The Effect of Identity on Smokers' Interpretation Bias: The Role of Cognitive Load

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Abstract

Interpretive bias toward relevant cues represents a crucial component of cognitive bias in addicted individuals; however, the characteristics and underlying mechanisms of smokers' interpretive bias toward smoking-related cues have yet to be elucidated. The present study examined, through three experiments, the characteristics of smokers' smoking-related interpretive bias, the influence of smoker identity on smoking-related interpretive bias, and the role of cognitive load in the effect of smoker identity on smoking-related interpretive bias. An ambiguous scenarios test was employed to assess smokers' interpretive bias. The results demonstrated that: (1) smokers exhibited significantly greater smoking-related interpretive bias compared to non-smokers; (2) smokers with high smoker identity showed significantly higher smoking-related interpretive bias than those with low smoker identity; and (3) as cognitive load increased, the influence of smoker identity on smokers' smoking-related interpretive bias diminished. These results indicate that sufficient cognitive resources facilitate the triggering effect of smoker identity on smokers' smoking-related interpretive bias. This research extends our understanding of the components of cognitive bias in smokers and their underlying mechanisms.

Full Text

The Effect of Smoker Identity on Interpretive Bias in Smokers: The Role of Cognitive Load

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Abstract

Interpretive bias toward addiction-related cues constitutes an important component of cognitive bias. However, the characteristics and underlying mechanisms of smokers' interpretive bias toward smoking-related cues remain unexplored. This study investigated the characteristics of smoking-related interpretive bias, the influence of smoker identity on smoking-related interpretive bias, and the role of cognitive load in this process through three experiments. Using ambiguous scenario tests to measure interpretive bias, the results showed that: (1) smokers' smoking-related interpretive bias was significantly higher than that of nonsmokers; (2) smokers with high smoker identity exhibited significantly higher smoking-related interpretive bias than those with low smoker identity; and (3) as cognitive load increased, the influence of smoker identity on smoking-related interpretive bias decreased. These findings indicate that sufficient cognitive resources facilitate the facilitative effect of smoker identity on smoking-related interpretive bias. The study expands our understanding of the components of smokers' cognitive bias and their underlying mechanisms.

Keywords: smokers, interpretive bias, identity, cognitive load

Introduction

Reducing national smoking rates and decreasing smoking behavior among smokers has long been a critical objective of tobacco control efforts in China. Numerous studies have shown that smokers exhibit cognitive biases in processing smoking-related cues (Wilcockson et al., 2021; Wittekind, Schiebel, & Simone Kühn, 2023), and such cognitive biases constitute important factors contributing to persistent smoking and failed quit attempts (Cheng et al., 2016). Cognitive biases include attentional bias, memory bias, interpretive bias, among others (Jones & Field, 2021). Current research on cognitive biases in smokers has primarily focused on attentional bias (Xia et al., 2024), with relatively fewer studies examining interpretive bias. Interpretive bias refers to a cognitive tendency to prioritize a particular interpretation among multiple possible interpretations when facing ambiguous information, reflecting an individual' s preference for a specific interpretive system (Hirsch et al., 2006). Compared to attentional bias, interpretive bias represents a later stage of cognitive processing of cue stimuli and is more likely to determine the meaning individuals assign to situations (李涛, 冯菲, 2013). Therefore, research on interpretive bias contributes to a more comprehensive understanding of smokers' cognitive biases.

Previous research on interpretive bias in addiction has primarily focused on alcohol users. Woud et al. (2012) developed a tool to measure alcohol-related interpretive bias in drinkers, designing several semantically ambiguous, open-ended scenarios lacking conclusions (e.g., "When a holiday arrives, you and your friends want to celebrate together, you quickly head to ___ "), with each scenario ending in a blank line for participants to complete. The study found

that heavy drinkers were more likely than light drinkers to interpret ambiguous situations in alcohol-related ways, indicating higher interpretive bias toward alcohol-related cues (Woud et al., 2012). Subsequent studies by Woud et al. consistently demonstrated that individuals with alcohol addiction exhibit interpretive bias toward alcohol-related cues (Woud et al., 2015; Woud et al., 2019). Smoking addiction, like alcohol addiction, represents a form of addiction resulting from drug-induced physiological responses. However, smoking differs from alcohol addiction not only in the addictive substance but also in that smokers are typically exposed to addiction-related cues more frequently than drinkers. Surveys indicate that smokers generally consume 10-20 cigarettes daily (于继刚等, 2022), meaning smokers use cigarettes approximately every 1-2 hours, which is more frequent than typical drinking patterns. Moreover, even when not actively smoking, smokers often carry cigarettes with them, increasing their exposure to smoking-related cues. Therefore, it is necessary to examine the characteristics of smokers' interpretive bias toward smoking-related cues.

Several theories in the addiction field explain the emergence of interpretive bias in addicted individuals. The Incentive Sensitization Theory of Addiction (Robinson & Berridge, 1993) posits that repeated exposure to potentially addictive drugs gradually alters the function of the nucleus accumbens-related brain systems in addicts, leading to enhanced sensitization to drugs and related stimuli. The Dual Process Model of Addiction (Salemink & Wiers, 2012) proposes that repeated exposure to addiction-related cues leads to the formation of positive associations with these cues. Once these associations become automated, related cues can rapidly activate these connections, thereby increasing impulses for corresponding behaviors. The Cognitive Mechanisms of Addiction model (Copersino, 2017) suggests that during the development of addictive behaviors, individuals gradually form a unique and complex network of associations that selectively guides and activates processing biases in information processing (such as interpretive bias, heuristic thinking, and attribution styles). Based on these theoretical explanations, it can be hypothesized that smokers may generate smoking-related interpretive bias when interpreting ambiguous information. Accordingly, we propose **Hypothesis 1**: Smokers' smoking-related interpretive bias is significantly higher than that of nonsmokers.

