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Environmental Factors Selectively Impact Co-occurrence of Problem/Pathological Gambling with Specific Drug-Use Disorders in Male Twins

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Abstract

Aims—Multiple forms of drug abuse/dependence frequently co-occur with problem/pathological gambling (PPG). The current study examines the extent to which genetic and environmental factors contribute to their co-occurrences.

Design—Bivariate models investigated the magnitudes and correlations of genetic and environmental contributions to problem/pathological gambling and its co-occurrence with nicotine dependence, cannabis abuse/dependence, and stimulant abuse/dependence.

Setting—Computer-assisted telephone interviews in the community.

Participants—Participants were 7,869 male twins in the Vietnam Era Twin Registry, a USA-based national twin registry.

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Measurements—Lifetime DSM-III-R diagnoses for problem/pathological gambling, nicotine dependence, cannabis abuse/dependence, and stimulant abuse/dependence were determined using the Diagnostic Interview Schedule.

Findings—All drug-use disorders displayed additive genetic and non-shared environmental contributions, with cannabis abuse/dependence also displaying shared environmental contributions. Both genetic (genetic correlation rA=0.22; 95%CI:0.10–0.34) and non-shared environmental components (environmental correlation rE=0.24; 95%CI:0.10–0.37) contributed to the co-occurrence of problem/pathological gambling and nicotine dependence. This pattern was shared by cannabis abuse/dependence (rA=0.32; 95%CI:0.05–1.0; rE=0.36; 95%CI:0.16–0.55) but not stimulant abuse/dependence (SAD), which showed only genetic contributions to the co-occurrence with problem/pathological gambling (rA=0.58; 95%CI:0.45–0.73).

Conclusions—Strong links between gambling and stimulant-use disorders may relate to the neurochemical properties of stimulants or the illicit nature of using “hard” drugs like cocaine. The greater contribution of environmental factors to the co-occurrences between problem/pathological gambling and “softer” forms of drug abuse/dependence (cannabis, tobacco) suggest that environmental interventions (perhaps relating to availability and legality) may help diminish the relationship between problem/pathological gambling and tobacco- and cannabis-use disorders.

INTRODUCTION

Pathological gambling is defined by persistent and recurrent maladaptive gambling [1]. Although currently categorized in DSM-IV-TR as an impulse-control disorder [1], pathological gambling is being recommended for inclusion in DSM-5 as an addictive disorder based on clinical and biological similarities [2–4]. Both subsyndromal and syndromal levels of pathological gambling, based on one or more inclusionary criteria for pathological gambling and termed disordered or problem/pathological gambling (PPG), co-occur with substance-use disorders [5–10]. Prior investigations have identified shared genetic and environmental contributions to PPG and alcohol abuse/dependence in men [11]. However, similar approaches have not been applied to the investigation of the relationships between PPG and other substance-use disorders. Information relating to the relative genetic and environmental contributions to PPG and its co-occurrences with specific substance-use disorders (e.g., involving tobacco, cannabis and stimulants like cocaine) may help improve prevention and treatment strategies [12]. Different environmental and genetic factors may contribute to specific substance-use disorders and their co-occurrence with PPG through specific actions of each drug. Given data indicating considerable genetic influences on criminal behaviors [13] and addictions involving illicit substances (e.g., cocaine and cannabis), genetic contributions between illicit substance-use disorders may overlap with genetic contributions to PPG [14, 15].

Given that PPG and drug-use disorders frequently co-occur (a relationship that has been observed in the general population for several decades) [12], it is important to understand the degree to which environmental and genetic factors contribute independently to their co-occurrences. To examine environmental and genetic contributions to PPG and drug-use disorders, we analyzed data from the Vietnam Era Twin Registry (VET-R). The VET-R offers advantages in that it is comprised of a large sample of twins with diagnostic assessments for gambling, drug-use and other psychiatric disorders [9]. Specifically, the VET-R includes over seven thousand male twins and has been used to investigate the environmental and genetics contributions to the co-occurrences between PPG and alcohol-use disorders [11], anti-social behaviors [16], major depression [17] and anxiety disorders [18]. The current study investigated the following hypotheses. First, lifetime PPG would be associated with lifetime drug abuse/dependence relating to nicotine, cannabis and stimulants. Second, given that both tobacco and alcohol are both legal substances and prior

