Startle cue–reactivity differentiates between light and heavy smokers

Anne K. Rehme1,2, Ingo Frommann1, Sandra Peters1, Verena Block1, Julia Bludau1, Boris B. Quednow1,3, Wolfgang Maier1, Christian Schütz1 & Michael Wagner1

Department of Psychiatry, University of Bonn, Bonn, Germany,1 Max Planck Institute for Neurological Research, Cologne, Germany2 and University Hospital of Psychiatry, Division of Neuropsychopharmacology and Brain Imaging, University of Zurich, Zurich, Switzerland3

ABSTRACT

Aims It was assumed that the startle amplitude in smokers is reduced while viewing pictures of smoking, suggesting that smoking cues are appetitive. The goal of the present study was to investigate (i) whether smoking scenes induce appetitive cue effects in smokers, and (ii) whether smoking intensity is related to cue–reactivity. Design Smokers and non-smokers participated in a single session. Participants A total of 62 individuals participated: 36 smokers and 26 non-smokers. Measurements Participants took part in an acoustic affective startle experiment using standardized pleasant, neutral and unpleasant scenes from the International Affective Picture System (IAPS), as well as pictures of smoking. The effect of smoking cues was assessed by comparing neutral and smoking scenes (termed cue-related startle suppression, CSS). Findings While there was no overall difference between smokers and non-smokers regarding the CSS, light smokers showed significantly increased cue–reactivity towards smoking-related cues, as compared with heavy smokers and non-smokers. In addition, light smokers also displayed stronger appetitive responses towards positive stimuli. Conclusions These data support recent theories which discriminate between habit-based and incentive-based drug abuse. This distinction may have consequences for the assessment and treatment of drug-addicted subjects. Furthermore, incentive-based light smoking seems to have general effects on the reward system.

Keywords Affective startle response, cue–reactivity, smoking, smoking intensity, startle reflex.

INTRODUCTION

Conditioned responses towards drug-associated stimuli and consumption habits play an important role in explaining the motivation for drug intake and the occurrence of relapses [1,2]. Classical conditioning theories of cue–reactivity differ with regard to the nature of those drug-associated stimuli. On one hand, cues are supposed to elicit aversive withdrawal-like responses [3], which may resemble homeostatic compensatory responses to drug effects [4–6]. On the other hand, cues may serve as appetitive cues or even incentives leading to similar behavioural and neurological responses like the drug itself [7–9]. The incentive sensitization theory [1,10], which outreaches the scope of classical conditioning models, proposes that repeated drug consumption increases the motivational salience of drug-associated cues via a sensitization of mesolimbic dopamine pathways, especially its projections into the nucleus accumbens. This sensitization turns drug-associated stimuli into powerful incentives, which produce compulsive drug-taking behaviour on a psychological level (i.e. wanting or craving). The authors further assume that as addiction proceeds, hedonic effects of drug consumption (i.e. liking) decrease, whereas wanting of the drug increases.

There are several well-established indirect measures of cue–reactivity that do not rely on self-report [1,11]. For example, the attentional bias towards smoking-related relative to neutral cues has been studied as an indirect index of cue–reactivity by means of the visual dot probe...
task or the Stroop Test (e.g. [12–15]). Several neuroimaging experiments also found stronger activations in the ventral striatum or in other parts of the mesolimbic network during the processing of smoking pictures in contrast to neutral pictures (e.g. [16,17]). Another well-known method to uncover the indirect quality of drug-associated cues is the affective modulation of the startle reflex [18]. The acoustic startle reflex is a fast defensive response to a sudden and loud burst of sound and consists of a contraction of the skeletal and facial musculature. The accompanying eye blink reflex has emerged as the most reliable measure for human startle responses. This reflex is modulated by the affective value of a foreground stimulus. Compared to neutral pictures, the reflex is inhibited when an individual views pleasant pictures and is potentiated when an individual views unpleasant pictures [19,20]. By including pictures depicting drug paraphernalia or drug intake rituals, the affect-modulated startle methodology has been applied repeatedly in drug research [21–28]. Two studies of smokers confirm incentive theories of drug addiction showing that smoking cues suppress the startle amplitude relative to neutral stimuli [27,28]. Others did not find such a smoking cue-related startle suppression (CSS) [21,26], although smoking-related stimuli produced lower startle amplitudes than negative stimuli. However, so far a direct comparison of smoking cue-related startle responses of active smokers and non-smokers is lacking.