The aforementioned theories emphasize the role of associations between addiction-related cues and corresponding cognitive responses in the formation of interpretive bias in addicted individuals. In fact, addiction-related cues not only form associations with cognitive responses but also become linked with the addict' s self, forming an addiction identity (Frings & Albery, 2015). For smokers, smoker identity refers to the degree to which an individual incorporates the identity of being a smoker into their self-concept, involving an understanding of the meaning of the smoker identity and recognition of what actions are required to be a smoker (Falomir et al., 2020). Currently, no empirical studies have examined the effect of smoker identity on smoking-related interpretive bias. However, numerous studies have demonstrated that smoker identity significantly influences smoking-related behaviors or behavioral intentions. For

instance, research has found that smokers with higher levels of smoker identity exhibit higher daily smoking frequency (Chen et al., 2022), more smoking behaviors in social situations (Kale et al., 2024), lower self-efficacy for refusing cigarettes (陈海德等, 2023), fewer quit attempts (Kale et al., 2024), and higher likelihood of relapse after quitting (Callaghan et al., 2021). Additionally, in non-smoking research domains, studies have shown that individuals' identification with a particular identity influences their cognitive processing biases (梁芳美等, 2022; Albery et al., 2022; Dunham & Emory, 2014; Hehman et al., 2010; Wang et al., 2017). For example, research has found that participants who more strongly identify as vegetarians are more likely to exhibit attentional bias toward healthy food-related cues (Albery et al., 2022).

Smoker identity may have a priming effect on interpretive bias. Schema Theory (Beck & Haigh, 2014) posits that individuals are more likely to selectively process information that is consistent with existing schemas in memory. When new information aligns with and connects to an individual' s existing schemas, it is more likely to receive further cognitive processing. For example, research has shown that compared to non-depressed individuals, individuals with depressive symptoms possess negative self-schemas, making negative items more likely to be recalled, recognized, or primed when understanding events or situations (冯正直等, 2008). When confronted with ambiguous information, specific schemas or sets of schemas become activated, influencing individuals' interpretations of ambiguous information. For smokers, smoking-related situations or cues often activate their identity with the smoking group (Chu et al., 2021), and this identity provides a schema for interpreting ambiguous information, leading smokers to be more likely to interpret ambiguous situations in ways consistent with their smoker identity. Additionally, researchers have proposed the self-relevant information processing advantage effect (杨红升等, 2012). Studies have found a self-reference effect, whereby material associated with the self receives optimal cognitive processing compared to conditions referencing others (辛聪等, 2025; 杨红升等, 2012). Research has also shown that avatar references in online games have greater memory processing advantages than references to others (曹敏等, 2021). For smokers, smoker identity, as a form of self-relevant information stored in memory, may also possess cognitive processing advantages. Accordingly, we propose **Hypothesis 2**: Smokers with high smoker identity exhibit significantly higher smoking-related interpretive bias than smokers with low smoker identity.

Does the effect of identity on cognitive bias in addicted individuals require the involvement of cognitive resources? This is a question worth exploring. The dual-process model of addiction proposes that the emergence of addictive behaviors involves both automatic and controlled processing (Salemink et al., 2019). Automatic processing is often driven by impulses, representing rapid associations triggered by drug-related stimuli that operate automatically without requiring cognitive resources. Controlled processing is determined by a reflective system, involving conscious reasoning based on weighing pros and cons that is characterized by controlled processing and requires cognitive resources. Hofmann et al. (2008) further proposed that the influence of impulsive and re-

flective systems on health behaviors is moderated by factors such as behavioral habit strength, ego depletion, and cognitive load, such that under conditions of strong behavioral habits, high ego depletion, or high cognitive load, health behaviors are more susceptible to the influence of the impulsive system (Hofmann et al., 2008). Lindgren et al. (2017) further constructed a dual-process model of addiction identity, proposing that smokers possess both implicit and explicit identities, both of which significantly influence smoking-related variables, with their processes sharing similar characteristics with automatic and controlled processing, respectively (Lindgren et al., 2017).

Manipulating cognitive load can test the role of cognitive resources in the process by which identity influences interpretive bias. Numerous studies have employed digit or letter memorization tasks to manipulate cognitive load, demonstrating that high cognitive load conditions impair performance on target tasks (Drichoutis & Nayga, 2020). Compared to low cognitive load conditions, the effect of smoker identity on smoking-related interpretive bias may be smaller under high cognitive load conditions. First, the activation of identity may require cognitive resources. Researchers have noted that identity is a self-regulatory control system in which individuals often use identity as a personal behavioral standard to compare with their actual behavior (Haslam et al., 2021). This comparison process may require cognitive resources to integrate information across multiple domains. Some studies have shown that the acquisition and processing of relatively complex social identity information is more likely to be affected by cognitive load (Roccas & Brewer, 2002). Lindgren et al. (2017) noted that the explicit component of addiction identity involves propositional reasoning and elaborative processing, requiring cognitive resources. Additionally, the generation of interpretive bias may also require cognitive resources. Unlike automated processes activated by stimulus-response associations, interpretive bias more closely resembles propositional processing (Sritharan & Gawronski, 2010). The processing of interpretive bias requires retrieving and extracting existing information stored in memory systems, as well as comparing, deducing, reasoning, and evaluating information—all processes that require cognitive resources. Accordingly, this study proposes **Hypothesis 3**: As cognitive load increases, the influence of smoker identity on smokers' smoking-related interpretive bias decreases.

This study aims to explore the characteristics and underlying mechanisms of smokers' smoking-related interpretive bias through three experiments. Study 1 compares differences in smoking-related interpretive bias between smokers and nonsmokers to examine the characteristics of smokers' interpretive bias. Study 2 employs the social identity salience paradigm to manipulate smoker identity and investigates the effect of smoker identity on smoking-related interpretive bias. Study 3 further uses a digit memorization task to manipulate cognitive load and examines the role of cognitive load in the process by which smoker identity influences smoking-related interpretive bias.

Study 1: Characteristics of Smoking-Related Interpretive Bias

Participants

Sample size was calculated using G*Power 3.1.9.7 software, with an effect size of 0.25, error probability of 0.05, and statistical power of 0.80, indicating a minimum required sample size of 34 participants. Participants were recruited through advertisements posted on online social platforms such as WeChat. A total of 40 smokers and 40 nonsmokers were recruited. Specific requirements for smokers were: (1) daily smoking with an average of at least 5 cigarettes per day; (2) no major physical or mental illnesses, and no history of other drug addictions. After all participants completed the experiment, 5 participants were excluded due to accuracy rates below 80% on scenario comprehension questions in the interpretive bias test, resulting in 75 valid participants. This included 36 smokers (all male) and 39 nonsmokers (38 male, 1 female), with mean ages of 23.61 years (SD = 2.72) and 23.59 years (SD = 2.67), respectively, with no significant difference between groups, $t(73) = 0.03$, $p = 0.973$. For smokers, the mean age of first smoking was 17.97 years (SD = 2.35), mean smoking duration was 5.62 years (SD = 2.60), mean daily cigarette consumption was 11.36 (SD = 7.64), mean nicotine dependence score was 3.08 (SD = 2.25), and mean smoking craving level was 3.71 (SD = 1.73).

