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A consistent attentional bias for drug-related material in active cocaine users across word and picture versions of the emotional Stroop task

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Abstract

Evidence from a number of drug-abuse populations suggests that an attentional bias for drug-related stimuli can be identified in chronic users. Such an effect has yet to be reliably demonstrated in cocaine users, despite mounting evidence of the salience and reinforcing properties of cocaine-related cues. The aim of the current study was to administer word (modeled on the versions shown to successfully identify attentional biases in alcohol abusers) and picture versions of the emotional Stroop tasks to gauge the reliability of cocaine-specific attentional biases across stimuli domains. A comparison of active cocaine users ($n = 23$), and their age and education matched controls revealed a significant bias for cocaine-related pictures and words in users. This attentional bias could not be attributed to confounding factors such as slowed response speed of cocaine users, cocaine-related material sharing category ownership, or that the cocaine-related material used in the current study was generally arousing for all participants. A comparison of the different classes of stimuli indicated that cocaine users had a very similar level of difficulty controlling their attention towards both cocaine-related material and incongruent-colour word stimuli, the latter being the traditional measure of attentional control from the Stroop task. These results provide corroborating evidence for cognitive biases being a hallmark of substance dependence.

Keywords: Cocaine; Emotional Stroop; Attentional bias; Addiction

1. Introduction

Previous research with emotional Stroop tasks have demonstrated an attentional bias for drug-related stimuli in abusers of alcohol (Cox et al., 2003; Duka and Townshend, 2004; Lusher et al., 2004) nicotine (Waters et al., 2003; Wertz and Sayette, 2001) and heroin (Franken et al., 2000b; Franken, 2003). These data have been interpreted as reflecting a preoccupation with drug-related stimuli caused by drug use. For example, when participants are pre-occupied with alcohol they take significantly longer to respond (verbally or motorically) with the colour of a word such as beer, than a neutral word such as table (Lusher et al., 2004). These studies provide support for the hypothesis that part of the addiction process is an alteration in attentional processing (Lyvers, 2000; Robinson and Berridge, 2003), whereby substance-related cues attain greater salience, particularly during craving for the drug (Cox et al., 2002).

While studies with active cocaine users have indicated a strong physical reaction to drug-related stimuli (Carter and Tiffany, 1999; Childress et al., 1993; Robbins et al., 2000), including activity in the limbic-based neural reward network that responds to the drug itself (Grant et al., 1996; London et al., 1999; Reid et al., 2003), research examining an attentional bias for cocaine-related stimuli has been limited (Franken et al., 2000a; Rosse et al., 1997). A recent study of patients with: (1) diagnosis of cocaine dependence; (2) schizophrenia; (3) schizophrenia and a comorbid diagnosis of cocaine dependence, administered a modified version of an emotional Stroop task (a task in which participants must respond to the font colour of emotionally charged

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words including cocaine-related words), and found that only cocaine-dependent patients demonstrated an attentional bias for cocaine-related stimuli (Copersino et al., 2004). A number of methodological considerations limit the generalisability of these results, including the inpatient status of cocaine users, medication regimes for some patients (including in the cocaine dependent group), the significant demographic (age and education) differences between the control and cocaine-dependent groups, and the task administration that utilized a card system requiring self-correction of errors (RT scores using this method can be influenced by a preponderency to inhibitory errors, which both cocaine users and schizophrenics are consistently shown to exhibit). Despite these limitations, the study was also able to demonstrate a relationship between an attentional bias for cocaine-related stimuli and self-reported craving for cocaine in the cocaine-dependent group, suggesting a wider clinical utility for such attentional measures.

Examining the salience of drug-related cues to attention is of interest for dual reasons. First, recent theories on the underlying neurobiological basis of drug addiction argue that the reactivity of neural reward circuits to drug-related cues represents an 'overvaluation' of drug reinforcers (Goldstein and Volkow, 2002). They propose that attention to drug-cues results from, and further reinforces, their salience because the activation of reward circuits appears to increase expectancy (and therefore craving) of the drug of abuse. Understanding the mechanism by which attention is captured by salient drug-related stimuli would appear critical to our understanding of craving and the addiction process (Robinson and Berridge, 2003). The mechanism underlying drug-related attentional bias might offer a potential target for treatment because of the association between drug craving and likelihood of relapse during withdrawal (Bordnick and Schmitz, 1998; Ciccocioppo et al., 2001; Weiss et al., 2001).

