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Interactions among attention-deficit hyperactivity disorder (ADHD) and problem gambling in a probabilistic reward-learning task

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HIGHLIGHTS

- We hypothesized that problem gambling and ADHD are linked by dysregulation of the neural processing involved in both reward processing and attention control.
- ADHD additionally impairs reinforcement-driven choice adaptation in subjects with problem gambling.
- Nongamblers participants tend to tolerate losses following good bets.
- Unmedicated ADHD gamblers tend to tolerate losses following bad bets.
- Stabilization of dopamine signaling by treating ADHD is itself also a treatment for certain forms of problem gambling.

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ABSTRACT

Problem gambling is thought to be highly comorbid with attention-deficit hyperactivity disorder (ADHD). We propose that the neurobiological pathologies underlying problem gambling overlap with those in ADHD. In this study, we used a simplified computerized version of the Iowa Gambling Task (IGT) to assess differences in reinforcement-driven choice adaptation among participants with pathological gambling and/or ADHD. The task contained two choice options with different net payouts over the session; a good bet that resulted in a win of +50 points on 60% of trials (and −50 points on 40%), and a bad bet that resulted in +100 points on 40% of the trials (and −100 points on 60%). We quantified participants' preference for the good bet over the session and their sensitivity to reinforcement. Both the control subjects and medicated ADHD nongamblers significantly increased the proportion of good bets over the 400-trial session. Subjects with problem gambling performed worse than controls and ADHD nongamblers, but better than our limited sample of unmedicated ADHD gamblers. Control subjects, medicated ADHD nongamblers, and unmedicated ADHD nongamblers tended to tolerate losses following good bets, whereas unmedicated ADHD gamblers tended to tolerate losses following bad bets. These data reveal that ADHD, particularly when treated with medication, is not associated with poor choices on the IGT, but may exacerbate pathological choices in problem gamblers. It seems that stabilization of dopamine signaling that occurs when ADHD is treated is itself also a treatment for certain forms of problem gambling.

1. Introduction

Attention-deficit hyperactivity disorder (ADHD) is a prevalent and impairing disorder characterized by developmentally extreme levels of hyperactivity-impulsivity and/or inattention-disorganization [1]. ADHD patients make poor decisions in several aspects of their life. Their increased preference for risky decisions [2] and small immediate rewards rather than large delayed ones [3] suggest that they will perform poorly on decision-making tasks such as the Iowa Gambling Task (IGT). The IGT is designed to study decision-making among choices with uncertain and unequal rewards and penalties [4]. In the original version of this task participants have the choice to select a playing card from one of four decks: two are disadvantageous decks (with high gains and high loses), and two are advantageous decks (with low gains and low loses). Here, we used a simplified computerized version of the IGT to assess differences in reinforcement-driven choice adaptation among subjects with pathological gambling and/or ADHD.

Problem gambling is characterized by uncontrolled gambling despite negative consequences, and is thought to be comorbid with

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ADHD [5]. This comorbidity is superficially paradoxical: ADHD is characterized by an inability to maintain attentional focus, whereas problem gamblers, at least while gambling at video-based games, entail hyper-engagement of attention. However, ADHD is best conceptualized as a disorder of attentional control rather than a deficit of attention itself. Once engaged with a highly rewarding behavior, individuals with ADHD have no systemic deficit in attention or perception [6] and may in fact exhibit better performance than controls [7]. This is consistent with reports by the parents of ADHD children. They indicated that although their children appear to have many difficulties with attention and concentration in many situations, their concentration, performance, distractibility, and motivation all appear to improve when they engage in computer games [7].

Our hypothesis was that problem gambling and ADHD are linked by dysregulation of the neural processing involved in both reward processing and attention control. A likely candidate is the neuromodulator dopamine, which has broad empirical and theoretical support for a central role in signaling information about reinforcements [8], and is centrally implicated in the pathobiology of ADHD [9]. Work from our group and others have proposed neurobiological mechanisms by which dopamine levels can affect attention by regulating the gating of information into working memory [10,11]. One theory of the etiology of ADHD suggests that the normal response of dopamine neurons to reward-predicting cues becomes deficient [12], which would then impair the gating and/or maintenance of information in working memory [13]. By contrast, the increased dopamine release associated with highly reinforcing behaviors (e.g., video games), or commonly prescribed amphetamine-based pharmaceutical therapies for ADHD, may serve to temporarily ameliorate gating problems in ADHD. In addition to attention effects, the firing of dopamine neurons appears to encode a reward prediction error signal that provide a neurobiological learning signal analogous to that in computational models of reinforcement learning [8,14,15]. Such learning models can account for gradual adaptation of animal choice behavior through trial-and-error [16–18]. Alterations of dopamine would thus be expected to impair learning from wins and losses, as has been shown in Parkinsonian patients [19]. Evidence suggests both reduced levels of dopamine signaling [5,20–22] and dopamine receptors [23] in people with problem gambling. Thus, comorbidity of ADHD and problem gambling may produce compounding deficiencies in learning from reinforcements.