Experimental Design

A 2 (participant type: smoker, nonsmoker) × 2 (target sentence type: smoking-related, smoking-unrelated) mixed experimental design was employed, with participant type as a between-subjects variable and target sentence type as a within-subjects variable. The dependent variable was interpretive bias.

Experimental Materials

(1) **Interpretive bias measurement tool**. Based on materials used in a series of alcohol-related interpretive bias studies by Woud et al. (2012, 2015, 2019), we developed 24 ambiguous scenarios related to smoking (each scenario included 2 target sentences). Thirty graduate students majoring in psychology were invited to rate the thematic relevance, interpretive fluency, and valence of the scenarios, and to provide modification suggestions. Nine ambiguous scenarios were finalized. Each scenario included two corresponding target sentences: one smoking-related target sentence and one smoking-unrelated target sentence. For example, the scenario: "You are pacing anxiously around the room. You are dissatisfied with your current situation, your work is piling up, and now you have lost your wallet. You want to forget all···" The two target sentences were: "You want to forget all your troubles, so you decide to smoke a cigarette" and "You want to forget all your troubles, so you decide to go for a run." Participants were asked to rate the degree to which the possible behavior described in each

target sentence fit the scenario described (1 = very unfitting, 4 = very fitting).

(2) **Nicotine Dependence Scale**. The Fagerström Test for Nicotine Dependence developed by Heatherton et al. (1991) was used. The scale includes 6 items (e.g., "In the past month, how many cigarettes did you smoke per day on average?"). After reverse scoring of certain items, total scores were calculated, with higher scores indicating greater nicotine dependence. The internal consistency coefficient Cronbach' s was 0.75 in this study.

(3) **Smoking Urges Scale**. The Brief Questionnaire of Smoking Urges developed by Cox et al. (2001) was used. The scale includes 10 items (e.g., "I really want to smoke a cigarette now") using a 7-point scale (1 = strongly disagree, 7 = strongly agree). Higher scores indicate stronger smoking urges. The internal consistency coefficient Cronbach' s was 0.95 in this study.

(4) **Self-designed demographic questionnaire**. The questionnaire included items on gender, age, history of brain organic disease and mental illness, and other substance addictions. Smokers also completed items on age of first smoking and daily cigarette consumption.

Procedure

The overall experimental procedure was as follows. First, on the day before the experiment, smokers were screened online and appointments were scheduled. To control for pre-experiment smoking cravings, participants were instructed not to smoke for 2 hours prior to the experiment (Huijding et al., 2005; Zhao & Chen, 2023). Second, before the experiment began, participants were informed of the specific experimental procedures and precautions. Third, participants were required to complete informed consent forms, demographic questionnaires, the Nicotine Dependence Scale, the Smoking Urges Scale, and other measures. Fourth, both smoker and nonsmoker groups completed the same interpretive bias test. Fifth, after the experiment, participants were compensated and thanked.

The interpretive bias testing procedure followed the methodology of Woud et al. (2015). During the test, participants completed 9 ambiguous scenario trials. The testing procedure for each ambiguous scenario is illustrated in Figure 1 [Figure 1: see original paper]. First, an ambiguous scenario was presented, with the final word of the descriptive sentence missing one character. Second, participants were required to fill in the missing character based on context. Third, feedback was provided: if the fill-in was correct, the complete word was displayed in green text; if incorrect, a red error message appeared prompting participants to fill in again. Fourth, after each scenario, a question assessing comprehension of the scenario' s meaning was presented, requiring participants to answer "correct" or "incorrect." Fifth, the ambiguous scenario and its two target sentences were presented again, and participants were asked to rate, based

on their understanding, the degree to which the possible behavior described in each target sentence fit the scenario.

Data Analysis and Statistical Methods

SPSS 26.0 was used for statistical analysis. First, participants with accuracy rates below 80% on the scenario fill-in task were excluded. Next, participants' ratings on the two types of target sentences (smoking-related and smoking-unrelated) across the 9 ambiguous scenarios were averaged to obtain each participant' s smoking-related interpretive bias score and smoking-unrelated interpretive bias score. Finally, repeated measures ANOVA was used to examine differences between the two groups on the two types of target sentences.

Results

The smoking-related and smoking-unrelated interpretive bias scores for Study 1 participants are shown in Figure 2 [Figure 2: see original paper]. Repeated measures ANOVA on participants' interpretive bias scores revealed a significant main effect of participant type, $F(1, 73) = 88.00$, $p < 0.001$, partial $^2 = 0.55$, with nonsmokers showing significantly lower interpretive bias than smokers. The main effect of target sentence type was also significant, $F(1, 73) = 58.15$, $p < 0.001$, partial $^2 = 0.44$, with participants' smoking-unrelated interpretive bias scores significantly higher than their smoking-related interpretive bias scores. The interaction between participant type and target sentence type was significant, $F(1, 73) = 133.61$, $p < 0.001$, partial $^2 = 0.65$.

Simple effects analysis showed that for smoking-related sentences, smokers' interpretive bias scores ($M = 3.01$, $SD = 0.32$) were significantly higher than those of nonsmokers ($M = 1.62$, $SD = 0.55$), $F(1, 73) = 175.85$, $p < 0.001$, partial $^2 = 0.71$. For smoking-unrelated sentences, smokers' interpretive bias scores ($M = 2.78$, $SD = 0.38$) did not differ significantly from those of nonsmokers ($M = 2.73$, $SD = 0.38$), $F(1, 73) = 0.31$, $p = 0.578$. Additionally, for smokers, interpretive bias scores for smoking-related sentences ($M = 3.01$, $SD = 0.32$) were significantly higher than for smoking-unrelated sentences ($M = 2.78$, $SD = 0.38$), $F(1, 73) = 7.44$, $p = 0.008$, partial $^2 = 0.09$. For nonsmokers, interpretive bias scores for smoking-related sentences ($M = 1.62$, $SD = 0.5$) were significantly lower than for smoking-unrelated sentences ($M = 2.73$, $SD = 0.38$), $F(1, 73) = 191.69$, $p < 0.001$, partial $^2 = 0.72$.