Recently, the contribution of individual factors, such as smoking deprivation and the intention to quit, received some attention in affective startle research [21,28]. However, the relationship between the severity of addiction and the magnitude of CSS is still unclear. Recent studies suggest that an indirect index of reactivity to smoking cues might be lower in individuals who smoke more cigarettes per day (CPD) [12–14]. These studies tested the attentional bias towards smoking-related pictures compared to neutral pictures using a visual dot probe task, and the behavioural approach towards those cues using a stimulus–response compatibility task. This inverse correlation would be consistent with theories of habit responding (e.g. [29,30]), which assume that the effect of incentive processes on behaviour declines during the progress of addiction.

First, we hypothesized that smokers have a greater CSS index, compared to non-smokers, because smoking cues produce appetitive effects in smokers but not in non-smokers. Secondly, because other bias measures have been shown to be correlated negatively with the number of CPD, we hypothesized a negative relationship between the CSS index and this measure of smoking intensity within active smokers. This means that light smokers are supposed to show stronger cue–reactivity compared to heavy smokers. As well as these two hypotheses, we tested whether smokers show stronger startle suppression during pleasant relative to neutral scenes, because smoking may lead to general changes in the processing of natural rewards [31,32].

**METHODS**

**Subjects**

The investigation was carried out with a group of 36 active smokers (18 women) and a group of 26 non-smokers (16 women) (total 62 participants) who were matched with respect to age, education and gender distribution. Active smokers were either current participants in a clinical smoking cessation programme and were tested before their final quit day (quitters, n = 27, 6–55 CPD) or recruits who had responded to an advertisement (sustainers, n = 9, at least 15 CPD) and did not wish explicitly to achieve abstinence. Non-smokers were defined as people who did not smoke more than 100 cigarettes during their life-time. The present study was approved by the local ethics committee of the Medical Faculty of the University of Bonn and is in accordance with the Declaration of Helsinki. After providing informed written consent, all subjects were screened for psychiatric disorders. They received €20 for their participation.

**Stimulus material and presentation**

The testing material consisted of 56 colour slides, presented with a 12-inch monitor notebook and a screen resolution of 600 × 800 pixels at 1 m in front of the participant. Sixteen pictures, which were taken from previous studies [21,33], depicted either the beginning or the end of smoking a cigarette. Control pictures were taken from the International Affective Picture System (IAPS) [34] and depicted eight unpleasant (9410, 3000, 3010, 3102, 3170, 3150, 3530, 6230), eight neutral (5534, 6150, 7002, 7030, 7050, 7190, 7002, 78203), eight pleasant (8030, 8080, 8380, 8370, 4180/4490, 4290/4510, 4660, 2840) objects or scenes. Pleasant pictures displayed mainly sportive events and erotic scenes. Unpleasant stimuli consisted of pictures depicting violence and injuries. Furthermore, the set contained 16 pictures showing alcohol-related scenes in order to compare, in a separate study, smokers with alcohol addicts. Responses to alcohol stimuli have not been analysed here. A 2 × 4 (group × stimulus) repeated-measures analysis of variance (ANOVA) for preliminary ratings of the stimulus material by 16 smokers and 15 non-smokers showed that all IAPS pictures were rated according to their assumed valence ($F_{1,187} = 144.077, P < 0.001$) and arousal ($F_{1,187} = 67.147, P < 0.001$) [34]. Both groups rated smoking scenes as more arousing.
than neutral scenes, and as less arousing than positive or negative scenes, but smokers judged smoking scenes as more positive than the non-smokers \((F_{1,87} = 5.585, P = 0.001)\).