Second, studies with alcohol-abuse participants indicate that monitoring attentional bias to alcohol-related stimuli can predict drug-seeking behaviour (Cox et al., 1999, 2003), and more importantly predict those individuals most at risk of relapse during withdrawal (Cox et al., 2002). Also, studies with smokers show that attentional bias has a predictive value for smokng cessation (Waters et al., 2003). These findings suggest that measuring attentional 'pre-occupation' with drug-related stimuli may have a clinical utility that has yet to be fully explored. The concept of monitoring cue-reactivity and relating it to cocaine seeking behaviour has been attempted previously with these studies primarily using physiological measures of cue-reactivity such as skin-conductance, blood pressure and heart rate (Childress et al., 1993). To date, this approach has been unable to demonstrate a relationship with either drug-use behaviour (Robbins et al., 2000) or treatment outcome (Margolin et al., 1994), though this research is continuing. A reliable cognitive measure of attentional bias in cocaine users, capable of predicting treatment outcome, would be a useful tool for clinicians, particularly one which was short and easy to administer.

The aim of the current study was to modify the computer administered version of the emotional Stroop paradigm for examining attentional biases in active cocaine users. Given the robust effect sizes previously identified with the alcohol-related emotional Stroop, it was hoped that this paradigm would provide a more sensitive measure than previous attempts at measuring attentional bias in cocaine users (Copersino et al., 2004; Franken et al., 2000a). Self-report measures of drug use were also obtained to ascertain whether attentional biases could be related to drug-use behaviour patterns such as length (years of drug-use), or frequency (number of uses per week, money spent per week, etc.) of use.

An additional aim of the current study was to compare word and picture versions of a cocaine version of the emotional Stroop task. The typical paradigm design for emotional Stroop tasks presents drug-related words in varying font colours, which the participant must respond to by providing the font colour. Given the argument that increased latencies for drug-related words are the result of extra-time taken to process the semantic properties of the stimulus (Lusher et al., 2004), we administered both a typical word-based emotional Stroop paradigm and a modified picture-based version. The latter task presented black and white pictures of cocaine-related, non-drug-related evocative, and neutral material within coloured borders. The participant's task was to press a button that corresponded with the colour of the picture border. We hypothesized that pictures, when compared to words, might have more salience for users, because previous research has suggested that cue-reactivity of cocaine-users does vary as a function of cue-type and modality (Johnson et al., 1998), and previous work with an eating-disorder version of the emotional Stroop task suggests greater effects for pictures when compared to words (Stormark and Torkildsen, 2004).

2. Methods

2.1. Participants

Twenty-three non-drug using participants (seven female, mean age 39.4, range 26–51) and 23 active cocaine users (seven female, mean age 40.3, range 22–48) participated in the current study. Educational attainment for the two groups was not significantly different (controls: 12.4 years, users: 11.8, $F(1, 44) = 3.09$, $p > 0.05$). All participants were right-handed and reported no current or past history of neurological or psychiatric disorders, dependence on any psychoactive substance other than cocaine (for user participants only), caffeine or nicotine. Participants were fully informed of the nature of the research and provided written consent for their involvement in accordance with the Institutional Review Board of the Medical College of Wisconsin (MCW). Urine samples were taken from all participants to test for drug use, with all non-drug participants returning negative tests for all drugs and active cocaine users returning positive tests

Table 1
Categories of words presented during the cocaine-related emotional Stroop task

Cocaine words	Music words	Neutral words
Chore	Bagpipes	Read
Hit	Bassoon	Chain
Cocaine	Pan pipes	Card
Tweeking	Clarinet	Invitation
Craving	Trombone	Shoe
Rock	Drums	Cape
Pipe	Keyboard	Building
Smack	Maracas	Floor
Blow	Violin	Windshield
Spoon	Trumpet	Watch
Cook	Banjo	Mirror
Eightball	Viola	Boots
Geeking	Flute	Que
Residue	Bongos	Window
Crack	Bass	Carpet
Money	Recorder	Key
Smoke	Cello	Mouse
Lighter	Guitar	Lamp
Coke	Oboe	Telephone
Rush	Piano	Box

