
The Australian Twin Study of Gambling (OZ-GAM): Rationale, Sample Description, Predictors of Participation, and a First Look at Sources of Individual Differences in Gambling Involvement

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Two major challenges to conducting a community-based twin study of pathological gambling (PG) disorder are that: (a) it is relatively rare, and (b) individuals with the disorder in the community may be difficult to locate and recruit. We describe a new study of 4,764 individuals recruited from the Australian Twin Registry in which we attempt to effectively deal with the first challenge and examine the impact of the second challenge. The lifetime prevalence of DSM-IV PG in this Australian twin sample was 2.2%, which is 400–500% higher than has been obtained in prevalence surveys conducted in the United States. A number of predictors of non-participation were identified, including a lifetime PG disorder diagnosis, but these did not have a large net effect on the estimated number of individuals with PG or related characteristics in the twin sample. Results of biometric modeling suggested that the effect of genetic, shared family environmental, and nonshared environmental influences on the propensity to engage in 11 different specific forms of gambling (e.g., playing the lottery, betting on horse or dog races, playing electronic gaming machines) were generally moderate, low, and moderate, respectively, with mean parameter estimates obtained of 43%, 10%, and 46%. An intriguing comparison with results from a 1963 US adolescent twin study conducted by Loehlin and Nichols (1976) suggests that: (a) propensity genes for gambling involvement may be more likely to be expressed in the heavy-gambling Australian culture, or that (b) the family environment has a transient effect on the gambling behavior of young people.

Keywords: gambling, twins, Australia, study participation, reliability, prevalence, genetic

In a recent US national survey of 43,093 adults, the number of individuals identified with past-year and

lifetime DSM-IV diagnoses (American Psychiatric Association, 1994) of pathological gambling disorder (PG) was only 74 (0.17%) and 185 (0.43%), respectively (Slutske, 2006). As it is currently defined, PG is no more prevalent than schizophrenia or anorexia nervosa. One of the greatest challenges to conducting community-based twin studies of PG is the fact that it is not especially prevalent.

In the book *A Mug's Game: A History of Gaming and Betting in Australia*, John O'Hara (1988) begins by stating that 'Australians have long thought of themselves as a nation of gamblers ... The belief that typical Australians would bet on two flies crawling up a wall is part of our folklore' (p. ix). Regulated forms of gambling have been more widely available for a much longer time in Australia than in the United States. For example, the first state government-operated lottery was established in 1920 in Australia (in Queensland; Australasian Gaming Council, 2008) compared to 1964 in the United States (in New Hampshire; National Research Council, 1999), and electronic gambling machines have been legally available outside of casinos in New South Wales (where about one-third of the Australian population resides) since 1956, and with the exception of Western Australia, from the 1990s in all other states and territories (Australasian Gaming Council, 2008).

The average Australian adult spent over AUD \$1100 on gambling in 2008 (Australasian Gaming Council, 2008). The 1999 Australian Productivity Commission reported that 'While international gambling statistics are patchy, evidence suggests that

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Australians are amongst the biggest gamblers in the world' (p. 3.2). The average per capita gambling expenditure as a percentage of net disposable income in 2003 was estimated for 21 industrialized nations (Pryor, 2008) — Australia ranked first and the United States ranked 14th among the countries included, with 5.85% and 1.75% of their average per capita net disposable incomes spent on gambling, respectively.

The density of gambling venues in Australia is also quite likely the highest in the world. Australia reportedly has the highest per capita number of high-intensity gaming machines (known as pokies in Australia, slot machines in the United States, fruit machines in the United Kingdom, and VLTs in Canada) in the world. Estimates of the percentage of worldwide gaming machines that are found in Australia vary somewhat — one source has suggested that Australia accounted for about 3% of machines worldwide, and about 7% of 'casino-style' gaming machines (Australian Gaming Council, 2004; Australasian Gaming Council, 2008), whereas another source has suggested that Australia accounted for 20% of the world's high-intensity gaming machines (Australians account for less than 1% of the world's population; Productivity Commission, 1999; see Table 1). Most of the Australian population lives within close proximity to gaming machines, which are distributed widely throughout the community in Australia in licensed premises: clubs, hotels and casinos. For these reasons, Australia may be the ideal setting for conducting a community-based twin study of PG, because along with the advantage afforded by the greater gambling involvement observed among Australians, it also allows for an examination of the genetic influence on PG susceptibility in a culture in which most individuals have been heavily exposed to gambling opportunities in relatively mature market segments.

Numerous studies have demonstrated that gambling involvement and problems run in families (e.g., Black et al., 2006; Gambino et al., 1993). For example, in a recent family study, Black et al. (2006) found that 8% of the first-degree relatives of PG-affected probands, compared to 2% of the first-degree relatives of PG-unaffected controls, had a lifetime history of PG. Many experts attribute the familial transmission of gambling and PG to social modeling influences (e.g., Gupta & Derevensky, 1997), but this conclusion is based upon the observation of parent-offspring transmission in nuclear families, which could be due to genetic as well as environmental factors. The role of a possible underlying biological diathesis in the development of PG has not been ignored by researchers; in fact, the search for putative indicators of biological vulnerability for PG (e.g., Blanco et al., 1996; Carrasco et al., 1994; Roy et al., 1988) and specific susceptibility genes associated with PG (e.g., Comings et al., 1996; Comings et al., 1997) actually preceded the behavioral genetic research documenting

Table 1

Overall Percentage of the World's High-Intensity Gambling Machines, 1999

Country	%	Population in millions
Australia	20	19
United States	64	273
Canada	6	31
France	6	59
New Zealand	2	4
South Africa	1	43
United Kingdom	0	59
Germany	0	82
Spain	0	39
Japan	0	126

Note: Productivity Commission (1999), p. 2.11.

the importance of genetic influences on the risk for PG (see Lobo & Kennedy, 2006 for a review).

The behavioral genetic literature on PG is scant, consisting of a single study. Eisen et al. (1998) studied 3,359 twin pairs from the Vietnam Era Twin Registry, a national sample of male twin pairs in which both men served in the United States military during the Vietnam Era. Despite the large size of the Vietnam Era twin cohort, there were still relatively few men who met the DSM-III-R criteria (American Psychiatric Association, 1987) for PG when interviewed in 1991–93. Of 7,869 interviewed men, only 112 met the DSM-III-R criteria for PG (Slutske et al., 2001), and there were only 6 monozygotic (MZ) and 2 dizygotic (DZ) twin pairs concordant for DSM-III-R PG. Nonetheless, the lifetime prevalence of PG was significantly elevated among the MZ (23%) and DZ (10%) co-twins of men with PG compared to the lifetime prevalence of PG in the full sample (1.4%). When standard twin structural equation models were fit to the data, it was not possible to discern whether this familial similarity for PG was due to genetic or environmental factors (Eisen et al., 1998). In a combined (and more powerful) bivariate analysis of PG and alcohol dependence, Slutske et al. (2000) found that 64% of the variation in the risk for PG could be accounted for by genetic factors, with the remaining variation accounted for by individual-specific environmental factors or errors of measurement. Family environmental factors did not significantly contribute to variation in PG (although these factors may still be important in either mediating genetic effects, or in their interaction with an existing genetic predisposition). The results of this study suggest that PG is as heritable as alcohol dependence, and that genetic factors, rather than social modeling, predominantly explain the familial transmission of PG. In a 10-year follow-up of the Vietnam Era twin cohort, Xian et al. (2007) found that the same genetic factors accounted for variation in liability for problem gambling at both

the baseline and at the 10-year follow-up and that the estimates of heritability at the two time points were similar (baseline: 49%; follow-up: 58%). The results of this follow-up study suggest that the changes in the availability of gambling that occurred in the United States between 1992 and 2002 did not alter the underlying genetic architecture of the liability to problem gambling. The extent to which the results from the Vietnam Era twin study generalize to women has still not been established.

