Drug and Alcohol Dependence xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Drug and Alcohol Dependence

journal homepage: www.elsevier.com/locate/drugalcdep

Review

Deficits in behavioural inhibition in substance abuse and addiction: A meta-analysis

Janette L. Smith[a,*], Richard P. Mattick[a], Sharna D. Jamadar[b], Jaimi M. Iredale[a]

[a] National Drug and Alcohol Research Centre, University of New South Wales, Sydney 2052, NSW, Australia
[b] Monash Biomedical Imaging & School of Psychological Sciences, Monash University, Melbourne 3800, VIC, Australia

ARTICLE INFO

Article history:
Received 11 April 2014
Received in revised form 14 August 2014
Accepted 14 August 2014
Available online xxx

Keywords:
Inhibition
Behavioural control
Substance abuse
Pathological gambling
Meta-analysis
Review

ABSTRACT

Aims: Deficits in behavioural inhibitory control are attracting increasing attention as a factor behind the development and maintenance of substance dependence. However, evidence for such a deficit is varied in the literature. Here, we synthesised published results to determine whether inhibitory ability is reliably impaired in substance users compared to controls.
Methods: The meta-analysis used fixed-effects models to integrate results from 97 studies that compared groups with heavy substance use or addiction-like behaviours with healthy control participants on two experimental paradigms commonly used to assess response inhibition: the Go/NoGo task, and the Stop-Signal Task (SST). The primary measures of interest were commission errors to NoGo stimuli and stop-signal reaction time in the SST. Additionally, we examined omission errors to Go stimuli, and reaction time in both tasks. Because inhibition is more difficult when inhibition is required infrequently, we considered papers with rare and equiprobable NoGo stimuli separately.
Results: Inhibitory deficits were apparent for heavy use/dependence on cocaine, MDMA, methamphetamine, tobacco, and alcohol (and, to a lesser extent, non-dependent heavy drinkers), and in pathological gamblers. On the other hand, no evidence for an inhibitory deficit was observed for opioids or cannabis, and contradictory evidence was observed for internet addiction.
Conclusions: The results are generally consistent with the view that substance use disorders and addiction-like behavioural disorders are associated with impairments in inhibitory control. Implications for treatment of substance use are discussed, along with suggestions for future research arising from the limitations of the extant literature.

Contents

* Corresponding author. Tel.: +61 2 9385 0274; fax: +61 2 9385 0222.
E-mail address: janette.smith@unsw.edu.au (J.L. Smith).

http://dx.doi.org/10.1016/j.drugalcdep.2014.08.009
0376-8716/

1. Introduction

There has been increasing interest in the contribution of impairments in inhibitory control of overt behaviour to the development and maintenance of addiction (e.g., Fillmore, 2003; Goldstein and Volkow, 2002; Hester et al., 2010; Jentsch and Pennington, 2014; Jentsch and Taylor, 1999; Leeman et al., 2014a,b; Lubman et al., 2004; Perry and Carroll, 2008; Yücel and Lubman, 2007). The ability to delay, withhold or interrupt a behavioural response is a key aspect of executive function; the suppression of an inappropriate immediate response allows time for other processes (e.g., formulating predictions of the consequences of possible actions) to facilitate the transition to a more appropriate course of behaviour (Barkley, 1997). Effective inhibitory control is required in everyday life, as when we must withhold the expression of spiteful, peculiar or otherwise socially inappropriate thoughts. In the context of substance use, impaired control is implicated in using more of the substance, or using more often, than intended, and in failed attempts to control or reduce use. These impairments are reflected in the DSM-5 criteria for substance use disorders (American Psychiatric Association, 2013).

The construct of behavioural inhibition is usually measured via self-report or observer-report measures of impaired control/rash impulsiveness as a trait, or via behavioural performance on tasks requiring inhibition. An extensive literature suggests that self-reported impairments in control are reliably associated with greater past and future substance use (e.g., Gullo et al., 2014; Leeman et al., 2014a,b, 2009; Lester et al., 2012; Ryan et al., 2013; Verdejo-García et al., 2008). In this article, we review the evidence for an inhibitory deficit in the two experimental paradigms most commonly used to assess inhibition, the 'Go/NoGo' and 'stop-signal' tasks.