Within each category, the words have been listed by the duration of response time for the cocaine-user sample, from longest to shortest duration.

for cocaine or its metabolites, indicating that they had used cocaine within the past 72 h. No user displayed overt signs of cocaine intoxication. User participants' who were positive for any drug (on the urine screen) other than cocaine, nicotine or marijuana were excluded. Twelve of the cocaine user sample reported occasional use of cannabis, with the average duration since last use 17 days and none had consumed in the 24 h prior to cognitive testing. The acute effects of cannabis intoxication on the cognitive performance of occasional users are short-lived, peaking at 2 h post consumption and lasting up to 8 h, but are not present after 24 h (Curran, 2002; Fant et al., 1998), and 'light' (once per week) use of cannabis has not been associated with decrements in cognitive test performance (Pope et al., 2001). Twenty-one participants (16 cocaine users and five control) also reported regular use of tobacco ($M = 9.5$ cigarettes per day).

2.2. Stroop tasks

The order of presentation for the two Stroop tasks was fixed, with the word preceding the picture version.

2.2.1. Word emotional Stroop

The alcohol-related emotional Stroop task described by Cox et al. (1999) was adapted for the current study. The stimuli in the cocaine-related emotional Stroop included twenty words from each of the following categories: cocaine-related (e.g., crack, pipe), music-related (e.g., flute, piano), and neutral words (e.g., box, telephone) (see Table 1 for full details). The music category provided a control for the semantic-relatedness of cocaine-related words, whereby distractedness for the cocaine words could be compared to another group of semantically-related words (music), or words that were neither linked together or to cocaine (neutral). Further replicating Cox et al.'s procedure, we also included a block of 20 incongruent (classic Stroop) colour words, and a block of coloured 'xxxx's; providing baseline measures of distractedness (Stroop) and response times (xxxx's).

The cocaine-related words were derived from two sources: the list of eight words used by Franken et al. (2000a) and the 12 most frequently nominated words from a questionnaire completed by 17 active cocaine-users seen in the General Clinical Research Centre at MCW. The questionnaire asked users to provide words they associated with cocaine and was administered during recruitment for a range of studies carried out at MCW during 2002 and 2003.

The five categories of stimuli were presented in blocks of 20 trials, with the order of blocks and the order of words within each block randomized across participants. Training prior to the main task familiarized participants with responding to the colour of the word stimuli via the keypad of a standard keyboard, with coloured stickers indicating the four different response buttons. A single trial presented the word stimulus (in Arial font—40 point) on a black background where it remained until the participant responded, following which a 250 ms blank screen and a 500 ms fixation cross would be presented prior to the next word stimulus.

2.2.2. Picture emotional Stroop

The picture emotional Stroop task was an attempt to further adapt the Stroop task to provide a measure of attentional bias for different semantic categories of pictures. The task required participants to respond to the border-colour of a centrally presented photograph (300×300 pixels). Three categories of stimuli were presented: cocaine-related, evocative non-cocaine-related and neutral. The cocaine-related pictures were drawn from the internet including the U.S. Drug Enforcement Agency (www.usdoj.gov/dea/photo_library.html) and the Alcohol and Drug Information Clearinghouse (http://www.prevlink.org/getthefacts/webphotoalbums/cocaine). The evocative and neutral pictures were drawn from the International Affective Picture System (Lang et al., 1998). While attempts where made to match visual properties of the different categories, including the presentation of all pictures in black and white, this process was particular difficult when matching to the cocaine-related material. Given this difficulty, we attempted to compare the attentional capture of cocaine-related pictures in relation to pictures with an evocative content, and compare them both to pictures that were neither cocaine-related nor evocative. As the cocaine-related material was likely to be highly arousing for cocaine users, we selected a series of pictures from the IAPS that had high arousal rating, with the average arousal rating for the evocative category 6.75 (range 6.03–7.35), and 2.5 for the neutral (range 1.72–2.93) pictures. The evocative stimuli set included both positive and negative valenced pictures, including those of snakes, spiders, sharks, erotica, aimed weapons, mutilated body parts, skydiving, skijumping

and rollercoasters (a list of the IAPS item numbers for the pictures used can be obtained from the corresponding author). An attempt was also made to balance the valence ratings for the evocative ($M = 5.20$) and neutral ($M = 4.74$) pictures.