analyses of VET-R data have indicated that genetic and unique environmental factors contribute to PPG's co-occurrence with alcohol-use disorders [11, 19], the co-occurrence of PPG and nicotine dependence (ND) would show shared genetic and unique environmental contributions. Third, given the illegal nature of cannabis and stimulants like cocaine, genetic factors would contribute strongly to the co-occurrence between PPG and cannabis abuse/dependence (CAD) and PPG and stimulant abuse/dependence (SAD).

METHODS

Participants

The VET-R is a large national sample of male twin pairs consisting of 10,253 male twins. Participants were born between 1939–1957 and served during the Vietnam era (1965–1975). In 1992, 7,869 (76.7%) participants were successfully interviewed to ascertain Diagnostic and Statistical Manual, Third Edition-Revised (DSM-III-R) diagnoses for various psychiatric disorders. Questionnaires assessing physical appearance and supplemental blood typing were administered, identifying 1,874 monozygotic and 1,498 dizygotic twin pairs, with remaining participants being singletons [20].

At the time of interviewing, the mean(SD) age of respondents was 42.0(2.8) years. The racial profile of the sample was predominantly white (93.4%; *n*=7,349), with the remainder acknowledging black (6.2%; *n*=489) and other (0.4%; *n*=30) racial identities. The majority of participants had at least a high-school education (64%; *n*=4929) and were above the poverty level, with annual household incomes generally falling between $20,000-$40,000 (49.1%, *n*=3,657).

Measures

Lifetime DSM-III-R diagnoses for ND, cannabis abuse and dependence and stimulant abuse and dependence and pathological gambling were determined using the Diagnostic Interview Schedule (DIS) [21]. Lay interviewers obtained verbal informed consent. Criteria for pathological gambling were only assessed in participants who gambled 25 times or more in a year. Participants who had acknowledged using a drug more than five times were administered structured DIS questions that assessed abuse and dependence [22]. Drug abuse/dependence for cannabis and stimulant refers to abuse and/or dependence on (1) marijuana (hashish, ganja, bhang) and (2) stimulants (uppers, amphetamines, speed, ice, crack, cocaine), respectively, and all subjects who met criteria for lifetime regular smoking, having smoked daily for at least 1 month or more, were asked questions to assess ND [23].

Respondents endorsing one or more inclusionary criteria for pathological gambling were categorized as exhibiting PPG. This threshold has been used in other studies examining gambling behaviors in the VET-R [16, 24, 25], Epidemiological Catchment Area study [12], and National Epidemiological Survey of Alcohol and Related Conditions [26] and the National Comorbidity Survey Replication [27].

Hypothesis Testing: Analyses Examining the Relationship Between PPG and Drug-Use Disorders

Odds ratios (ORs) were determined for drug-use disorders in subjects with PPG in order to examine the hypothesis that lifetime drug-use disorders are comorbid with lifetime PPG. In order to adjust for errors of variance of non-independent observations, the SURVEYLOGISTIC procedure in SAS v9.2 was used. Using logistic regression, both unadjusted and adjusted ORs were examined by adjusting for sociodemographic variables (education, age, and income), affective disorders and antisocial personality disorder in a step-wise fashion, controlling first for influences of internalizing disorders (generalized

anxiety disorder, panic disorder, depression) and then externalizing disorders (alcohol dependence, antisocial personality disorder).

To examine the hypothesis that drug-use disorders would correlate more strongly in monozygotic twins than dizygotic twins, tetrachoric correlations were examined. To investigate the hypotheses regarding genetic and environmental contributions to PG and drug-use disorders, bivariate model fitting was used. Genetic and environmental contributions were deconstructed into three factors: additive genetic (A), shared environmental (C) and unique environmental, including influences of measurement error (E). The bivariate model thus allowed for the genetic and environmental associations between PPG and drug-use disorders to be examined [11]. Models of maximum likelihood were fitted using MX software [28]. Models were tested for their goodness of fit against a saturated model that included no constraints on the correlation matrices that were estimated for monozygotic and dizygotic twin correlations. The most parsimonious model was selected as best-fitting, with ninety-five-percent confidence-intervals (95% CIs) used to evaluate whether the genetic and environmental contributions to PG and drug-use disorders differed significant from 0 to 1.

