RUNNING HEAD: GAMBLING DISORDER AND SUICIDALITY**An Epidemiologic and Behavioral Genetic Investigation of the
Co-Occurrence of Gambling Disorder and Suicidality in Men and Women**

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Abstract

Individuals with a gambling disorder are more likely to engage in suicidal behaviors, but it is not yet clear whether this is due to common etiologic factors or to gambling disorder being causally related to suicidality. In a large national community-based twin sample, the temporal relation and the underlying causes of the association between gambling disorder and suicidality were examined. In the majority of instances of co-occurring gambling disorder and suicidality, suicidality actually preceded the onset of gambling disorder. The association between disordered gambling and suicidality was due to overlapping genetic influences among women ($r_g = 0.42$ [0.23 to 0.82]), but due to overlapping unique environmental influences among men ($r_e = 0.26$ [0.03 to 0.48]). These results suggest that whereas the association may be primarily due to common etiologic factors among women, gambling disorder may be causally related to suicidality among some men. Potential mechanisms underlying these effects are discussed.

Key words: gambling disorder, suicidal behaviors, twins, genetic

An Epidemiologic and Behavioral Genetic Investigation of the Co-Occurrence of Gambling Disorder and Suicidality in Men and Women

Gambling disorder is a pattern of gambling behavior, sometimes recurrent or persistent (Slutske, 2006), that is associated with substantial distress or impairment and that affects about 1% of the population (Potenza et al, 2019). Individuals with gambling disorder experience higher rates, relative to those without a gambling disorder, of nearly every other psychiatric disorder (Petry et al, 2005). Especially alarming is the elevated rate of suicide. For example, in a comprehensive national Swedish study of 2,099 individuals who had received treatment for gambling disorder between 2005 and 2016, 22 of 67 deaths (31%) were due to suicide. Suicide was the leading cause of death in this population-based sample of individuals who had received treatment for a gambling disorder (Karlsson & Håkansson, 2018).

It may be tempting to draw a causal link between gambling disorder and suicide. Individuals with a gambling disorder may accumulate unmanageable financial debt or be forced to face dire legal consequences – both factors that may lead some to consider suicide (Blaszczynski & Farrell, 1998; Chen et al, 2006; Wong et al, 2010). Although there is the necessary temporal order between gambling disorder and suicide consistent with causality, suicides are often preceded by thoughts about suicide, plans to commit suicide, and previous attempts (Kessler et al, 1999; Wong et al, 2010).

To our knowledge, there have been only five previous general population surveys that focused on the association between gambling disorder and suicidal behaviors. Only three assessed suicidal thoughts (Meltzer et al, 2011; Moghaddam et al, 2015; Park et al, 2010), one assessed suicidal plans (Park et al, 2010), and four assessed suicide attempts (Moghaddam et al, 2015; Newman & Thompson, 2003; Newman & Thompson, 2007; Park et al, 2010).

Unfortunately, three of the five studies did not assess suicidal behaviors outside of the context of a screening for major depression (Moghaddam et al, 2015; Newman & Thompson, 2003; Newman & Thompson, 2007). That is, suicidal behaviors were only assessed among those who endorsed a two-week period of depressed mood or anhedonia. This leads to measures of suicidal behaviors that are confounded with depressed mood/anhedonia and excludes suicidal behaviors that occur outside of the context of depression¹. (Other than the present study), the only study that examined the relation between gambling disorder and suicidal thoughts, plans, and attempts assessed outside of the context of a depression screening in a representative sample of the general population was a study of 5,333 Korean individuals (Park et al, 2010) in which there were significant associations of gambling disorder with suicidal thoughts and plans, but not attempts. This counter-intuitive result can probably be explained by the small number of individuals ($n = 43$) with gambling disorder.

Although cross-sectional studies have documented substantial associations between gambling disorder and suicidal thoughts and behaviors, they cannot tell us which came first – suicidal behaviors or gambling disorder? There are no longitudinal studies that have tracked the timing of the onsets of suicidal thoughts and behaviors and disordered gambling. In the absence of longitudinal data, researchers have used retrospectively-recalled ages-of-onset obtained in a cross-sectional study to examine the temporal priority of co-occurring disorders. For example, in the National Comorbidity Survey Replication study, gambling disorder had a later onset than did the co-occurring disorder (including mood, anxiety, impulse-control, and substance use disorders) 74% of the time, an earlier onset 24% of the time, and first occurred in the same year

¹ A non-trivial percentage of suicidal thoughts and behaviors occur outside of the context of depression. In the present study sample, 47%, 31%, and 28% of those who reported lifetime suicidal thoughts, plans or attempts, respectively, did not have a history of major depression.

2% of the time (Kessler et al, 2008). In a small sample of 35 individuals with co-occurring gambling disorder and suicidal behaviors selected from a Swedish population-based study, gambling disorder had a later onset than did suicidal behaviors 63% of the time, an earlier onset 31% of the time, and first occurred in the same year 6% of the time (Sundqvist & Rosendahl, 2019). These data on the relative timing of the onsets of gambling disorder and suicidal behaviors suggest that the possibility of gambling disorder causing suicidal behavior can be ruled out in the majority of cases.

An alternate explanation for the relation between gambling disorder and suicidal behavior is that they have a shared etiology. Hodgins, Mansley, and Thygesen (2006) proposed that a common factor shared between gambling, substance use, and mood disorders was related to the propensity to attempt, and ultimately, to commit suicide. This is supported by the results of an epidemiologic survey demonstrating that a significant relation between gambling disorder and suicidal behavior was substantially reduced after controlling for substance use disorders, major depression, phobia, and antisocial personality disorder (Newman & Thompson, 2003).

A more comprehensive approach for documenting a shared etiology between gambling disorder and suicidal behavior would be via a twin study in which the association between gambling disorder and suicidal behavior is compared in monozygotic (MZ) and dizygotic (DZ) twin pairs. Evidence from previous twin studies showing that the genetic predisposition to gambling disorder overlaps with the genetic predisposition to substance use disorders, major depression, and antisocial personality disorder (Slutske, 2019) suggests that there is likely to be an overlapping genetic predisposition to gambling disorder and suicidal behavior as well, although there are no existing twin studies that have addressed this question. The best available data come from a family study in which there was a significantly higher rate of suicide attempts

(9% versus 1%; odds ratio [OR] = 12.35) among 103 offspring of 95 parents affected with a gambling disorder compared to 130 offspring of 91 unaffected control parents (Black et al, 2015). These results suggest that there is a shared familial predisposition (that may include genetic and shared environmental factors) that are common to gambling disorder and suicidal behavior. A twin study would have many of the same features of this family study, yet could also parse the shared familial predisposition into genetic and shared environmental components and estimate the portion of the association between gambling disorder and suicidal behavior that is due to unique (i.e. individual-specific) environmental influences.