The three categories of stimuli were presented in blocks of 20 trials, with the order of blocks and the order of pictures within each block randomized across participants. Coloured stickers were placed on the 8, 6, 4 and 2 buttons of the keypad to indicate the relationship between response buttons and the border-colour of picture stimuli. Training, prior to the main task, was used to familiarize participants with responding using the keypad of a standard keyboard. A single trial presented the picture and border (10 pixels in width) on a black background where it remained until the participant responded, following which a 250 ms blank screen and a 500 ms fixation cross would be presented prior to the next word stimulus.

3. Results

3.1. Word emotional Stroop task

Accuracy performance for both users and controls was close to ceiling (over 95% for all word categories), and did not indicate any group or categorical influences. Inspection of the reaction time data revealed one cocaine-user participant was a significant outlier for RT measures from both versions of the task, being greater than three standard deviations higher than the mean for several of the measures derived, and was omitted from the subsequent analyses. The mean RT and standard deviation scores for correct responses from both the control and cocaine user samples are presented in Table 2. The RTs were analysed using a 2 × 5 repeated measures ANOVA, with group (cocaine-user, control) the between-participants variable and stimulus type (cocaine, music, neutral, xxxx, incongruent) the within-participant variable. There was a significant main effect for stimulus type $F(4, 172) = 22.02, p < 0.01$, but not group, $F(1, 43) = 2.23, p = 0.14$, and a significant interaction between group and stimulus type, $F(4, 172) = 3.09$, $p = 0.01$. Due to the significant interaction effect, a repeated measures ANOVA was performed for each group, with stimulus type the within participant variable. Post-hoc comparisons (least squared differences) of the data from control participants showed a significant difference between incongruent and each of the four other classes of stimuli ($p < 0.01$), while cocaine-related, music, neutral and colour (xxxx) RT's were not significantly different from each other. The RT scores for cocaine users showed a different pattern, with incongruent and cocaine-related scores significantly different to the other categories of stimuli ($p < 0.01$) but not significantly different from each other ($p = 0.289$) and nor were there any differences between the other categories of stimuli.

Table 2
Mean reaction time and S.D. scores for cocaine users ($n = 22$) and matched controls ($n = 23$) on the word emotional Stroop task, categorised by word type

Category	Cocaine users		Controls		p
	M	*S.D.*	*M*	*S.D.*	
Cocaine	922.7	224.9	772.2	116.9	[a]
Incongruent	952.6	251.3	957.5	262.6	
Music	823.4	126.3	755.4	161.7	
Neutral	808.7	161.6	734.0	97.4	
xxxx	786.4	115.3	758.3	120.2	

[a] Significant *t*-test difference between cocaine user and control ($p < 0.05$).

Table 3
Mean reaction time and S.D. scores for cocaine users ($n = 22$) and matched controls ($n = 23$) on the picture emotional Stroop task, categorised by word type

Category	Cocaine users		Controls		p
	M	*S.D.*	*M*	*S.D.*	
Cocaine	1001.7	495.1	752.0	223.2	[a]
Evocative	1070.9	463.5	906.9	215.8	
Neutral	843.1	236.1	755.5	142.6	

[a] Significant *t*-test difference between cocaine user and control ($p < 0.05$).

To further explore the specificity of attentional biases we created two separate interference scores by subtracting from each participant's mean RT to cocaine-related words their mean RT to: (1) neutral words; (2) music words. Cocaine users showed a significantly greater attentional bias than control participants for cocaine-related material when compared to other random non-valenced words, $F(1, 43) = 4.28$, $p < 0.05$, or non-valenced words that shared category membership, $F(1, 44) = 4.37, p < 0.05$.

