobacco consumption and negatively impact emotion regulation abilities. The five studies widely differ regarding sample sizes (some[48,49,56] having a sample lower than 100 participants, while others[50,52] proposed a sample higher than 750 participants) and in the criteria used for inclusion in the TUD groups. These variations might account for some of the disparities seen in the results.

Conclusion

Overall, most studies investigating emotion regulation in TUD, except one,[56] suggest a correlation between tobacco use and reduced emotion regulation abilities, particularly in managing negative emotional states.[48–50,52] However, the diversity of tasks and questionnaires used to assess emotion regulation across studies complicates efforts to determine the precise impact of emotion regulation abilities in TUD. Consequently, it remains unclear whether lower emotional regulation abilities are predictors of TUD or whether TUD directly causes impairments in emotion regulation abilities.

Emotional Attention

Description of the Results.

Emotional attention has been evaluated by four studies. First, a study[51] used a Two-Choice Picture-Attention Task (TC-PAT) and a No-Choice Picture-Attention Task (NC-PAT) and measured eye-gaze during these tasks. The TC-PAT and NC-PAT are two identical tasks, with the only exception that the first one delivers the participants with two pictures, while the second one delivers them with one. They require participants to keep viewing the picture/s and keep their eyes open throughout the 3s presentation. After this phase, participants are free to move their gaze wherever they prefer on the presented pictures.[51] Using these paradigms, the authors observed that nicotine biases attention away from negative stimuli when equally salient benign or positive stimuli are presented. Moreover, nicotine enhances attention to more salient stimuli than to less salient ones. Additionally, from their results, men seem to be more sensitive than women to these nicotine's effects. A second study[52] that extracted results from the TIEBDA questionnaire, stated that there is a higher probability of TUD among adolescents with a higher level of emotional attention. Moreover, two other studies[54,57] used emotional variations of the Stroop task. The Stroop task gives a measure of the delay in reaction time between congruent and incongruent stimuli. Therefore, longer naming latencies can be observed when people's attention is affected by the emotional content conveyed by the carrier words even though they are irrelevant to the color-naming task at hand. The first study,[54] through the use of an emotional version of the Stroop task and the Ishihara Colour Blindness Test,[63] found that participants with TUD avoid smoking-related threat words, compared to nonsmokers. The second one[57] observed that participants with TUD, compared to nonsmokers, exhibit a smaller classic-Stroop effect but a significantly higher smoking-Stroop effect.

Impact of Age, Gender, Psychopathology, and Sample Size.

The four studies included in this section significantly differ on the number of participants tested, from 100[54,57] to 150[51] or 700,[52] as well as on the age range and mean age of participants (adolescents[52] or adults[51,54,57]). Additionally, they differ in the criteria used for inclusion in the TUD groups, which contributes to explaining some of the disparities in the results. Regarding gender differences, a study[51] found that men are more sensitive than women to nicotine effects, while others did not find any significant result related to gender[52,57] or did not mention anything about gender.[54] Moreover, there was no mention of psychopathological effects.

Conclusion.

The four studies included in this section suggest that TUD is associated with enhanced attention to salient stimuli (ie, emotional and/or smoking). Moreover, it seems that TUD biases attention away from negative stimuli,[51] particularly when they are smoking-related.[54,57] Overall, the findings from these studies align with the STAR model,[31] which proposes that attentional biases towards stimuli linked to reward or threat may contribute to enhanced reactivity in TUD. Specifically, attentional biases toward smoking cues could increase craving and stress reactivity, while the tendency to avoid negative cues, particularly those associated with smoking, might reflect an automatic response aimed at reducing distress. Additionally, Baker's model[33] highlights hownegative reinforcement may strengthen this bias, as nicotine can act as a coping tool in response to stress or threat cues, thereby maintaining maladaptive attentional patterns. However, the limited number of studies included and the differences in the questionnaires and tasks used to measure emotion regulation impairments in TUD limit our understanding of these impairments.