The current study was based on data from a large national community-based sample of adult Australian twins that was used to explore the reasons for the elevated rates of suicidal thoughts and behaviors among individuals with a gambling disorder. We examined cross-sectional, longitudinal, and MZ and DZ cross-twin associations between gambling disorder and suicidal behaviors, and conducted biometric twin modeling of the underlying causes of the association. Overlapping genetic or shared environmental influences would provide support for a shared etiology, whereas overlapping unique environmental influences would also be consistent with a potential causal relation between suicidality and gambling disorder.

Method

Participants

Participants were 8,327 members of the Australian Twin Registry (ATR) Cohorts II and III (ATR-II and ATR-III). They represented a broad cross-section of the general population of Australia. Similar to most community-based twin cohorts, however, the sample was relatively socio-economically advantaged; 16.49% of the participants had attained less than a high school education but 39.4% had graduated from college.

ATR cohort II. ATR-II members included adult twins ($n = 4,542$) born between 1964 and 1971; 57.8% of the participants were female. Nearly all of the participants were of European (mostly Northern European) ancestry; 2.0% of the participants had at least one grandparent of indigenous Australian or New Zealand ancestry, and 2.7% reported Asian or Pacific Islander ancestry. For additional details see Slutske et al. (2009).

ATR cohort III. The ATR-III members included adult twins ($n = 3,298$) and siblings ($n = 487$) born between 1972 and 1979; 63.9% of the participants were female. Nearly all of the participants were of European (mostly Northern European) ancestry; slightly less than 2% of the participants had at least one grandparent of indigenous Australian ancestry, and less than 1% reported Asian ancestry. For additional details see Lynskey et al. (2012).

ATR cohorts II and III combined twin sample. The combined sample included 2,995 complete twin pairs (1,403 MZ [903 female, 500 male], 1,592 DZ [647 female-female, 327 male-male, and 618 female-male]), 1,844 individual twins from incomplete pairs (608 MZ [324 female, 284 male], 1,236 DZ [309 females and 345 males from same-sex pairs, 409 females and 173 males from opposite-sex pairs]), and six individual twins of unknown zygosity.

Procedure

In both cohorts, interviews were administered by trained lay-interviewers who were supervised by project editors. All interviews were tape-recorded and a random sample of 5% of the interview tapes was reviewed for quality control.

ATR cohort II. Two Phases of assessment were conducted with ATR-II (see Table 1). At the Phase 1 assessment, participants reported on suicidality, and at the Phase 2 assessment, an in-depth assessment of gambling behaviors and a brief assessment of suicidality were conducted. The mean age was 29.9 years (range = 24-36) at Phase 1 and 37.7 years (range = 32-43) at Phase

2. The average time interval between the Phase 1 and Phase 2 interviews was 7.8 years ($SD = 1.4$, range = 4–11). The ATR-II studies were approved by the Institutional Review Boards at Washington University, the University of Missouri, and QIMR. All participants provided informed consent.

ATR cohort III. Gambling behaviors and suicidality were assessed via computer-assisted telephone interviews conducted between 2005 and 2009 (see Table 1). The mean age at assessment was 32.1 years (range = 21–46). The ATR-III study was approved by the Institutional Review Boards at Washington University and Berghofer QIMR, and secondary analysis of the data was approved by the University of Missouri. All participants provided informed consent.

Measures

Gambling disorder. The nine DSM-5 lifetime symptoms of gambling disorder were assessed using the National Opinion Research Center DSM Screen for Gambling Problems (Gerstein et al., 1999) in both cohorts. From these symptoms, two categorical phenotypes were created: a diagnosis of DSM-5 gambling disorder and having at least one symptom of gambling disorder (“disordered gambling”). In ATR-II, the age of onset of each symptom of disordered gambling was also ascertained. Age of onset of gambling disorder was the age at which the first symptom occurred. Age of onset of gambling disorder symptoms was not queried in ATR-III. The three-month test-retest reliabilities among 166 participants from ATR-II were very good: gambling disorder: $r = .95$, disordered gambling: $r = .95$ (tetrachoric correlations), and age of onset of gambling disorder: $r = .63$ (Pearson correlation).

Suicidality. At Phase 1, the assessment of suicidality was the same in both cohorts. Suicidal thoughts were assessed with the following question, “Have you ever thought about taking your own life?” Those who endorsed suicidal thoughts were asked about plans of suicide

with the question “Did you ever have a [suicide] plan?” Suicide attempts were assessed for all participants, even those without suicidal thoughts or plans, by asking “Have you ever tried to take your own life?” Participants who reported suicidal thoughts or attempts were also asked to indicate the ages when each of these behaviors first and last occurred (the ages of first and last suicide plan was not queried). A composite variable indicating endorsement of any form of suicidality (i.e., thoughts, plans, or attempts) at Phase 1 was created for use in biometric twin analyses. This composite variable was used to maximize statistical power. The four-year test-retest reliabilities (tetrachoric correlations) among 216 participants from ATR-II were very good (with the exception of suicidal plans): suicidal thoughts: $r = .85$, suicidal plans: $r = .56$, suicide attempt: $r = .97$, and any suicidality: $r = .85$.

At Phase 2, ATR-II participants were asked “Have you ever tried to or made a plan to take your own life?” Participants who endorsed this symptom were asked to indicate the ages at which this behavior first and last occurred and whether it was “ever related to your gambling.” A composite age-of-onset of suicidality variable was created based on the earliest age reported for the three items of suicidal thoughts, suicide attempts (both from Phase 1), or suicide plans/attempts (from Phase 2).

Other psychiatric disorders. Interviews with both cohorts were based on the Australian version of the Semi-Structured Assessment for the Genetics of Alcoholism (Bucholz et al., 1994) and using the DSM-IV diagnostic criteria (American Psychiatric Association, 2000). The following psychiatric disorders were included: major depression, alcohol use disorder, nicotine dependence, and conduct disorder. The diagnosis of alcohol use disorder combined abuse and dependence in accordance with changes in the DSM-5 (because craving was not assessed, it could not be included). The four-year test-retest reliabilities (tetrachoric correlations) among 216

participants from ATR-II were very good: major depression: $r = .81$, alcohol use disorder: $r = .72$, nicotine dependence: $r = .91$, and conduct disorder: $r = .84$.