RESULTS

Lifetime criteria for PPG, ND, CAD and SAD were met by 614 (7.83%), 3762 (47.81%), 564 (7.20%) and 359 (4.58%) of participants, respectively. Sociodemographics are presented (Table 1A). In unadjusted models, PPG frequently co-occurred with all drug-use disorders: odds ratios (ORs) of 2.08 (95% CI:1.75–2.49) for ND, 2.82 (95% CI:2.23–3.56) for CAD and 3.42 (95% CI:2.61–4.50) for SAD, respectively. After adjusting for sociodemographics and internalizing disorders, ORs remained elevated for ND at 1.69 (95% CI:1.40–2.05), CAD at 2.13 (95% CI:1.63–2.80), and SAD at 2.51 (95% CI:1.83–3.42). After also adjusting for externalizing disorders, all relationships (with the exception of that with CAD) remained significantly elevated: ORs of 1.30 (95% CI:1.06–1.60) for ND, 1.35 (95% CI:0.99–1.84) for CAD, and 1.52 (95% CI:1.06–2.18) for CAD (Table 1B).

In tetrachoric correlations between PPG and drug-use disorders, within-diagnosis concordance frequencies were higher in monozygotic twins than in dizygotic twins (Table 2). These findings are consistent with genetic contributions to each of the gambling and drug-use disorders. The cross-diagnosis cross-twin concordance frequencies were also numerically higher in monozygotic as compared to dizygotic twins. Although this pattern is suggestive of shared genetic contributions to each condition, the overlapping standard errors preclude a definitive interpretation.

Bivariate genetic models investigated relationships between PPG and individual drug-use disorders (Figure 1). Parameter estimates in these models generally suggested significant genetic and environmental contributions. The best-fitting bivariate model for the relationship between PPG and ND demonstrated significant correlations in the additive genetic (r_A=0.22; 95% CI:0.10–0.34) and unique environmental (r_E=0.24; 95% CI:0.10–0.37) domains (Supplemental Table 1A). For the relationship between PPG and CAD (Supplemental Table 1B), the best-fitting bivariate model demonstrated correlations in the additive genetic (r_A=0.32; 95% CI:0.05–1.0) and unique environmental (r_E=0.36; 95% CI:0.16–0.55) domains. Lastly, for PPG and SAD, the best fitting model displayed significant correlations only within the genetic domain (r_A=0.58; 95% CI: 0.45–0.73) (Supplemental Table 1C).

When comparing PPG and ND, of the 49% genetic variance observed in PPG, 2% (95% CI: 1–6%) was shared with ND. Of the 61% genetic variance contribution to ND, 3% (95% CI: 1–7%) was shared with PPG. In PPG and ND, the unique environmental component

accounted for 51% (95% CI:42–62%) of the variance in PPG and 39% (95% CI:35–44%) of that observed in ND. Of the 51% of the unique environmental component contributing to PPG, 3% (95% CI:1–7%) was shared with ND. Of the 39% of the unique environmental component contributing to ND, 2% (95% CI:4–6%) was shared with PPG.

When comparing PPG and CAD, of the 48% genetic variance observed in PPG, 5% (95% CI:1–54%) was shared with CAD. Of the 28% genetic variance contribution to CAD, 3% (95% CI:1–9%) was shared with PPG. The unique environmental component accounted for 52% (95% CI:42–62%) of the variance in PPG and 39% (95% CI:30–49%) of that observed in CAD. Of the 52% of the unique environmental component contributing to PPG, 7% (95% CI:1–16%) was shared with CAD. Of the 39% of the unique environmental component contributing to CAD, 5% (95% CI:1–12%) was shared with PPG.