Figure 2. Smoking-related and smoking-unrelated interpretive bias in Study 1 participants
Note: $p < 0.05$, *** $p < 0.001$, the same below.*

Study 2: Effect of Smoker Identity on Interpretive Bias

Participants

Sample size was calculated using G*Power 3.1.9.7 software, with an effect size of 0.25, error probability of 0.05, and statistical power of 0.80, indicating a minimum required sample size of 34 participants. Participants were recruited through advertisements posted on online social platforms such as WeChat. A total of 66 participants were recruited. Requirements for smoker participants were the same as in Study 1. Participants were randomly assigned to either the high-smoker-identity group or the low-smoker-identity group. Four participants were excluded due to accuracy rates below 80% on scenario comprehension questions in the interpretive bias test, leaving 62 valid participants, including 49 males and 13 females. The high-smoker-identity group comprised 31 participants (26 males, 5 females), while the low-smoker-identity group comprised 31 participants (23 males, 8 females). The mean ages of the two groups were 20.84 years (SD = 2.34) and 21.32 years (SD = 1.85), respectively, with no significant difference, $t(60) = -0.91$, $p = 0.370$. Mean age of first smoking was 17.42 years (SD = 1.57) and 17.03 years (SD = 1.72), respectively, with no significant difference, $t(60) = 1.29$, $p = 0.201$. Mean smoking duration was 3.42 years (SD = 2.42) and 4.29 years (SD = 2.08), respectively, with no significant difference, $t(60) = -1.51$, $p = 0.135$. Mean daily cigarette consumption was 8.26 (SD = 3.37) and 8.71 (SD = 3.86), respectively, with no significant difference, $t(60) = -0.49$, $p = 0.625$. Mean nicotine dependence scores were 2.81 (SD = 1.70) and 3.45 (SD = 1.61), respectively, with no significant difference, $t(60) = -1.53$, $p = 0.130$. Mean smoking urge levels were 4.17 (SD = 1.19) and 4.52 (SD = 1.10), respectively, with no significant difference, $t(60) = -1.20$, $p = 0.237$.

Experimental Design

A 2 (smoker identity group: high, low) × 2 (target sentence type: smoking-related, smoking-unrelated) mixed experimental design was employed, with smoker identity as a between-subjects variable and target sentence type as a within-subjects variable. The dependent variable was interpretive bias.

Experimental Materials

(1) The interpretive bias measurement tool was the same as in Study 1.

(2) **Smoker identity manipulation materials**. The social identity salience paradigm (Haslam et al., 1999) was used to manipulate smoker identity. In the high-smoker-identity group, participants were asked to write down three things for each of the following four situations: "Three things that you and most of your smoking friends or important members of the smoking group often do," "Three things that you and most of your smoking friends or important members of the smoking group rarely do," "Three things that you and most of your smoking friends or important members of the smoking group do well,"and "Three things that you and most of your

smoking friends or important members of the smoking group do poorly." In the low-smoker-identity group, participants were asked to write down three things for each of the following four situations: "Three things that you yourself often do," "Three things that you yourself rarely do," "Three things that you yourself do well," and "Three things that you yourself do poorly."

(3) **Smoker Identity Scale**. The Smoker Self-Identity Scale developed by Moan and Rise (2005) was used. The scale includes 4 items (e.g., "I consider myself a smoker"). A 7-point scale was used (1 = completely disagree, 7 = completely agree). Higher scores indicate stronger identification with the smoker identity. The internal consistency coefficient Cronbach' s was 0.75 in this study.

(4) Nicotine dependence scale, smoking urges scale, demographic questionnaire, and other measurement tools were the same as in Study 1.

Procedure

The overall experimental procedure was as follows. First, participants were instructed not to smoke for 2 hours prior to the experiment. Second, after participants arrived at the laboratory, they were informed of the specific experimental procedures and precautions. Third, participants were required to complete informed consent forms, demographic questionnaires, the Nicotine Dependence Scale, the Smoking Urges Scale, and other measures. Fourth, participants were randomly assigned to either the high-smoker-identity group or the low-smoker-identity group to undergo the corresponding identity manipulation. Fifth, participants completed the smoker identity manipulation effectiveness check. Sixth, participants completed the interpretive bias test. Seventh, after the experiment, participants were compensated and thanked.

Data Analysis and Statistical Methods

Data processing methods were similar to those in Study 1, with the addition of one-sample t-tests and independent samples t-tests to examine the effectiveness of the smoker identity manipulation.

Results

Effectiveness of Identity Manipulation One-sample t-tests were conducted to examine differences between each group' s smoker identity level and the median value of 5.13. Results showed that the low-identity group' s smoker identity level ($M = 4.39$, $SD = 0.82$) was significantly lower than the median value of 5.13, $t(30) = -5.05$, $p < 0.001$. The high-identity group' s smoker identity level ($M = 6.13$, $SD = 0.44$) was significantly higher than the median value of 5.13, $t(30) = 12.72$, $p < 0.001$. An independent samples t-test examining differences in smoker identity levels between the two groups revealed that the high-identity group showed significantly higher smoker identity than

the low-identity group, t(60) = 10.45, p < 0.001, Cohen' s d = 2.65. This indicates that the smoker identity manipulation was effective.

Effect of Smoker Identity on Interpretive Bias The smoking-related and smoking-unrelated interpretive bias scores for Study 2 participants are shown in Figure 3 [Figure 3: see original paper]. Repeated measures ANOVA on participants' interpretive bias scores revealed a significant main effect of smoker identity, F(1, 60) = 10.00, p = 0.002, partial ^{2} = 0.14, with the low-identity group showing significantly lower interpretive bias scores than the high-identity group. The main effect of target sentence type was significant, F(1, 60) = 17.52, p < 0.001, partial ^{2} = 0.23, with participants showing significantly higher interpretive bias for smoking-related sentences than smoking-unrelated sentences. The interaction between identity and target sentence type was significant, F(1, 60) = 15.91, p < 0.001, partial ^{2} = 0.21.