Data Analysis

Cross-sectional phenotypic analyses. Prevalences of gambling disorder and indicators of suicidality were evaluated. Mixed effects logistic regression was conducted within SAS v9.4 (SAS Institute Inc., 2013) to account for the clustering of data within families. To test whether the effects differed for men and women, an interaction term between sex and gambling disorder (or disordered gambling) was included. We tested whether the cross-sectional phenotypic associations between gambling disorder (or disordered gambling) and indicators of suicidality remained after accounting for other frequently comorbid disorders (major depressive episode, nicotine dependence, alcohol use disorder, and conduct disorder). Additionally, given the differing timing of assessments across cohorts, we tested whether the effects of gambling disorder (or disordered gambling) on suicidal behaviors were moderated by cohort.

Longitudinal phenotypic analyses. These analyses were based on data from ATR-II. The mean ages of onset of suicidal behaviors and gambling disorder were examined, and the relative temporal precedence of onsets of suicidal behaviors and gambling disorder were compared with a chi-squared test for equality of proportions. The prospective effects of suicidal thoughts, plans, and attempts on later gambling disorder were evaluated with mixed effects logistic regression.

Biometric twin modeling. In a previous paper, a series of biometric twin modeling analyses were conducted based on different gambling disorder phenotypes, ranging from endorsing one or more symptoms of gambling disorder, that is, disordered gambling, to full DSM-5 gambling disorder (Davis, Slutske, Martin, Agrawal, & Lynskey, 2019). The results were similar for the different definitions, but the confidence intervals around the parameter estimates

were narrower for the broader disordered gambling phenotype. In order to maximize statistical power and the precision of estimates, we focused on the broader disordered gambling phenotype in the biometric twin modeling.

Twin correlations in liability were estimated and biometric modeling was conducted in Mplus (Muthén & Muthén, 2017). In a twin study, one compares the similarity of MZ twins, who share 100% of their genetic information, to the similarity of DZ twins, who share on average 50% of their genetic information (specifically, the genetic information that varies in the population)². When MZ twin pairs are more similar than DZ twin pairs, one can infer that there is a contribution of genetic factors to a trait. If the DZ twin similarity is greater than half the MZ twin similarity, then one can infer that shared environmental influences contribute to individual differences in a trait. A contribution of unique (individual-specific) environmental influences is inferred when the MZ twin similarity is less than 1.0 (this also includes measurement error). This is the contribution to individual differences that is not shared by twins and cannot be explained by genes or common environments.

Biometric model-fitting partitioned the variation in disordered gambling and suicidality liability into genetic (“A”) shared environmental (“C”), and unique environmental influences (“E”, which also includes measurement error). Models were fitted by the method of robust weighted least squares directly to the raw twin data, which uses data from incomplete as well as complete twin pairs. An assumption was made that there existed latent liability continua underlying the disordered gambling and suicidality categories by employing a liability-threshold model (Neale & Cardon, 1992). In all models, the thresholds (prevalences) for men and women were allowed to differ. Bootstrapping was used to generate confidence intervals around

² Two unrelated humans share about 99.9% of their genetic information; studies of individual differences are concerned with the 0.1% that varies.

parameter estimates. Evidence for quantitative sex differences (i.e., differences in the proportions of variation attributable to genetic, shared, and unique environmental influences) was assessed by constraining parameter estimates to be equal for men and women. Qualitative sex differences (i.e., differences in the sources of genetic variation for men and women) were evaluated by constraining the genetic correlation between opposite-sex twin pairs to that of same-sex twin pairs. Model comparisons were conducted using Wald chi-square tests. Because the correlations between age and disordered gambling ($r = 0.05$) and suicidality ($r = .004$) were very modest, we did not incorporate age in the biometric models.

Bivariate twin modeling was conducted among same-sex twin pairs to evaluate potential overlap in the genetic and environmental contributions to disordered gambling and suicidality. The logic of bivariate twin modeling is similar to that of univariate twin modeling (the analysis of a single trait). With bivariate twin modeling, one is interested in the cross-trait as well as the within-trait similarity. For example, one examines the similarity of disordered gambling in one twin with suicidality in the other twin. If the MZ cross-trait, cross-twin similarity is greater than the DZ cross-trait, cross-twin similarity, then one infers that genetic factors are contributing to the association between disordered gambling and suicidality. In other words, there is at least one gene that is a risk factor for both disordered gambling and suicidality. If the DZ cross-trait, cross-twin similarity is greater than half the MZ cross-trait, cross-twin similarity, then one infers that shared environmental factors are contributing to the association between disordered gambling and suicidality. Unique environmental factors are implicated when the MZ cross-trait, cross-twin similarity is substantially less than the cross-trait within-twin correlation between disordered gambling and suicidality. This represents the correlation between disordered gambling and suicidality that remains after controlling for genetic and shared environmental

influences, that is, the factors that are not shared between twins. The unique environmental correlation represents the within-twin-pair association between disordered gambling and suicidality and is consistent with a potentially causal association (Turkheimer & Harden, 2014).

Results

Cross-sectional Phenotypic Analyses in ATR-II and ATR-III

Prevalences. About one quarter of participants (26.05%) reported having had suicidal thoughts, 6.77% reported having made a suicide plan, and 4.04% had attempted suicide. Men and women were equally likely to report having had suicidal thoughts or made a suicide plan, but men were significantly less likely to report having made a suicide attempt (OR = 0.59 [0.47 – 0.76]). As expected, suicide attempts were strongly correlated with having had suicidal thoughts and having made a plan (Table 2), and it was exceedingly rare to report a suicide attempt without also reporting having had suicidal thoughts (0.89%). On the other hand, suicide attempt was frequently reported in the absence of ever having made a plan (38.39%). Regarding gambling disorder, 2.50% met the criteria for a lifetime diagnosis of DSM-5 gambling disorder (4.21% of men and 1.39% of women), and 10.47% (16.67% of men and 6.44% of women) met the criteria for disordered gambling.

Associations between gambling disorder and suicidal behaviors. Individuals with gambling disorder were about three times as likely as those without a diagnosis to report suicidal thoughts (OR = 2.62 [1.95 – 3.51]), plans (OR = 3.48 [2.39 – 5.05]), or attempts (OR = 3.05 [1.91 – 4.87]); 47.60% of those with gambling disorder reported having suicidal thoughts, 19.71% reported having made a suicide plan, and 11.06% had made a suicide attempt. The magnitude of the associations between gambling disorder and suicidal behaviors did not differ for men and women (thoughts: $F_{(1,3386)} = 0.17, p = 0.68$; plans: $F_{(1,3386)} = 0.02, p = 0.89$;

attempts: $F_{(1,3386)} = 0.00, p = 0.96$). They also did not differ between the ATR-II and ATR-III cohorts (thoughts: $F_{(1,3386)} = 0.16, p = 0.69$; plans: $F_{(1,3386)} = 0.14, p = 0.71$; attempts: $F_{(1,3386)} = 1.34, p = 0.25$), which suggests that the different timing of assessments for the two cohorts did not affect the results.