3.2. Picture emotional Stroop task

Accuracy performance for both users and controls was close to ceiling (over 96% for all stimuli categories), and did not indicate any group or categorical influences. The mean and standard deviation RT scores for correct responses from both the control and cocaine user samples are presented in Table 3. The RTs were analysed using a 2 × 3 repeated measure ANOVA, with group (cocaine-user, control) the between-participants variable and stimulus type (cocaine, evocative, neutral) the within-participant variable. There was a significant main effect for stimulus type $F(2, 86) = 21.36$, $p < 0.01$, but not for group, $F(1, 43) = 3.45$, $p = 0.07$, and a significant interaction between group and stimulus type, $F(2, 86) = 3.86$, $p = 0.05$. Given the significant interaction effect, a repeated measures ANOVA was performed for each group. Data from control participants indicated a significant effect of stimulus type, $F(2, 44) = 19.32, p < 0.01$, with the RT for evocative stimuli significantly different to both the neutral ($p < 0.001$) and cocaine-related stimuli ($p < 0.001$), while the RTs for the latter two classes of stimuli were not significantly different ($p = 0.88$). Cocaine users also showed a significant effect of stimulus type, $F(2, 42) = 10.2, p < 0.01$, with the RT for evocative material significantly different to neutral pictures ($p = 0.001$), and cocaine-related ($p = 0.036$), while the

RT difference between cocaine-related and neutral pictures, was also significant ($p = 0.019$).

To explore further the specificity of attentional biases we created an interference score by subtracting from each participant's mean RT to cocaine-related stimuli their mean RT to: (1) neutral pictures; (2) evocative pictures. Cocaine users showed a substantial attentional bias for cocaine-related material when compared to neutral pictures (cocaine users: 158.5 ms versus controls: −3.2 ms), which represented a significant group difference, $F(1, 43) = 6.02$, $p = 0.018$. Similarly, no significant group difference was observed for the cocaine-evocative difference score (cocaine users: −69.2 ms versus controls: −154.9 ms), or the evocative-neutral difference score (cocaine users: 227.7 ms versus controls: 151.4 ms).

3.3. Relationship between attentional bias and self-reported cocaine use behaviour

To examine the relationship between individual differences in attentional bias for cocaine-related stimuli and cocaine use behaviour, the RT difference scores (cocaine-related RT minus neutral RT) for both word and picture data were entered into a correlation analysis with self-report measures of cocaine use. Cocaine users provided the following estimates: years of use (USEYEARS: range 5–27 years, $M = 13.4$); frequency of use per week (USEFREQ: range 1–7, $M = 4.6$); amount spent on cocaine per week (USEDOLLARS: range $25–$1000, $M = 244.0); amount paid for most recent use of cocaine (USELAST: range $10–$100, $M = 25). Users were asked to provide responses for USEFREQ and USEDOLLARS as an average across their years of cocaine use. To provide an index of amounts used weekly, the amount paid for most recent use of cocaine was multiplied by the frequency of use per week (USEWEEK: range $30–$700, $M = 119.80).

No significant correlations were found between the self-reported indices of use and either Stroop difference score. The correlation between the word and picture stroop versions was also non-significant ($r = 0.21$, $p = 0.17$)

4. Discussion

The results of the current study indicate that active cocaine users demonstrate a significant attentional bias for cocaine-related stimuli, consistent across both word and picture versions of the emotional Stroop task. Our analyses also suggest that the attentional bias could not be attributed to confounding factors such as slowed response speed of cocaine users, cocaine-related material sharing category ownership, or that the cocaine-related material used in the current study was generally arousing for all participants. A comparison of the different classes of stimuli indicated that cocaine users had a very similar level of difficulty controlling their attention towards both cocaine-related material and incongruent-colour word stimuli, the latter being the traditional measure of attentional control from the Stroop task. Furthermore, the picture Stroop data suggests that users, in comparison to control participants, found cocaine-related material as distracting as highly evocative pictures of a non-drug-related content.

