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BRIEF COMMUNICATION

Relation of individual differences in impulsivity to nonclinical emotional decision making

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Abstract

Impulsivity has been identified as a behavioral precursor to addiction, and may be the manifestation of a neurological vulnerability. The present study investigated whether individual differences in impulsivity were associated with performance on the Iowa Gambling Task (IGT, a test of emotional decision making thought to be associated in part with ventromedial prefrontal cortex function) and the Wisconsin Card Sorting Task (WCST, a set-shifting thought to be associated in part with dorsolateral prefrontal cortex function). Subjects were screened for impulsivity using the BIS-11 (self-report) and a delay discounting questionnaire (a behavioral measure of impulsivity). High impulsivity was associated with poorer performance on the final block of trials of the IGT but was not significantly related to WCST performance. Both measures were significantly correlated with scores on the BIS. These results provide support for hypothesis that, in a nonclinical sample, impulsivity may vary systematically with performance on neuropsychological indicators of prefrontal function. (*JINS*, 2008, *14*, 878–882.)

Keywords: Impulsive behavior, Personality, Decision making, Delay-aversion, Frontal lobe, Choice behavior

INTRODUCTION

Impulsivity is a multidimensional construct, characterized as a tendency to place immediate gain ahead of long-term consequences (Logue, 1995), quickly responding to stimuli without adequate forethought (Moeller et al., 2001), and failure to inhibit a prepotent response (Horn et al., 2003). This construct has been consistently linked to various addictive behaviors, including substance abuse and pathological gambling (Petry, 2001). In addition, impulsivity has been posited as a predisposing factor linking substance abuse with aggression (Fishbein, 2000), pathological gambling (Chambers & Potenza, 2003), and conduct disorder and borderline personality disorder (Moeller et al., 2001).

Importantly, an impulsive personality style might represent a behavioral marker underlying a predisposition toward externalizing psychopathology—a notion supported by prospective studies relating neurobehavioral disinhibition with later adult development of substance abuse (e.g., Habeych et al., 2005). As such, a neuropsychological framework might be of particular value in exploring the mechanisms through which nonclinical individual differences in impulsivity are expressed in behavior.

Naturally, the prefrontal cortex is of particular interest given its role in personality (e.g., Stuss et al., 1992), social–emotional decision-making behavior (Bechara et al., 2000), executive processes, and inhibitory control (Stuss & Alexander, 2000). Moreover, studies implicate the prefrontal cortex in addictive disorders and pathological gambling (see Goldstein & Volkow, 2002), while further suggesting that response inhibition and delay-of-gratification might also depend on prefrontal inhibitory control mechanisms (Chambers & Potenza, 2003). Arguably, impulsive behavior might reflect inefficient inhibitory signaling expressed as increased motivation for immediate reward (i.e., poor

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delayed gratification). As such, individual differences in impulsivity might be expected to relate inversely to performance on tasks associated with prefrontal function.

To test this hypothesis, we used two measures differentially associated with frontal lobe function: the Iowa Gambling Task (IGT) and the Wisconsin Card Sorting Test (WCST). The IGT, commonly associated in part with the ventromedial prefrontal cortex (VMPFc; see Bechara et al., 2000), yields optimal performance when participants avoid immediate high-stakes winnings in favor of a response strategy emphasizing the long-term, slow but steady gain. The WCST is thought to be somewhat more reflective of dorsolateral prefrontal cortex (DLPFc) activity, emphasizing attention, learning from verbal feedback, and adaptation to changes in task contingencies. It is important to note that both the IGT and the WCST rely heavily on overlapping regions of the brain that extend beyond those mentioned above, thereby precluding specific assessment of distinct areas of the prefrontal cortex. However, the executive and attentional neurocognitive skills recruited during the WCST are somewhat different than the motivational and emotive aspects of decision making associated with the IGT, thereby allowing a rough dissociation between some of the processes that may be relevant for impulsivity.

Previous comparisons between IGT and WCST performance and measures of impulsivity have been made with psychiatric samples involving prefrontal impairment (IGT: Bechara et al., 1994; WCST: Lyvers & Yakimoff, 2003); however, little is known about variations in performance within a nonpsychiatric population, with whom early identification and intervention might prove most beneficial. As such, we screened participants for impulsivity, using both the Barratt Impulsivity Scale (BIS-11; Patton et al., 1995) and a delay discounting questionnaire (Kirby et al., 1999), which assesses the degree to which an individual will choose a small, immediate reward over a larger delayed reward. Using these measures, participants were identified as high, medium, or low on impulsivity and then compared in terms of IGT and WCST performance. Controlling for verbal intelligence and general IQ (i.e., Mill-Hill Vocabulary Test), it was expected that higher impulsivity would be associated with lower IGT and WCST performance, potentially reflecting a neuropsychological indicator(s) worth examining as a predisposing factor to impulsivity-related variations in behavior.

