BIS impulsivity and acute nicotine exposure are associated with discounting global consequences in the Harvard game

Lee Hogarth*, David J. Stillwell and Richard J. Tunney

School of Psychology, University of Nottingham, Nottingham, UK

Objective  The Barratt Impulsivity Scale (BIS) provides a transdiagnostic marker for a number of psychiatric conditions and drug abuse, but the precise psychological trait(s) tapped by this questionnaire remain obscure.

Method  To address this, 51 smokers completed in counterbalanced order the BIS, a delay discounting task and a Harvard game that measured choice between a response that yielded a high immediate monetary payoff but decreased opportunity to earn money overall (local choice) versus a response that yielded a lower immediate payoff but afforded a greater opportunity to earn overall (global choice).

Results  Individual level of BIS impulsivity and self-elected smoking prior to the study were independently associated with increased preference for the local over the global choice in the Harvard game, but not delay discounting.

Conclusions  BIS impulsivity and acute nicotine exposure reflect a bias in the governance of choice by immediate reward contingencies over global consequences, consistent with contemporary dual-process instrumental learning theories. Copyright © 2013 John Wiley & Sons, Ltd.

INTRODUCTION

The Barratt Impulsivity Scale (BIS) is a commonly used questionnaire which provides a marker for a number of psychiatric conditions including drug abuse, bipolar disorder, suicide, psychopathy and attention deficit hyperactivity disorder (Stanford et al., 2009). This questionnaire asks participants to endorse such items as ‘I do things without thinking’ and derives three main factors: nonplanning, attentional and motor impulsivity (Patton et al., 1995). Given the ubiquity of this questionnaire in neuropsychiatric research it is of great importance to clarify what psychological trait(s) this questionnaire taps. A number of studies have addressed this question by examining the relationship between BIS impulsivity and behavioural measures in experimental procedures. However, such studies often employ multiple questionnaires, each with multiple subscales, so the chances of obtaining a false positive is typically higher than $p = 0.05$ (Simmons et al., 2011). Thus, to isolate the psychological processes tapped by the BIS, one must focus on behavioural correlates that have been replicated.

Several studies have examined the relationship between BIS impulsivity and behavioural measures of inhibition, including the Stroop task, stop signal reaction time task, and go/no-go task (Cheung et al., 2004; Enticott et al., 2006; Reynolds et al., 2006). The failure of these studies to find a consistent association suggests that BIS impulsivity does not simply reflect impaired inhibitory control. The delay discounting task has shown a similarly inconsistent correlation with BIS impulsivity. In the delay discounting task, subjects are required to state whether they would prefer a smaller monetary value now or a larger monetary value later, and the tendency to choose the immediate reward reflects great sensitivity to immediate reward contingencies and/or a shorter temporal horizon for evaluating future rewards (Bickel and Johnson, 2003). Although preference for immediate reward has been associated with the BIS nonplanning subscale (de Wit et al., 2007) and with the BIS attentional subscale (Mitchell, 1999), at least three studies have found no such associations (Reynolds et al., 2006; Krishnan-Sarin et al., 2007; Bjork et al., 2009). Thus, there remains a question as to the reliability of the correlation between BIS impulsivity and delay discounting, and whether temporal horizon is an underlying trait.

Hogarth et al. (2012c) examined the relationship between BIS impulsivity in a sample of smokers and performance in a human outcome-devaluation task.
This method was translated from behavioural neuroscience to quantify the extent to which reward seeking was goal-directed, that is, governed by an expectation of the current value of the outcome versus habitual, that is, elicited by contextual stimuli that formed a direct association with the response without retrieving an expectation of the outcome (so called S–R learning; Dickinson and Balleine, 2010). The results showed that the BIS motor impulsivity subscale was associated with impaired goal-directed control over reward seeking, and correspondingly, a tendency to perform habitually. As this same effect can be produced by extended practice (Tricomi et al., 2009), stress induction (Schwabe et al., 2011), acute alcohol administration (Hogarth et al., 2012a) and by conflicting appraisal of alternative rewards (Ostlund et al., 2010; Hogarth et al., 2012d), one may argue that BIS impulsivity reflects a reduced capacity to retrieve future prospects in the service of action selection (for reviews of this issue, see Dalley et al., 2011; Hogarth et al., 2012b).