When comparing PPG and SAD, of the 50% genetic variance observed in PPG, 17% (95%CI:10–26%) was shared with SAD. Of the 54% genetic variance contribution to SAD, 17% (95% CI:10–26%) was shared with PPG. The unique environmental component accounted for 50% (95% CI:43–61%) of the variance in PPG and 46% (95% CI:35–59%) of that observed in SAD; however, there was no unique environmental overlap between PPG and SAD. Thus, the overlap between PPG and SAD appeared entirely genetic in nature.

DISCUSSION

The hypothesis that individual classes of drug-use disorders would be frequently comorbid with PPG was confirmed in both unadjusted and adjusted models. PPG and all three classes of drugs (ND, CAD and SAD) remained elevated following adjustments for sociodemographic, externalizing and internalizing psychiatric variables, with the exception of CAD (which approached significance). The results from the tetrachoric correlations and bivariate models for PPG and drug-use disorders are consistent with the hypothesis that common environmental and genetic factors contribute to the co-occurrence of PPG and ND. Our third hypothesis was partially supported in that models indicated solely genetic contributions to the co-occurrence of PPG and SAD, whereas both common environmental and genetic factors contributed to the co-occurrence of PPG and CAD.

This study has clinical significance in both understanding of comborbid drug use with PPG and developing targeted interventions. First, the shared environmental contribution to PPG and ND and PPG and CAD suggest that environmental factors may contribute significantly to the co-occurrence of gambling and licit/”soft” drug-use disorders. Multiple factors (multiple genes and environmental factors relating to peers, parents, perceptions and other factors) have been proposed to contribute to gambling and substance-use disorders amongst youth and adults [29, 30]. While the current study does not identify specific factors, one possibility relates to accessibility. Increased rates of substance use have been found in contexts where drug accessibility is greater and where there are strong social influences such as substance-using peers [31–35]. The extent to which accessibility might influence the co-occurrence of PPG and ND warrants additional examination. For example, as cigarettes and lottery tickets may be purchased in common venues such as convenience stores, improving interventions (particularly for youth who may purchase such products illegally) should be examined further [36]. Although such efforts have not been examined to our knowledge, data linking early age of gambling, lottery gambling and problem-gambling severity in youth suggest a need for such studies [37]. Additional environmental factors that might contribute to both PPG and ND (like tobacco smoking in casinos) also warrant consideration, particularly given the increased accessibility in the United States of casino gambling over the past several decades. The extent to which peer influences might influence the co-occurrences of PPG and ND and PPG and CAD also warrants additional

investigation. Limiting accessibility and targeting peer influences may influence the initiation and maintenance of inter-related ND, CAD and PPG behaviors, although this hypothesis warrants direct investigation.

It has been reported that when examining genetic and environmental variances, the relationship between drug availability and drug-use disorders differs for stimulants as compared to tobacco and cannabis [38, 39]. For example, with cigarette availability, there is an increase in additive genetic variance and a decrease in shared environmental variance over time [38]. Shared environmental contributions to cannabis use peak between 12 and 17 years and then decline and instead are favored for additive genetic factors. However, for stimulants, additive genetic factors account for more of the variance between ages 8 and 17 years, and then there is an increase in the variance explained by shared environmental variance. As stimulants did not share a pattern observed with other classes of drug-use disorders, it suggests that there may be different risk factors and outcomes for SADs compared to other drug-use disorders with respect to their co-occurrence with PPG [38].

It may be that “harder” drugs, as represented by stimulants (including cocaine) in the current study, have lower accessibility and carry greater consumption-related risks, particularly at the time of data collection for this study [39]; as such, there may be higher thresholds for use and consumption may be mediated more so by hereditary components. The stronger genetic association that exists between PPG and stimulants might relate to shared underlying neurobiologies relating to dopaminergic or noradrenergic systems and/or interactive effects of stimulants and gambling [40]. Additionally, the psychoactive property of stimulants versus cannabis and nicotine may relate to the magnitude of the genetic contributions to the co-occurrence of PPG and drug-use disorders. Neurochemical factors linking gambling and stimulants may overlap at a genetic level to a greater extant than do gambling and nicotine or cannabis. Stimulants, perhaps through dopaminergic and/or adrenergic mechanisms, have been linked with gambling behaviors [41], with stimulants having been found to promote gambling motivations and behaviors [42]. While some research suggests that common genetic elements relating to the dopamine system might underlie PPG and SAD and substance-use disorders more broadly (e.g., with respect to allelic variations in genes coding for dopamine receptors) [43], other data do not support such findings [44]. Further research is needed to identify specific genetic factors underlying the co-occurrence of PPG and SAD and to translate these findings into improved interventions. As shared genetic contributions were also identified for PPG and ND and PPG and CAD, studies examining nicotinic and cannabinoid genes and neurochemicals are warranted in PPG.