METHOD

Participants

A total of 128 undergraduate psychology students at the University of Akron, ages 18–54 ($M = 22$; 64.6% women) participated in the study. Ninety-seven of these completed the impulsivity screening questionnaires during the initial phase of the study. Those scoring in the upper or lower 25% on the screening measures were later contacted to complete the second phase of the study (WCST; IGT testing) of which 29 (i.e., 63% of those contacted) complied. An additional 31 participants were not prescreened but completed both the screening questionnaires and the neuropsychological measures in one session, yielding a total of 60 participants completing the entire study. This research was approved by the Institutional Review Board of the University of Akron, and all participants provided written informed consent.

Impulsivity Screening Questionnaires

The Barratt Impulsivity Scale (BIS-11; Patton et al., 1995) consists of 30 statements rated on a 4-point Likert scale reflecting frequency of occurrence. The 27 items on the delay discounting questionnaire ask subjects to choose between a sum of money *now* and a larger sum of money *later*. Immediate and delayed dollar amounts were varied, along with the interval of delay (Kirby et al., 1999). Derived k values were transformed using the natural log to normalize the distribution.

A composite impulsivity score, derived by averaging standardized total BIS scores and $\log[k]$ values, was used to identify participants as High Impulsive (HI; top 25%, $n = 20$), Medium Impulsive (MI; middle 50%, $n = 21$), and Low Impulsive (LI; bottom 25%, $n = 19$).

Neuropsychological Tasks

We used the original version of the Iowa Gambling Task (Bechara et al., 2000). Four decks (40 cards each), labeled A, B, C, and D, were set before the participants, each of whom began with \$2000 in "game money" and instructions to win as much money as possible while avoiding losses. Unbeknownst to participants at the outset, selection from decks A and B yielded a large immediate reward (\$100 per card), but a long-term net loss (i.e., −\$1000 for all 40 cards); alternatively, decks C and D offered a smaller immediate reward (\$50 per card), but a long-term net gain (+ \$1000 for all 40 cards). Optimal performance involved learning the reward contingencies by means of repeated selections and feedback (maximum 100 selections), and ultimately forgoing the high immediate reward and making more selections from decks C and D.

For the Wisconsin Card Sorting Task (Kongs et al., 2000), participants were asked to match 64 presorted cards to one of four stimulus cards according to the dimensions of stimulus color, shape, and number. The matching criterion shifted each time 10 correct consecutive matches occurred, at which time participants needed to abandon a previously correct strategy and adopt a new one to optimize performance. Dependent measures included perseverative errors (i.e., continued matching to a *previously* correct criterion), nonperseverative errors, and number of categories completed.

The Mill Hill vocabulary test (Raven et al., 1997), a multiple-choice measure of synonym knowledge, was used as an index of verbal intelligence.

RESULTS

Impulsivity Screening Measures

Table 1 presents the demographic data, impulsivity scores, and Mill-Hill scores for the overall screening sample (i.e., phase 1), participants comprising the final data set (i.e., phase 2), and for the three composite subgroups based on impulsivity scores. Participants in the final data set were not significantly different from the overall screening sample on any measure. By design, scores on the BIS differed significantly between the HI ($M = 78.5$), MI ($M = 61.38$), and LI ($M = 53.47$) groups, as did the $\log[k]$ for the three groups (respective *Ms* = −3.72, −4.70, and −6.21). No significant group differences in age, gender, or Mill-Hill vocabulary scores were evident. As expected, BIS scores and $\log[k]$ values were correlated ($r = .259$; $p < .01$). Age and gender were not related to impulsivity scores.

Neuropsychological Tasks

The IGT was scored for net monetary winnings and for total net advantageous choices using the formula (C + D) − (A + B), where C and D are advantageous choices and A and B are disadvantageous choices. Scores were broken down into five 20-trial blocks (see Figure 1), with positive numbers representing more advantageous selections. A 3 (group) × 5 (block) mixed-design ANOVA revealed a significant improvement in advantageous selections across blocks [$F(4,228) = 38.468$; $p < .001$], but no overall group effect [$F(2,57) = 1.645$; *ns*]. However, a significant Group × Block interaction was found [$F(8,228) = 3.003$; $p < .05$] (partial eta-squared = .095), with a significant linear interaction trend [$F(2,57) = 6.449$; $p < .01$; note, the quadratic trend did not reach significance, $p = .196$]. Dropping the first block of trials, when participants are typically learning the task, increased the magnitude of the interaction effect [$F(6,171) = 3.601$; $p < .01$].