In a related study, Hogarth (2011) found that the propensity to smoke was increasingly decoupled from subjective craving (intent) as level of BIS nonplanning impulsivity increased. This finding suggests that whereas the smoking behaviour of low nonplanning impulsive individuals is governed by desire (nominally goal-directed), smoking behaviour in high nonplanning impulsive individuals is elicited directly by contextual cues independently of desire (nominally habitual). These two studies (Hogarth, 2011; Hogarth et al., 2012c) are consistent in suggesting that BIS impulsivity reflects impaired goal-directed control, but are discordant in which subscale is the crucial correlate (nonplanning versus motor). Of relevance to this question is a brain imaging study by Matsuo et al. (2009) which found that grey matter volumes were reduced in the right orbitofrontal cortex (OFC) as BIS nonplanning impulsivity increased, and reduced in the left OFC as BIS motor impulsivity increased. Importantly, the OFC is thought to play a role in both the representation of economic prospects (Padoa-Schioppa, 2007; Wallis, 2007; FitzGerald et al., 2009), and in goal-directed control of action selection based upon such representations (Valentin et al., 2007; Balleine and O’Doherty, 2010). Thus, although these studies leave a question concerning the relevant BIS subscale, they nevertheless converge on the view that BIS impulsivity is driven by a neurocognitive impairment in capacity to control choice by knowledge of the consequences.

The primary aim of the current experiment was to test whether BIS impulsivity would be associated with preference for the immediate payoff in the Harvard game. The Harvard game was developed by behavioural economists to assess the capacity of individuals to utilise knowledge of long-term consequences to determine choice (Herrnstein and Prelec, 1991; Herrnstein et al., 1993). In the Harvard game, participants can choose a ‘local’ option that yields an immediately higher valued monetary reward, but ultimately decreases ‘global’ value by reducing the payoff for all choices made in the future. By contrast, the ‘global’ choice yields a lower immediate payoff than the local choice, but because the global choice does not impact on the payoff of all future choices, ultimately it yields greater overall value. Studies using this procedure have indicated that participants initially prefer the local choice, but with experience of the task, there is a linear increase in choice of the global response as participants acquire knowledge of the greater overall payoff of this response (Tunney and Shanks, 2002; Stillwell and Tunney, 2009). Using this task, Heyman and Dunn (2002) found that illicit drug users favoured local choice compared with non-drug users, suggesting a preference for immediate reward or impaired use of global outcomes in decision making. However, the two groups did not differ significantly with respect to BIS impulsivity, and BIS impulsivity did not correlate significantly with local choice across the sample as a whole. However, given that we have found that BIS impulsivity within a sample of smokers was associated with behavioural proxies of intentional control over behaviour (Hogarth, 2011; Hogarth et al., 2012c), the aim here was to assess whether within a similar smoker sample, a correlation between BIS impulsivity and performance in the Harvard game would be found.

A delay discounting task was also included to reassess the equivocal association with BIS impulsivity reported in the published literature (Mitchell, 1999; Reynolds et al., 2006; de Wit et al., 2007; Krishnan-Sarin et al., 2007; Bjork et al., 2009). Finally, as nicotine dependence and/or acute nicotine exposure has been associated with delay discounting (Bickel et al., 1999; Mitchell, 1999; Mitchell, 2004; Skinner et al., 2004; Heyman and Gibb, 2006; Johnson et al., 2007; Reynolds et al., 2007; Sweitzer et al., 2008; Spillane et al., 2010), we examined whether level of dependence (daily versus non-daily smoking) and/or acute nicotine exposure (self-elected smoking prior to the study or not) would be associated with delay discounting and/or performance in the Harvard game.

METHOD
Participants
Fifty-one healthy students from Nottingham University volunteered to take part in the experiment after being
reduced by e-mails, posters and leaflets (54.9% women, mean age = 21.6, STD = 4.2). This sample was selected because smokers typically show greater impulsivity than the general population (Bickel et al., 1999; Mitchell, 1999; Mitchell, 2004; Skinner et al., 2004; Heyman and Gibb, 2006; Johnson et al., 2007; Reynolds et al., 2007; Sweitzer et al., 2008; Spillane et al., 2010). Only participants who self-identified as smokers for greater than 2 years were included in the study. Only minimal screening of demographics and smoking history/dependence was obtained to constrain the procedure under half an hour. Participants reported their age, gender and then answered the questions (i) ‘How often do you usually smoke’, by ticking the phrase ‘At least once per day’ or ‘Less than once per day’ (which defined smoking status: Daily, non-daily), and (ii) ‘Did you smoke at any point prior to the experiment today’, by ticking the answer ‘yes’ or ‘no’ (which defined prior smoking).