Limitations

Several limitations exist. First, as data were collected in 1992, the findings may not extend fully to the current gambling and drug-use environments that include greater availability of gambling and possibly differential accessibility of drugs (e.g., arguably greater accessibility of methamphetamine and lesser accessibility of crack cocaine) and gambling (e.g., greater accessibility of casinos and Internet gambling). Additionally, there are different trends in substance-use behaviors, with smoking no longer as socially acceptable in public places, decreased frequency of SAD, and increased frequency of CAD [45]. Attitudes towards certain drugs may have also changed, with increased knowledge of the health risks of tobacco more prevalent and increased acceptance towards cannabis as reflected in more states in the US having legalized its use. Despite these differences, several studies suggest that relationships between gambling and alcohol-, tobacco- and other drug-use disorders have remained relatively consistent across time [9, 12]. These relationships, consistent with those in current sample, suggest that the reported findings may generalize to the current environment, although this warrants direct examination, particularly as some other data (including those from the VET sample) suggest that alterations in socio-cultural factors in

the environment may contribute differentially to PPG across time [46]. Second, the sample included only males; therefore, the results may not generalize to women, and future studies should examine the relationship between PPG and drug-use disorders in women. Such studies are particularly relevant given gender-related differences in environmental factors contributing to substance use and gambling [10], even though studies have found similar genetic and environmental contributions to PPG in women and men. Third, due to the cross-sectional nature of the data, we could not examine the temporal relationship between drug-use disorders and PPG. Future longitudinal studies would help better understand the relationships between PPG and drug-use disorders. Fourth, the extent to which PPG represents a reasonable threshold for considering problematic gambling may be questioned. Using more stringent thresholds in analyses generated similar results (data not shown), with the exception that significance levels were more robust using the current approach, likely due to the larger sample of individuals with PPG versus pathological gambling. Fifth, drug-use disorders were based on self-report. Although toxicological screening may be helpful in verifying current diagnoses, the current study's use of validated diagnostic-interview methodologies is a strength. Six, the diagnostic criteria for gambling and substance-use disorders in DSM-5 differ from those used in the present study. Future studies should examine the potential impact of changes in diagnostic criteria on the relationships between gambling and drug-use disorders, as has been recently done for gambling and alcohol use disorders [47].

Conclusion

In conclusion, our findings suggest different patterns of genetic and environmental contributions to the co-occurrence of PPG and different drug-use disorders among adult males. The predominantly genetic contributions to the co-occurrence of PPG and SAD as compared to the combination of genetic and environmental contributions to the co-occurrences of PPG and ND and PPG and CAD suggest that biological mechanisms linking gambling to specific drug-use disorders may differ. As a result, interventions targeting the co-occurrences of specific addictive behaviors may vary, with the environmental contributions to the co-occurrences of PPG and ND and PPG and CAD suggesting consideration of interventions targeting environmental factors that might link the behaviors.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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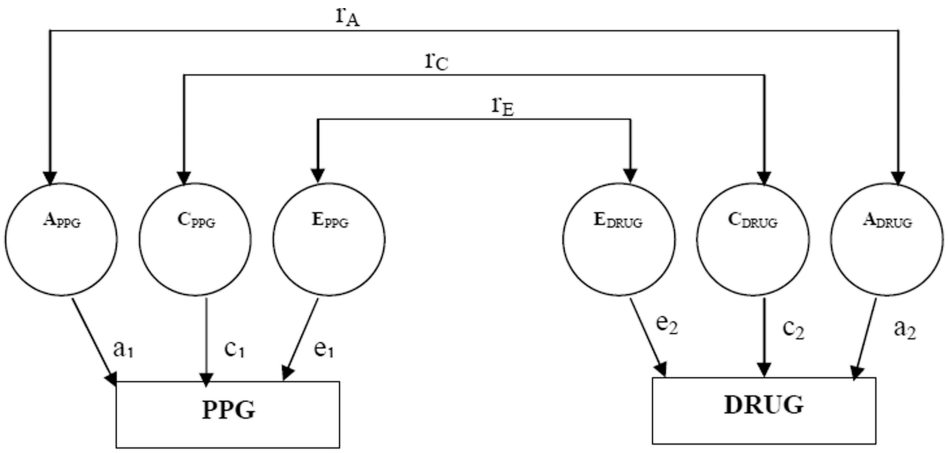

