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Selective attention to smoking cues in former smokers

Anne K. Rehme[a,b,*], Katharina Bey[a,c], Ingo Frommann[f], Karin Mogg[d], Brendan P. Bradley[d], Julia Bludau[a], Verena Block[a], Birgitta Sträter[a], Christian G. Schütz[e], Michael Wagner[a,c,f]

[a]*Department of Psychiatry and Psychotherapy, University of Bonn, Bonn, Germany*
[b]*Department of Neurology, University of Cologne, Kerpener Str. 62, 50937 Cologne, Germany*
[c]*German Center for Neurodegenerative Diseases (DZNE), Bonn, Germany*
[d]*School of Psychology, University of Southampton, Southampton, United Kingdom*
[e]*Department of Psychiatry, University of British Columbia, Vancouver, Canada*
[f]*Department for Neurodegenerative Diseases and Geriatric Psychiatry, University Hospital Bonn, Bonn, Germany*

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Abstract
Repeated drug use modifies the emotional and cognitive processing of drug-associated cues. These changes are supposed to persist even after prolonged abstinence. Several studies demonstrated that smoking cues selectively attract the attention of smokers, but empirical evidence for such an attentional bias among successful quitters is inconclusive. Here, we investigated whether attentional biases persist after smoking cessation. Thirty-eight former smokers, 34 current smokers, and 29 non-smokers participated in a single experimental session. We used three measures of attentional bias for smoking stimuli: A visual probe task with short (500 ms) and long (2000 ms) picture stimulus durations, and a modified Stroop task with smoking-related and neutral words. Former smokers and current smokers, as compared to non-smokers, showed an attentional bias in visual orienting to smoking pictures in the 500 ms condition of the visual probe task. The Stroop interference index of smoking words was negatively related to nicotine dependence in current smokers. Former smokers and mildly dependent smokers, as compared to non-smokers, showed increased interference by smoking words in the Stroop task. Neither current nor former smokers showed an attentional bias in maintained attention (2000 ms visual probe task). In conclusion, even after prolonged abstinence smoking cues retain incentive salience in former smokers, who differed from non-smokers on two attentional bias indices. Attentional biases in former smokers operate mainly

*Corresponding author at: Department of Neurology, University of Cologne, Kerpener Str. 62, 50937 Cologne, Germany.
E-mail address: anne.rehme@uk-koeln.de (A.K. Rehme).

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in early involuntary rather than in controlled processing, and may represent a vulnerability factor for relapse. Therefore, smoking cessation programs should strengthen self-control abilities to prevent relapses.

1. Introduction

In drug addicts, drug-associated stimuli elicit conditioned responses on psychological, physiological, and behavioural levels (Carter and Tiffany, 1999; Drummond, 2001). This cue-reactivity may play an important role in the maintenance of drug use and in relapse. According to the incentive sensitization theory of addiction (Robinson and Berridge, 1993), repeated drug consumption sensitizes mesolimbic dopaminergic pathways. This neural sensitization assigns incentive salience to formerly neutral cues, which are then supposed to trigger craving and approach behaviour, as well as to capture attentional resources. The latter effect is also known as selective attention or attentional bias for drug-associated cues. Robinson and Berridge (1993) suggest that incentive sensitization entails permanent neuroadaptations, which persist even after prolonged abstinence. These long-lasting neuroadaptations are supposed to render addicts hypersensitive to drugs and to drug-related stimuli, even after years of abstinence.

Attentional biases are assumed to be mediated by several processes. One aspect involves the suppression of involuntary processing of task-irrelevant drug cues. This is commonly assessed using the modified Stroop task, which requires participants to name the colour of words with either a neutral or drug-related content. Selective processing of drug-related information impairs performance and slows down reaction times for naming the colour of drug-associated words relative to naming the colour of neutral words. This colour-naming interference effect indicates *involuntary processing of drug cues* (Field et al., 2009). Another aspect of attentional biases involves visual orienting towards the spatial location of drug cues, which is commonly assessed using the visual probe task. On each trial of this task, two pictures with either drug-specific or matched neutral content are presented simultaneously. One of these pictures is subsequently replaced by a target cue ("probe") to which the participant has to respond to as quickly as possible. As people generally respond faster to probes which appear in attended than unattended locations (Posner et al., 1980), an attentional bias for drug cues is inferred from faster reaction times to probes that follow drug-associated pictures as compared to neutral pictures. Furthermore, varying the picture stimulus duration allows the assessment of different attentional processes. Short durations of up to 500 ms have been widely used to measure *initial visual orienting*, as there is evidence from eye-tracking studies that the bias at 500 ms reflects the direction of the initial shift in gaze. For example, Bradley et al. (2000) report that subjects who made frequent eye movements to the presented picture stimuli showed concordance between reaction times and eye movement bias measures, leading the authors to the conclusion that the reaction time measure of attentional bias at 500 ms provides a valid index of the direction of initial visual orienting. Longer presentations of 2000 ms are assumed to assess *voluntary maintenance of attention*, with evidence that biases observed at 2000 ms relate to prolonged dwelling of gaze (Mogg, et al., 2003; Robbins and Ehrman, 2004). Presentation times of 500 ms and 2000 ms have been used most frequently in the investigation of attentional biases in smokers, and thus allow for substantiated comparison across studies (e.g., Bradley et al., 2003; Ehrman et al., 2000).

A number of studies provided evidence for an attentional bias towards smoking-related cues in smokers in the Stroop task (Drobes et al., 2006; Gross et al., 1993; Munafo et al., 2003; Waters et al., 2009) and in the visual probe task (Bradley et al., 2004; Ehrman et al., 2002; Mogg et al., 2003; Yan et al., 2009). However, smokers as an overall group have not always differed from non-smoking controls, with attentional biases sometimes being observed only in subgroups of smokers, such as light smokers or those with low levels of nicotine dependence (Bradley et al., 2003; Hogarth et al., 2003; Mogg et al., 2005; Waters et al., 2003a, 2003b). Furthermore, some studies found that short-term abstinence is associated with an enhanced attentional bias for smoking stimuli (Gross et al., 1993; Waters and Feyerabend, 2000) but others did not (Field et al., 2004; Mogg and Bradley, 2002; Munafo et al., 2003).

To date, only a few studies have examined the effect of long-term abstinence on attentional biases for smoking cues. Ehrman et al. (2002) reported that former smokers displayed an intermediate level of attentional bias in a 500 ms visual probe task as compared to current smokers and non-smokers. However, differences in bias scores between former smokers and neither of the other groups were statistically significant. Another study (Munafo et al., 2003) also did not find a significant difference in Stroop interference effect of smoking-related words between former smokers and non-smokers. Still, more recent research provides evidence for an attentional bias in a subset of former smokers with specific genetic characteristics (Munafo and Johnstone, 2008). Overall, the available evidence for a persistent attentional bias in ex-smokers is limited and mixed.

Cognitive processes underlying successful long-term abstinence in former smokers are important for the implementation of smoking cessation therapies. Hence, our primary aim was to investigate how successful abstinence is associated with an attentional bias for smoking cues. We examined three groups with different smoking experiences (i.e., former smokers, current smokers, and non-smokers) using three measures of attentional bias for smoking cues, which are related to different attentional processes:

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