Participants then completed the BIS impulsivity questionnaire (Patton et al., 1995). This questionnaire contains three subscales: (i) Motor impulsivity, for example, ‘I do things without thinking’, assesses propensity for action without thought; (ii) nonplanning impulsivity, for example, ‘I plan tasks carefully’, assesses capacity for purposive future action; and (iii) attentional impulsivity, for example, ‘I don’t pay attention’, assesses capacity for sustained attention. These subscales were examined following analysis of the total BIS score to determine if there was any selectivity. The sample’s mean BIS score was 67.2 (SD = 10.5), which is slightly higher than a published norm of 62.3 (Stanford et al., 2009).

Procedure

Participants provided written informed consent to participate followed by the Harvard game, delay discounting task and BIS questionnaire in counterbalanced order. Finally, participants were debriefed and paid in accordance with their performance in the Harvard game (see following text).

Harvard game

Participants first read the following instructions on the screen:

Your task is simple. You will have to repeatedly choose between two buttons, marked ‘Left’ and ‘Right’. Simply click on a button with the mouse to register your choice. As a result of your choices you will win Points. After every choice you will be shown your Points from each choice as well as your cumulative Points. As you gain more Points, Pacman will eat more dots and get larger! However, choices will also use up Game Units. After every choice you will be shown, the Game Units used up from each choice as well as your Game Units remaining. Once these have run out, then the game is over. You will play the game eight times. Try and beat your previous score in every game! Your payment from this experiment will be based on the number of points that you gain during the games. This will be calculated on the basis of 0.12p/point. This means you can earn between £5 and £7.20. After each game, you will be shown your current earnings so far. That’s all there is to it—just try to win as many Points from the computer as you can before you run out of Game Units. Take as much time as you wish and please do not write anything down during the experiment.

Participants were then told that payment for the whole experiment would be based on the number of points that they gained and multiplied by 0.12p/point to calculate their earnings.

The Harvard task (Stillwell and Tunney, 2009) consisted of eight games, each with 150 game units. This equated to between 53 and 150 trials per game, depending upon participants’ choices. Figure 1 shows the main screen of the game. At the top centre of the screen, a horizontal bar labelled ‘Game Units Remaining’ provided clear feedback concerning the global losses associated with each key. Above this, another horizontal bar labelled ‘Points’ depicted the total number of points gained during that game. This bar was based around an animated Pac-Man figure that moved from left to right and grew larger as the total number of Points increased. These were designed in order to increase the salience of feedback concerning the payoff (rewards and costs) associated with each key. Participants made their
choices by selecting one button or another using the mouse. On each trial, the points gained and game units lost information was updated, overwriting the outcome of the previous trial, so that participants would learn the differential payoffs associated with left and right responses (counterbalanced between participants).

After each choice, both buttons were disabled for between 0.5 and 1.5 s in proportion to the number of game units lost on that trial. This variable delay was imposed to ensure that the total duration of each game was the same irrespective of the proportion of local or global responses, given that choosing the local key used up more game units and so would otherwise result in faster termination of the experiment, which may act as an incentive.

At the end of each game, a new screen summarised the total points gained during that game and the previous games. The top-centre of the screen displayed textually the total points gained during the game, how much those points were worth monetarily, and the maximum number of points that it was possible to gain during a game. Below this, a cartoon face was presented, contingent upon whether the participant gained more points during the recently completed game than the previous game. If the participant gained more points, the face smiled; if an equal number of points were earned, it was neutral; and if a lesser number of points were collected, it frowned. Beneath these, a bar chart graphically detailed the total points gained on that game and on all previous games.