The behavioral genetic literature on (nonpathological) gambling involvement is also nearly nonexistent. The first twin study of gambling involvement comes from the landmark National Merit Scholarship Qualifying Test (NMSQT) twin study (Loehlin & Nichols, 1976). Twins were identified among high school juniors in the United States who were taking the 1962 NMSQT. The twins were subsequently invited to participate in a study, and an extensive mailed survey was completed by 850 pairs. Included in the survey were four questions about the frequency of participation (frequently, occasionally, or not at all) in gambling in the past year. Because these data appear to be at risk of forever falling through the cracks, they have been retabulated and are presented here in Table 2.

What is especially noteworthy about the NMSQT twin study is that it was conducted in 1963, during a period in the United States when there were no casinos outside of Nevada, the first legal lottery had not yet been established, and there were few opportunities for legal gambling. Nonetheless, a substantial portion of these 17–18 year old students had participated in gambling activities in the past year (see Table 2) — these would invariably have been in the form of unregulated or illegal gambling. The results of this twin study represent a rare glimpse into the sources of variation in individual differences in gambling in a prohibitive (versus the currently more permissive) gambling environmental context. With the exception of card gambling among young men, a comparison of the correlations obtained among MZ versus DZ twins suggests little evidence for an important genetic influ-

ence and some evidence of shared family environmental influences on variation in the frequency of gambling among these young people.

To our knowledge, the only other twin study of gambling involvement is a small-scale study of 155 Minnesota-born male and female same-sex twin pairs (born between 1964–1972, with a mean age at assessment of 26 years; Winters & Rich, 1998). The frequency of involvement in eight different gambling activities in the past year, as well as three categorical indexes of gambling (any gambling in the past year, monthly gambling in the past year, and onset of gambling prior to age 18), and two composite indexes of gambling involvement (frequency of engaging in ‘high-action’ and ‘non-high-action’ games in the past year) were examined. Winters and Rich (1998) found that participation in ‘high-action’ gambling activities (scratch tabs, lottery, casino cards, and gambling machines) was significantly heritable among men, but not among women, and participation in ‘non-high-action’ gambling activities (cards with friends, betting on sports events or games of skill, and bingo) was not significantly heritable in either sex. (Three activities were assessed but were not included in the genetic analyses due to low base rates: betting on pull tabs, dice games, and horse/dog races.) The authors concluded from this study that there may be genetic influences contributing to individual differences only for certain types of gambling behaviors. However, inspection of the twin intraclass correlations for the composite indexes of the two types of gambling activities suggest that genetic influences may be important for both (high-action: $r_{MZ} = 0.56$, $r_{DZ} = 0.25$; non-high-action: $r_{MZ} = 0.57$, $r_{DZ} = 0.40$), and inspection of the prevalences of the activities belonging to each of the composite categories (high-action: mean prevalence = 58%; non-high-action: mean prevalence = 26%) suggests that the differences obtained may not be meaningful but could easily be attributable to differences in statistical power.

Another challenge to conducting community-based twin studies of PG, or any community-based study of PG (twin or otherwise), is that individuals with gam-

Table 2

Results From the 1963 United States National Twin Study of Loehlin & Nichols: Frequency of Participation in Four Different Gambling Activities in the Past Year Among High School Seniors

Gambling activity	Prevalence ^a (%)		Twin correlations (ICC)			
	Men	Women	Men		Women	
			MZ (N = 215)	DZ (N = 134)	MZ (N = 292)	DZ (N = 195)
Gambled with cards	47	17	0.53	0.31	0.51	0.42
Gambled with dice	13	3	0.37	0.43	0.27	0.23
Made bets on a game or other event (not cards or dice)	46	22	0.45	0.43	0.21	0.14
Played a slot machine	11	11	0.18	0.40	0.34	0.41

Note: ^a = represents the prevalence of participating frequently or occasionally (versus not at all); ICC = intraclass correlation, MZ = monozygotic, DZ = dizygotic.

bling problems may not be as easy to recruit into research as individuals without gambling problems. For example, in an 11-year longitudinal study of US college students, those with gambling problems were less likely to participate at later waves of the study (Slutske et al., 2003), and in the family study of Black et al. (2006), the family members of PG-affected probands were less likely to participate in the study than the family members of PG-unaffected controls. This may be because individuals with gambling problems are more geographically mobile than those without gambling problems, may be more likely to move or disconnect their telephone because of financial difficulties or to escape from creditors, or more likely to be incarcerated. Whatever the reason, the issue of non-participation likely affects all community-based studies of gambling pathology. Longitudinal and family-based studies like those of Slutske et al. (2003) and Black et al. (2006) are especially well-suited for documenting and potentially assessing the impact of this phenomenon.

The purpose of this article is to describe a new twin study of gambling involvement among men and women in Australia. There are three aims of this report. First, we provide a detailed description of the composition of the twin sample that was recruited for this study. Second, we present an analysis of gambling-related predictors of participation (and thus nonparticipation) in the study. Third, we present a 'first look' at sources of individual differences in gambling involvement by presenting biometrical model-fitting analyses of the propensity to engage in 11 different gambling activities and of four composite indexes of gambling involvement.

Method

Participants

In 1980–1982, a sample of 4,268 twin pairs born between 1964 and 1971 were registered as children by their parents with the Australian Twin Registry (ATR), maintained by the Australian National Health and Medical Research Council, in response to systematic appeals through the media and the Australian school systems. This cohort has variously been referred to in publications and presentations as the ATR 'younger cohort', the '1989 cohort', or 'Cohort II'. In 1989–1992, when the panel was 18 to 28 years old, the first survey of the twins was conducted by mailed questionnaire (the basis for the designation of this twin sample as the '1989 cohort'). In cases where twins did not respond to the original questionnaire mailing and a follow-up mailing, an abbreviated questionnaire was administered by telephone whenever possible, which increased the overall individual response rate for the 1989 questionnaire survey to 59.3% (Heath et al., 2001).

In 1996–2000, a telephone psychiatric interview containing a wide range of assessments including diagnostic assessments of alcohol dependence, childhood conduct disorder, and major depression (but not gam-

bling problems or involvement) was conducted with twin pairs from the ATR Cohort II (e.g., see Hansell et al., 2008; Lynskey et al., 2002; Waldron et al., 2008). The target sample for the interview study was all members of the ATR Cohort II dating back to the baseline sample of 1980–1982. By the time of the diagnostic interview survey, a total of 252 pairs (6%) were identified as 'lost', that is, no leads could be found after extensive efforts to retrace either twin or other family members. Telephone interviews were completed with 6,265 individuals, 2,803 men and 3,462 women, who were 30 years old on average (range = 24–36) at the time of the interview. Allowing for individuals who could not be located, who were deceased or incapacitated or otherwise unable to complete a telephone interview, or who were not assigned for interview by the end of the study, the individual response rate for the telephone interview was 84.2%. The 6,265 interviewed individuals included 2,765 complete twin pairs (in which both twins participated in the telephone interview) and an additional 735 twins from incomplete twin pairs (whose co-twin did not participate in the interview).