After a 4-minute acclimatization period of 70-dB background white noise, pictures were presented for 7–8 seconds in a fixed-randomized order. Interstimulus intervals (black screen) lasted from 16.5 to 25.5 seconds. An acoustic startle response was evoked during 75% of the pictures from one category by 40-ms burst of 116-dB white noise presented binaurally through headphones (Maico, TDH-39-P) 2.5, 4.0 or 5.5 seconds after picture onset. The order of picture type and startle onset (no startle, 2.5 seconds, 4.0 seconds or 5.5 seconds after picture onset) were counterbalanced for the first and the second half of the experiment. Consecutive stimuli were not from the same picture type.

**Experimental procedures**

The active smokers arrived at the laboratory having not smoked for 4–6 hours. They were tested for their exhaled alveolar carbon monoxide [parts per million (p.p.m.)/CO]-level (Smokerlyzer Micro IV, Bedfont Instruments, Kent, UK). Next, smokers were questioned about their smoking history and daily cigarette consumption. They were asked about their current desire to smoke a cigarette on a percent scale and to complete the Fagerström Test for Nicotine Dependence (FTND) [35]. The startle experiment was carried out in a darkened room. Participants were instructed to look at the pictures and to ignore any noises from the headphones. Immediately after the startle experiment, all participants rated the valence of every picture on a 100-mm visual analogue scale (i.e. ‘How pleasant is this picture?’: 0 = very unpleasant, 100 = very pleasant) [21, 33]. Active smokers also rated the degree of craving induced by the pictures (i.e. ‘How much desire does this picture evoke?’: 0 = no desire, 100 = strong desire to smoke). Only ratings for trials where a startle tone was presented were included in the statistical analysis. At the end of the session, smokers were asked again to rate their momentary desire to smoke on a percent scale.

**Data recording**

The startle response was recorded digitally (EMG-SR-Laboratory, San Diego Instruments, Inc., San Diego, CA, USA) as electromyographic (EMG) activity from the right orbicularis oculi muscle using two silver/silver chloride electrodes and a ground electrode placed on the glabella. All electrode resistances were less than 10 kΩ. Recorded EMG activity was bandpass filtered (1–1000 Hz). A 50-Hz notch filter was applied to eliminate 50-Hz interference. The EMG activity was recorded from the onset of the acoustic startle stimulus for 250 ms, with a sampling rate of 1 ms.

**Data reduction**

Spontaneous eye blinks were excluded from further analysis, using the registration parameters described by Braff et al. [36]. The latency to startle response onset was defined by a shift of 2.28 μV (6 digital units) from the baseline value in a time window of 21–120 ms after the acoustic startle stimulus. Response rejections were made in both in the case of onset-to-peak latencies >95 ms and baseline shifts >34.2 μV (>90 digital units). Additionally, startle responses were discarded if the amplitude was more than 3 standard deviations above the individual mean or if the amplitude was less than 25 digital units. The subject was excluded from the study if there were less than two values per picture category after application of these criteria. In summary, six subjects had to be excluded. In the final sample, a total number of 117 trials were rejected because of baseline shifts and latencies >95 ms (64 trials) or because of outliers (53 trials). Because the amplitude of the startle response underlies a habituation effect over trials [37], and the decline of startle magnitude was stronger for smoking-related scenes than for the IAPS pictures, we computed separate regression analyses for emotional and smoking-related trials to correct our data against this effect. For both trial types, the habituation was best described by a linear trend. Consequently, the raw data for every subject in the different trials were corrected for the habituation of the startle response. Finally, the available responses for the different picture categories were averaged to obtain the actual score.

**Data analysis**

Because the raw blink magnitude showed strong variations across subjects, individual startle amplitudes were standardized according to the individual mean and standard deviation of the startle amplitudes of pleasant, neutral and unpleasant scenes. Startle reactions towards pictures depicting the start and the end of smoking did not differ substantially from each other; therefore, they were subsequently analysed together.