Associations between disordered gambling and suicidal behaviors. Participants with at least one symptom of gambling disorder were about twice as likely as those without any symptoms to report suicidal thoughts (OR = 1.78 [1.52 – 2.08]), plans (OR = 2.08 [1.65 – 2.63]) or attempts (OR = 1.89 [1.41 – 2.55])³. These associations also did not differ in magnitude for men and women (thoughts: $F_{(1,3386)} = 1.57, p = 0.21$; plans: $F_{(1,3386)} = 0.06, p = 0.81$; attempts: $F_{(1,3386)} = 0.58, p = 0.44$). They also did not differ across the two cohorts (thoughts: $F_{(1,3386)} = 0.38, p = 0.54$; plans: $F_{(1,3386)} = 0.03, p = 0.87$; attempts: $F_{(1,3386)} = 0.33, p = 0.57$), again supporting the decision to combine the two cohorts.

Role of psychiatric comorbidity. There were significant associations between suicidal thoughts, plans, and attempts and psychiatric disorders; the magnitudes of the associations were highest for major depression, then conduct disorder, and were similar for nicotine dependence and alcohol use disorder (see Table 2); note that the magnitudes of the associations between suicidal behaviors and gambling disorder were similar to the other addictive disorders, that is, alcohol use disorder and nicotine dependence. There were also significant associations between gambling disorder and psychiatric disorders; here the magnitudes of the associations were highest for conduct disorder and nicotine dependence, then major depression, and were lowest for alcohol use disorder (see Table 2).

³ Even a single symptom of disordered gambling was significantly associated with an increased odds of suicidal thoughts (OR = 1.58 [1.30 – 1.93]), plans (OR = 1.54 [1.11 – 2.14]), and attempts (OR = 1.57 [1.04 – 2.36]) relative to zero disordered gambling symptoms.

After accounting for psychiatric comorbidity, the associations between gambling disorder and suicidal thoughts and plans remained significant but were attenuated (thoughts: OR = 1.40 [1.01 – 1.94]); plans: OR = 1.73 [1.15 – 2.59]) and the association with suicide attempts became non-significant (OR = 1.25 [0.76 – 2.06]). On average, the odds ratios of the associations between gambling disorder and the three suicidal behaviors were attenuated by 84.48%, and this did not substantially differ for men (87.47%) and women (81.49%). We also examined the extent to which co-occurring gambling disorder and suicidal behaviors occurred in the absence of a history of major depression, alcohol use disorder, and conduct disorder (nicotine dependence was not included in this analysis). Among those with a history of gambling disorder, suicidal thoughts (6%), plans (2%), and attempts (0%) never or rarely occurred in the absence of comorbid psychopathology.

Compared to gambling disorder, the magnitudes of the associations between disordered gambling and psychiatric disorders were somewhat weaker. The magnitude of the associations now were highest for nicotine dependence, then conduct disorder, then alcohol use disorder, and were lowest for major depression (Table 2). As with gambling disorder, the associations between disordered gambling and suicidal thoughts and plans remained but were attenuated (thoughts: OR = 1.29 [1.08 – 1.53]; plans: OR = 1.43 [1.11 – 1.84]), and the associations of disordered gambling with suicide attempts became non-significant (OR = 1.11 [0.81 – 1.54]), after accounting for history of major depression, alcohol use disorder, nicotine dependence, and conduct disorder. On average, the odds ratios of the associations between disordered gambling and the three suicidal behaviors were attenuated by 68.06%, and this did not substantially differ for men (67.04%) and women (69.08%). Among those with a history of disordered gambling,

suicidal thoughts (15%), plans (7%), and attempts (5%) rarely occurred in the absence of a history of comorbid major depression, alcohol use disorder, or conduct disorder.

Longitudinal Phenotypic Analyses in ATR-II

Ages of onset of gambling disorder and suicidal behaviors. There were 1,251 (27.54%) individuals in ATR-II with a history of any suicidal behavior. The mean age of onset of suicidal behavior was 20.40 (SD = 6.4), and this did not differ for men and women (men: 20.77; women: 20.14; $t = 1.72$, $p = .09$).

There were 125 individuals (2.75%) with a history of gambling disorder, and 559 (12.33%) who had experienced at least one symptom of disordered gambling in their lifetime. The mean age of onset of gambling disorder was 24.40 (SD = 6.39), which differed for men and women (men: $M = 22.87$; women: $M = 27.14$; $t = -3.74$, $p = .0003$). The age of onset of having at least one symptom of disordered gambling also significantly differed for men and women (men: $M = 24.59$; women: $M = 28.20$; $t = -6.44$, $p < .0001$).

Temporal precedence of gambling disorder and suicidal behavior. Among 66 individuals with co-occurring gambling disorder and suicidal behavior, 61% of the time gambling disorder had a later onset than did suicidal behavior, 29% of the time it had an earlier onset, and 11% of the time gambling disorder and suicidal behavior first occurred in the same year (test of unequal proportions of later versus earlier onset: $\chi^2(1) = 7.47$, $p < 0.006$). These proportions differed between men and women (men: later = 54%, earlier = 38%, same year = 10%; women: later = 75%, earlier = 13%, same year = 13%; difference between later v. earlier: $\chi^2(1) = 4.79$, $p = 0.03$).

A small fraction of individuals attributed their suicidal behavior to gambling. At the Phase 2 interview, 8 of 424 participants who reported a suicide plan or attempt acknowledged that it was related to their gambling. Seven had a lifetime history of gambling disorder, which

represented 20.00% of participants with co-occurring gambling disorder and suicidal behavior (based on this single question about suicide plans or attempts).

