Selective attention moderates the relationship between attentional capture by signals of nondrug reward and illicit drug use

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ABSTRACT

Background: The current study examined whether cognitive control moderates the association between (non-drug) reward-modulated attentional capture and use of alcohol and other drugs (AOD).

Methods: Participants were 66 university students who completed an assessment including questions about AOD use, a visual search task to measure value-modulated attentional capture, and a goal-directed selective attention task as a measure of cognitive control.

Results: The association between the effect of value-modulated attentional capture and illicit drug use was moderated by level of cognitive control. Among participants with lower levels of cognitive control, value-modulated attentional capture was associated with illicit drug use. This was not the case among participants with higher levels of cognitive control, who instead showed a significant association between illicit drug use and self-reported impulsivity, as well as alcohol use.

Conclusions: These results provide support for models that view addictive behaviours as resulting from interaction and competition between automatic and more reflective processes. That is, the mechanisms that ultimately drive addictive behaviour may differ between people low or high in cognitive control. This has important implications for understanding the development and maintenance of substance use disorders and potentially their treatment and prevention.

1. Introduction

According to dual-process models of addictive behaviours (for a review, see Stacy and Wiers, 2010), problematic substance use arises when relatively automatic, impulsive processes begin to dominate reflective processes in addiction-related decision making. This imbalance is considered to arise primarily from repeated exposure to alcohol and/or other drugs (AOD), which (through various proposed mechanisms) acts to strengthen the influence exerted by automatic appetitive processes over behaviour, relative to that exerted by reflective processes. For instance, a number of models propose that repeated and heavy exposure to AOD can sensitise the automatic system via the operation of learning processes, rendering an individual especially susceptible to maladaptive control by drug-related cues (Robinson and Berridge, 2000; Wiers et al., 2007). Specifically, it has been argued that through repeated pairing of certain stimuli with the rewarding consequences of taking a drug, those previously neutral stimuli come to acquire incentive salience, subsequently attracting attention and evoking powerful approach responses in their own right (Berridge et al., 2009; Robinson and Berridge, 2000). Conversely, repeated exposures to AOD are proposed to weaken the reflective system, rendering it less able to oppose the influence exerted by the progressively stronger automatic system.

Aside from the long-term effects of substance use on both automatic and reflective processes, most models agree that premorbid individual differences in both type of processes can also influence the development and maintenance of addictive behaviours. Indeed, animal studies have shown individual differences in incentive salience attribution to play a role in predisposing individuals to addictive behaviours (Squeglia et al., 2014). Especially strong support for dual-process theories comes from studies showing that individual differences in cognitive control moderate the relationship between automatic responding to AOD cues and actual AOD use. For
instance, Houwen and Wiers (2009) found that positive implicit alcohol associations predicted alcohol use only in participants with poor response inhibition (i.e., weak cognitive control), whereas implicit alcohol associations were not related to future alcohol use among participants with good inhibitory control. Other findings have found a similar moderating effect of working memory on the ability of automatic AOD-related associations to predict later AOD use (Grenard et al., 2008; Thush et al., 2008), although some inconsistencies have been observed (for a review, see Wiers et al., 2015).

As suggested above, many studies have shown that AOD use and disorders are associated with abnormal attentional biases towards drug-related stimuli (see Field and Cox, 2008; for a review). Notably, recent studies have also linked AOD use and disorders with abnormal attentional biases for non-drug reward-related stimuli. One such study found that adolescents who reported higher levels of alcohol, tobacco, and cannabis use showed greater attentional engagement with cues that predicted non-drug reward (van Hemel-Ruiter et al., 2013). In another study, people in methadone treatment for opiate dependence showed significantly greater attentional capture stimuli related to non-drug reward in a visual search task, compared to healthy controls (Anderson et al., 2013). On the basis of this finding, Anderson et al. (2013) suggested that previous findings of attentional biases toward AOD-related cues in people with substance use disorders may in fact have arisen from a pre-existing attentional bias toward cues associated with reward in general. In other words, those individuals with a general predisposition towards automatic attentional capture by reward-related stimuli may be more susceptible to developing AOD-use disorders.

Individual differences in attentional capture by stimuli associated with non-drug reward may be considered to reflect a vulnerability within automatic processes, somewhat parallel to individual differences in attribution of incentive salience to reward-associated cues in the animal literature. Importantly, as mentioned above, animal studies suggest that such individual differences in attribution of incentive salience may indicate individual vulnerability to developing AOD-use problems. According to dual-process theories, the degree to which such individual differences in attentional capture by stimuli associated with reward actually influence behaviour would depend on the degree of cognitive control available to the individual. To date, however, studies have focused on automatic/implicit behaviour and attitudes toward AOD-related cues only; no existing study has explored whether cognitive control (measured as quickly as possible. On most trials, one of the non-target circles is of similar salience in this task, performance may around a randomly-chosen circle), the trial was deemed an omission trial and no reward be considered a re-
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![Fig. 1. Sequence of trial events in the value-modulated attentional capture (VMAC) task.](image)

On each trial, participants responded by moving their eyes to the diamond target in the search display. One of the non-target circles could be a colour singleton distractor. Fast, correct responses received monetary reward, depending on the distractor colour. A high-value distractor colour reliably predicted large reward (500 points); a low-value colour reliably predicted small reward (1 point); on distractor-absent trials, large and small rewards were equally likely. If any gaze fell within a small region of interest (ROI) surrounding the distractor (or, on distractor-absent trials, an equivalent ROI positioned around a randomly-chosen circle), the trial was deemed an omission trial and no reward was delivered.

eye-movement (a saccade) to a diamond-shaped target among circles, as quickly as possible. On most trials, one of the non-target circles is coloured, either red or blue (all other shapes are grey; see Fig. 1); hence this is an example of an additional singleton task (Theeuwes, 1991, 1992). The colour-singleton circle is referred to as the distractor. The colour of the distractor on a particular trial signals the magnitude of reward that is available. As such, these colours constitute Pavlovian signals of reward magnitude. Crucially, under these conditions the reward-predictive stimulus (the coloured distractor) is not the target to which participants must orient their gaze (or attention) in order to receive reward. In fact, the task is arranged such that, if participants look at or near the distractor prior to looking at the target, the reward on that trial is omitted. Nevertheless, participants are more likely to look at the distractor when it appears in the colour signalling high reward than the colour signalling low reward (Failing et al., 2015; Le Pelley et al., 2015; Pearson et al., 2015; Pearson et al., 2016), a finding referred to as value-modulated attentional capture (VMAC). Since participants are never rewarded for looking at the distractor in this task, there is no reinforcement for the instrumental response of looking at the distractor. Consequently, the VMAC procedure used by Le Pelley et al. (2015) provides a clearer demonstration of the modulation of attentional capture as a result of Pavlovian reward prediction.

The current study used the VMAC procedure to examine how (non-drug) reward-modulated attentional capture is related to AOD use in a sample of university students, and whether cognitive control (measured using a goal-directed selective attention task) moderates such a relationship. In this task, participants are required to select a target stimulus while ignoring a distractor stimulus. As the target and distractor stimuli are of similar salience in this task, performance may be considered a reflection of the extent to which participants are applying top-down, goal-directed attention to select the target and
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