A schematic diagram for the bivariate biometric model examining the relationship between problem/pathological gambling (PPG) and drug-use disorders (DRUG). Factors including PPG and DRUG include additive genetic factors (A), shared environment (C), and unique environment plus error (E). Correlations between these factors across disorders are represented as r_A, r_C, and r_E respectively. The contributions of each of these factors to PPG (a_{PPG}, c_{PPG}, e_{PPG}) and DRUG (a_{ND}, c_{ND}, e_{ND}) are also indicated. Lowercase a, c, and e refer to path loading for factors A, C, and E respectively. In the tables, 95% confidence intervals are provided in parentheses for each value in each model.

Parameter Estimates From The Best-Fitting Model for PPG and ND

	a^2	c^2	e^2	r_A	r_C	r_E
PPG	0.49 (0.38, 0.58)	0.0	0.51 (0.42, 0.62)	0.22 (0.10, 0.34)	0.0	0.24 (0.10, 0.37)
ND	0.61 (0.56, 0.65)	0.0	0.39 (0.35, 0.44)			

Parameter Estimates for the Best-Fitting Model for PPG and CAD

	a^2	c^2	e^2	r_A	r_C	r_E
PPG	0.48 (0.38, 0.58)	0	0.52 (0.42, 0.62)	0.32 (0.05, 1.0)	0	0.36 (0.16, 0.55)
CAD	0.28 (0.01, 0.59)	0.34 (0.06, 0.58)	0.39 (0.30, 0.49)			

Parameter Estimates for the Best-Fitting Model for PPG and SAD

	a^2	c^2	e^2	r_A	r_C	r_E
PPG	0.50 (0.39, 0.57)	0	0.50 (0.43, 0.61)	0.58 (0.45, 0.73)	0	0
SAD	0.54 (0.41, 0.65)	0	0.46 (0.35, 0.59)			

Figure 1.

Bivariate Model: Problem/Pathological Gambling and Drug-Use Disorders [1]

1 The schematic diagram is a representation of the bivariate models which were similarly independently conducted for all the disorders: nicotine abuse/dependence, cannabis abuse/ dependence and stimulant/abuse/ dependence

Table 1

A. Frequency and Percentage of DSM-III-R Disorders and Sociodemographic Variables

DSM-III-R Diagnostic Information	Percent	Frequency (n)	Missing (n)
Conditions of Focus in Manuscript			
Problem/Pathological Gambling	7.83%	614	26
Nicotine Dependence	47.81%	3762	0
Cannabis Abuse/Dependence	7.20%	564	31
Simulant Abuse/Dependence	4.58%	359	30
Internalizing Diagnoses			
General Anxiety Disorder	2.25%	177	18
Panic Disorder	1.75%	137	18
Major Depression Disorder	9.61%	755	16
Posttraumatic Stress Disorder	10.05%	785	56
Externalizing Diagnoses			
Alcohol Dependence	35.89%	2817	20
Antisocial Personality Disorder	2.89%	227	18
Sociodemographic Information	Percent	Frequency (n)	Missing (n)
Annual Household Income (≥ $30,000)	45.76%	3407	424
White Race	93.40%	7349	1
Other Race	6.60%	519	1
Employed	95.77%	7296	251
Less Than a High School Education	3.60%	274	268
High School Education	31.55%	2398	268
More Than a High School Education	64.85%	4929	268