The 6,265 individuals from the ATR Cohort II who were interviewed by telephone in 1996–2000 and the 735 non-interviewed co-twins of those interviewed were targeted for the OZ-GAM study. After excluding 267 twins who were no longer available for study (they were deceased or no longer in the twin registry), the target sample of twins from Cohort II was 6,733 individuals. Of these 6,733 targeted individuals, 4,763 (70.7%) were interviewed for the OZ-GAM study. Reasons that interviews were not obtained were that the twin: (a) was deceased ($n = 14$), (b) was no longer a member of the ATR ($n = 222$), (c) could not be located even after extensive tracing efforts ($n = 319$), (d) was incapacitated or otherwise unable to conduct a telephone interview ($n = 65$), (e) did not have a telephone or had a silent (unlisted) telephone number ($n = 48$), (f) was currently overseas ($n = 49$), (g) was not assigned for an interview by the end of the study ($n = 90$), and (h) was contacted but declined the interview ($n = 1,163$). After excluding twins who could not be located, were deceased or otherwise unable to complete the interview, or were not assigned for an interview by the end of the study, the individual response rate for the OZ-GAM study was 80.4%. One twin was interviewed who was not in the target sample, bringing the total sample size to 4,764. There were 3,750 individual twins from 1,875 complete twin pairs and 1,014 individual twins from incomplete pairs. Figure 1 illustrates the history of the ATR Cohort II and the relation between the previous surveys and the OZ-GAM study. The average time interval between the 1996–2000 interview and the OZ-GAM interview was 7.8 years ($SD = 1.4$, range = 4–11). During this time interval some of the ATR Cohort II members were also recruited for and participated in a number of different studies including

surveys on alcohol involvement, tobacco involvement, male pattern baldness, and childhood trauma (not shown). Figure 2 shows the sample overlap between the two previous ATR Cohort II surveys and the OZ-GAM study depicted in Figure 1.

Procedure

The twins were assessed by both structured telephone interview and mailed self-report questionnaire. The interviews were administered by a team of trained lay-interviewers; different interviewers conducted the interviews of the two members of a twin pair. Interviewers were supervised by a project coordinator, a clinical psychologist with over 10 years of experience. All interview protocols were reviewed either by the project coordinator or by research editors (veteran skilled interviewers from previous studies who had maintained consistently low error rates in coding). All interviews were tape-recorded and a random sample of interview tapes was reviewed for quality control and coding inconsistencies. Midway through the course of the study the interview was adapted from a paper-and-pencil administered interview to a computer-assisted interview. The change in the format of the interview was transparent from the perspective of the respondent, and differed only from the perspective of the interviewer. Forty-eight per cent ($N = 2,297$) of the interviews were conducted using the computer-assisted interview. The immediate availability of the interview data with the computer-assisted interview

made it easy to conduct a small-scale short-term test-retest reliability study ($N = 166$, mean test-retest interval = 3.4 months, $SD = 1.4$ months, range = 1.2–9.5 months) that over-sampled individuals with gambling problems.

After an initial invitation letter was sent, the twins were contacted by telephone by an interviewer who asked whether they were willing to participate in the study. Twins who agreed to participate in the study were sent a packet that included a respondent booklet to be used with the interview and a copy of the self-report questionnaire along with a reply-paid envelope. The interview, lasting about 60 minutes, contained questions about: (1) demographics, (2) lifetime involvement in gambling activities, (3) a detailed assessment of current gambling involvement, the heaviest period of gambling involvement, and the period when gambling involvement first began, (4) lifetime and past-year symptoms of PG, (5) a screen for mania (an exclusion criterion for DSM-IV PG), (6) family history of gambling behavior and problems, (7) lifetime history of alcohol use and alcohol use disorders, (8) lifetime history of smoking (9) lifetime history of major depression, (10) history of childhood disruptive behavior disorders, and (11) history of adult antisocial personality disorder symptoms. The self-report questionnaire contained a variety of personality assessments. After extensive follow-up, 92% ($N = 4,369$) of the twins who participated in the interview portion of the study also returned the self-report questionnaire.

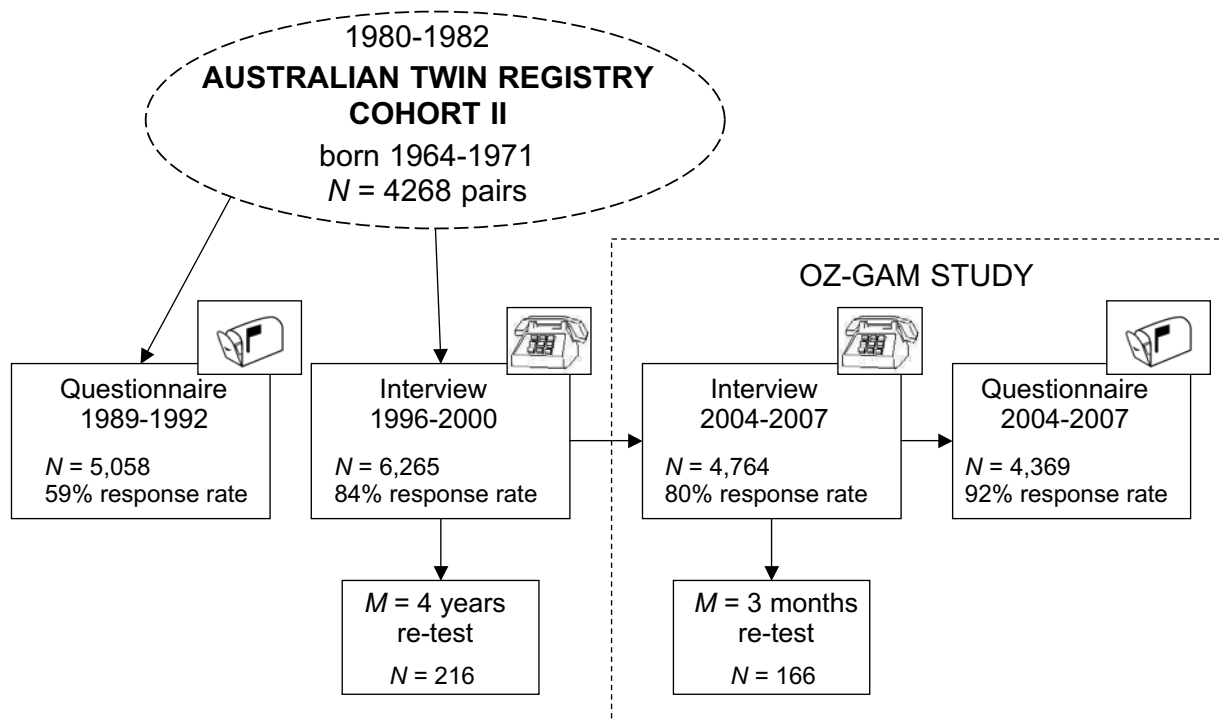


Figure 1
The relation between the OZ-GAM study and previous surveys of Cohort II of the Australian Twin Registry.

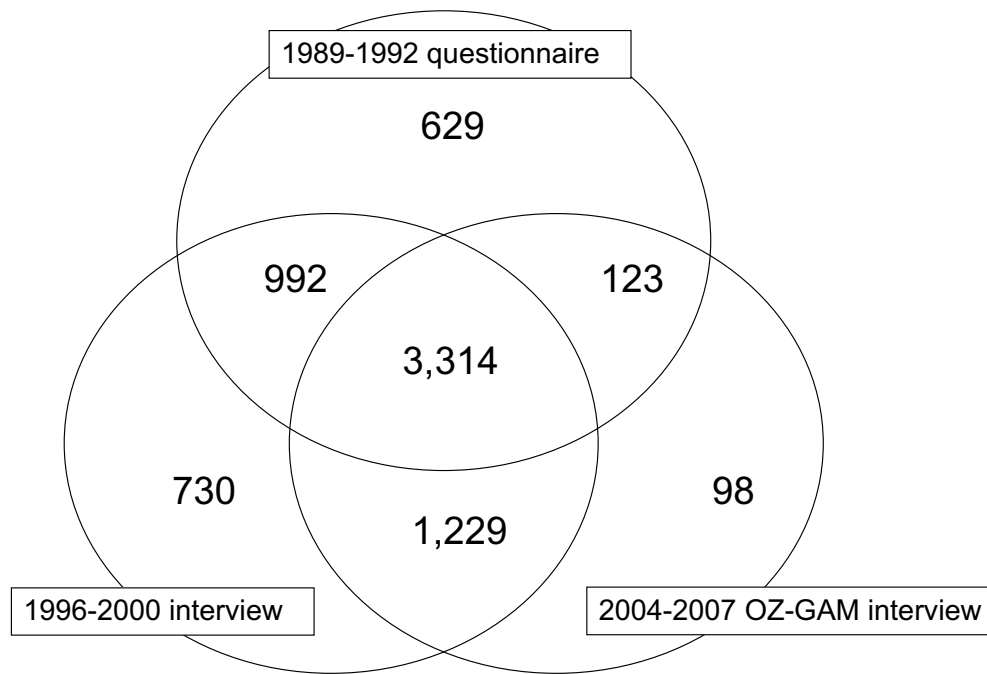


Figure 2

Venn diagram representing the sample overlap between the OZ-GAM study and two previous surveys of Cohort II of the Australian Twin Registry. Numbers represent the frequency of individual twins participating in only one survey, in two surveys, or in all three surveys.