Comorbidities

Among the 14 studies included in the paper, only two specifically analyzed emotional processing abilities considering potential comorbidities[50,55] and another[53] just reported that participants with TUD are more reactive to anxiety than nonsmokers in a threat task. However, these studies are insufficient to draw conclusions. In fact, it has been suggested that MDD and TUD may play nonoverlapping and noncumulative roles in affective decrements,[55] but the concurrent presence of poor emotion regulation abilities and depressive symptoms might be stronger predictors of TUD than poor emotional

regulation abilities alone.[50] Additionally, while one study[55] assumes that TUD is a predisposing factor for emotion regulation and affective impairments, others[50] consider TUD as a consequence of lower emotional regulation abilities and depressive symptoms.

Discussion

This systematic review is the first to summarize the evidence regarding emotional processing abilities in TUD. We showed that studies on this topic are scarce, as only 14 studies fulfilled our inclusion criteria. As research shows, cultural factors can significantly shape emotional experiences and responses,[64,65] it is thus important to underline that evidence presented in this systematic review was mostly collected in North America and Europe, with limited representation of other cultures. Moreover, the 14 studies identified in the systematic review targeted different emotional processes. To provide a better understanding of emotional abilities in TUD, we organized results according to a model of emotional processing,[22,23] and we added a fourth category (ie, emotional attention, exploring the interaction between affective and cognitive abilities) to comprehensively cover the range of emotional abilities. While most studies focused on one specific emotional component, two studies attempted to give an overarching view of the emotional processing abilities in TUD.[52,56] The tasks and measures used to assess emotional processing across studies are highly heterogeneous. This methodological variability complicates direct comparison of results and may contribute to inconsistencies in findings. Nonetheless, several main findings can be underlined.

The few available studies on emotional appraisal/identification abilities suggest that TUD is associated with impairments in this subcomponent. Specifically, TUD appears to be correlated with difficulties in correctly identifying[45,52,55] and understanding emotions,[52] as well as slower response times.[45] However, even though these difficulties seem to be circumscribed to some specific emotions—worst identification of happiness and sadness[55] and slower response times related to anger[45]—the paucity of studies investigating this aspect makes it complicated to draw conclusions about which specific emotions are impacted. Regarding emotional response, all the available studies suggest that TUD is associated with blunted emotional responding at the physiological and behavioral levels. At the physiological level, participants with TUD have significantly higher autonomic responses to smoking-related pictures than nonsmokers.[46,47] Additionally, abstinent and non-abstinent participants with TUD display greater fear-potentiated startle than nonsmokers in unpredictable conditions.[53] However, contrary to nonsmokers and abstinent smokers, participants with TUD do not show robust fear-potentiated startle responses to unpleasant pictures, compared to neutral ones.[47] At the behavioral level, participants with TUD took more electrical shocks than nonsmokers when they were allowed to smoke (ie, lower avoidance responses), but less electrical shocks than nonsmokers when they were smoke-deprived (ie, higher avoidance responses).[35] When self-reported measures were used to investigate possible emotional response impairments, no differences could be observed between TUD and nonsmokers.[46,56] Moreover, studies focusing on emotional regulation showed that nicotine consumption correlated with lower emotional regulation abilities across different tasks and methods.[48–50,52] Only one study[56] observed intact emotion regulation abilities during tobacco withdrawal, in a sample of 24 adolescents. However, due to the limited number of studies and differences in the tasks used, it is not clear whether low emotion regulation abilities are predictors of TUD or if TUD leads to a decrement of emotion regulation abilities. Finally, regarding the studies exploring emotional attention, it seems that TUD was associated with enhanced attention to salient, particularly smoking-related, stimuli[51] and with higher overall levels of emotional attentiveness.[52] However, people with TUD also show higher avoidance rates of negative stimuli,[51] especially when these are smoking-related,[54,57] suggesting a complex attentional pattern where positive or smoking-related cues are prioritized, while distressing stimuli are actively avoided. This pattern can be contextualized through the STAR[31] and Baker[33] models, which suggest that TUD-related attentional biases, particularly toward smoking-related cues, may shape emotional reactivity at each stage of processing, reinforcing tobacco use as a maladaptive response to distressing cues.