In general, data were evaluated parametrically using Statistical Product and Service Solutions (SPSS) version 12. First, we calculated a one-way ANOVA across the whole sample with the three IAPS picture categories as a within-subject variable in order to prove the validity of the startle paradigm, as has been shown previously by Lang et al. [20]. As usual in cue–reactivity research [12–17], further analyses were based on the CSS index. Therefore, we subtracted standardized amplitudes during
smoking-related trials from neutral trials. In advance, we analysed whether there were any differences in the CSS index of smokers planning to quit smoking soon (quitters) and smokers who did not try to reach abstinence (sustainers) [28]. Then, we tested the overall difference between the smokers and non-smokers in the CSS effect. Afterwards, in line with previous findings [12–14], we examined non-parametric correlations between the CSS index and measures of smoking intensity [i.e. CPD, FTND score and pack-years (based on 20 CPD per year)]. Based on a significant correlation between CPD and the CSS effect, we made a median split in the group of smokers and subsequently tested differences between light, heavy and non-smokers in a one-way ANOVA. Accordingly, picture valence ratings where evaluated by a $2 \times 3$ [stimulus (neutral versus smoking) $\times$ group (non-smoker versus light versus heavy smoker)] ANOVA. The craving induced by neutral and smoking scenes was compared between heavy and light smokers using a $2 \times 2$ (stimulus $\times$ group) ANOVA. Analogous to the CSS analysis, we tested whether smoking history is associated with generally altered reward processing by analysing the relative startle suppression during neutral minus positive scenes among the three groups. Throughout the analysis, the level of significance was $P < 0.05$ (two-tailed). Significant group differences in the one-way ANOVA were followed-up by Dunnett’s $T$ post hoc tests. Effect size calculations between groups refer to Cohen’s $d$.

RESULTS
Sample characteristics
The two groups did not differ in terms of gender ($\chi^2 (1) = 0.812$, $P = 0.368$), level of education ($\chi^2 (2) = 5.349$, $P = 0.07$) or age ($F_{(1,60)} = 0.865$, $P = 0.356$).

Affective startle modulation
As reported previously [20], acoustic cues during negative, neutral and positive pictures from the IAPS evoked a linear startle pattern (Table 1, Fig. 1).

Smoking cue-related startle suppression (CSS)
In smokers, there was no difference between the CSS of smokers planning to quit smoking soon (quitters) and

Table 1  Startle analysis: summary of tests, statistical values, $P$-values and effect sizes for startle analysis.

<table>
<thead>
<tr>
<th>Statistical value</th>
<th>$P$-value</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affective startle modulation (one-way ANOVA with positive, neutral and negative IAPS scenes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main effect stimulus</td>
<td>$F_{(2,122)} = 13.379$</td>
<td>$P &lt; 0.001$</td>
</tr>
<tr>
<td>Dependent variable: standardized startle amplitudes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-way ANOVAs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within smokers:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quitters ($n = 27$) versus sustainers ($n = 9$)</td>
<td>$F_{(1,14)} = 0.451$</td>
<td>$P &lt; 0.506$ NS</td>
</tr>
<tr>
<td>Smokers ($n = 36$) versus non-smokers ($n = 26$)</td>
<td>$F_{(1,60)} = 1.097$</td>
<td>$P &lt; 0.299$ NS</td>
</tr>
<tr>
<td>Light ($n = 17$) versus heavy smokers ($n = 19$) versus non-smokers ($n = 26$)</td>
<td>$F_{(2,59)} = 3.82$</td>
<td>$P &lt; 0.028^*$</td>
</tr>
<tr>
<td>Light smokers versus heavy smokers</td>
<td>Post hoc: $T_{(14)} = 3.013$</td>
<td>$P &lt; 0.025^*$</td>
</tr>
<tr>
<td>Light smokers versus non-smokers</td>
<td>Post hoc: $T_{(41)} = 2.229$</td>
<td>$P &lt; 0.042^*$</td>
</tr>
<tr>
<td>Heavy smokers versus non-smokers</td>
<td>Post hoc: $T_{(41)} = -0.369$</td>
<td>$P &lt; 0.899$ NS</td>
</tr>
<tr>
<td>Dependent variable: standardized startle amplitudes during neutral minus smoking trials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-way ANOVAs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light ($n = 17$) versus heavy smokers ($n = 19$) versus non-smokers ($n = 26$)</td>
<td>$F_{(2,59)} = 3.441$</td>
<td>$P &lt; 0.039^*$</td>
</tr>
<tr>
<td>Light smokers versus heavy smokers</td>
<td>Post hoc: $T_{(14)} = 2.013$</td>
<td>$P &lt; 0.120$ NS</td>
</tr>
<tr>
<td>Light smokers versus non-smokers</td>
<td>Post hoc: $T_{(41)} = 2.682$</td>
<td>$P &lt; 0.023^*$</td>
</tr>
<tr>
<td>Heavy smokers versus non-smokers</td>
<td>Post hoc: $T_{(41)} = 0.564$</td>
<td>$P &lt; 0.773$ NS</td>
</tr>
<tr>
<td>Dependent variable: valence ratings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$2 \times 3$ [stimulus (neutral versus smoking) $\times$ group (light smokers versus heavy smokers versus non-smokers)] ANOVA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main effect stimulus</td>
<td>$F_{(1,14)} = 46.512$</td>
<td>$P &lt; 0.001**$</td>
</tr>
<tr>
<td>Interaction group $\times$ stimulus</td>
<td>$F_{(2,9)} = 4.679$</td>
<td>$P &lt; 0.013^*$</td>
</tr>
<tr>
<td>Dependent variable: craving ratings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$2 \times 3$ [stimulus (neutral versus smoking) $\times$ group (light smokers versus heavy smokers)] ANOVA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main effect stimulus</td>
<td>$F_{(1,14)} = 31.569$</td>
<td>$P &lt; 0.001**$</td>
</tr>
</tbody>
</table>