Measures

Zygoty

Among the 1,875 complete twin pairs who participated in the OZ-GAM study, 867 were MZ (520 female, 347 male) and 1,008 were DZ (367 female–female, 227 male–male, and 414 female–male). Among the 1,014 individual twins from incomplete pairs there were 304 individuals from MZ pairs (151 female, 153 male) and 710 individuals from DZ pairs (181 female–female, 216 male–male, and 313 female–male).

Zygoty was initially determined using self-report questions from the 1989–1992 questionnaire and the 1996–2000 interview surveys regarding physical similarity (e.g., height, eye and hair color, ‘as alike as two peas in a pod’) and the degree to which parents, relatives, friends, or teachers could tell the co-twins apart. If co-twins gave inconsistent answers, they were followed up by telephone, and if there was still inconsistency or uncertainty, they were asked to send in photographs from various ages, from which a zygoty assignment was made by project staff.

The zygoty assignment in the OZ-GAM study was compared to zygoty assignments derived from an analysis of DNA obtained for 241 same-sex twin pairs in the OZ-GAM who had also participated in an unrelated genome-wide linkage study. At least 200 microsatellite markers were genotyped for each individual twin, and the genetic relatedness was determined based on the proportion of genetic markers in which the allele sharing between twins conformed to the pattern expected for MZ and DZ

pairs. The original zygoty diagnosis was confirmed by DNA testing for all 33 MZ twin pairs (100%), and for 202 of 208 DZ twin pairs (97%). The DNA testing indicated that 6 MZ twin pairs had originally been misclassified as DZ, which yielded an overall estimated error rate of 2.5% for zygoty assignments in the OZ-GAM study.

OZ-GAM Interview Measures

Demographic characteristics. Three of the demographic characteristics assessed in the OZ-GAM interview warrant explanation because they are unique to Australia — high school graduation, place of residence, and ancestry. All of these characteristics were assessed for the OZ-GAM study to potentially examine their relation to gambling behavior. In addition, ancestry was assessed in order to assemble genetically homogeneous samples for future molecular genetic studies.

Because of differences in their educational systems, designation as a high school graduate may have different meanings in Australia than in the United States or other countries. In Australia, schooling is compulsory through age 15 (16 in Tasmania) compared to 16–18 in the United States (differing across states). High school usually continues through grade 10 in Australia, whereas in the United States it continues through grade 12. After grade 10, young people in Australia can choose to either: (1) complete grades 11 and 12 and matriculate from high school, (2) enter a vocational or technical school, or (3) enter the workforce. Currently, about 80% of Australians opt to

complete grades 11 and 12, but this represents an increase over previous cohorts; about 68% of individuals who were 35–44 years old, 63% of individuals who were 45–54 years old, and 52% of individuals who were 55–64 years old in 2006 completed high school (Organisation for Economic Co-operation and Development, 2008). Based on these differences, there may be fewer high school graduates in Australia than in the United States among individuals in the age range of the OZ-GAM cohort.

Twins were asked whether their current (and also previous) place(s) of residence was a metropolitan area, regional city, or rural area. A metropolitan area (or metropolitan city) is typically defined as the urban and suburban spread surrounding the eight major capital cities in Australia — Canberra, Sydney, Melbourne, Brisbane, Perth, Adelaide, Hobart, and Darwin. Regional cities include all other cities in Australia.

Australia is a nation of immigrants much like the United States, but the national censuses in the two countries use different approaches for characterizing the ethnic diversity of their populations. In the United States census, one will find questions about race, whereas this is not included in the Australian census. Instead, the Australian census focuses on the heritage of the residents and where they and their parents and ancestors were born. The assessment in the OZ-GAM interview followed more closely the method used in the Australian census. Twins were not asked their 'race' but instead were asked where their parents and grandparents were born and the ancestry of their parents or grandparents, explained as 'the place or ethnic group where most of your ancestors came from.' For the ancestry questions, twins were instructed by the interviewers that the response 'Australia' was only appropriate for Indigenous individuals (likewise for the responses of 'United States,' 'Canada,' and 'New Zealand').

Gambling involvement. Eleven different gambling activities that were included in the 1999 Australian national prevalence survey (Productivity Commission, 1999) were assessed in the OZ-GAM study. Although the Australian prevalence survey only assessed gambling within the past 12 months, the OZ-GAM assessment included several different timeframes, including lifetime as well as the past year. For the purposes of this paper, we focus on any involvement in each of the 11 activities over the entire lifetime of the respondent. Two composite indexes of gambling involvement were created based on involvement in the 11 specific gambling activities: any gambling and gambling versatility. Any gambling was a dichotomous indicator of whether the participant had ever engaged in any of the 11 different gambling activities at any time. Gambling versatility was a continuous indicator of the number of different activities in which the respondent had ever been engaged, which reflects the extensiveness or diversity of the respondent's gambling involvement. The internal consistency reliability

(Cronbach's alpha) of the gambling versatility index was 0.68. Also included in this report are two other indicators related to the overall frequency and 'quantity' of gambling involvement: the number of days within a 12 month period in which gambling occurred during the respondent's heaviest period of gambling, and the most that the respondent ever spent on gambling in a single day. The largest amount of money ever spent on gambling in a single day was defined for participants as net expenditure, that is 'the total amount that you started out with at the beginning of the day minus the total amount that you ended up with at the end of the day. So this would be the single day in which you lost the most money overall.' Two different measures of gambling-related problems were included in the OZ-GAM study, the NODS (NORC DSM-IV Screen for Gambling Problems; Gerstein et al., 1999) that was developed for a national United States gambling prevalence survey conducted in 1999, the Gambling Impact and Behavior Study (Gerstein et al., 1999), and the South Oaks Gambling Screen (SOGS; Lesieur & Blume, 1987) that was originally developed to assess problems among individuals seeking treatment. The NODS assessment more closely matches the current diagnostic criteria used for diagnosing PG, whereas the SOGS has been the instrument used in the majority of PG epidemiologic research worldwide, including a 1999 Australian national prevalence survey (Productivity Commission, 1999). For both the NODS and SOGS, both lifetime and past-year problems were assessed. For the purposes of this paper, we focus on lifetime diagnoses of PG, as well as symptom counts based on the NODS and SOGS lifetime assessments. Both sets of PG measures were very reliable. The test-retest reliabilities for the lifetime diagnoses of PG from the NODS and the SOGS were 0.67 and 0.78, respectively, using the kappa coefficient, and were 0.79 and 0.82 using Yule's Y, and 0.92 and 0.95 using the tetrachoric correlation, based on data obtained from the 166 individuals in the retest sample. The internal consistency reliabilities (Cronbach's alpha) of the NODS and SOGS lifetime symptom counts were 0.85 and 0.81, respectively.

1996–2000 Interview Measures

Assessments from the 1996–2000 interview were used to predict participation in the OZ-GAM study. Although gambling behaviors were not assessed in the 1996–2000 interview, other gambling-relevant features were, such as demographic characteristics (age, sex, income, high school graduation, and religion), other addictive behaviors (alcohol use, smoking), and comorbid disorders (alcohol dependence, major depression, conduct disorder). We also examined other characteristics (e.g., zygosity) that have been associated with participation in previous ATR surveys.