**Payoff schedules**

Participants received points for every choice that they made, but lost game units. Choosing the local button returned 10 points per trial, but increased the rate at which game units were lost over the next 10 trials for both buttons. In contrast, choosing the global key returned 5 points per trial but cost fewer game units in the long term. The number of game units lost after each choice was determined by the following formula:

\[ GU = 1 + 2 \times P(b1 - 10) \]

Where \( GU \) is the number of game units lost, and \( P(b1-10) \) is the proportion of choices allocated to the local button over the preceding 10 trials. In essence, choosing the local button over the global button earned twice the number of points but used up three times as many game units over the next 10 trials, and so the lost game units represent a lost opportunity to earn money in the future.

By choosing the local key, the participant is committed to losing an extra 0.2 game units for the next 10 trials, with each additional lost unit relinquishing the potential to consistently earn 5 points per game unit. This is why although for any single trial the participant would earn more by choosing the local option, in the long term it is optimal to choose the global option. Over the 150 game units of each game, consistently choosing the global button would return a cumulative payoff of 750 points, whereas consistently choosing the local button would return a cumulative payoff of 530 points.

The average number of points gained by participants was 5188 (\( SD = 420 \)), leading to an average payment of £6.23 (maximum obtained: £7.12; minimum obtained: £5.26). The proportion of responses allocated to the global button was recorded across eight games. A low proportion of responses allocated to the global button indicates increased discounting of the overall payoff in favour of the immediately higher payoff.

**Delay discounting task**

Participants first read instructions on the screen: ‘You are going to be asked to make choices between an immediate monetary reward and another monetary reward delayed by a certain length of time. Please use the mouse to select the option that you would prefer. Assume that the delayed amount will be adjusted for inflation. The rewards are hypothetical, however please make the choices as if you were given the choice for real. An example of the kind of choice you will be asked to make is between £50 now and £100 tomorrow. Take a second to consider which you would prefer, and then press the OK button to continue to the experiment.’ The experimenter then verbally explained that adjusting for inflation would mean that the delayed amount would still have the same purchasing power as having the same amount today. Participants were then repetitively presented with various monetary rewards on the left-hand side of the computer screen to be earned immediately versus £1000 delayed by various lengths of time on the right-hand side. Participants pressed the button below the option that they preferred with the mouse, which highlighted the button, and then chose ‘New Choice’ in the centre, which confirmed their choice and updated the screen with the next available choice. This meant that, for each decision, the participant’s mouse started in the centre of the screen, and so it did not bias a particular choice. Participants could change their mind by choosing the other option before pressing ‘New Choice’.

---

Copyright © 2013 John Wiley & Sons, Ltd.

DOI: 10.1002/hup
The delays and amounts used have been commonly used in previous delay discounting research (Rachlin et al., 1991; Bickel et al., 1999), although the amounts were denominated in British Pounds rather than US Dollars. The 27 immediate monetary rewards were £1000, £990, £960, £920, £850, £800, £750, £700, £650, £600, £550, £500, £450, £400, £350, £300, £250, £200, £150, £100, £80, £60, £40, £20, £10, £5 and £1. The seven delays associated with the delayed £1000 alternative were 1 week, 2 weeks, 1 month, 6 months, 1 year, 5 years and 25 years. Each delay was presented in a block, with the monetary amount randomised across trials. Moreover, the order of the delays was randomised as sequential ordering of delays can alter participants’ preferences (Stillwell and Tunney, 2012). Between each delay, a pop-up message alerted the participant to the change in delay.

To calculate a participant’s delay discounting parameter (k), an indifference point was first established by calculating an average between the maximum immediate monetary amount chosen and the minimum delayed monetary amount chosen (Bickel et al., 1999). This value reflects the point at which the participant is indifferent between the immediate reward and the delayed reward. Next, nonlinear regression was used to fit the seven indifference points from each participant to a hyperbolic function, according to the methodology established by Bickel et al. (1999). Because the distribution of k is often found to be non-normal (Rachlin et al., 1991; Bickel et al., 1999), the data were approximately normalised using the natural-log transformation. The k parameter reflects the steepness of the discount curve, whereby greater k values reflect a sharper decline in the subjective value of money as the delay to obtain that money increases.

RESULTS

Participants

Of the 51 participants, there were 16 non-daily smokers and 11 daily smokers who had not smoked prior to the experiment, and 24 daily smokers who had smoked prior to the experiment. This smoker group variable (3) was analysed to determine the impact of dependence level (daily vs non-daily) and acute nicotine exposure (prior vs no prior smoking). Total BIS scores were entered into the same analysis of covariance (ANCOVA) as a continuous variable. Subsequent analysis was undertaken to examine BIS subscales and potential confounding variables.