A separate one-way ANOVA identified a group difference only in the final block [$F(2,57) = 10.728$; $p < .001$], with Tukey *post hoc* comparisons suggesting less advantageous selections for group HI relative to group MI ($p < .05$), and HI relative to LI ($p < .001$).

On the WCST, data from three subjects (2 LI, 1 HI) were discarded due to interference during testing or participant failure to understand instructions. Of those remaining, there were no statistically significant differences in number of perseverative errors between the HI ($M = 8.94$), MI ($M = 8.14$), and LI ($M = 7.39$) groups, nor were there any group differences in number of nonperseverative errors (respective *Ms* = 10.33, 6.76, and 9.28) or categories completed (respective *Ms* = 2.78, 3.57, and 3.72).

Regression analyses using BIS and DD were used to determine IGT and WCST performance predicted beyond demographic correlations. Individual demographic variables did not correlate with IGT performance. More specifically, when entered as a group, age, gender, and Mill-Hill scores failed to account for the variance in advantageous selections on block 5 of the IGT (i.e., where group differences were most evident; $R^2 = .056$, *ns*). However, when BIS and DD were added, the overall model explained 29.7% of block 5 IGT performance ($\Delta R^2 = .242$; $p < .001$). Controlling for demographic variables, both BIS ($\beta = -.491$; $p < .001$) and DD ($\beta = -.274$; $p < .05$) individually predicted block 5 IGT performance. However, when considering both impulsivity measures simultaneously, BIS scores continued to explain unique variance in block 5 IGT performance ($\beta = -.462$; $p = .001$), while DD scores did not ($\beta = -.067$; *ns*).

WCST categories completed was significantly predicted by gender ($r = .301$; $p < .05$; i.e., women completing more categories than men) and BIS scores ($r = -.298$; $p < .05$), but not DD ($r = -.219$; $p > .10$). BIS scores significantly predicted categories completed after controlling for gender ($\beta = -.282$; $p < .05$).

DISCUSSION

The present study offers partial support for the hypothesis that self-reported levels of impulsivity vary systematically with performance on neuropsychological indicators of prefrontal function. High impulsivity was associated with poorer IGT performance on the final block of trials, but was not significantly related to WCST performance. How-

Table 1. Mean screening scores and demographic characteristics by group assignment (with standard deviations in parentheses)

			Impulsivity level		
Measure	Overall sample ($n = 128$)	Selected participants ($n = 60$)	High ($n = 20$)	Medium ($n = 21$)	Low ($n = 19$)
BIS Total[a]	64.77 (10.33)	64.58 (12.3)	78.5 (5.97)	61.4 (7.05)	53.5 (6.79)
K Natural Log[b]	−4.87 (1.28)	−4.85 (1.05)	−3.72 (.73)	−4.70 (.73)	−6.21 (.62)
Mill-Hill	N/A	16.07 (3.5)	15.65 (3.4)	16.86 (4.1)	15.63 (2.9)
Age	22.3 (5.6)	23.1 (6.1)	23.1 (7.3)	23.7 (5.6)	22.4 (5.4)
% Female	64.6%	63.3%	55.0%	61.9%	73.7%

[a] $F(2,57) = 73.268$, $p < .001$.
[b] $F(2,57) = 38.538$, $p < .001$.

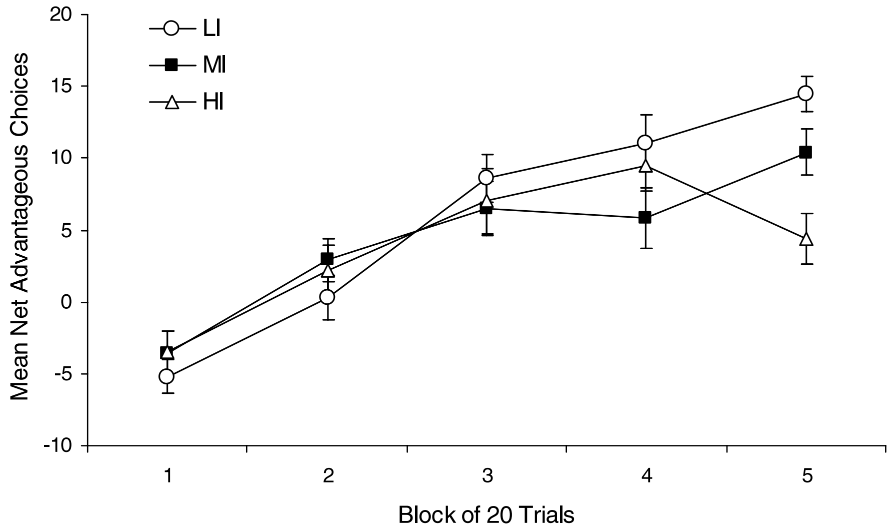

Fig. 1. Mean net advantageous card selections for each block of trials on the Iowa Gambling Task for high, medium, and low impulsive individuals. High impulsive (HI) individuals made significantly fewer net advantageous selections than low (LI) and middle (MI) impulsive individuals during the final block of trials [$F(2,57) = 10.728$, $p < .001$].