Demographic characteristics. The demographic predictors are all self-explanatory except for the measure of income. Twins reported their overall yearly combined gross household income by choosing from a list

of 11 income ranges, presented in three formats corresponding to amounts per week, fortnightly, or annually. Individuals were categorized as being 'high income' and 'low income' based on whether they were in about the upper 25% and the lower 25% of the income distribution on this 11-point scale. The median yearly household incomes of the high and low income groups corresponded to greater than AUD \$62,500 and less than AUD\$30,000, respectively, in 1996–2000.

History of substance use and psychiatric disorder. 'Regular drinker' was defined as ever drinking at least once a month for at least 6 months. 'Regular smoker' was defined as ever smoking cigarettes daily or nearly daily for a period of at least three weeks. Lifetime diagnoses of alcohol dependence, major depression and childhood conduct disorder were made according to the DSM-IV criteria, except that clustering of symptoms of alcohol dependence and of conduct disorder within a 12 month period were not required.

Data Analysis

Predictors of participation in the OZ-GAM study. Longitudinal twin studies offer at least two clues for detecting sampling bias. First, one can use assessments obtained at previous study waves to predict participation at later waves. Second, one can examine differences between twins whose co-twin did not participate in the interview with those whose co-twin participated in the interview. The rationale here is not unlike that underlying the interpretation of the participation rates of the family members of the probands and controls in the family study of Black et al. (2006). Rather than starting with individuals with and without PG and checking to see how many of their relatives participated in the study, we are starting with individuals whose relatives (co-twin) did and did not participate in the study and checking to see how many of the probands and controls (twins) had PG. If twins with PG were systematically under-sampled, then higher rates of PG would be expected among twins whose co-twin did not participate in the interview than among twins concordant for participation in the interview (assuming that PG, like nearly all traits, is correlated in twin pairs). Following from this logic, one would also infer that twin pairs in which neither twin participated in the study would also have higher rates of PG, perhaps even higher than the pairs in which one twin participated. We cross-sectionally examined within the OZ-GAM study whether there were systematic differences in gambling behaviors between twins from pairs that were concordant versus discordant for participation.

For both sets of analyses, procedures for analyzing survey data were used to adjust for the nonindependence of the observations obtained from two members of a twin pair. Essentially, the data were treated as clustered, with the family unit (in this case, the twin pair) serving as the cluster.

Sources of individual differences in gambling involvement. As a 'first look' at the sources of individual differences in gambling involvement, we conducted biometrical model-fitting analyses of the 11 different gambling activities and the four composite indexes of gambling involvement. Models were fit by the method of maximum likelihood directly to the raw twin data using the Mx program (Neale et al., 2003). The data from incomplete as well as complete twin pairs were included in the analyses. This method reduces potential biases in parameter estimates due to nonparticipation if the data are missing at random (Little & Rubin, 1987). Although it has become standard practice in twin analysis to fit a series of nested submodels in order to drop nonsignificant parameters, the focus of these analyses of gambling involvement was on the estimated parameters and 95% confidence intervals around parameters from a full model allowing for additive genetic, shared environmental or nonadditive genetic, and non-shared environmental factors as sources of variation. This is the most effective way of communicating the results of univariate analyses of twin data, because estimates from reduced models can be easily misunderstood (a genetic parameter may be significant or an environmental parameter may be nonsignificant, but with extremely broad confidence intervals).

The sources of individual differences in whether or not a twin had ever participated in 11 different gambling activities, as well as any of the 11 activities, were examined. These were treated as categorical variables in the analyses, which assumed that the underlying liability, or propensity, to engage in a particular gambling activity or in any gambling activity is normally distributed. We also examined the sources of individual differences for three different continuous indicators of gambling involvement. All three of these measures were rank-normalized with a Blom transformation in an effort to reduce their positive skew.

For this 'first look' we did not examine whether there were sex differences in the estimates of the genetic and environmental variance components. Threshold or mean differences between men and women were included in all of the analyses, however, to take into account sex differences in the prevalences or mean levels for the different gambling behaviors.

Results

Sample description

The twins in the OZ-GAM study represent a relatively broad cross-section of the Australian general population of 32–43 year olds (see Table 3). Similar to most community-based twin cohorts, the OZ-GAM sample tends to be relatively socio-economically advantaged. However, the sample also includes individuals without post-secondary education (38.0%), who are unemployed (2.3%), and who are on public assistance (5.7%). The twins come from all walks of life, including truck driver, construction worker, mechanic, farmer, waitress, police officer, garbage collector,

plumber, hairdresser, secretary, teacher, nurse, lawyer, and doctor. Included in Table 3 is the religion in which the twins were raised; they also reported their current religion, which showed only moderate agreement with their childhood religion ($\kappa = 0.55$). Most of the lack of agreement was due to the fact that over one-quarter of the OZ-GAM sample went from being Christian as children to having no religion as adults. Eighty-six per cent and 13% of the twins reported that they were raised Christian, or with no religion, respectively (see Table 3), compared to 61% and 38% who were currently Christian or no religion, respectively (not shown).

Table 4 shows the current state or territory of residence for the OZ-GAM sample along with the rank of the states or territories in their average per capita expenditure on gambling. What is especially noteworthy is that 47% of the twins live in the two states in Australia (Victoria and New South Wales) with the highest average per capita expenditure on gambling and 14% of the twins live in the state with the lowest average per capita expenditure on gambling (Western Australia). For the 63.2% of individuals who reported that they lived in a metropolitan area (see Table 3), the current state or territory of residence also provides information about the particular metropolitan area in

which they are living. For example, of the 912 twins who are living in New South Wales, 558 indicated that they live in a metropolitan area. Therefore, we know from these two pieces of information that about 12% of the OZ-GAM sample is currently living in the Sydney metropolitan area.

The ancestry of the participants is presented in Table 5. As expected from the original settlement of Australia, most of the twins are of Northern European ancestry, especially from the United Kingdom and Ireland. There are also a sizable number of twins with Southern, Western, Eastern European and Asian ancestry, and also a small minority with some indigenous Australian (Aboriginal) ancestry.

Predictors of Participation in the OZ-GAM Study

Nearly all of the predictors from the 1996–2000 interview (with the exception of age, being raised Anglican or with no religion, and having a history of major depression) significantly predicted participation in the OZ-GAM study. Twins who participated in the OZ-GAM study were *more likely to*: be female, from MZ and same-sex twin pairs, have a higher household income and be a high school graduate, and *less likely to*: have been raised Catholic, be a regular drinker or smoker, and have a history of alcohol dependence or

Table 3
Demographic Characteristics of the OZ-GAM Sample ($N = 4,764$)

Characteristic	<i>M (SE)</i>	<i>Range</i>
Age	37.7 (0.04)	32–43 ^a
	%	<i>N</i>
Married	64.2	3,058
Parent	74.2	3,532
Homeowner	78.9	3,737
Occupational status		
Employed full-time	60.7	2,877
Employed part-time	26.5	1,255
Homemaker	42.3	2,006
Unemployed	2.3	110
Retired/disability	5.7	272
Student	7.0	334
Education		
8–10 years	21.1	998
High school graduate	16.9	803
Vocational or technical college	29.0	1,376
University education	17.5	828
Post graduate education	15.5	736
Religion		
Catholic	31.4	1,484
Anglican	29.4	1,391
Other Christian	25.4	1,200
No religion	13.1	618
Residence		
Metropolitan area	63.2	2,956
Regional city	15.9	743
Rural area	20.9	976
Both parents born in Australia	64.2	3,054

Note: ^a one participant was 30 years old and one was 31 years old; 99% of participants were 32–42 years of age.