Simple effects analysis showed that for smoking-related sentences, the high-identity group' s interpretive bias scores (M = 3.44, SD = 0.25) were significantly higher than those of the low-identity group (M = 2.88, SD = 0.49), F(1, 60) = 31.72, p < 0.001, partial ^{2} = 0.35. For smoking-unrelated sentences, the high-identity group' s interpretive bias scores (M = 2.84, SD = 0.53) did not differ significantly from those of the low-identity group (M = 2.86, SD = 0.44), F(1, 60) = 0.03, p = 0.862. Additionally, for the high-identity group, interpretive bias scores for smoking-related sentences (M = 3.44, SD = 0.25) were significantly higher than for smoking-unrelated sentences (M = 2.84, SD = 0.53), F(1, 60) = 33.41, p < 0.001, partial ^{2} = 0.36. For the low-identity group, interpretive bias scores for smoking-related sentences (M = 2.88, SD = 0.49) did not differ significantly from smoking-unrelated sentences (M = 2.86, SD = 0.44), F(1, 60) = 0.02, p = 0.890.

Figure 3. Smoking-related and smoking-unrelated interpretive bias in Study 2 participants

Study 3: Role of Cognitive Load

Participants

Sample size was calculated using G*Power 3.1.9.7 software, with an effect size of 0.25, error probability of 0.05, and statistical power of 0.80, indicating a minimum required sample size of 24 participants. Participants were recruited through advertisements posted on online social platforms such as WeChat. A total of 64 participants were recruited. Requirements for smoker participants were the same as in Study 1. Participants were randomly assigned to either the high-smoker-identity group or the low-smoker-identity group. Four participants were excluded due to accuracy rates below 80% on scenario comprehension questions in the interpretive bias test, leaving 60 valid participants, including 50 males and 10 females. The high-identity group comprised 30 participants (25 males, 5 females), and the low-identity group comprised 30 participants (25

males, 5 females). The mean ages of the two groups were 21.17 years (SD = 2.87) and 20.97 years (SD = 1.56), respectively, with no significant difference, t(58) = 0.34, p = 0.738. Mean age of first smoking was 17.20 years (SD = 1.75) and 16.93 years (SD = 2.00), respectively, with no significant difference, t(58) = 0.55, p = 0.585. Mean smoking duration was 3.97 years (SD = 3.27) and 4.03 years (SD = 2.09), respectively, with no significant difference, t(58) = -0.09, p = 0.925. Mean daily cigarette consumption was 8.10 (SD = 5.33) and 8.57 (SD = 4.58), respectively, with no significant difference, t(58) = -0.36, p = 0.717. Mean nicotine dependence scores were 3.83 (SD = 1.80) and 4.07 (SD = 1.23), respectively, with no significant difference, t(58) = -0.59, p = 0.560. Mean smoking urge levels were 4.72 (SD = 1.08) and 4.96 (SD = 0.57), respectively, with no significant difference, t(58) = -1.09, p = 0.283.

Experimental Design

A three-factor mixed experimental design of 2 (smoker identity group: high, low) × 2 (target sentence type: smoking-related, smoking-unrelated) × 2 (cognitive load: high, low) was employed, with smoker identity as a between-subjects variable and target sentence type and cognitive load level as within-subjects variables. The dependent variable was interpretive bias.

Experimental Materials

(1) The interpretive bias test instrument was the same as in Study 1.

(2) Smoker identity manipulation materials and the smoker identity scale were the same as in Study 2.

(3) **Cognitive load manipulation materials and effectiveness check materials**. The cognitive load manipulation tool from Drichoutis and Nayga (2020) was used, which involves memorizing random digits of different lengths. The high cognitive load manipulation material was a 7-digit random number, such as "1473268." The low cognitive load manipulation material was a 2-digit random number, such as "41." The questionnaire for checking the effectiveness of the cognitive load manipulation included three items: "How much mental effort did you invest in the digit memorization task? (1 = none at all, 7 = complete effort)," "I did not have enough mental capacity to carefully consider my decision (1 = completely disagree, 7 = completely agree)," and "The digit memorization task distracted me when making decisions (1 = completely disagree, 7 = completely agree)."

(4) Nicotine dependence scale, smoking urges scale, demographic questionnaire, and other measurement tools were the same as in Study 1.

Procedure

The overall experimental procedure was as follows. First, on the day before the experiment, daily smokers were screened online or by phone, and were instructed

not to smoke for 2 hours prior to the experiment. Second, after participants arrived at the laboratory, they were informed of the specific experimental procedures and precautions. Third, participants were required to complete informed consent forms, demographic questionnaires, the Nicotine Dependence Scale, the Smoking Urges Scale, and other measures. Fourth, participants were randomly assigned to either the high-smoker-identity or low-smoker-identity group to undergo the corresponding identity manipulation, and were required to complete the identity manipulation effectiveness check questionnaire. Fifth, cognitive load manipulation was administered, with a balanced design used to control for order effects of the two cognitive load conditions. Participants first received one cognitive load condition (high or low) and completed the cognitive load manipulation effectiveness check questionnaire. Sixth, participants completed the interpretive bias test. Seventh, participants received the other cognitive load condition (low or high) and completed the cognitive load manipulation effectiveness check questionnaire. Eighth, participants completed the interpretive bias test again. Ninth, after the experiment, participants were compensated and thanked.

Data Analysis and Statistical Methods

Data processing methods were similar to those in Study 2, with the addition of cognitive load manipulation effectiveness checks.

Results

Effectiveness of Smoker Identity Manipulation One-sample t-tests were conducted to examine differences between each group' s smoker identity level and the median value of 5.38. Results showed that the low-identity group' s smoker identity level ($M = 4.47$, $SD = 0.87$) was significantly lower than the median value of 5.38, $t(29) = -5.73$, $p < 0.001$. The high-identity group's smoker identity level ($M = 6.11$, $SD = 0.42$) was significantly higher than the median value of 5.38, $t(29) = 9.53$, $p < 0.001$. An independent samples t-test examining differences in smoker identity levels between the two groups revealed that the high-identity group showed significantly higher smoker identity than the low-identity group, $t(58) = 9.29$, $p < 0.001$, Cohen' s $d = 2.40$. This indicates that the smoker identity manipulation was effective.

Effectiveness of Cognitive Load Manipulation A paired samples t-test was conducted to examine differences in cognitive load levels between the two cognitive load conditions. Results showed that participants' scores under high cognitive load conditions ($M = 5.23$, $SD = 1.84$) were significantly higher than under low cognitive load conditions ($M = 3.21$, $SD = 1.00$), $t(59) = 19.03$, $p < 0.001$, Cohen' s $d = 1.64$. This indicates that the cognitive load manipulation was effective.

