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Breakdowns of eye movement control toward smoking cues in young adult light smokers

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HIGHLIGHTS

- LS make more antisaccade errors to smoking cues than neutral cues
- LS make more errors toward smoking cues than alcohol cues
- LS make more errors toward smoking cues than NS
- Cognitive control to smoking cues is disrupted in LS prior to daily smoking or addiction

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ABSTRACT

Background: Many studies suggest that dependent smokers have a preference or attentional bias toward smoking cues. The purpose of this study was to test the ability of infrequent non-dependent light smokers to *control* their eye movements by look away from smoking cues. Poor control in the lightest of smokers would suggest nicotine cue-elicited behavior occurring even prior to nicotine dependency as measured by daily smoking.
Methods: 17 infrequent non-dependent light smokers and 17 lifetime non-smokers performed an antisaccade task (look away from suddenly appearing cue) on smoking, alcohol, neutral, and dot cues.
Results: The light smokers, who were confirmed light smokers and non-dependent ($M_{\text{Faegerström Dependency Score}} = 0.35$), were significantly worse at controlling their eye movements to smoking cues relative to *both* neutral cues ($p < .04$) and alcohol cues ($p < .02$). Light smokers made significantly more errors to smoking cues than non-smokers ($p < .004$).
Conclusions: These data suggest that prior to developing clinical symptoms of severe dependence or progressing to heavier smoking (e.g., daily smoking), the lightest of smokers are showing a specific deficit in control of nicotine cue-elicited behavior.

1. Introduction

Despite the well-known and highly adverse health effects of tobacco use, most notably, heart disease, cancers of the lung, throat and mouth, and chronic obstructive pulmonary disease (Surgeon General's Report's, 2004), people continue to smoke. These rates are significantly elevated among 18–25 year olds, with young adults having the highest rate of current tobacco use in the last month (37%) amongst all ages (Substance Abuse and Mental Health Services Administration, 2013). Within this age range, only half (43.1%) of these smokers were daily smokers (Substance Abuse and Mental Health Services Administration, 2013). Low-rate and non-daily smoking is, thus, common among young adults. However, intermittent smoking is an unstable pattern that typically progresses to either regular smoking or abstinence (Zhu, Sun, Hawkins, Pierce, & Cunningham, 2003). This progression to dependency is usually indexed by regular daily smoking. However, other more subtle cognitive and behavioral measures may be a more sensitive marker to *nicotine cue-elicited behavior* prior to developing severe nicotine dependency.

One method of assessing sensitivity to smoking cues in *dependent* smokers is to measure their attentional bias toward smoking cues relative to neutral cues. A plethora of studies (Bradley, Field, Mogg, & De Houwer, 2004; Bradley, Mogg, Wright, & Field, 2003; Ehrman et al., 2002; Field, Mogg, & Bradley, 2004; Hogarth, Mogg, Bradley, Duka, & Dickinson, 2003; Kwak, Na, Kim, Kim, & Lee, 2007; Mogg & Bradley, 2002; Mogg, Bradley, Field, & De Houwer, 2003; Mogg, Field, &

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Bradley, 2005; Powell, Pickering, Dawkins, West, & Powell, 2004; Waters, Shiffman, Bradley, & Mogg, 2003; Waters, Shiffman, Sayette, et al., 2003) have demonstrated attentional biases to smoking cues in dependent smokers. These studies used a probe-detection task in which cues are presented briefly and a dot occurs at the location of one of the cues. Probes presented at the location where smoking cues were presented are responded to faster than probes at the location where neutral cues were presented, demonstrating an attentional bias toward smoking cues. This attentional bias has been seen in both light (defined as at least 1 cigarette per day) and heavy (≥20 cigarettes per day) dependent smokers (Hogarth, Dickinson, & Duka, 2009; Mogg et al., 2005). This attentional bias to smoking cues continues in former smokers, with ex-smokers showing attentional avoidance to smoking cues (Peuker & Bizarro, 2014).

Likewise, the location and duration of where subjects look when presented with smoking cues are measured to demonstrate dependent smokers' preferences and/or attentional bias. These eye movement studies (Field et al., 2004; Field, Mogg, & Bradley, 2005; Hogarth et al., 2009; Kwak et al., 2007; Mogg et al., 2003; Mogg et al., 2005) have demonstrated more frequent and longer fixations on smoking cues than neutral cues in dependent smokers. For example, Mogg et al. (2003) demonstrated that smokers, but not control subjects, looked longer at smoking cues than neutral cues. Furthermore, this bias to look longer at smoking cues was associated with an urge to smoke. Even in natural environments with cigarettes, ashtrays and other smoking related objects present, smokers look longer at smoking objects than neutral objects (Baschnagel, 2013). In short, a large body of research suggests that dependent smokers prefer smoking cues to neutral cues and that their attention is drawn more toward smoking cues than neutral cues.