Table 4
Distribution of Twins in the OZ-GAM Sample by State or Territory of Residence

State or territory	Gambling rank	<i>N</i>	%	2006 Australian census
Victoria	2	1,311	27.5	24.8
New South Wales	1	912	19.1	32.9
Western Australia	8	685	14.4	9.9
Queensland	3	513	10.8	19.7
South Australia	5	470	9.9	7.6
Australian Capitol Territory	6	129	2.7	1.6
Tasmania	7	96	2.0	2.3
Northern Territory	4	31	0.7	1.0
Live overseas	—	96	2.0	—
Unknown	—	21	0.0	—
Total	—	4,764	100	

Note: Gambling rank is from Productivity Commission (1999), and is based on the average per capita expenditure on gambling.

conduct disorder. After adjusting for the main effect of sex, having a higher household income and being a regular drinker were no longer statistically significant predictors, and having a history of major depression became a statistically significant predictor of participation in the OZ-GAM study. Odds ratios of the unadjusted associations between each predictor and OZ-GAM participation are presented in Table 6. Also presented in Table 6 are the characteristics of the targeted sample and the final OZ-GAM sample to illustrate the net effect of this differential attrition. Note that the statistical tests were not based on comparing these two groups (because the OZ-GAM is a subset of the target sample) but is based on a

comparison of the participating (in OZ-GAM) and nonparticipating twins from the target sample. Inspection of Table 6 shows that the OZ-GAM sample was fairly close to the target sample on all of the demographic, other addictive behavior, and psychiatric characteristics examined.

A comparison of twins from pairs concordant (i.e. complete pairs) and discordant (i.e., incomplete pairs) for participating in the OZ-GAM study is presented in Table 7. For the continuous indicators of gambling involvement, estimates of the standardized mean difference (effect size, *d*) are presented as an index of the magnitude of the difference between the two types of twins (from complete versus incomplete

Table 5
Ancestry of Twins in the OZ-GAM Sample

Region of ancestry ^a	Percentage of grandparents belonging to ancestral group			
	100%	75%	50%	25%
	Number of participants			
Europe	3603	418	370	136
Northern Europe	2358	774	685	237
United Kingdom ^b	1499	870	1019	429
Ireland	71	74	418	688
Western Europe	89	28	250	603
Southern Europe	229	23	121	148
Eastern Europe	14	9	65	50
Asia	30	7	34	44
Africa	2	1	1	12
South America	2	0	1	2
North America (indigenous)	0	0	0	2
Australia (indigenous)	6	4	16	53
New Zealand (indigenous)	0	0	3	10
Pacific Islands	1	0	3	11
Missing information	170	113	296	335

Note: ^a see <http://unstats.un.org/unsd/methods/m49/m49regin.htm> for the composition of the geographical regions used; ^b United Kingdom includes England, Wales, and Scotland.

Table 6

Longitudinal Predictors from the 1996–2000 Interview of Participation in the 2004–2007 OZ-GAM Study

1996–2000 predictor	Odds ratio (95% CI)	Target sample (<i>N</i> = 6,136 ^a) (%)	In OZ-GAM (<i>N</i> = 4,542 ^b) (%)
Sex (male)	0.68 (0.60, 0.76)	44.7	42.2
Zygoty (MZ)	1.37 (1.21, 1.56)	40.6	42.8
Zygoty (same-sex pairs)	1.20 (1.05, 1.37)	75.0	76.0
High income (upper ~25%)	1.26 (1.10, 1.44)	22.0	23.2
Low income (lower ~25%)	0.50 (0.45, 0.56)	31.9	27.4
High school graduate	1.63 (1.44, 1.84)	54.5	57.7
Catholic	0.85 (0.74, 0.97)	30.3	29.4
Anglican	1.02 (0.89, 1.17)	30.4	30.6
No religion	1.06 (0.87, 1.29)	11.5	11.6
Ever regular drinker	0.78 (0.63, 0.97)	90.4	89.9
Ever regular smoker	0.64 (0.56, 0.72)	48.2	45.3
History of alcohol dependence	0.70 (0.58, 0.83)	10.3	9.4
History of major depression	0.90 (0.79, 1.02)	27.7	27.1
History of conduct disorder	0.71 (0.58, 0.85)	9.9	9.1

Note: ^a analyses were based on 6,136 of the 6,733 individuals in the target sample who participated in the 1996–2000 interview; ^b analyses were based on 4,542 of the 4,764 individuals in the OZ-GAM sample who participated in the 1996–2000 interview.

pairs), and for categorical indicators, odds ratios are presented as an index of the strength of the association between the type of twin (from complete versus incomplete pairs) and the gambling-related outcome. Twins from pairs that were discordant for participation in the study reported a larger maximum number of dollars ever spent gambling in a day, had more symptoms of DSM-IV PG, and were more likely to have a lifetime diagnosis of PG by both the DSM-IV and SOGS definitions. For example, the prevalences of DSM-IV and SOGS PG diagnoses were about 50% higher among the twins from incomplete pairs than among the twins from complete pairs. Overall, the lifetime prevalences of DSM-IV and SOGS PG diagnoses in the full OZ-GAM sample were 2.2% and 3.5%, respectively.

Sources of Individual Differences in Gambling Involvement

The lifetime prevalence, test–retest reliability, twin correlations, and results of biometric model-fitting for 11 different gambling activities are presented in Table 8. Table 8 shows that: (a) many of the Australian twins in the OZ-GAM have participated in most of the 11 different gambling activities in their lifetime (*M* prevalence = 47%), (b) the test–retest reliability of self-reports of participation for all of the 11 gambling activities was very high (*M* reliability = 0.89), (c) the MZ twin correlations exceeded the DZ twin correlations for all 11 of the gambling activities (*M* r_{MZ} = 0.56, *M* r_{DZ} = 0.32), and (d) across the different activities, the estimates of genetic, shared

Table 7

Gambling Involvement Among Twins From Complete and Incomplete Pairs in the OZ-GAM

Indicator of gambling involvement	Complete pairs		Incomplete pairs		<i>d</i>
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	
Versatility (0–11 activities)	5.15	0.04	5.19	0.06	–0.02 (<i>p</i> = .60)
Max. frequency (days/year)	46.04	1.14	50.93	2.18	–0.06 (<i>p</i> = .08)
Max. spent (\$/day)	137.97	8.08	189.37	20.09	–0.10 (<i>p</i> = .005)
DSM-IV PG symptoms (1–10)	0.28	0.01	0.40	0.04	–0.06 (<i>p</i> = .02)
SOGS symptoms (1–20)	0.78	0.03	0.94	0.06	–0.04 (<i>p</i> = .20)
	Complete pairs		Incomplete pairs		OR (95% CI)
	%		%		
DSM-IV PG diagnosis	1.9		3.4		0.55 (0.36, 0.83)
SOGS PG diagnosis	3.2		4.7		0.67 (0.47, 0.96)

Note: Means and SEs are based on untransformed data, effect sizes (*d*) are computed with rank-normalized scores. DSM-IV = Diagnostic and Statistical Manual of Mental Disorders, 4th edition; SOGS = South Oaks Gambling Screen; PG = pathological gambling.

family environmental, and nonshared environmental influences were generally moderate, low, and moderate, respectively, with mean parameter estimates obtained of $A = 0.43$, $C = 0.10$, $E = 0.46$. There were only a few deviations from this general pattern. In particular, Internet casino gambling was of very low prevalence, the test–retest reliability of self-reports of ever participating were somewhat lower than for the other activities, and probably due to its very low prevalence, the estimates of A and C were not significantly different from zero (although the estimates of A and C were nonsignificant, the estimates of the combined familial influences was statistically significant; $A + C = 0.64$ [95% CI = 0.16, 0.91]). Also, betting on games of skill (such as billiards) appeared to be less heritable than the other forms of gambling (again, although the estimates of A and C were nonsignificant, the estimates of the combined familial influences was statistically significant; $A + C = 0.39$ [95% CI = 0.24, 0.55]).