Effects of Smoker Identity and Cognitive Load on Interpretive Bias
The smoking-related and smoking-unrelated interpretive bias scores for Study 3 participants are shown in Figure 4 [Figure 4: see original paper]. Repeated measures ANOVA on participants' interpretive bias scores revealed a significant main effect of smoker identity, $F(1, 58) = 9.77$, $p = 0.003$, partial $^2 = 0.14$, with the low-identity group showing significantly lower interpretive bias than the high-identity group. The main effect of target sentence type was significant, $F(1, 58) = 29.4$, $p < 0.001$, partial $^2 = 0.34$, with participants showing significantly higher interpretive bias for smoking-related sentences than smoking-unrelated sentences. The main effect of cognitive load was not significant, $F(1, 58) = 2.80$, $p = 0.100$. The interaction between identity and target sentence type was significant, $F(1, 58) = 5.28$, $p = 0.025$, partial $^2 = 0.08$. The interaction between identity and cognitive load was significant, $F(1, 58) = 7.78$, $p = 0.007$, partial $^2 = 0.12$. The interaction between target sentence type and cognitive load was not significant, $F(1, 58) = 2.79$, $p = 0.100$. The three-way interaction was marginally significant, $F(1, 58) = 3.35$, $p = 0.073$, partial $^2 = 0.06$.

Simple effects analysis showed that for interpretive bias toward smoking-related sentences, under low cognitive load conditions, the high-identity group' s interpretive bias scores ($M = 3.55$, $SD = 0.36$) were significantly higher than those of the low-identity group ($M = 3.07$, $SD = 0.43$), $F(1, 58) = 21.27$, $p < 0.001$, partial $^2 = 0.27$. Under high cognitive load conditions, the high-identity group' s interpretive bias scores ($M = 3.44$, $SD = 0.39$) were significantly higher than those of the low-identity group ($M = 3.18$, $SD = 0.51$), $F(1, 58) = 4.97$, $p = 0.030$, partial $^2 = 0.08$, but the significance was reduced. For interpretive bias toward smoking-unrelated sentences, under low cognitive load conditions, the high-identity group' s interpretive bias scores ($M = 2.84$, $SD = 0.36$) did not differ significantly from those of the low-identity group ($M = 2.83$, $SD = 0.38$), $F(1, 58) = 0.04$, $p = 0.848$. Under high cognitive load conditions, the high-identity group' s interpretive bias scores ($M = 2.90$, $SD = 0.35$) did not differ significantly from those of the low-identity group ($M = 2.93$, $SD = 0.44$), $F(1, 58) = 0.06$, $p = 0.801$.

Figure 4. Smoking-related and smoking-unrelated interpretive bias in Study 3 participants

General Discussion

This study examined the characteristics of smokers' smoking-related interpretive bias, the influence of smoker identity on smoking-related interpretive bias, and the role of cognitive load in this process through three experiments. Study 1 results showed that smokers' smoking-related interpretive bias was significantly higher than that of nonsmokers. Study 2 results showed that smokers with high smoker identity exhibited significantly higher smoking-related interpretive bias than those with low smoker identity. Study 3 results showed that as cognitive load increased, the influence of smoker identity on smokers' smoking-related interpretive bias decreased.

Regarding the characteristics of smokers' interpretive bias, this study demonstrates that smokers exhibit interpretive bias toward smoking-related cues, supporting Hypothesis 1. Similar results have been found in other substance addiction domains, particularly in numerous studies showing that drinkers exhibit interpretive bias toward alcohol-related cues (Woud et al., 2012; Woud et al., 2015; Woud et al., 2019). For example, research has found that heavy drinkers are more likely than light drinkers to interpret alcohol-related ambiguous scenarios in alcohol-related ways (Woud et al., 2012). Possible reasons for smokers' smoking-related interpretive bias are as follows. First, the association between cues and automatic responses. According to the incentive sensitization theory of addiction (Robinson & Berridge, 1993) and the dual-process model (Salemink & Wiers, 2012), repeated exposure to smoking-related cues leads smokers to form automatic cue-response associations, which cause smokers to automatically generate smoking-related interpretive bias when encountering smoking-related stimuli or situations. Second, the impact of cues on cognitive functioning. According to the cognitive mechanisms of addiction model (Copersino, 2017), smoking-related cues or situations activate smokers' existing smoking-related implicit cognitions and weaken the metacognitive system and executive functions that monitor smoking behavior, leading to the emergence of cognitive bias. Third, the role of rationalization beliefs. According to the theory of smoking rationalization beliefs (陈海德等, 2024), smokers often perceive that smoking is harmful to health, which conflicts with their actual smoking behavior. This conflict creates discomfort, leading smokers to develop rationalization beliefs to reduce this discomfort. Rationalization beliefs may enhance or trigger smokers' smoking-related interpretive bias.

Regarding the factors that trigger smokers' smoking-related interpretive bias, this study shows that smoker identity can elicit smoking-related interpretive bias in smokers, supporting Hypothesis 2. Similar results have been found in other domains regarding the effect of identity on cognitive bias (Albery et al., 2022; Lakritz, 2023). For example, research has shown that individuals who identify as vegetarians exhibit increased attentional bias toward healthy food-related cues (Albery et al., 2022). Possible reasons why identity influences smoking-related interpretive bias are as follows. First, the salience of smoker identity activates the association between self and smoking. In fact, smokers have multiple identities (Lindgren et al., 2017), and when the smoker identity is made salient, the association between self and smoking is activated (Grigutsch et al., 2019). Due to the self-relevant information processing advantage effect (杨红升等, 2012), individuals may anchor their interpretation of ambiguous information within the framework of the self-smoking association. Second, smoker identity activates positive smoking attitudes and beliefs about smoking benefits. Because of long-term contact with cigarettes and pleasant experiences during smoking, smokers have formed positive evaluations and attitudes toward smoking (Poole et al., 2022). According to schema theory (Beck & Haigh, 2014), when deep processing of ambiguous situations is required, smokers are more inclined to selectively process information consistent with existing smoking-related schemas in mem-

ory. Identity salience activates these evaluations and attitudes, providing a content basis for smokers' interpretation of ambiguous information. Third, smoker identity activates smoking action schemas. Smoking action schemas include processes related to smoking behavior, such as the actions from lighting to smoking a cigarette (Motschman & Tiffany, 2016). Smoking actions are signature behaviors of smokers. The salience of smoker identity may activate smoking action schemas. According to schema theory (Beck & Haigh, 2014), activated smoking action schemas or sets of schemas may combine with individuals' current ambiguous information, providing a content basis for smoking-related interpretive bias.