* $P < 0.05$, ** $P < 0.001$; NS: not significant ($P > 0.05$). ANOVA: analysis of variance; CSS: cue-related startle suppression; IAPS: International Affective Picture System.
that of smokers who did not try to reach abstinence (sustainers) (Table 1). There was no overall difference in the CSS of smokers and non-smokers. Correlation analysis revealed significant correlations between the CSS and CPD \((r_{sp} = -0.41, P < 0.013)\) as well as between the CSS and the FTND score \((r_{sp} = -0.35, P < 0.034)\). The correlation with pack-years failed to reach significance \((r_{sp} = -0.23, P < 0.229)\). Subsequently, active smokers were differentiated into light and heavy smokers by means of a median split (median = 25 CPD). The group of light smokers consisted of 17 smokers who smoked less than 25 CPD; the group of heavy smokers comprised 19 smokers who smoked at least 25 CPD. Table 2 summarizes the characteristics of smoking behaviour of the two groups. In a three-group comparison, we found significant differences between light, heavy and non-smokers (Table 1, Fig. 2). Light smokers showed a stronger CSS effect, compared to heavy smokers as well as non-smokers. There was no difference in the CSS of heavy smokers and non-smokers. Effect sizes for differences between the light smokers and the other two groups were large: \(d = 1.01\) as compared to heavy smokers, and \(d = 0.73\) compared to non-smokers, respectively. A comparison of the startle response during the presentation of pleasant relative to neutral stimuli revealed a similar pattern of results (Table 1). Light smokers displayed a higher level of startle suppression, compared to non-smokers, and a trend towards stronger suppression in comparison to the heavy smokers. There was no difference between heavy smokers and non-smokers.

**Table 2** Characteristics [mean and standard deviation (SD)] of smoking behaviour of light \((n = 17)\) and heavy smokers \((n = 19)\).

<table>
<thead>
<tr>
<th></th>
<th>Light smoker mean (SD)</th>
<th>Heavy smoker mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTND* (0–10)</td>
<td>4.35 (2.09)</td>
<td>6.53 (1.95)</td>
</tr>
<tr>
<td>Cigarettes smoked daily (CPD)</td>
<td>17.00 (5.12)</td>
<td>31.21 (9.51)</td>
</tr>
<tr>
<td>Years of smoking</td>
<td>22.46 (8.45)</td>
<td>25.47 (8.83)</td>
</tr>
<tr>
<td>Pack-yearsb</td>
<td>17.87 (7.80)</td>
<td>40.18 (25.50)</td>
</tr>
<tr>
<td>p.p.m.CO</td>
<td>11.87 (7.48)</td>
<td>15.47 (10.64)</td>
</tr>
<tr>
<td>Desire to smoke (before startle, 0–100)</td>
<td>28.20 (27.07)</td>
<td>47.68 (31.57)</td>
</tr>
<tr>
<td>Desire to smoke (after startle, 0–100)</td>
<td>43.53 (29.87)</td>
<td>51.11 (26.87)</td>
</tr>
</tbody>
</table>