Longitudinal associations between suicidal behaviors and gambling disorder. Those who reported suicidal thoughts (OR = 2.58 [1.79 – 3.71]), plans (OR = 3.74 [2.36 – 5.94]), or attempts (OR = 2.41 [1.23 – 4.72]) at Phase 1 were more likely to meet the lifetime criteria for gambling disorder nearly eight years later at Phase 2⁴, and this did not significantly differ for men and women (all $ps > .36$). After accounting for psychiatric comorbidity, the prospective association between suicidal plans and gambling disorder remained significant but was attenuated (OR = 1.85 [1.13 – 3.04]) and the prospective associations between suicidal thoughts and attempts and gambling disorder became non-significant (thoughts: OR = 1.38 [0.93 – 2.04]); attempts: OR = 0.90 [0.42 – 1.93]). Note that these are very similar to the cross-sectional phenotypic associations reported above, which again suggests that the different timing of assessments for the two cohorts did not affect the results and supports combining them in the cross-sectional phenotypic and biometric analyses.

Biometric Twin Modeling in ATR-II and ATR-III

Twin correlations in liability. The within-trait twin correlations for disordered gambling were greater among MZ twins than among DZ twins, indicating that genetic factors likely contribute to disordered gambling liability. The within-trait twin correlations for suicidal behaviors and the composite suicidality measure were also greater among MZ than among DZ twins, again supporting the importance of genetic factors (top panel of Table 3). The only cross-trait twin correlations that were statistically significant were among the MZ female twin pairs (bottom panel of Table 3); the magnitude of these correlations of .17 to .25 were (with one

⁴ Among those who met the diagnostic criteria for gambling disorder, the majority of onsets actually occurred prior to the Phase 1 interview (76%), so these are not truly prospective associations.

exception) slightly larger than the within-person correlations of .21 to .22 (see Table 2). This pattern of findings suggests that shared genetic influences contribute to the overlap between disordered gambling and suicidality among women. The nonsignificant MZ male cross-trait twin correlations of .03 to .13 suggests that the same was not true among men.

It is worth highlighting that the cross-trait twin correlations with disordered gambling were largely similar for the specific suicidal behaviors and the composite suicidality measure. This pattern of findings suggests that the biometric analysis results based on the composite suicidality measure will probably also apply to the specific behaviors of suicidal thoughts, plans, and attempts.

Univariate twin modeling of disordered gambling and suicidality. A univariate model of disordered gambling allowing men's and women's parameter estimates to differ fit the data well ($\chi^2(8) = 6.14, p = 0.63$; see Table S1 in Supplemental Materials). Constraining the parameter estimates to be equal for men and women did not significantly reduce model fit (Wald $\chi^2(2) = 1.19, p = 0.55$). In this constrained model, genetic influences accounted for 53.9% of the variance in disordered gambling liability, with the remaining variance accounted for by unique environmental influences (46.1%). There was no evidence for qualitative sex differences (Wald $\chi^2(1) = 1.35, p = 0.56$).

A univariate model of suicidality allowing men's and women's parameter estimates to differ did not fit the data especially well ($\chi^2(8) = 21.13, p = 0.007$; see Table S1). Constraining the parameter estimates to be equal for men and women did not significantly worsen model fit (Wald $\chi^2(2) = 3.04, p = 0.22$). In this constrained model, genetic influences accounted for 51.1% of the variance in suicidality liability, with unique environmental influences accounting for the remaining variance (48.9%). There was no evidence for qualitative sex differences (Wald $\chi^2(1) =$

1.59, $p = 0.21$). (The results of univariate models for each of the three components of suicidality considered individually, that is, for thoughts, plans, and attempts, can be found in the Supplemental Materials.)

Bivariate twin modeling of disordered gambling and suicidality. A bivariate ACE twin model that allowed the parameter estimates for men and women to differ fit the data well ($\chi^2(18) = 17.47$, $p = 0.49$; CFI = 1.00, RMSEA = 0.00). Dropping shared environmental influences did not significantly worsen model fit ($\Delta\chi^2(6) = 0.16$, $p = 1.00$) and estimates for C were near or at zero (all p s > 0.82), so we retained a bivariate AE model. A bivariate AE model that allowed the parameter estimates for men and women to differ fit the data well ($\chi^2(24) = 17.31$, $p = 0.84$; CFI = 1.00, RMSEA = 0.00). Dropping genetic (Wald $\chi^2(6) = 269.00$, $p < 0.00001$) and unique environmental influences (Wald $\chi^2(6) = 45.58$, $p < 0.0001$) from this model led to significant decrements in model fit. Constraining the parameter estimates to be equal for men and women did not significantly worsen model fit (Wald $\chi^2(4) = 6.08$, $p = 0.19$). In a model that constrained the parameter estimates for men and women, the genetic and unique environmental correlations between disordered gambling and suicidality were $r_g = 0.33$ (0.17 to 0.51) and $r_e = 0.10$ (-0.05 to 0.25).

There were clues from the pattern of cross-trait twin correlations among men and women and among the opposite-sex twin pairs that there might be important sex differences. Therefore, although constraining the parameter estimates to be equal for men and women did not significantly worsen model fit, we also evaluated sex-specific models (see Figure 1). Among men, genetic covariance could be constrained to be equal to zero (Wald $\chi^2(1) = 1.06$, $p = 0.30$), but unique environmental covariance could not (Wald $\chi^2(1) = 6.39$, $p = 0.01$); the genetic and unique environmental correlations between disordered gambling and suicidality were $r_g = 0.16$ (-

0.19 to 0.45) and $r_e = 0.33$ (0.09 to 0.56) among men. Among women, the opposite pattern was found. That is, constraining genetic covariance to be equal to zero significantly worsened model fit (Wald $\chi^2(1) = 19.38, p < 0.0001$), whereas constraining unique environmental covariance did not (Wald $\chi^2(1) = 0.24, p = 0.63$); the genetic and unique environmental correlations between disordered gambling and suicidality were $r_g = 0.42$ (0.23 to 0.60) and $r_e = -0.06$ (-0.34 to 0.16) among women.

Discussion

Gambling disorder and suicidal behaviors are relatively rare. In the present study sample, the lifetime prevalences of gambling disorder and suicide attempts were 2.50% and 4.04%, respectively. This may be why there is a dearth of research examining their association in a general population sample. Combining data from two large community-based twin surveys made it possible to rigorously examine the association between gambling disorder and suicidal behaviors, and to establish for the first time in a general population sample significant associations between gambling disorder and suicidal thoughts, plans, and attempts, as well as to dissect for the first time their association into genetic and environmental components. Of particular interest was whether there was evidence to support a causal association between gambling disorder and indicators of suicidality.