The results of the current study are consistent with previous findings of attentional biases for drug-related material in alcohol and nicotine addicted groups. These findings, along with our own, offer support to the hypothesis that the addiction process involves an alteration in attentional processing (Lyvers, 2000; Robinson and Berridge, 2003), whereby attention to drug-cues results from, and further reinforces, their salience because the activation of reward circuits by these drug-cues appears to increase expectancy of the drug of abuse (Goldstein and Volkow, 2002). While this hypothesis should be applicable to cocaine addiction, given the significant alterations to functioning of limbic and attentional networks in chronic cocaine users (Bolla et al., 2001; Goldstein et al., 2001; Hester and Garavan, 2004; Kaufman et al., 2003), and the significant physiological reactivity of users to cocaine-related material (Carter and Tiffany, 1999; Johnson et al., 1998; Modesto-Lowe and Kranzler, 1999), we believe the current study is the first to demonstrate a reliable attentional bias for cocaine-related material in active users (Copersino et al., 2004; Franken et al., 2000a).

The results of the current study did not offer support for a relationship between the level of attentional bias shown by different cocaine users and individual differences in drug-use behaviour. Existing evidence suggests that the level of pre-occupation with drug-related material correlates with the strength of drug cravings (Copersino et al., 2004), and, further, that the strength of craving correlates with drug-use behaviour and the likelihood of relapse during treatment (Lu et al., 2004; Weiss et al., 2001). For example, Cox et al. (2002) demonstrated that fluctuations in attentional bias (as measured by a verbal alcohol-related emotional Stroop task) related directly to outcomes for alcohol abusers in treatment, with only those patients who failed the treatment program showing an increase in their attentional bias over time. The sample of cocaine users participating in the current study were not part of a treatment program, nor were any seeking to abstain from using cocaine. Consequently, we relied on self-report of drug use behaviour, rather than routine tracking of physical measures of use (e.g., urine screening of cocaine metabolite levels (Robbins and Ehrman, 1998)). The reliability of these data is unknown and may have influenced the reliability of the correlations between use behaviour and attentional bias, suggesting that the use of more objective measures of drug-use behaviour is critical to establishing this relationship in any future study.

A further aim of the current study was to compare word and picture versions of the emotional Stroop task. The results suggested only a small degree of consistency across the two versions, including a small correlation between cocaine users' attentional biases from the word and picture tasks ($r = 0.21$). A high degree of variability amongst users on the

picture version was evident in the attentional bias scores, substantially more than for the word version of the task (picture: $M = 158$ ms, S.D. = 292; word: $M = 123$ ms, S.D. = 174). While creating the picture version of the task we noted a number of difficulties/limitations that may have contributed to the variability amongst users. Stimuli were obtained from drug abuse education and law enforcement websites and some of our more experienced user participants (our sample ranged from 5 to 27 years of use) reported that a number of stimuli were 'outdated' or 'old-fashioned'. In addition, our task presented pictures of the various forms in which cocaine can exist (e.g., crack, powdered, rock), and the variety of administration paraphernalia. However, our sample, representative of cocaine users generally, may have had limited exposure to such a variety of stimuli due to the exclusive/favoured use of certain forms of cocaine, and tools/modes of use. This limitation can, to a greater extent, be avoided in word versions of the Stroop through the use of different words that represent essentially the same emotional cue, for example, the use of 'off-licence', 'Pub', 'Bar' in Cox et al.'s (1999) alcohol-related emotional Stroop. Future administrations of a visual task might benefit from tailoring task stimuli to their sample, in particular, generating stimuli from insights of a drug-using sample (as was done for word stimuli in the current study). Similarly, the cocaine-related and neutral words were not matched for word use frequency in the current study, primarily because of the method used to select cocaine-related words. This method produced a number of word with low use frequency (e.g., tweeking, geeking, eightball), however the absence of a significant difference between neutral and cocaine-related words for control participants, and the exact opposite for cocaine-users would suggest that this potential confound did not significantly influence our results. Despite these limitations, the results of the current study would support the use of a picture Stroop as a sensitive measure of attentional biases to drug-related material.

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