Any lifetime gambling involvement bore striking similarities to any alcohol involvement. Both were extremely common in this Australian sample, were very reliably measured, and were strongly familial (MZ twin correlations of 0.79 and 0.77). For any gambling, the combined familial influences of $A + C$ was statistically significant ($A + C = 0.76$ [0.58, 0.88]). For any alcohol use, the broad-sense heritability ($A + D$) was estimated rather than A and D individually because additive and nonadditive genetic effects are not well parsed in the classic twin study (Martin et al., 1978; Williams, 1993). This combined

influence of additive and nonadditive genetic influences was 0.75 (95% CI = 0.57, 0.87).

The indicators of any gambling involvement and any alcohol use can also be interpreted as reversed indicators of lifetime abstinence from gambling and from drinking alcohol. Any lifetime gambling involvement was based on endorsing at least one of the 11 different gambling activities; because there are so many different ways one can gamble, it is possible that a twin's gambling experiences may not have been captured by this list. Therefore, participants were also asked to report any other gambling activities that were not included in the list. Five per cent of the twins ($N = 242$) reported another gambling activity; the three most commonly reported additional activities were 'two-up' (a traditional Australian coin-flipping game), betting on snail, mouse, rat, cockroach, rabbit, fly, and yabby (crawfish) races, or betting on the outcome of events. All of the twins who reported an additional activity also endorsed at least one of the 11 standard activities, and so the list appears to have provided adequate coverage of any gambling involvement. For both gambling and alcohol, abstinence was rare — 2% of these Australian twins were lifetime abstainers. Abstention from both gambling and alcohol were strongly familial; it was not possible to discern the extent to which the familial factors contributing to individual differences in abstinence from gambling were genetic or environmental.

The mean, test–retest reliability, twin correlations, and results of biometric model-fitting for versatility, frequency, and quantity of gambling involvement are presented in Table 9. On average, these Australian twins

Table 8

Lifetime Involvement in 11 Different Gambling Activities (and Alcohol Use, for Comparison): Prevalence, Reliability, Twin Correlations, and Variance Decomposition

Activity	Prevalence	Reliability ^a	Twin correlations		Variance components ^b (95% CI)		
	%	<i>r</i>	MZ	DZ	A	C	E
Lottery	90	0.87	0.59	0.28	0.58 (0.20, 0.68)	0.00 (0.00, 0.32)	0.42 (0.32, 0.54)
Electronic gaming machines	88	0.99	0.54	0.29	0.50 (0.13, 0.65)	0.04 (0.00, 0.34)	0.46 (0.35, 0.59)
Instant scratch tickets	86	0.84	0.56	0.22	0.54 (0.29, 0.64)	0.00 (0.00, 0.20)	0.46 (0.36, 0.56)
Horse or dog races	75	0.94	0.54	0.32	0.41 (0.13, 0.61)	0.11 (0.00, 0.34)	0.48 (0.39, 0.58)
Casino table games	47	0.94	0.60	0.30	0.54 (0.29, 0.64)	0.03 (0.00, 0.23)	0.43 (0.36, 0.52)
Keno	44	0.91	0.57	0.33	0.46 (0.22, 0.64)	0.10 (0.00, 0.30)	0.43 (0.36, 0.52)
Bingo	33	0.96	0.58	0.37	0.43 (0.18, 0.65)	0.14 (0.00, 0.34)	0.42 (0.34, 0.51)
Card games	28	0.84	0.57	0.38	0.29 (0.01, 0.56)	0.23 (0.01, 0.44)	0.49 (0.39, 0.59)
Betting on sporting event	14	0.90	0.50	0.26	0.44 (0.05, 0.58)	0.02 (0.00, 0.31)	0.54 (0.42, 0.68)
Betting on games of skill	9	0.86	0.51	0.35	0.10 (0.00, 0.54)	0.29 (0.00, 0.48)	0.61 (0.45, 0.76)
Internet casino games	1	0.71	0.60	0.44	0.46 (0.00, 0.91)	0.18 (0.00, 0.74)	0.36 (0.09, 0.84)
Any gambling	98	1.00	0.79	0.49	0.55 (0.00, 0.88)	0.21 (0.00, 0.72)	0.24 (0.12, 0.42)
					A + D		E
Any alcohol	98	0.94	0.77	0.23	0.75 (0.57, 0.87)		0.25 (0.13, 0.43)

Note: ^a based on 166 participants who completed the interview on two occasions 1.2–9.5 months apart (mean = 3.4 months); ^b controlling for the main effects of sex; reliability coefficient and twin correlations are tetrachoric correlations; MZ = monozygotic; DZ = dizygotic; A = additive genetic influences, C = shared family environmental influences, E = nonshared environmental influences.

had participated in 5 of the 11 different gambling activities listed in Table 8 in their lifetime, during their heaviest period of gambling they gambled about once a week, and on the single day that they spent the most on gambling, they lost AUD\$149. The sources of individual differences for versatility, frequency, and quantity of gambling involvement were similar to the sources of individual differences in the liability or propensity to participate in the individual gambling activities in Table 8 — there was evidence for moderate genetic effects and very modest to no shared family environmental effects.

Discussion

In this article, we describe a new twin study of gambling involvement conducted in Australia. The rationale for conducting a twin study of gambling in this particular setting is that Australia has higher rates of gambling involvement and problems than anywhere else in the world (with the possible exception of Taiwan; Hwu et al., 1989), or at least than in the United States. Below we discuss the extent to which the recruitment of a heavy-gambling twin sample was accomplished, comment on the composition of the OZ-GAM sample, and then summarize the findings regarding potential sampling biases and our ‘first look’ at the sources of individual differences in gambling involvement.

In the United States National Epidemiologic Survey of Alcohol and Related Conditions (NESARC; National Institute on Alcohol Abuse and Alcoholism; Grant et al., 2004; Petry et al., 2005), a national survey of 43,093 adults conducted in 2001–2002, the lifetime prevalence of DSM-IV PG was 0.43% in the full sample and 0.41% when the sample was restricted to 32–43 year olds (the same age range as the OZ-GAM). In the United States Gambling Impact and Behavior Study (GIBS; NORC Gambling Impact and Behavior Study; Gerstein et al., 1999), a survey of 2,417 adults conducted in 1998–1999 that used the interview on which the OZ-GAM DSM-IV PG assessment was based, the lifetime prevalence of DSM-IV PG was 0.80% in the full sample and 0.50% when the sample was restricted to 30–39 year olds (only age ranges were available in the public domain dataset in order to protect confidentiality). In comparison, the lifetime prevalence of DSM-IV PG in the OZ-GAM was 2.2%, that is, more than 500% and 400% higher than

same-aged individuals from the United States NESARC and GIBS surveys. (It is worth noting that in addition to being the first community-based twin study of gambling involvement conducted in Australia, the OZ-GAM also may be the first community-based epidemiologic survey of lifetime DSM-IV PG conducted in Australia — previous community-based surveys have focused on past-year problems, or were typically based on the SOGS assessment.) Another perspective is the relative efficiency of conducting community-based PG research in Australia versus the United States. In the Australia OZ-GAM, 4,764 participants were screened in order to identify 104 individuals with DSM-IV PG, whereas in the United States NESARC, 43,093 participants needed to be screened in order to identify 185 individuals with DSM-PG. Nonetheless, even in a heavy-gambling culture in Australia where PG is more common than in the rest of the world, it is still a relatively rare disorder.

The lifetime prevalences of ever participating in different forms of gambling were generally high, with the exception of internet casino gambling. Internet gambling has come under a great deal of scrutiny over the last decade, in Australia and in the United States, because of concerns that it will potentially make gambling opportunities more easily available to an even larger segment of the population, and thus lead to increased rates of gambling problems. Australia was the first country to legalize online gambling, and was also one of the first countries to quickly respond to the potential harms associated with online gambling. With the passing of the Interactive Gambling (Moratorium) Act in 2000, it has become illegal for any gambling service provider, in Australia or overseas, to provide services to individuals in Australia. Online casinos in Australia that were in operation prior to the moratorium have been allowed to remain available for Australia customers (but perhaps not surprisingly, the largest proportion of their customers is from the United States and other countries).