Temporal Relation between Gambling Disorder and Suicidality

Given significant cross-sectional associations, we attempted to discern which occurred first temporally, gambling disorder or suicidal behaviors? Based on retrospectively-reported ages-of-onset, the mean age of onset of suicidal behaviors (20.40) was earlier than the mean age of onset of gambling disorder (24.40), and for the majority of those who experienced both, suicidal behaviors were more likely to precede the onset of gambling disorder (61%) than the

reverse (29%). These results are similar to a Swedish population-based study in which gambling disorder had a later onset than did suicidal behaviors 63% of the time and an earlier onset 31% of the time (Sundqvist & Rosendahl, 2019). These data on the relative timing of the onsets of gambling disorder and suicidal behavior suggest that the possibility of gambling disorder causing suicidal behavior can be ruled out in the majority of cases. This is consistent with the finding that only a minority of those with co-occurring gambling disorder and suicidal behavior (20%) attributed the suicidal behavior to gambling. Although this was based on a small number of individuals, it is strikingly similar to the rate observed among those with co-occurring gambling disorder and suicide attempt (21%) in a Canadian study (Hodgins et al, 2006).

Both the present Australian study and the previous Swedish study suggest that there might be important differences between men and women in the sequence of gambling disorder and suicidal behavior. In the present Australian study, men were significantly more likely than women to experience an onset of gambling disorder that preceded the onset of suicidal behavior (38% versus 13%). Although the differences were not statistically significant, the Swedish study (Sundqvist & Rosendahl, 2019) also found that suicidal behavior onset more often came after or in the same year as the onset of gambling disorder among men (42%) than among women (27%). These data raise the possibility that gambling disorder may be more likely to be a cause of suicidal behavior among men than among women.

Role of Psychiatric Comorbidity

Even if gambling disorder has a causal influence on subsequent suicidal thoughts, plans, or attempts, however, it is unlikely to be the whole story. Suicidal behaviors rarely occurred in the absence of a history of co-occurring major depression, alcohol use disorder, or conduct disorder, and the odds ratios of the associations between gambling disorder and the three suicidal

behaviors were attenuated by 85% after taking into account a history of the aforementioned disorders and nicotine dependence. Previous research has demonstrated that, much like suicidal behaviors, when these disorders co-occur with gambling disorder, they are much more likely to be antecedent than subsequent (Kessler et al, 2008), so they are unlikely to be part of a causal chain leading from gambling disorder to suicidal thoughts and behaviors. Rather, the attenuation of the association between gambling disorder and suicidal behaviors by comorbid psychopathology more likely reflects a shared etiology (Hodgins et al, 2006).

Biometric Twin Modeling of Disordered Gambling and Suicidality

Shared genetic and environmental risk factors for disordered gambling and suicidality were explored with biometric twin models. As expected from our previous twin study of disordered gambling (Davis et al, 2019), and consistent with previous twin studies of suicidality (Fu et al, 2002; Statham et al, 1998), the variation in liability for both traits was explained by genetic and unique environmental factors, with no evidence for shared environmental influences. In a bivariate twin model that did not take into account sex differences, there was a significant correlation between the genetic risk factors for disordered gambling and suicidality, but the unique environmental risk factors were essentially uncorrelated. These results suggest that the reason that disordered gambling and suicidality are correlated is because of a shared genetic liability. This is similar to the results of a bivariate twin study of gambling disorder and major depression among men in which all of the covariation was explained by shared genetic risk factors (Potenza et al., 2005).

The results were substantially altered once differences between men and women were taken into account. Among women, the association between disordered gambling and suicidality was completely explained by overlapping genetic risk factors, which is consistent with a shared

etiology (Hodgins et al, 2006). Analyses showing that most of the overlap at the phenotypic level was accounted for by four common psychiatric disorders provide a clue to a possible source of the genetic overlap. A more comprehensive investigation based on data from a large United States national survey examined the associations of suicide attempt with 11 Axis I psychiatric disorders (including gambling disorder) and 7 personality disorders; they compared the relative influences of (a) specific disorders, (b) externalizing and internalizing dimensions, or (c) a general psychopathology factor in predicting suicide attempt. The results suggested that “effects of mental disorders on the risk of suicide attempt were exerted almost exclusively through a general psychopathology factor representing the shared effect across all mental disorders” (Hoertel et al, 2015, p. 718). A genetically-informed study among youth suggested that the association between a general psychopathology factor (not including gambling disorder) and suicide attempt was explained by overlapping genetic risk factors (O’Reilly et al, 2020). Taken together, these findings suggest that the genetic association between disordered gambling and suicidality among women is unlikely to be specific to disordered gambling, but rather non-specific genetic risk factors that increase the general liability for developing a mental disorder.

Among men, the association between disordered gambling and suicidality was completely explained by overlapping unique environmental risk factors, with little contribution of shared genetic risk factors. Such overlapping individual-specific environmental risk factors are consistent with the possibility that disordered gambling actually may be causally related to suicidal thoughts and behaviors, at least among some men. Other evidence consistent with this possibility is that there were more instances of disordered gambling emerging prior to suicidal behaviors among men than among women in the present as well as a previous Swedish study (Sundqvist & Rosendahl, 2019).

Possible Explanation for the Potentially Causal Effect of Disordered Gambling among Men

The processes by which disordered gambling may potentially cause suicidality specifically among men remain unclear. We hypothesize that this may have to do with the uniquely life-altering financial toll that disordered gambling can exact. Historically, population rates of suicide have been associated with major economic downturns, with the highest rate of suicide in the last 100 years in the United States and Australia occurring during the Great Depression of 1929-1933 (Morrell et al, 1993; Tapia Granados & Diez Roux, 2009), with all of the excess suicides occurring among men (Macmahon et al, 1963; Morrell et al, 1993). The more recent Great Recession of 2008 similarly led to an uptick in “economic suicides” with a fourfold greater increase among men than among women (Reeves, McKee, & Stuckler, 2014)⁵. A psychological autopsy study conducted in Hong Kong of 150 completed suicides, compared to 150 matched living controls, demonstrated that suicides were more likely to be preceded by unmanageable debt or unemployment (Chen et al, 2006), and of the 17 gambling-related suicides, all were characterized by unmanageable debt (Wong et al, 2010). These financial crises may pose a greater suicide risk among men than women because they may threaten the traditional primary role identities of men as being financially stable and competitive in the labor force (Girard, 1993; Stack, 2000), leading to feelings of burdensomeness and hopelessness (Klonsky & May, 2015; van Orden et al, 2010).

Limitations

Combining suicidal thoughts, plans, and attempts into a single phenotype of “suicidality” runs counter to modern theories positing that the causes of suicidal ideation and suicide attempt are distinct (Klonsky & May, 2015; van Orden et al, 2010). The decision to combine these into a

⁵ A similar uptick in “economic suicides” is predicted in the wake of the COVID-19 pandemic (McIntyre & Lee, 2020).

single phenotype was primarily based on power considerations because, despite the large sample size, the biometric analyses of suicide attempt were underpowered (see Supplemental Materials). The results for the composite suicidality indicator appeared to be largely driven by suicidal thoughts given the similarity of results for these two phenotypes (see within-trait and cross-trait correlations in Table 3).