Harvard game

The proportion of global responses obtained in the eight games was examined with smoker group (3) as a categorical variable and BIS impulsivity as a covariate in ANCOVA. This analysis yielded a main effect of game, $F(7,329) = 2.10, p < 0.05$, indicating that participants acquired an increased choice of the global response across training on the Harvard game. There was no interaction between game and smoker group or BIS impulsivity, $F_s < 1$, indicating that these groups acquired a preference for the global response at a comparable rate.

However, there was a main effect of BIS impulsivity, $F(1,47) = 6.70, p < 0.02$, shown in Figure 2(A/B). This effect could not be explained by age, because multiple regression with the proportion of global responses as the dependent variable, and BIS impulsivity and age as predictors indicated that BIS impulsivity served as an independent predictor in this model, $t = -2.18, p < 0.05$, whereas age did not, $t = -0.56, p = 0.58$. Moreover, there was no significant difference in BIS impulsivity between the smokers groups, $F < 1$, suggesting the effect shown in Figure 2(A/B) could not be attributed to either differential tobacco dependence or prior smoking across levels of BIS. Finally, separate assessment of the three BIS scales (as continuous variables) indicated that the greater proportion of global responses was predicted more strongly by the BIS motor scale, $F(1,49) = 5.30, p < 0.03$, compared with the nonplanning, $F(1,49) = 1.84, p = 0.18$, or attentional scales, $F(1,49) = 2.51, p = 0.12$. However, none of the three scales emerged as an independent predictor of global responses in multiple regression, $ts < -1.06, ps > 0.28$, suggesting that these scales are too highly interrelated to partial out their independent effect. Overall, therefore, the data suggest that BIS impulsivity is associated with discounting global consequences in the Harvard game.

The initial ANCOVA also yielded a main effect of smoker group, $F(2,47) = 3.22, p < 0.05$, shown in Figure 2(C/D). Exploration of this effect indicated that there was no reliable difference between daily and non-daily smokers who had not smoked prior to the experiment, $F < 1$, whereas these two groups collapsed chose the global response significantly more frequently than daily smokers who had smoked prior to the experiment, $F(1,49) = 4.24, p < 0.05$. This effect of prior smoking on global responses remained significant when age and BIS impulsivity were included as covariates, $F(1,47) = 6.12, p < 0.02$, indicating that these potentially confounding variables could not explain the effect. Therefore, these analyses suggest that acute smoking prior to the experiment increased discounting of global consequences in the Harvard game.
Delay discounting task

The delay discounting parameters ($k$) was natural-log transformed and entered into ANCOVA with smoker group (3) as a categorical variable and BIS impulsivity as a continuous variable. This analysis yielded no significant main effects of smoker group, $F < 1$, or BIS impulsivity, $F(1,47) = 1.39$, $p < 0.24$. Moreover, delay discounting was not predicted by any of the three BIS subscales entered separately, $F_s(1,49) < 1.41$, $p_s > 0.24$.

The mean $k$ value for the sample as a whole was $k = 0.31$, SEM = 0.10. There was no significant correlation between $k$ values and the mean proportion of global choices, $r = 0.035$, $p = 0.80$.

DISCUSSION

The current experiment found that preference for the local choice in the Harvard game was associated with BIS impulsivity and acute prior smoking in a sample of young adult smokers. The results showed that the proportion of global responses in the Harvard game increased with training, suggesting participants acquired knowledge about the higher overall payoff of the global choice with training, and there were no group differences in the acquisition of this preference. However, BIS impulsivity and acute prior smoking were associated with a greater overall proportion of local responses across this learning curve. These two-group effects were independent in that they were not confounded and could not be readily attributed to the other potentially confounding variables, age or daily smoking status. These data support the view that BIS impulsivity and acute nicotine exposure reduced the impact of global consequences, and/or increased the impact of immediate payoff, increasing tendency towards the local choice.