In a 1999 Australian national survey, 0.41% of adults reported that they had played Internet casino games in the past year, similar to 0.55% of twins from the OZ-GAM surveyed in 2004–2007 (not shown in Table 8). The lifetime prevalence of Internet gambling of 1% obtained in the OZ-GAM is the same as that obtained in a United States survey conducted in 2001–2003 (the National Comorbidity Survey Replication;

Table 9

Versatility, Frequency, and Quantity of Gambling Involvement: Mean, Reliability, Twin Correlations, and Variance Decomposition

Gambling index	<i>M</i> (<i>SE</i>)	Reliability <i>r</i>	Twin correlations		Variance components ^a (95% CI)		
			MZ	DZ	A	C	E
Versatility (0–11 activities)	5.16 (0.03)	0.73	0.58	0.28	0.56 (0.43, 0.61)	0.01 (0.00, 0.13)	0.43 (0.39, 0.47)
Max. frequency (days/year)	47.07 (1.01)	0.64	0.48	0.21	0.47 (0.38, 0.51)	0.00 (0.00, 0.07)	0.53 (0.49, 0.58)
Max. spent (\$/day)	148.87 (7.67)	0.70	0.58	0.31	0.43 (0.30, 0.56)	0.09 (0.00, 0.21)	0.47 (0.43, 0.52)

Note: ^a controlling for the main effects of sex; MZ = monozygotic; DZ = dizygotic; A = additive genetic influences, C = shared family environmental influences, E = nonshared environmental influences.

Kessler et al., 2008). Either Internet gambling has not become as popular in Australia as anticipated, or the measures taken to control it have been effective.

The OZ-GAM sample is broadly representative of Australian individuals 32 to 43 years of age. However, it must be recognized that the sample was originally assembled in 1980–82 (see Figure 1), and so might not match current Australian national demographic characteristics. As would be expected from any community-based longitudinal study, the OZ-GAM sample probably reflects the demographics from the period when the cohort was originally recruited. Longitudinal twin data provide several checks on sampling biases that are not possible with cross-sectional surveys of unrelated individuals. In a previous paper, Heath et al. (2001) examined the predictors (actually, ‘postdictors’) of participation in the 1989 questionnaire survey from later participation in the 1996–2000 interview in the ATR Cohort II (see Figure 1). The target sample for both surveys was the entire ATR Cohort II, but a much higher response rate was achieved with the 1996–2000 interview, and so the question was the extent to which the smaller questionnaire sample was biased. The postdictors that were identified by Heath et al. (2001) of participation in the questionnaire were very similar to the predictors of participation in the OZ-GAM interview — being female, from an MZ twin pair, obtaining a higher educational attainment, and not being Catholic, a smoker, or having a history of alcohol dependence or conduct disorder.

Comparisons of twin pairs concordant and discordant for participation in the OZ-GAM also suggested that individuals who spent more money on their gambling and who had lifetime symptoms of DSM-IV PG and PG disorder were less likely to participate. The prevalence of DSM-IV PG was 2.2 in the OZ-GAM sample overall, but it was 3.4% among those twins whose co-twin did not participate in the study. Although this seems like a big difference, it does not have much of a net effect. For example, if one assumes that the prevalence of DSM-IV PG was 3.4% among all of the 1969 twins from the target sample of 6,733 individual twins who did not participate in the OZ-GAM (for all reasons), this would have yielded an estimated prevalence of 2.5% in the full target sample. If one assumes that the prevalence of DSM-IV PG in twins who did not participate was double that estimated in the OZ-GAM, that is 4.4%, the estimated prevalence in the full target sample would have been 2.8%.

The propensity to gamble was strongly familial, but because gambling was so common, it was not possible to determine the extent to which the familial influences for any lifetime gambling was due to shared genes or shared environments. Although a different conclusion was reached, the Minnesota twin study of Winters and Rich (1998) obtained similar results. Winters and Rich reported twin concordances of any gambling in the past year of 86% for MZ twins and 81% for DZ twins, which did not significantly differ, and that led them to conclude that there were not

widespread genetic influences on all gambling behavior, but only for ‘high-risk’ gambling involvement. However, the MZ and DZ concordances were also not substantially different from the reported prevalence of 88% of any gambling in the past year among singletons obtained from a state of Minnesota survey, suggesting that the high base rate of the behavior made it difficult to disentangle the causes of individual differences. Extremely common binary traits such as any gambling can be as difficult to study as extremely uncommon binary traits such as PG disorder.

When the focus was narrowed to the propensity to participate in a particular gambling activity, the results were more straightforward. For 9 of the 11 activities assessed, the propensity to ever participate was primarily due to genetic and individual-specific environmental factors. For none of the activities was there statistically significant evidence for shared family environmental influences, although the confidence intervals were generally broad and could not rule out the possibility of shared family environmental influences accounting for as much as 30% of the variation in liability for most forms of gambling. A comparison of the results obtained for the 11 different gambling activities suggests that there were more similarities than differences, but when the ‘high-action’ and ‘non-high-action’ groupings of Winters and Rich (1998) are examined, a pattern similar to the findings of the previous study emerges. Four activities that were ‘high-action’ — lottery, electronic gaming machines, instant scratch tickets, and casino table games — had an average heritability of 54%. The four activities that were ‘non-high-action’ — bingo, card games, betting on a sporting event, and betting on games of skill — had an average heritability of 32%. Winters and Rich (1998) describe ‘high-action’ games, as those that tend to be associated with heavy player promotion and potentially high-payoffs, and ‘non-high-action’ games, as those which tend to reflect lower payoffs and informal involvement, such as social betting. Although the difference between high-action and non-high-action gambling was not rigorously tested, it looks to be a promising distinction that may potentially identify more and less heritable gambling activities.

It is also intriguing to consider the extent to which the differences between the results of the NMSQT twin study (which was conducted in the early 1960s in the United States — a gambling prohibitive milieu) and the OZ-GAM (conducted in the early 2000s in Australia — a permissive gambling milieu) may be an example of a genotype \times environment interaction. In other words, perhaps the genes that influence the propensity to gamble are more likely to be expressed in a more gambling permissive environment. An alternative explanation for the differences between the results of the NMSQT and OZ-GAM studies may rest with the ages of the samples. The NMSQT participants were high school seniors still living at home with their parents,

whereas the OZ-GAM participants were adults, most with children of their own. Perhaps the effect of the family environment on the propensity to gamble may be relatively transient and limited to the developmental period when young people are currently living with their family of origin.

Other indicators of gambling involvement showed a similar pattern of genetic and environmental influence. The number of different gambling activities an individual ever tried in their lifetime (versatility) was partially due to genetic differences, as was the frequency (number of days gambled) and quantity (amount spent) of gambling in any form of gambling. Again, there was limited evidence for an important influence of the shared family environment. These results cast doubt on theories that look to social modeling influences to explain the familial transmission of gambling.

Although an important initial step, this 'first look' at the sources of individual differences in gambling involvement in some ways raises more questions than it answers. Not presented in this report was an examination of differences in the causes of variation in men versus women. We also focused on a few crude indices of gambling involvement, and primarily reported on what is typically termed 'initiation' in the substance use literature — that is, whether one has ever used, or participated in a given gambling activity. We did not look at more fine-grained approaches to characterizing an individual's level of involvement, or the extent to which genetic and environmental influences might play somewhat different roles in the different stages or levels of involvement (i.e., initiation, regular involvement, frequent involvement, problematic involvement). We have documented genetic influences on the propensity to engage in 9 different forms of gambling, but it is extremely unlikely that there are 9 different sets of genes involved. Future research (including analyses of our own data) may be able to identify groupings of activities that have similar underpinnings, that is, common susceptibility genes, or identify a general propensity to gamble, with the same genes involved in the propensity to engage in all the different forms of gambling. Given the high rates of involvement in many different gambling activities in Australia, the OZ-GAM sample would appear to be ideal for answering such questions.

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