Rather than being distinct, it might be more useful to conceptualize and analyze the spectrum of suicidal behaviors as stages through which an individual may progress. Multivariate twin models have been developed to capture the stage-like nature of the genetic contributions to substance use disorders (Heath et al, 2002) and have been applied to the progression from the initiation of alcohol use to heavy alcohol use (Fowler et al, 2007), from the initiation of illicit drug use to drug use disorder (Agrawal et al, 2005), and from binge-eating to bulimia nervosa (Wade et al, 2000). Application of such models to the stages of suicidal behavior would be informative about the extent to which there are overlapping versus specific genetic and environmental risk factors for suicidal thoughts, plans, and attempt. Based on the previous research on substance use and eating disorders, it is likely that a portion of the genetic and environmental risk for suicide attempt is shared with the genetic and environmental influences contributing to suicidal ideation, and that another portion is specific to the risk for suicide attempt. An important future direction will be to employ such models to disentangle the different sources of genetic and environmental variation in order to obtain a more complete picture of the underpinnings of suicidal behaviors.

The other notable limitation of this study is that the participants represented a narrow age range (27-43 years), were primarily of Northern European ancestry, and resided in Australia. It is

not clear the extent to which the results of this study can be generalized to other ages, ethnicities or racial groups, or countries.

Conclusions and Future Directions

This study represents the largest and most comprehensive epidemiologic study and the only genetically-informed study of the relation between gambling disorder and suicidality. The significant associations of gambling disorder with suicidal thoughts, plans, and attempts appeared to be primarily due to common genetic factors among women, and potentially due to a causal relation between gambling disorder and suicidality among (some) men.

Great progress had been made in the past decade in elucidating the genetic overlap between different psychiatric disorders by interrogating the results of genome-wide association studies (GWAS; Harden & Koellinger, 2020). Importantly, the genotype-phenotype associations of interest (for example, for gambling disorder and suicidality) do not have to come from the same study. There have now been a handful of large-scale GWASs of suicidality (e.g. Erlangsen et al, 2020; Mullins et al, 2019); a top priority will be to conduct a large-scale GWAS of gambling disorder so that the genetic overlap with suicidal behaviors (and other disorders and traits) can be more thoroughly probed.

The results of a large scale GWAS of gambling disorder would also make it possible to conduct a Mendelian randomization study (provided that there are significant variants to use as instruments) (Davies et al, 2018) to explicitly test whether there is evidence for a causal relation between gambling disorder and suicidal behaviors. A recent Mendelian randomization study found evidence from cross-sectional data that the use of tobacco, alcohol, and cannabis were causally related to suicide attempt, with no evidence for reverse causation (Orri et al, 2020). A Mendelian randomization study of gambling and suicidal behaviors would provide a more

stringent test of a potentially causal relation and confirm the results obtained from a bivariate twin analysis in the present study.

Another approach for tackling the question of causality in the absence of longitudinal data is the discordant twin design. The rationale is to test whether a relation between an exposure and an outcome remains after removing the contribution of genetic and shared environmental confounds (as in the association between disordered gambling and suicidality among men in the present study). In previous research we demonstrated using a discordant twin design that there was a potentially causal relation between neighborhood disadvantage and disordered gambling (Slutske et al, 2019), and that genetic variation in the frequency of gambling was associated with exposure to neighborhood disadvantage (Slutske et al., 2015). Interestingly, exposure to neighborhood disadvantage has also been associated with suicidal behaviors (Wardle et al., 2019). This emerging evidence suggests that disordered gambling and genetic risk for disordered gambling might shape the environment, for example, in the quality of the neighborhood in which one lives and whether one has experienced homelessness and severe financial problems (Roberts et al, 2017; Wong et al, 2010) that might precipitate suicidal thoughts and behaviors. It remains an important question for future genetically-informed research to determine which aspects of the environment might be critical in explaining the potential causal link between disordered gambling and suicidality.

Authorship

W.S.S developed the study concept and the study design. Testing and data collection were performed by W.S.S, A.C.H., M.T.L, and N.G.M. C.N.D. and W.S.S. performed the data analysis and interpretation. W.S.S. and C.N.D. drafted the paper, and A.C.H., M.T.L, and N.G.M provided critical revisions. All authors approved the final version of the paper for submission.

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Figure 1. Estimates of the proportion of variation in liability to disordered gambling and suicidality explained by genetic (A) and unique environmental (E) factors, and the correlations between the genetic and unique environmental liability for disordered gambling and suicidality; 95% confidence intervals are in brackets. The upper estimates are for men and the lower estimates are for women. Significant estimates are in bold.

Table 1. Overview of assessments in the two twin cohorts.

	Twin Cohort					
	ATR-II			ATR-III		
Phase 1	years	ages	assessments	years	ages	assessments
	1996-2000	24-36	<ul style="list-style-type: none"> • suicidality -age of onset • major depression • alcohol use disorder • nicotine dependence • conduct disorder 4 year retest interview ($n = 216$)	2005-2009	21-46	<ul style="list-style-type: none"> • suicidality -age of onset (not used) • gambling disorder • major depression • alcohol use disorder • nicotine dependence • conduct disorder
Phase 2	years	ages	assessments	NA	NA	NA
	2004-2007	32-43	<ul style="list-style-type: none"> • suicidality -age of onset • gambling disorder -age of onset 3 month retest interview ($n = 166$)			

Note: ATR-III also includes siblings, ATR = Australian Twin Registry

Table 2. Correlations between study variables among men (N=3,281) and women (N=5,046).											
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	lifetime prevalence men (%)
1. gambling disorder (4+ sxs)	.95	-- ^a	.26	.31	.27	.25	.33	.29	.30	.36	4.21
2. disordered gambling (1+ sxs)	-- ^a	.95	.17	.21	.16	.17	.14	.29	.27	.29	16.67
3. suicidal thoughts	.26	.21	.85	-- ^a	.83	-- ^a	.52	.22	.21	.40	25.78
4. suicide plan	.30	.21	-- ^a	.56	.78	-- ^a	.50	.24	.21	.38	6.34
5. suicide attempt	.27	.22	.91	.80	.97	-- ^a	.52	.31	.33	.49	2.90
6. suicidality (thoughts, plan, or attempt)	.26	.21	-- ^a	-- ^a	-- ^a	.85	.53	.22	.21	.40	25.85
7. major depression	.25	.23	.60	.58	.52	.60	.81	.19	.27	.28	19.72
8. alcohol use disorder	.21	.17	.24	.27	.32	.24	.19	.72	.41	.42	43.16
9. nicotine dependence	.40	.39	.23	.24	.34	.23	.26	.40	.91	.39	35.14
10. conduct disorder	.40	.31	.36	.37	.43	.36	.31	.45	.52	.84	15.79
lifetime prevalence women (%)	1.39	6.44	26.22	7.06	4.78	26.24	31.05	21.94	30.94	4.76	

Note: Cell entries are tetrachoric correlations. Correlations among men are in the upper diagonal, correlations among women are in the lower diagonal, retest reliabilities are on the diagonal (for the first two variables, the mean retest interval was three months, for the remaining variables, the mean retest interval was four years). All correlations are significant at $p < 0.05$.