Globally, available evidence suggests that TUD is associated with impairments across various emotional processing levels, with performance differences being most pronounced in tasks involving negative emotions. These findings underscore the potential role of nicotine in modulating sensitivity to negative emotional states. However, it is still difficult to draw clear conclusions regarding the specific profile of impairments in the various subcomponents of emotional processes. Indeed, some of the differences in the results could be due to differences in (1) tasks and questionnaires used to investigate possible impairments; (2) sample sizes (from 81[54] to 1752[50] participants in the included studies); (3) age ranges of participants included (eg, adolescents[52] or adults)[49]; and (4) the selection criteria of participants, that varied a lot across studies.

Regarding gender, both sexes appear to be similarly affected, as only two of the 11 studies controlled for gender effects and reported gender-specific differences. Some[51] observed that men were more sensitive than women to nicotine effects, which biased attention away from negative stimuli and enhanced attention to salient ones, as measured by a TC-PAT, a NC-PAT, and eye-gaze tracking. In contrast, others[53] found that women exhibited greater fear-potentiated startle responses during a fear conditioning experiment. These findings are insufficient to draw definitive conclusions about gender differences in emotional processing in TUD, as they pertain to distinct emotional processes (ie, emotional attention and emotional response). Indeed, existing evidence highlights differences in emotional development[66] and subsequent differences in emotional processing between men and women. This is particularly notable for emotional response,[67] where research has demonstrated marked differences in neural activation patterns following emotional stimuli.[68] Therefore, future studies should systematically consider gender differences to better understand their role in emotional processing in TUD.

Furthermore, regarding comorbidities, it seems that TUD has a positive relationship with the occurrence of affective disorders.[50,53,55] However, it is not clear whether TUD represents a predisposing factor for emotional impairments[55] or it is instead one of their consequences.[50] Interestingly, recent research highlights the role of anhedonia (ie, the reduced capacity to experience pleasure) and diminished positive affect in TUD, suggesting that emotional impairments are not limited to negative emotions but extend to blunted responses

to positive stimuli.[69,70] Given that anhedonia and positive affect deficits are often implicated in depression and contribute to smoking behaviors, they may also exacerbate emotional dysregulation in TUD, creating a self-perpetuating cycle of dependence and emotional impairment.

Overall, this systematic review highlights the presence of emotional processing impairments in TUD and their potential role in the development and persistence of the disorder, organizing existing evidence through Phillips' model of emotional processing.[22,23] The STAR model[31] and Baker's model[33] provide additional insights, highlighting how attentional and situational factors significantly influence TUD-related emotional processing deficits, reinforcing them through stress responses and attentional biases. Nevertheless, while emotional and attentional deficits appear consistent across the four subcomponents, some inconsistencies in the findings persist.

Research Implications

The present findings may have important implications to help developing new integrated experimental approaches, with the aim of systematically exploring the preserved emotional processing abilities in TUD at the four levels (ie, emotional appraisal/identification, emotional response, emotional regulation, and emotional attention). This should be done through an ecologically, theory-grounded and multimodal approach, which includes behavioral, psychophysiological, and self-reported measures. Moreover, since the selection criteria varied across studies, the standardization of tobacco use and the systematic use of TUD diagnosis criteria is critically needed from a methodological standpoint. Incorporating Baker's Reformulated model of addiction[34] and Gilbert's STAR model[31] may further advance this research agenda. For instance, Baker's focus on negative reinforcement highlights how TUD-related attentional biases and emotional dysregulation might reinforce maladaptive behaviors. Meanwhile, the STAR model's emphasis on situational factors, particularly the impact of proximal and distal influences on reward sensitivity, attentional bias, and emotional stress responses, could clarify how nicotine's effects vary in response to situational and trait-dependent factors like neuroticism and depression. This combined theoretical perspective could guide research in exploring how personal and psychological factors (eg, age, sex, and comorbidities) may modulate emotional processing deficits and stress reactivity, as evidence remains limited and contradictory. Additionally, future research should investigate not only negative emotional processing in TUD but also the impact of TUD on positive emotions, as the presence of anhedonia and positive affect deficits could be particularly relevant in the disorder's persistence.