The relevance of this type of attentional bias toward smoking cues has come under question (Hogarth, Dickinson, Janowski, Nikitina, & Duka, 2008). Some research has suggested a direct relationship between attentional bias and nicotine cessation treatments (Waters, Shiffman, Sayette, et al., 2003). In this study (Waters, Shiffman, Sayette, et al., 2003), smokers who were treated with either nicotine replacement therapy or placebo were asked to name the color of ink of words which were either smoking or neutral words. Smokers who showed more attentional bias (more errors or longer color naming times) toward smoking cues were significantly more likely to relapse than smokers who showed less bias. Furthermore, the smokers receiving active nicotine replacement therapy had less attentional bias toward smoking cues than those smokers on placebo. However, an additional study by Waters and colleagues (Waters, Shiffman, Bradley et al., 2003) found that the amount of attentional bias, as measured by the dot probe task, did not predict subsequent nicotine cessation treatment outcome. A recent review paper (Christiansen, Schoenmakers, & Field, 2015) has suggested no direct relationship between attentional bias and outcomes in addiction treatment. Hence, the attentional bias paradigm might be less directly related to clinical relevance than previously thought.

While the aforementioned studies have investigated dependent smokers' preferences or attentional biases toward smoking cues (and the clinical relevance of attentional bias has been questioned), these studies have not asked smokers to *control* their behavior toward smoking cues. In the above studies, smokers are not specifically instructed to avoid looking at these smoking cues; particularly, to control behavior and inhibit a motoric response to smoking cues. A hallmark of smoking cessation, relapse prevention, and likely prevention of progression to severe dependence is the ability to control one's behavior toward cigarettes. Here we use a new paradigm (drug antisaccade task) to test the ability of young adult light smokers to control their eye movements toward smoking cues. Rather than measuring where light smokers looked when presented with a smoking cue, we specifically asked these them to control their behavior and look away from a suddenly presented cue and make an eye movement in the opposite direction (an antisaccade task, see Blaukopf & DiGirolamo, 2005, 2006; Hallett, 1978). In this task, subjects are presented with a suddenly appearing visual stimulus in the periphery (left or right) and have to suppress an eye movement towards it, in order to look to the opposite empty hemi-field (an antisaccade). Subjects fail frequently to suppress this involuntary response; therefore, a good number of both successful control (antisaccades) and breakdowns of control (prosaccadic errors) are made. Within this empirical paradigm, we can test in light smokers control over eye movements to smoking cues, alcohol cues and neutral cues, and determine if smoking cues elicit more deficits in control than other cue types. Note, that we use the term breakdown to index a failure to follow goal-directed behavior in this task. The goal-directed behavior is to look away from the suddenly appearing stimulus regardless of its content, and failure to do so indexes a breakdown in cognitive control (Posner & DiGirolamo, 1998).

Unlike the attentional bias paradigms used previously, this drug antisaccade paradigm tests directly the ability of patients to control their actions (eye movements) toward drug cues. We have used this adapted drug antisaccade task to look at deficits in cognitive control toward cocaine cues in patients with cocaine use disorder (DiGirolamo, Smelson, & Guevremont, 2015). In this novel drug antisaccade task, using cocaine and neutral cues and patients with cocaine use disorder, we found significantly higher error rates in cocaine dependent patients for cocaine cues than neutral cues (DiGirolamo et al., 2015) demonstrating a cue-specific breakdown in cognitive control for cues related to the substance of addiction. Here, we look at cognitive control deficits, as indexed by eye movement errors in the drug antisaccade task, in people who are very light smokers and *not addicted* as indexed by daily or even frequent intermittent smoking toward smoking cues.

In the current study, we asked if *any* breakdowns in control over behavior toward smoking cues relative to alcohol or neutral cues, measured as percentage of antisaccade errors, would be found in even the lightest of young adult smokers who had not progressed yet to severe dependency (see, Mogg et al., 2005 for attentional biases in low but dependent smokers). Also, we asked if alcohol, a drug which young adults have a significant familiarity and use of, would elicit also this type of breakdown of control over behavior, or if any deficits in control that we saw would be specific for smoking cues in these light, infrequent smokers.

2. Methods

2.1. Participants

17 young adult light smokers (M = 20.12 yrs. old; SEM = 0.256), and 17 lifetime non-smoking young adults (M = 19.76; SEM = 0.398) were recruited from an undergraduate institution, gave informed consent, had normal or corrected-to-normal vision, and were either paid or received credit for participation. The non-smoking participants (NS) were recruited intentionally based on *never* smoking or using any nicotine products at any point in their lifetime. The smoking participants were recruited intentionally to be light and non-dependent smokers (LS). These LS were non-daily smokers and frequently went several days between smoking episodes. One index of this infrequent smoking in the LS was the last cigarette smoked prior to participating in the experiment was, on average, more than 2 days prior to the experiment (M = 56.64 h, SEM = 14.69 h).

2.2. Assessments

Participants were administered the Fagerström Test for Nicotine Dependence (FTND, Heatherton, Kozlowski, Frecker, & Fagerström, 1991); a 9-item questionnaire for nicotine dependence derived from the DSM-V (American Psychiatric Association, 2013); and, the very liberal "Hooked on Nicotine Checklist" (HONC, DiFranza et al., 2002), where any "yes" response qualifies the participant for nicotine dependence (see Hughes & Shiffman, 2008 for a critique of this measure). Alcohol