In the Go/NoGo task, participants must make a button press response to stimuli of one type (Go stimuli, e.g., a green shape) and withhold that response to stimuli of another type (NoGo stimuli, e.g., a red shape). The need for inhibition to NoGo stimuli can be manipulated by requiring button presses to Go stimuli to be fast (e.g., Benikos et al., 2013; Jodo and Kayama, 1992) or by decreasing NoGo stimulus probability, ensuring the Go response is prepotent by virtue of its high frequency. Variations on the Go/NoGo task may include a cue which precedes and predicts the Go or NoGo stimulus; the urgency of inhibition is increased when the cue incorrectly predicts a Go stimulus (e.g., Randall and Smith, 2011). Note that many continuous performance tasks fall under this umbrella, although they may not be explicitly referred to as Go/NoGo tasks. The main variables of interest are the rate of commission errors (failure to inhibit a response to NoGo targets, or false alarms), the rate of omission errors (failure to respond to Go targets, or misses), and the reaction time (RT) to Go stimuli.

The pattern of performance differences is important in determining the underlying deficit. A high rate of commission errors, with no change in omission errors and (sometimes) a short RT, is the clearest evidence of a deficit in inhibition. In contrast, a high rate of omission errors may reflect problems with sustained attention (Trommer et al., 1988), or in conjunction with long RT, slowing of responses in order to compensate for a deficit in inhibition (Wright et al., 2014). Further, increased rates of both commission and omission errors may be interpreted as a failure to adequately discriminate between stimuli requiring and not requiring a response. When increases are observed in all three measures, a more general deficit in executive control is suggested (Wright et al., 2014). Thus, the pattern of performance as a whole must be taken into account when interpreting group differences in the Go/NoGo task.

The stop-signal task is a second experimental paradigm viewed as a prototype for measuring inhibitory control (Logan and Cowan, 1984). In a typical stop-signal task, participants press one button with the left hand to stimuli of one type (e.g., a leftward arrow), and another button with the right hand to stimuli of another type (e.g., a rightward arrow). On some trials, a "stop-signal" (e.g., an auditory tone) is presented after the primary (Go) stimulus, indicating that the participant should withhold their response to the Go stimulus. The stop-signal is presented randomly and at variable delays on a low percentage of trials, often, but not always, 25%, so that participants cannot predict when stop-signals will occur. Note that several methods are available for setting stop-signal delays; these are functionally equivalent (Logan, 1994; Logan et al., 1984). According to Logan and Cowan's (1984) seminal model, whether a response is successfully inhibited on a stop-signal trial depends on the relative finishing times of response execution processes (triggered by the Go stimulus) and response inhibition processes (triggered by the stop-signal). A unique feature of this task is that it allows the calculation of the stop-signal reaction time (SSRT), the time required to stop a response, estimated from the probability of stopping at different stop-signal delays (Logan, 1994). Healthy control adults usually require 200–250 ms to stop a response (e.g., Band et al., 2003). The ability to estimate the SSRT represents a strong advantage of the stop-signal task over the Go/NoGo task, as it is not possible to estimate the time required for inhibition in the Go/NoGo task. The stop-signal task holds an additional advantage over the Go/NoGo task in that the speed of the Go response and the speed of the Stop response are considered to be independent (Logan and Cowan, 1984; Logan et al., 1984). Thus, a longer SSRT is reflective of an inhibitory deficit, while a longer Go RT is reflective of inattention (e.g., Lijffijt et al., 2005); the meaning of a longer SSRT is not altered by the pattern of results for Go RT. Disadvantages of the stop-signal task relative to the Go/NoGo task include that the stop-signal task is designed to achieve approximately 50% failures of inhibition overall, and participants may thus feel that the task

Please cite this article in press as: Smith, J.L., et al., Deficits in behavioural inhibition in substance abuse and addiction: A meta-analysis. Drug Alcohol Depend. (2014), http://dx.doi.org/10.1016/j.drugalcdep.2014.08.009