Clinical Implications

At the clinical level, elucidating the nature and impact of emotional processing deficits in TUD is crucial, especially considering its frequent co-occurrence with polyconsumption and/or comorbidity with other psychiatric and neurological disorders.[14,18,50,53,55] Utilizing an integrated framework that includes the Phillips' model,[22,23] Baker's Reformulated model[33] and the STAR model[31] could support targeted interventions aimed at rehabilitating specific deficits across each emotional processing level. Furthermore, such interventions may reduce TUD-related deficits and alleviate associated psychopathologies, such as heightened sensitivity to anxiety.[71] This approach thus recognizes the interconnectedness of emotional processing with other mental health conditions, such as mood disorders, eating disorders, and schizophrenia,[18,50,72] suggesting that improvements in one domain could yield significant benefits across concurrent disorders.

Strengths and Limitations

While this review offers valuable insights, it is essential to acknowledge the limitations associated with the articles included. Firstly, the predominance of cross-sectional studies restricts our ability to infer causality, making it difficult to determine the direction of the observed relationships between TUD and emotional impairments. Longitudinal studies are needed to clarify whether TUD causes such impairments or whether preexisting emotional deficits contribute to the development of TUD. Addressing this limitation could significantly enhance our understanding of the underlying mechanisms in TUD. Moreover, the wide variety of tasks and measures used to assess emotional processing introduces heterogeneity that limits comparability across studies. To improve future research on TUD-related emotional processing, there is a pressing need for standardized assessment approaches that could consist in a battery of tasks reliably and efficiently measuring each emotional subcomponent identified in the present paper. Standardizing measures would not only enhance comparability but also help to clarify the specific profile of emotional impairments in TUD. Another important limitation is the variability in sample sizes across the studies included in this review. Some studies involved relatively small samples,[46] while others included much larger ones.[50] This heterogeneity in sample sizes may influence the robustness of the conclusions, as smaller samples are often limited in statistical power, potentially affecting the reliability and generalizability of the findings. Therefore, each study's conclusions should be interpreted considering its sample size, and future research should strive to standardize sample sizes for more consistent and reliable results. Additionally, most research reported in this systematic review was conducted in North America and Europe. This lack of cultural diversity restricts our understanding of how emotional processing and smoking behaviors might vary worldwide. Future studies should include more diverse populations to examine potential cultural variations. Additionally, the lack of standardized diagnosis for TUD poses a challenge, as it encompasses individuals with varying levels of cigarette consumption per day. Consequently, the studies included may capture different severity profiles and present diverse clinical manifestations. Another limitation is the absence of a meta-analysis section, which could have provided a quantitative synthesis of the findings. Moreover, it is important to note that the relatively small number of papers included in this review is due to the frequent co-occurrence of TUD with psychiatric conditions. Our exclusion criteria generated their omission from our analysis because it was impossible to disentangle the tobacco effects on emotional processing, as opposed to the isolated effect of the psychiatric conditions. However, due to the intrinsic relationship between addictions and psychiatric disorders, and the role of emotional processing in these conditions, we find of the utmost importance that future studies explore these comorbidities in a more systematic way. Despite these limitations, this review offers significant strengths. First, the review's systematic approach, which comprehensively covers core peer-reviewed evidence, sourced from prominent medical and psychological

databases. Additionally, by adhering to a theory-grounded approach, this review provides a robust framework for understanding the complexities of emotional processing deficits in TUD.

Conclusion

There is substantial evidence of an association between TUD and emotional processing impairments. Available data show that smokers display impairments in emotional appraisal/identification, emotional response, emotional regulation, and some emotional processes overlapping with cognitive ones (ie, emotional attention), although these difficulties merit further exploration. Additionally, despite both genders appear to be similarly affected, more studies are needed to confirm this assumption. It is also established that tobacco smoking often co-occurs with other drugs consumption and psychopathological comorbidities. However, the nature of these interactions and their joint impact on emotional processing remain to be defined. Further clarification is also required regarding possible rehabilitation programs of emotional processing abilities. To sum up, greater efforts should be devoted to exploring the associations between TUD and emotional processing impairments and to determine whether they are a consequence of TUD or rather a predisposing factor.

Supplementary Material

Supplementary material is available at *Nicotine and Tobacco Research* online.

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Declaration of Interests

None declared.

Author Contributions

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Data Availability

The systematic review protocol has been fully preregistered at PROSPERO (registration number CRD42022330348). This paper does not include original data.

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