B. Logistic Regression Model Examining the Relationships Between Problem/Pathological Gambling and Drug Abuse/Dependence Adjusting for Sociodemographics, Internalizing and Externalizing Disorders

Variable	Odds Ratio (95% CI)
Age	1.00 (0.97 – 1.04)
Annual Household Income	0.97 (0.80 – 1.16)
High School Education	0.95 (0.59 – 1.54)
College	0.83 (0.51 – 1.33)
White Race	1.83 (1.31 – 2.55)
Employed	0.72 (0.50 – 1.04)
Alcohol Dependence	1.89 (1.54 – 2.34)
Antisocial Personality Disorder	2.23 (1.47 – 3.37)
Generalized Anxiety Disorder	1.29 (0.78 – 2.14)
Panic Disorder	1.35 (0.77 – 2.37)
Major Depression Disorder	1.40 (1.05 – 1.87)
Posttraumatic Stress Disorder	1.10 (0.83 – 1.47)
Nicotine Dependence	1.30 (1.06 – 1.60)
Stimulant Abuse/Dependence	1.52 (1.06 – 2.18)
Cannabis Abuse/Dependence	1.35 (0.99 – 1.84)

B_ND1. Logistic Regression Model Examining the Relationships Between Problem/Pathological Gambling and Nicotine Dependence without Adjustment

Variable	Odds Ratio (95% CI)
Nicotine Dependence	2.08 (1.75 – 2.49)

B_ND2. Logistic Regression Model Examining the Relationships Between Problem/Pathological Gambling and Nicotine Dependence, Adjusting for Sociodemographics

Variable	Odds Ratio (95% CI)
Nicotine Dependence	1.88 (1.56 – 2.27)
Age	0.98 (0.94 – 1.01)
Annual Household Income	0.91 (0.76 – 1.09)
High School Education	0.89 (0.57 – 1.40)
College	0.80 (0.51 – 1.24)
White Race	1.91 (1.38 – 2.64)
Employed	0.61 (0.43 – 0.88)

B_ND3. Logistic Regression Model Examining the Relationships Between Problem/Pathological Gambling and Nicotine Dependence, Adjusting for Sociodemographics and Internalizing Disorders

Variable	Odds Ratio (95% CI)
Nicotine Dependence	1.68 (1.39 – 2.04)
Age	0.98 (0.95 – 1.01)
Annual Household Income	0.93 (0.78 – 1.12)
High School Education	0.92 (0.58 – 1.45)
College	0.79 (0.50 – 1.23)
White Race	1.89 (1.37 – 2.61)
Employed	0.67 (0.47 – 0.95)
Generalized Anxiety Disorder	1.49 (0.91 – 2.44)
Panic Disorder	1.54 (0.88 – 2.69)
Major Depression Disorder	1.70 (1.29 – 2.24)
Posttraumatic Stress Disorder	1.39 (1.06 – 1.81)

B_SAD1. Logistic Regression Model Examining the Relationships Between Problem/Pathological Gambling and Stimulant Abuse/Dependence without Adjustment

Variable	Odds Ratio (95% CI)
Stimulant Abuse/Dependence	3.42 (2.61 – 4.50)

B_SAD2. Logistic Regression Model Examining the Relationships Between Problem/Pathological Gambling and Stimulant Abuse/Dependence, Adjusting for Sociodemographics

Variable	Odds Ratio (95% CI)
Stimulant Abuse/Dependence	3.19 (2.36 – 4.32)
Age	0.98 (0.95 – 1.02)
Annual Household Income	0.91 (0.75 – 1.09)
High School Education	0.83 (0.53 – 1.32)
College	0.70 (0.45 – 1.11)
White Race	1.67 (1.20 – 2.31)
Employed	0.65 (0.45 – 0.93)

B_SAD3. Logistic Regression Model Examining the Relationships Between Problem/Pathological Gambling and Stimulant Abuse/Dependence, Adjusting for Sociodemographics and Internalizing Disorders