ever, group means on all three WCST measures were in the predicted direction but failed to reach significance. This pattern implicates impulsivity as a behavioral correlate of prefrontal-related processes in a nonclinical population, but suggests an effect related more to motivational decision-making processes rather than general executive functioning. Although precise localization of brain regions can not be inferred from task performance here, the pattern is nevertheless suggestive of a relatively greater association between impulsivity and VMPFc mechanisms than DLPFc activity (Bechara et al., 2000).

It should be noted that all three impulsivity levels (groups HI, MI, LI) showed increases in net advantageous choices across trials for the first four blocks—suggesting comparable sensitivity to task contingencies. Clearly, discernment of the most advantageous decks was used to guide selections. None of the groups exhibited the magnitude of deficits typically observed in patients with prefrontal damage (i.e., primarily disadvantageous choices during blocks 4 and 5; Bechara et al., 2000). However, group HI showed a decrease in performance during the final block amidst peak advantageous choices for the other two groups (see Figure 1).

One interpretation of these results is that, while impulsivity among nonclinical college students is not associated with the decision making failure seen in brain-damaged patients, it might be related to difficulty in sustaining optimal decision making after a delay. For example, such individuals might have the ability to inhibit their impulsivity, yet may require greater self-regulation to resist the impulsive desire for a large, immediate payoff compared with nonimpulsive counterparts. Toward the end of the task, following a period of sustained and now diminishing inhibitory efforts, a less efficient decision making strategy might be observed. Alternatively, it is possible that even in the absence of diminished inhibitory control, a greater propensity toward immediate payoff among highly impulsive individuals may be more apparent after an extended period of time performing the task. Once the task is learned and the contingencies become clear and routine, highly impulsive individuals may become less interested in safer long-term advantageous selections, and begin taking somewhat greater risks.

Although we cannot distinguish between the aforementioned hypotheses based on the present data, both interpretations would predict that given additional trials disadvantageous selections would have persisted or even increased. Of interest, recent fMRI data suggest impulsivity among healthy individuals is associated with a pattern of greater ventral striatal activation in response to reward (Hariri et al., 2006) and reduced prefrontal activation during an inhibitory control task (Brown et al., 2006). In the context of the current findings, this is consistent with the interpretation that highly impulsive individuals may experience both greater activation toward the high-reward, immediate payoff, and a diminished ability to inhibit that activation for the sake of long-term gain.

Delay discounting has previously been associated with poorer performance on the second half of the IGT among cocaine users (Monterosso et al., 2001), underscoring the notion that decision making—as reflected in IGT performance—is associated with a decisional bias against reinforcement delay. The present study extends these findings by showing a similar relationship in a healthy, nonpatient population. However, it is of note in the current study that the BIS accounted for unique variance in IGT performance beyond delay discounting, while the converse was not true. Since both delay discounting and the IGT involve motivational decision making, requiring trade-offs between immediate reward and long-term gain, this suggests that these two tasks might be tapping into the same construct. The fact that the BIS was a better predictor of block 5 IGT performance than delay discounting supports the conclusion that a more general construct of impulsivity is related to IGT performance, and this effect is not simply restricted to reward-related decision making.

Certainly, caution is warranted in localizing impulsivity to the VMPFc region based solely on the IGT used here, and such interpretations are speculative at this stage. However the significant relationship between self-reported levels of nonclinical impulsivity and performance on the IGT —but not the WCST—suggests that impulsivity is inversely related to the ability to sustain advantageous decision making in a motivational/emotive context, while general executive function is unaffected. The dissociation between these general constructs suggests that impulsivity is in some way associated preferentially with one prefrontal mechanism (VMPFc) but not another (DLPFc).

Several limitations of this study must be considered when evaluating these results. Our small sample size ($n = 60$) limited statistical power, and restrictions regarding age, education, and lack of participant drug history limit generalizability of results. Despite these limitations, the present findings underscore the importance of further exploration of the relationship between nonclinical impulsivity and prefrontal function, which could have implications for understanding the development of externalizing psychopathology.

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