^a correlations between contingent/nested phenotypes could not be calculated

Table 3. Twin correlations for disordered gambling and suicidal thoughts and behaviors.					
	Monozygotic		Dizygotic		
	Men	Women	Men	Women	Opposite Sex
	N = 500 pairs	N = 903 pairs	N = 327 pairs	N = 647 pairs	N = 618 pairs
Within-trait correlations					
Disordered gambling (1+ symptom)	0.48	0.60	0.23	0.23	0.11
Suicidal thoughts	0.41	0.59	0.12	0.13	0.11
Suicidal plans	0.58	0.47	0.30	0.32	0.13
Suicide attempts	0.57	0.41	0.28	0.47	0.00
Suicidality (thoughts, plans, or attempts)	0.40	0.59	0.11	0.13	0.11
Cross-trait correlations with disordered gambling ^a					
Suicidal thoughts	0.09	0.25	-0.03	0.08	0.01 / -0.12
Suicidal plans	0.13	0.23	0.19	0.12	0.08 / -0.33
Suicide attempts	0.03	0.17	0.03	0.17	0.20 / -0.14
Suicidality (thoughts, plans, or attempts)	0.09	0.25	-0.03	0.08	0.01 / -0.12
Note: Cell entries are tetrachoric correlations. Correlations in bold are significantly different from zero at $p < .05$.					
^a For opposite-sex twin pairs, first correlation is female twin's suicidality with male twin's disordered gambling, the second is male twin's suicidality with female twin's disordered gambling.					

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Supplemental Materials

An Epidemiologic and Behavioral Genetic Investigation of the Co-Occurrence of Gambling Disorder and Suicidality in Men and Women

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Univariate twin models of liability for suicidal thoughts, plans, and attempts

The univariate twin models of liability for lifetime disordered gambling and suicidality are summarized in the manuscript and are tabled in the top half of Table S1. Here we summarize results for the components of suicidality that were not included in the manuscript, that is, thoughts, plans, and attempts (bottom half of Table S1).

Suicidal thoughts. The parameter estimates from a univariate model of suicidal thoughts allowing men's and women's parameter estimates to differ were nearly identical to the estimates for the suicidality composite indicator (see Table S1). Constraining the parameter estimates to be equal for men and women did not significantly worsen model fit ($\Delta\chi^2(2) = 5.65, p = 0.059$). However, constraining the genetic correlation in opposite-sex twin pairs to 0.5 did ($\Delta\chi^2(1) = 4.19, p = 0.041$), suggesting potential qualitative sex differences in the genetic liability for suicidal ideation. When the estimates for men and women were constrained, genetic influences accounted for 51% of the variance in suicidality, with unique environmental influences accounting for the remaining variance (49%).

Suicidal plans. The parameter estimates from a univariate model of suicidal plans allowing men's and women's parameter estimates to differ yielded non-significant estimates of genetic and shared environmental influences. Constraining the parameter estimates to be equal for men and women did not significantly worsen model fit ($\Delta\chi^2(2) = 0.38, p = 0.829$). When the estimates for men and women were constrained, the contribution of genetic influences was significant, accounting for 44% of the variance in suicidal plans.

Suicide attempt. The parameter estimates from a univariate model of suicide attempt allowing men's and women's parameter estimates to differ also yielded mostly non-significant estimates of genetic and shared environmental influences; the exception was a significant

influence of shared environmental influences, accounting for 43% of the variation in liability, among women. Although the parameter estimates for men and women did not significantly differ ($\Delta\chi^2(2) = 4.214, p = 0.122$), they were quite discrepant, with genetic influences accounting for 57% of the variation in liability among men, but none of the variation in liability among women, and shared environmental influences accounting for 43% of the variation in liability among women, but none of the variation in liability among men. When the parameter estimates for men and women were constrained, genetic influences accounted for 32%, shared environmental influences accounted for 17%, and unique environmental influences accounted for 52% of the variance in liability to make a suicide attempt.

Table S1. Estimates of variance components from univariate twin models of liability for lifetime disordered gambling, suicidality, and for the three components of suicidality (thoughts, plans, attempts).

	Men			Women			Constrained across sex		
	A	C	E	A	C	E	A	C	E
Disordered gambling	0.48	0	0.52	0.59	0	0.41	0.54	0	0.46
95% CI	.37 – .61	0 – 0	.34 – .63	.42 – .70	0 – 0	.28 – .54	.42 – .68	0 – 0	.33 – .56
Suicidality	0.38	0	0.62	0.56	0	0.44	0.51	0	0.49
95% CI	.05 – .47	0 – .21	.49 – .77	.50 – .62	0 – .01	.38 – .50	.45 – .57	0 – 0	.42 – .55
Suicidality components									
Suicidal thoughts	0.39	0	0.61	0.56	0	0.44	.51	0	.49
95% CI	.22 – .51	0 – .12	.49 – .78	.49 – .65	0 – .002	.34 – .51	.39 – .57	0 – 0	.43 – .55
Suicide plans	0.49	0.08	0.43	0.42	0.07	0.52	0.44	0.07	0.49
95% CI	0 – .71	0 – .54	.25 – .68	0 – .64	0 – .45	.34 – .64	.18 – .64	0 – .32	.32 – .61
Suicide attempts	0.57	0	0.43	0.002	0.43	0.57	0.32	0.17	0.52
95% CI	0 – .83	0 – .44	.15 – .78	0 – .52	.31 – .59	.38 – .67	.002 – .58	0 – .36	.31 – .64

Note: A = additive genetic influences, C = shared environmental influences, E = unique environmental influences, CI = confidence interval. Bold indicates significance.