Regarding the role of cognitive load in the effect of smoker identity on smoking-related interpretive bias, this study shows that the influence of smoker identity on smokers' smoking-related interpretive bias decreases as cognitive load increases, supporting Hypothesis 3. This result indicates that sufficient cognitive resources enhance the effect of smoker identity on smoking-related interpretive bias. Possible reasons for this effect are as follows. First, the processing of information generated by identity activation may require cognitive resources. Identity provides relevant information for interpretive bias, which may be processed in different ways. According to the dual-process model (Hofmann et al., 2008; Lindgren et al., 2017; Salemink et al., 2019), processing modes include both automatic and controlled processing. Under high cognitive load conditions, smokers' automatic processing of smoking-related information is activated; under low cognitive load conditions, sufficient cognitive resources enable controlled processing of smoking-related information. Second, processing the information required for interpretive bias demands cognitive resources. The activation of smoker identity brings information related to smoking identity, smoking pros and cons, smoking actions, and other aspects to interpretive bias. According to the cognitive mechanisms of addiction model (Copersino, 2017), sufficient cognitive resources help smokers fully process this information. In particular, smokers need to effectively extract, encode, compare, organize, sort, filter, and evaluate relevant information—all processes that require cognitive resources. Third, effective interpretive bias requires inhibition of interference from other irrelevant information. According to the cognitive mechanisms of addiction model (Copersino, 2017), interpretive bias may be subject to interference from irrelevant information, and inhibiting this interference requires cognitive resources. For smokers, in addition to their smoker identity, information related to other identities (e.g., professional identity) is also stored in long-term memory and can interfere with smoking-related interpretive bias, and inhibiting this information requires cognitive resources.

This study makes several theoretical contributions. First, by examining the characteristics of smokers' smoking-related interpretive bias, this study expands understanding of the components of smokers' cognitive bias and broadens the explanatory scope of incentive sensitization theory, the dual-process model, and the cognitive mechanisms model of addiction. Second, this study demonstrates the facilitative effect of smoker identity on smoking-related interpretive bias, en-

riching research on factors influencing smokers' smoking-related interpretive bias and supplementing previous theories that emphasize the role of cue-response associations in influencing cognitive bias (e.g., incentive sensitization theory of addiction). This provides a new perspective for understanding the mechanisms underlying interpretive bias in addicts from a social-cognitive orientation. Third, this study reveals the role of cognitive resources in the effect of smoker identity on smoking-related interpretive bias, enriching empirical research on how identity influences smoking-related responses, revealing potential conditions under which identity influences interpretive bias, supplementing previous theories explaining identity mechanisms (e.g., schema theory), and providing a basis for explaining the mechanisms by which identity influences interpretive bias based on the dual-process model.

This study offers insights for reducing national smoking rates and helping smokers decrease their smoking behavior in China. First, for government authorities, it is necessary to continue strictly implementing smoke-free policies and substantially increase smoke-free situations. This both promotes smokers' reconstruction of interpretations of smoking-related situations and increases situations that elicit nonsmoker identity, thereby reducing smokers' smoking-related interpretive bias. Second, for media communication, on the one hand, smoking-related scenes in film and television productions should be strictly prohibited; on the other hand, advertisements promoting reinterpretation of smoking-related situations should be increased, helping smokers understand that common situations can be interpreted through multiple perspectives rather than just smoking (for example, for stress situations, stress can be relieved through deep breathing, exercise, venting, and other methods besides smoking). Third, for clinical practitioners in smoking interventions, when helping smokers quit, it is important to focus on correcting their smoking-related interpretive bias. During correction, it is necessary to guide smokers' "smoker identity" to transform into "quitter identity" or "nonsmoker identity." Simultaneously, smokers should be guided to allocate more cognitive resources to problem-solving when encountering difficulties, rather than to smoking-related content, thereby preventing the activation of smoking-related interpretive bias by smoker identity. Fourth, for smokers themselves, it is necessary to increase interactions with nonsmokers or successful quitters, thereby reducing smoker identity and learning to view situations considered closely related to smoking from multiple perspectives, ultimately reducing smoking-related interpretive bias.

This study has several limitations. First, all participants were young smokers. Compared to middle-aged and older smokers, young smokers have relatively shorter smoking histories and lower levels of nicotine dependence. Future research could compare smoking-related interpretive bias characteristics across smokers with different smoking durations. Second, this study employed behavioral experiments. Future research could combine cognitive neuroscience techniques to explore the neural mechanisms underlying the effects of smoker identity and cognitive load on smoking-related interpretive bias. Third, in laboratory settings, smokers know they are in an experiment and may anticipate

the appearance of cues, which can affect experimental validity. Future research could use ecological momentary assessment methods with higher ecological validity to study the effect of identity on interpretive bias. Fourth, smoking-related interpretive bias does not necessarily translate into actual smoking behavior. The process by which cognitive bias influences actual behavior may be affected by numerous factors. Future research could further explore the specific psychological processes through which smoking-related interpretive bias translates into smoking behavior.

In summary, this study demonstrates that smokers exhibit interpretive bias toward smoking-related cues, that smoker identity has a facilitative effect on smokers'smoking-related interpretive bias, and that sufficient cognitive resources promote the facilitative effect of smoker identity on smokers' smoking-related interpretive bias.

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English Abstract

Cognitive biases have been widely recognized as significant impediments to successful smoking cessation. Although a growing body of studies has examined attentional biases in smokers, potential interpretive biases towards smoking-related cues remain underexplored.

According to the incentive sensitization theory of addiction, the dual-process model, and the cognitive mechanisms of addiction, cognitive bias towards drugs originates from associations between addiction-related cues and associated cognitive responses. On the basis of schema theory and the self-reference effect, a smoker identity, which refers to an association between smoking and self-concept, may act as a trigger interpretive bias towards smoke-related cues.

Additionally, remains unclear whether cognitive load modulates formation of smoking-related interpretive bias. Given these issues, the present study aimed to explore the characteristics of smoking-related interpretive bias and to examine the roles of a smoker identity and cognitive load on this bias.