*FTND: Fagerström Test for Nicotine Dependence. Pack-years were based on 20 cigarettes per day over 1 year; p.p.m.CO: parts per million carbon monoxide.

**DISCUSSION**

This first study comparing drug cue-related startle suppression (CSS) between smokers and non-smokers found that only light smokers, but not heavy smokers, differed from non-smokers regarding the CSS \((d = 0.73)\). In addition, light smokers differed substantially from heavy
The strong startle suppression in light smokers during the presentation of drug paraphernalia replicates the findings of Cinciripini et al. [27], Dempsey et al. [28] and Geier et al. [21]. These studies employed samples who were younger, and their smoking characteristics were similar to our sample of light smokers. No other startle study has looked at startle suppression in heavy smokers. Hence, for light smokers, our finding corroborates—in line with incentive theories [2,7–9], and in contrast to withdrawal or homeostatic response models [3–5]—that smoking cues serve as emotional or even motivational incentives and are not perceived as aversive.

Whereas the issue of smoking intensity and cue-modulated startle responses has not yet been considered, negative correlations between attentional and behav-

ioral approach biases towards smoking relative to neutral cues and the number of CPD have been reported in several studies [12–14]. These findings are consistent with integrated incentive-habit theories of addiction, e.g. [29,30], which propose a distinction between incentive smokers and habit smokers. Incentive smoking may represent an early stage of addiction, where external cues trigger pleasant associations and consumption behaviour [2]. In contrast, smoking in habit smokers may be triggered by internal cues, based upon underlying neuronal adaptations. Accordingly, smoking in habit smokers might reflect later stages in addiction, characterized by strong motivational components (i.e. wanting) and compulsive consumption habits [10,30]. Thus, as we measured stronger appetitive effects of cigarette cues in light smokers, startle methodology appears to capture appetitive effects reflecting the hedonic liking of the drug, rather than motivational processes underlying wanting of the drug.

Recently, the contribution of different individual factors received some attention in startle research attempting to clarify the heterogeneity of smoking cue-related startle responses. Both smoking deprivation and the intention to quit have been discussed in terms of whether or not they affect CSS modulation in active smokers. Whereas Geier et al. [21] found no deprivation effect, Cinciripini et al. [27] demonstrated stronger suppression of the startle response after 12 hours of deprivation than immediately after smoking. In the present study, we had required our subjects to refrain from smoking for 4–6 hours and found robust CSS effects, suggesting that a relatively mild deprivation is sufficient to elicit the CSS, at least in light smokers. Dempsey et al. [28] provided partial support for their new hypothesis that voluntary commitment to quit smoking suppresses CSS effects among active smokers. However, we found no CSS difference between smokers who wanted to quit smoking soon and the rest of the group. This finding suggests that startle modulation is probably not under voluntary control.

An alternative interpretation of the difference between heavy and light smokers has to be considered. Heavier smokers might show a reduction in their sensitivity for smoking-related cues because they are more affected by even a short deprivation period. As mentioned above, Geier et al. [21] did not find an effect of deprivation on the startle suppression while viewing smoking cues, and Cinciripini et al. [27] found a stronger (rather than weaker) CSS after deprivation, making this alternative explanation less likely.

In addition to an enhanced CSS effect, light smokers also showed enhanced startle suppression during the presentation of pleasant scenes relative to the presentation of neutral scenes. This finding is interesting, because

smokers ($d=1.0$). The strong startle suppression in light smokers during the presentation of drug paraphernalia replicates the findings of Cinciripini et al. [27], Dempsey et al. [28] and Geier et al. [21]. These studies employed samples who were younger, and their smoking characteristics were similar to our sample of light smokers. No other startle study has looked at startle suppression in heavy smokers. Hence, for light smokers, our finding corroborates—in line with incentive theories [2,7–9], and in contrast to withdrawal or homeostatic response models [3–5]—that smoking cues serve as emotional or even motivational incentives and are not perceived as aversive.