It is not easy to isolate the information within the Harvard game to which the groups were differentially sensitive. Figure 1 shows that following a local choice, the high BIS group and prior smokers may have been hypersensitive to the greater increment in points won or hyposensitive to greater number of game units lost, or following a global choice, may have been hyposensitive to the greater total points won or hypsensitive to the reduced number of game units lost, or any combination or comparison over time of these sources of feedback. A study by Potts et al. (2006) may be relevant in resolving this question insofar as in this study BIS impulsivity was associated with a reduced electroencephalographic (EEG) error related negativity following erroneous responses to targets that produced punishment (decreases in money). The implication is that high BIS impulsive individuals in the Harvard game were less sensitive to the loss of game units following a local choice, but this remains to be proven.
The high BIS group’s preference for the local choice in the Harvard game found here may reflect the same trait that is responsible for their impaired goal-directed control (Hogarth et al., 2012c) and the decoupling of their drug self-administration from subjective desire (Hogarth, 2011). According to this claim, the global response may be goal-directed in that it is governed by the retrieval of an expectation of the global value of this response, whereas the local response may be habitual in that it is elicited by procedural stimuli that have formed a direct association with that response as a result of contingent reinforcement by the immediate payoff. This interpretation favours the link between impulsivity and habit learning voiced by behavioural neuroscience (Dalley et al., 2011) and cognitive neuroscience (Koob and Volkow, 2010), but remains to be experimentally confirmed with respect to action control within the Harvard game.

The finding that BIS impulsivity was associated with increased local choice in the Harvard game is discordant with Heyman and Dunn (2002). They found that illicit drug users favoured the local choice compared with non-drug users, but these groups were matched with respect to BIS impulsivity, and BIS impulsivity did not correlate with local choice in the sample as a whole. The difference between these studies might suggest that correlations within drug user populations are superior at revealing behavioural correlates of impulsivity, and that inclusion of non-drug using individuals washes out such relationships.

We found that acute nicotine exposure (self-elected smoking prior to the experiment) was more strongly associated with a preference for the local choice in the Harvard game than was level of nicotine dependence (daily vs non-daily smoking). Although we cannot unconfound nicotine exposure and dependence within these correlational data, several animal studies support the causal role for acute nicotine exposure in generating preferences for immediate payoff. Specifically, three studies have shown that acute nicotine administration increases delay discounting (Dallery and Locey, 2005; Locey and Dallery, 2009; Kolokotroni et al., 2011), and similar effects have been found with cocaine administration (Mendez et al., 2010; see also; Heil et al., 2006; Setlow et al., 2009; Tsutsui-Kimura et al., 2010). This claim suggests that preference for immediate payoff is part of the acute drug exposed state rather than pre-existing vulnerability factor for drug dependence (Bickel and Johnson, 2003; Stillwell and Tunney, 2012).

More troubling is why we obtained no effects with delay discounting. The absence of a correlation between BIS impulsivity and delay discounting adds weight to the currently equivocal literature in suggesting there is little evidence for this association (Mitchell, 1999; Reynolds et al., 2006; de Wit et al., 2007; Krishnan-Sarin et al., 2007; Bjork et al., 2009). However, it is less clear why we found no association between proxies for nicotine dependence/exposure and delay discounting when such associations have been reported a number of times (Bickel et al., 1999; Mitchell, 1999; Mitchell, 2004; Skinner et al., 2004; Heyman and Gibb, 2006; Johnson et al., 2007; Reynolds et al., 2007; Sweitzer et al., 2008; Spillane et al., 2010). It is possible that our within-smoker contrast is less sensitive than comparison of smokers versus non-smokers, although within-smoker associations with delay discounting have been reported within this literature. Another possibility is that our use of a hypothetical delay discounting task versus the Harvard game that used actual rewards was responsible for the delay discounting task less sensitive to group effects (Heyman and Gibb, 2006). However, relationships between recent smoking and a hypothetical delay discounting task have been demonstrated with larger smoker samples (Sweitzer et al., 2008), so it is possible that a combination of small sample size, hypothetical discounting and use of within-smokers contrasts combined to yield null result. Overall, therefore, we conclude that the Harvard game was more sensitive to individual differences in BIS impulsivity and acute nicotine exposure than was the delay discounting task, and may thus be a better tool for studying decision making abnormalities in addict populations.

CONFLICT OF INTERESTS
The authors declared no conflict of interest in this research.

ACKNOWLEDGEMENTS
This work was supported by a supported by an ESRC studentship (R.T.; ES/F021801/1) and an MRC award (L.H.; G0701456).

REFERENCES