The present study included three experiments. Experiment 1 compared discrepancies in interpretive bias between smokers and nonsmokers. Interpretive bias was measured with open-ended scenarios that contained smoking-related and

neutral target sentences. Thirty-six smokers and thirty-nine nonsmokers were recruited and completed the experimental task.

Experiment 2 examined the effect of a smoker identity on smoking-related interpretive bias. Sixty-two smokers were recruited and were randomly assigned to either the high-smoker-identity group or the low-smoker-identity group. A smoker identity was manipulated by the social identity salience paradigm. Experiment 3 examined the role of cognitive load in the process by which a smoker identity influences smoking-related interpretive bias. Sixty smokers were recruited and were randomly assigned to two groups according to their degree of smoker identity. Cognitive load was manipulated by a digit memorization task.

Experiment 1 revealed that the score for smoking-related interpretive bias in smokers was significantly greater than the score for nonsmokers. Experiment 2 revealed that the score for smoking-related interpretive bias in smokers with a higher smoker identity was significantly greater than the score for smokers with a lower smoker identity. Experiment 3 revealed that the interactive effect of smoker identity and cognitive load on interpretive bias was marginally significant. Simple effects analyses revealed that the impact of smoker identity on smoking-related interpretive bias under the low cognitive load condition was stronger than the impact under the high cognitive load condition.

The present study demonstrates notable theoretical relevance and practical implications. First, the findings concerning the characteristics of smoking-related interpretive bias expand understanding of the components of smokers' cognitive bias. Second, the findings concerning the role of smoker identity in smoking-related interpretive bias provide a novel perspective for understanding the psychosocial mechanisms of this bias. Finally, the findings of the effect of cognitive load on smoking-related interpretive bias suggest the potential pathways and conditions of cognitive resources should be considered to understand the process of smoking-related interpretive bias. The results enrich the theoretical framework of a cognitive perspective on smoking-related research and provide insight on the promotion of tobacco control in China.

Keywords: smoker; interpretive bias; smoker identity; cognitive load

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Sample Materials

Target Sentences: Materials for Measuring Smoking-Related Interpretive Bias

Overwhelmed by Work
Your supervisor has assigned you to submit a project proposal tonight, yet you currently have no idea where to begin. You want to temporarily forget this tedious work, and the impulse to escape reality···(impulse_) keeps surfacing in your mind.

- Smoking-related target: The impulse to escape reality keeps surfacing, and smoking a cigarette can bring you momentary relief.
- Smoking-unrelated target: The impulse to escape reality keeps surfacing, and breathing fresh air outdoors can help you relax for a moment.
- Comprehension question: Your supervisor requires you to submit the project proposal tonight.
  Correct

When Feeling Down
You are pacing anxiously around the room. You are dissatisfied with your current situation, your work is piling up, and now you have lost your wallet. You just want to forget all···(trou___)

- Smoking-related target: You want to forget all your troubles, so you decide to smoke a cigarette.
- Smoking-unrelated target: You want to forget all your troubles, so you decide to go for a run.
- Comprehension question: You are very satisfied with your current situation.
  Incorrect

On Days of Continuous Rain
During days of continuous rain, your mood is as gloomy as the weather. Faced with life' s disappointments, you seem unable to find good solutions. Watching the rain fall on the window, your mood is very···(low___)

- Smoking-related target: Your mood is very low, and you plan to smoke a cigarette to temporarily escape anxiety and pain.
- Smoking-unrelated target: Your mood is very low, and you want to play some uplifting music to feel better.
- Comprehension question: The weather is not good today.
  Correct

Supervisor Takes You to an Important Dinner
Your supervisor takes you to an important business dinner, and you sit next to the client, trying to maintain a smile and communicate. At this moment, the client pats your shoulder and hands you something, making you feel···(press___)

- Smoking-related target: You feel pressured and accept the cigarette offered by the client.
- Smoking-unrelated target: You feel pressured and accept the chopsticks offered by the client.
- Comprehension question: You are sitting next to the client.
  Correct

At a Family Gathering
At a family gathering, your uncles are chatting on the balcony. When you walk over, they use various reasons to persuade you to join their group and hand you what they have in their hands, making you feel somewhat···(uncomf___)

- Smoking-related target: You feel somewhat uncomfortable, so you accept the invitation to smoke together.
- Smoking-unrelated target: You feel somewhat uncomfortable, so you accept the wine glass they hand you.
- Comprehension question: You are attending a company gathering.
  Incorrect

Disagreement with Mom
Last night after work, you returned home and immediately sensed a tense atmosphere in the house. Both you and your mom have furrowed brows because a small matter triggered···(arg___)

- Smoking-related target: Because a small matter triggered an argument, she thinks you smoke too much.
- Smoking-unrelated target: Because a small matter triggered an argument, she thinks you spend money too freely.
- Comprehension question: You had an argument with your dad.
  Incorrect

Conflict with Team Member
Recently, you had some conflicts with a member of your team. During today' s meeting, he directly denied the idea you proposed, and his attitude made you angry. You couldn' t help but···(arg___) with him.

- Smoking-related target: You couldn' t help but argue with him, and afterward you smoked a cigarette to calm down.
- Smoking-unrelated target: You couldn' t help but argue with him, and afterward you found someone else to talk to.
- Comprehension question: You argued with several supervisors.
  Incorrect

After High-Intensity Work
After working overtime all night, you return home and collapse on the sofa. The prolonged sitting and high-intensity work make your limbs feel sore. You realize you need to take some measures to relieve your body' s···(fatig___)

- Smoking-related target: You realize you need to take some measures to relieve your body' s fatigue, and you plan to smoke a cigarette to relax.
- Smoking-unrelated target: You realize you need to take some measures to relieve your body' s fatigue, and you plan to listen to music to relax.
- Comprehension question: After working overtime, you feel some physical discomfort.
  Correct

In the Cold Winter
On a cold winter day, you have symptoms of coughing and nasal congestion. You want to ignore the physical pain and continue with your daily work. So, you start looking for a way to relieve your body' s···(discomf___)

- Smoking-related target: You start looking for a way to relieve your body'

s discomfort, and smoking a cigarette can help you temporarily forget the trouble of coughing and nasal congestion.
- Smoking-unrelated target: You start looking for a way to relieve your body' s discomfort, and drinking more hot water can help you get rid of coughing and nasal congestion sooner.
- Comprehension question: Air conditioning cold air made you catch a cold. **Incorrect**

Note: Figure translations are in progress. See original paper for figures.