Whereas the issue of smoking intensity and cue-modulated startle responses has not yet been considered, negative correlations between attentional and behav-

ioral approach biases towards smoking relative to neutral cues and the number of CPD have been reported in several studies [12–14]. These findings are consistent with integrated incentive-habit theories of addiction, e.g. [29,30], which propose a distinction between incentive smokers and habit smokers. Incentive smoking may represent an early stage of addiction, where external cues trigger pleasant associations and consumption behaviour [2]. In contrast, smoking in habit smokers may be triggered by internal cues, based upon underlying neuronal adaptations. Accordingly, smoking in habit smokers might reflect later stages in addiction, characterized by strong motivational components (i.e. wanting) and compulsive consumption habits [10,30]. Thus, as we measured stronger appetitive effects of cigarette cues in light smokers, startle methodology appears to capture appetitive effects reflecting the hedonic liking of the drug, rather than motivational processes underlying wanting of the drug.

Recently, the contribution of different individual factors received some attention in startle research attempting to clarify the heterogeneity of smoking cue-related startle responses. Both smoking deprivation and the intention to quit have been discussed in terms of whether or not they affect CSS modulation in active smokers. Whereas Geier et al. [21] found no deprivation effect, Cinciripini et al. [27] demonstrated stronger suppression of the startle response after 12 hours of deprivation than immediately after smoking. In the present study, we had required our subjects to refrain from smoking for 4–6 hours and found robust CSS effects, suggesting that a relatively mild deprivation is sufficient to elicit the CSS, at least in light smokers. Dempsey et al. [28] provided partial support for their new hypothesis that voluntary commitment to quit smoking suppresses CSS effects among active smokers. However, we found no CSS difference between smokers who wanted to quit smoking soon and the rest of the group. This finding suggests that startle modulation is probably not under voluntary control.

An alternative interpretation of the difference between heavy and light smokers has to be considered. Heavier smokers might show a reduction in their sensitivity for smoking-related cues because they are more affected by even a short deprivation period. As mentioned above, Geier et al. [21] did not find an effect of deprivation on the startle suppression while viewing smoking cues, and Cinciripini et al. [27] found a stronger (rather than weaker) CSS after deprivation, making this alternative explanation less likely.

In addition to an enhanced CSS effect, light smokers also showed enhanced startle suppression during the presentation of pleasant scenes relative to the presentation of neutral scenes. This finding is interesting, because

© 2009 The Authors. Journal compilation © 2009 Society for the Study of Addiction

Addiction, 104, 1757–1764
conditioning and electrophysiological experiments in animals show that nicotine enhances not only the incentive value of smoking-associated cues, but also the value of natural rewards [31], due probably to an amplification of the difference between tonic and phasic dopamine release in the ventral striatum [32]. While plausible, this finding is preliminary and has to be examined systematically in further studies.

CONCLUSION

In summary, the affect-modulated startle paradigm is suitable to investigate the implicit valence of smoking-associated cues. The present findings support recent theories which discriminate between habit-based and incentive-based drug abuse, because heavy (and presumably habit-driven) smokers had decreased cue–reactivity towards smoking-related cues in comparison to light (and incentive-driven) smokers. On the contrary, light smokers displayed the expected cue-related suppression of the acoustic startle response when smoking scenes were shown. Further studies should consider carefully the smoking behaviour in their sample. Furthermore, longitudinal studies are necessary to follow up whether smoking behaviour changes over time from incentive-based smoking at a juvenile age towards habit-based smoking in long-term smokers.

Declarations of interest

None.

Acknowledgements

The present study was funded by the German Ministry of Education and Research (grant number: 01 EB 0432) and by the Addiction Network NRW. The study was not supported by tobacco, alcohol or pharmaceutical industries.

References


This document is a scanned copy of a printed document. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material.