Variable	Odds Ratio (95% CI)
Stimulant Abuse/Dependence	2.47 (1.81 – 3.37)
Age	0.99 (0.95 – 1.02)
Annual Household Income	0.94 (0.78 – 1.23)
High School Education	0.86 (0.54 – 1.37)
College	0.71 (0.45 – 1.12)
White Race	1.70 (1.22 – 2.35)
Employed	0.68 (0.48 – 0.97)
Generalized Anxiety Disorder	1.49 (0.90 – 2.45)
Panic Disorder	1.51 (0.87 – 2.61)
Major Depression Disorder	1.65 (1.24 – 2.20)
Posttraumatic Stress Disorder	1.43 (1.09 – 1.88)

B_CAD1. Logistic Regression Model Examining the Relationships Between Problem/Pathological Gambling and Cannabis Abuse/Dependence without Adjustment

Variable	Odds Ratio (95% CI)
Cannabis Abuse/Dependence	2.82 (2.23 – 3.56)

B_CAD2. Logistic Regression Model Examining the Relationships Between Problem/Pathological Gambling and Cannabis Abuse/Dependence, Adjusting for Sociodemographics

Variable	Odds Ratio (95% CI)
Cannabis Abuse/Dependence	2.68 (2.07 – 3.49)
Age	0.99 (0.95 – 1.02)
Annual Household Income	0.93 (0.78 – 1.13)
High School Education	0.86 (0.54 – 1.37)
College	0.72 (0.46 – 1.15)
White Race	1.73 (1.25 – 2.39)
Employed	0.62 (0.43 – 0.88)

B_CAD3. Logistic Regression Model Examining the Relationships Between Problem/Pathological Gambling and Cannabis Abuse/Dependence, Adjusting for Sociodemographics and Internalizing Disorders

Variable	Odds Ratio (95% CI)
Cannabis Abuse/Dependence	2.12 (1.62 – 2.78)
Age	0.99 (0.95 – 1.02)
Annual Household Income	0.95 (0.79 – 1.15)
High School Education	0.90 (0.56 – 1.44)
College	0.74 (0.46 – 1.17)
White Race	1.74 (1.25 – 2.40)
Employed	0.66 (0.47 – 0.94)
Generalized Anxiety Disorder	1.50 (0.92 – 2.43)
Panic Disorder	1.49 (0.85 – 2.62)
Major Depression Disorder	1.64 (1.24 – 2.18)
Posttraumatic Stress Disorder	1.41 (1.07 – 1.84)

Appendix: Abuse/Dependence refers to an individual who met the DSM-III-R criteria for abuse and/or dependence on (1) nicotine (dependence only) (2) cannabis (hashish,ganja, bhang); (3) stimulants (uppers, amphetamines, speed, ice, crack, cocaine); (Xian, et al., 2000).

Abbreviations: CI = confidence interval

Table 2

Tetrachoric Correlations Between Problem/Pathological Gambling and Drug-Use Disorders in Monozygotic and Dizygotic Twins

	Within-Diagnosis Tetrachoric Correlations (SE)		**Cross-Diagnosis Tetrachoric Correlations Between PPG and Drug-Use Disorder (SE)**	
Zygosity	PPG	ND	Within-twin	Cross-twin
Monozygotic	0.49 (0.05)	0.60 (0.03)	0.21 (0.05)	0.10 (0.05)
Dizygotic	0.19 (0.08)	0.31 (0.04)	0.24 (0.05)	0.04 (0.07)
Zygosity	PPG	CAD	Within-twin	Cross-twin
Monozygotic	0.49 (0.05)	0.62 (0.05)	0.23 (0.06)	0.13 (0.07)
Dizygotic	0.19 (0.08)	0.46 (0.07)	0.30 (0.06)	–0.02 (0.09)
Zygosity	PPG	SAD	Within-twin	Cross-twin
Monozygotic	0.49 (0.05)	0.53 (0.07)	0.26 (0.07)	0.20 (0.08)
Dizygotic	0.19 (0.08)	0.23 (0.11)	0.34 (0.07)	0.04 (0.10)