This proposed link between the reward processing and attention orienting systems means that a disruption in normal reward processing can be manifested as a disorder of attention. In particular, the normal shift of dopaminergic bursting responses from rewards themselves to the cues that predict these rewards [8,12]. In this view, abnormally high dopamine during gambling or abnormally low dopamine signaling as in ADHD [9] could disrupt the normal disengage-shift-engage cycle by manipulating the attention control system. This framework linking dopamine with both reward processing and gating of information into working memory provides a means to explore the relationship between disorders of reward processing such as problem gambling, and disorders of attention such as ADHD. Here, we examined how subjects with pathological gambling and/or ADHD weigh risks and benefits in a probabilistic reward-learning task, compared with normal controls. To our knowledge, this is the first study comparing the behavioral performance of problem gamblers and ADHD subjects using several IGT-based behavioral measures.

2. Materials and methods

2.1. Participants

We assessed differences in reinforcement-driven choice adaptation among subjects with pathological gambling and/or ADHD, and contrasted these data with a sex and age-matched control group. The gamblers group consisted of a population of young-adult gamblers who screened in the problem range indicated by DSM-IV or in the lower end of the pathological range of scores on the Canadian Problem Gambling Index (CPGI) [24]. In order to assess gambling propensity as well as possible co-morbidities, participants completed the CPGI, the National Institute on Drug Abuse – modified Alcohol, Smoking and Substance Involvement Screening Test (NIDA – modified ASSIST) [25], the National Opinion Research Center DSM Screen for gambling problems (NODS) [26], and the World Health Organization Composite International Diagnostic Review (WHO CIDI) [27]. ADHD subjects were confirmed by the Conners' ADHD scale as well as the WHO Adult ADHD Self-Report Scale (ASRS – v 1.1). Procedures were in accordance with the declaration of Helsinki and were approved by the University of Lethbridge Human Subjects Review Committee; all participants gave written informed consent.

2.2. Gambling task

In our simplified computerized version of the IGT, players could choose either a small (50 points) bet or a large (100 points) bet. The win/loss sequence for each bet type was pseudorandom (randomized within runs of 20 trials) with a 0.6/0.4 win/loss probability for the 50-point bet and a 0.4/0.6 win/loss probability for the 100-point bet. Thus as in the IGT, the optimal strategy over the long run was to choose the small lower-risk bet type to maximize the final score. The display sequence is shown in Fig. 1. The main screen contained

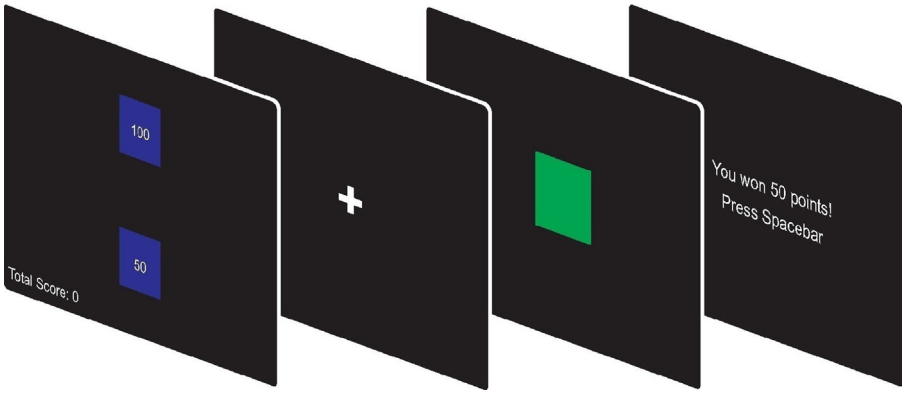

Fig. 1. Schematic of the behavioral task display.
On each trial, subjects chose the size of the wager (50 or 100) with the computer mouse. Fixation cross then appeared and lasted for 800–1200 ms followed by a colored square indicating win (green) or loss (red). This feedback remained visible for 1000 ms followed by text indicating the amount of either won or lost.