Genetic and Environmental Influences on Lifetime Alcohol-Related Problems in a Volunteer Sample of Older Twins*

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ABSTRACT. Few studies have employed genetically informative designs to study the causes of alcohol-related problems in nonclinical populations. We report patterns of alcohol abuse in a community-based U.S. volunteer sample of 3,049 female and 1,070 male twins aged 50 to 96. Significant gender and age effects were found for self-report measures of current and lifetime alcohol-related problems, with higher prevalence among males and lower frequency among older birth cohorts. Significant associations were found between severity of alcohol abuse (adapted from Feighner criteria) and age of drinking onset, parental history of alcohol problems and, among males, lower educational attainment. Model-fitting analyses based on data from 650 identical and 479 fraternal twin pairs indicate substantial family resemblance for a variety of definitions of lifetime alcohol abuse and alcohol problems. The median estimate of genetic variance across several definitions of alcohol problems was 38.5%, while that for shared environmental influence was 15.5%. Gender heterogeneity was not found for magnitude of genetic and environmental influences, but these comparisons were limited by low statistical power. Findings are discussed with reference to the literature on alcohol abuse among older adults and the genetic epidemiology of alcoholism (J. Stud. Alcohol 55: 184-202, 1994)

ALCOHOL ABUSE and associated disorders account for a substantial proportion of the demand for mental health and other health care services in the United States (Institute of Medicine, 1987). Due to a combination of greater longevity and increased alcohol use in successive birth cohorts, alcohol abuse represents a growing medical and social problem (Maddock et al., 1986). Despite such demographic trends, patterns and causes of alcohol use and abuse among older persons have only recently begun to be studied systematically. In this article we review the evidence for the effects of genetic and shared environmental sources of variation on alcohol abuse and then present data from a recently completed study of problem alcohol use among twins born prior to 1942.

A large number of studies have addressed the familial nature of alcohol use and abuse. Twin, family and adoption studies of alcohol abuse generally have supported some genetic contribution to the transmission of liability for alcohol abuse (cf., Gurling et al., 1981; Searles, 1990), but have varied in the degree to which they implicate shared environmental influences (see Heath, in press; McGue, in press; Merikangas, 1990; and Hodgkinson et al., 1991, for reviews). We discuss the literature and present data on twin resemblance for patterns of alcohol intake in a separate paper (Prescott et al., 1994). Here we limit our discussion of the literature to twin studies of alcohol abuse.

Twin studies provide a means of estimating the relative contributions of genetic and environmental influences on variation in human characteristics. Identical, or monozygotic (MZ), twins share 100% of their genes as well as sharing experiences such as parenting variables, family socioeconomic status and intrauterine environment. Similarity of MZ twins within a pair reflects genetic and shared environmental influences. To the extent that MZ twins are not 100% alike, unique (nonshared) experiences and environment are implicated. Fraternal, or dizygotic (DZ), twins are assumed to share family environmental influences to the same extent as MZ twins but on average share only 50% of their genes. Thus, if MZ twin pairs are more similar for a characteristic (or phenotype) than DZ pairs, genetic influences are supported, while, if MZ and

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DZ pair resemblance is equal, all similarity is attributed to shared environmental factors. (See the Method section herein; Fuller and Thompson, 1978; Heath et al., 1989; or Neale and Cardon, 1992, for more detailed treatments of twin methodology.)

Clinically ascertained samples: Archival data

Twin studies of alcohol abuse and dependence can be divided into those employing clinically ascertained samples and those based on general population samples. Among studies which ascertained twins through treatment or legal settings, four relied solely on diagnoses from medical or legal records.

Kaij (1960) studied 32 MZ and 102 DZ male twin pairs ascertained through the Swedish Temperance Board (a government agency that registers alcohol-related offenses and referrals for alcohol treatment). He found evidence for moderate genetic influence with the impact of shared environmental influences varying with the definition of affected status. The strongest evidence for genetic influences was obtained with a definition of chronic alcoholism, with 10 of 14 MZ pairs (71%) concordant compared to 10 of 31 DZ pairs (32%).

Hrubec and Ommen (1981) used U.S. military records to identify 271 MZ and 441 DZ pairs of male veterans in which at least one had alcoholism or an alcohol-related diagnosis. Subjects were aged 51 to 61 years at the time of this study, making it the only published report of a sample that had passed through the majority of the risk period for alcohol-related problems. The study found evidence of substantial genetic (estimates of 57% to 72%), but not shared environmental, contributions to alcohol abuse. This sample includes only pairs in which both twins served in the armed forces and is thus screened for medical and psychiatric conditions that would have barred military service.

Investigators in Finland (Koskenvuo et al., 1984; Romanov et al., 1991) crossed data from the national twin registry with psychiatric and medical records to identify male twin pairs aged 30 and over in which at least one twin had an alcohol-related diagnosis. Seven of 64 MZ (10.9%) and 12 of 186 DZ (6.5%) pairs were concordant for having at least one diagnosis. When combined with the national base rate of 2.5%, this yielded a heritability estimate of 35% (Romanov et al., 1991). Twins residing in the same geographical region were more likely to be concordant than twins living at a distance, a finding that appears to be due to differential social mobility rather than the influence of shared experiences on greater similarity for alcohol abuse. After controlling for differences in residence, however, the evidence for genetic factors remained significant.

Allgulander et al. (1991) studied resemblance for ICD-8 diagnosed alcoholism among 12,884 twin pairs from the Swedish Twin Registry. Intraclass correlations for alcoholism were similar across MZ and DZ pairs for both males (.40 and .36) and females (.62 and .51), yielding low estimates of genetic influences (16%) and moderate shared environmental contributions (32%). This sample was selected for severe abuse, with only about 1% of the sample meeting criteria for inclusion.

Clinically ascertained samples: Interview data

Three other groups of investigators have reported studies based on samples ascertained through treatment settings but diagnosed using clinical interviews or self-report questionnaires. Gurling et al. (1981) found modest evidence for shared environmental influences and minimal evidence for genetic influences among 15 MZ and 20 DZ male and 13 MZ and 8 DZ female twin pairs ascertained through consecutive admissions to the Maudsley Hospital in London. The authors report that for both males and females, younger pairs had higher resemblance than older twins, but these sample sizes are prohibitively small for reliable estimation of genetic and environmental influences, even before subdividing by age or gender.

Caldwell and Gottesman (1991; Caldwell, 1992) reported data from 27 MZ and 26 DZ male, 16 MZ and 24 DZ female, and 55 opposite-sex DZ twin pairs ascertained through psychiatric inpatient and outpatient admissions in St. Louis. For DSM-III diagnoses of alcohol dependence and alcohol abuse (with or without dependence), they found significant genetic variation for males. Among females, shared environmental but not genetic influences were found to be significant for both diagnoses. With these small sample sizes these gender differences were not significant, however, and the most parsimonious model included moderate genetic and shared environmental sources of variation for both genders. This sample differs from other clinically ascertained twin studies in that subjects were not selected specifically for alcohol dependence. Some probands had other psychiatric diagnoses (particularly antisocial personality disorder), and it is uncertain what effect this selection may have had on model-fitting results.

Pickens et al. (1991) interviewed 169 twin pairs originally ascertained through alcoholism treatment facilities in Minnesota. Additive genetic variation in liability for DSM-III-R-defined alcohol dependence among 50 MZ and 64 DZ male pairs was estimated as 60% with another 17% of the variance in risk due to shared environmental factors. When alcohol abuse and dependence (with or without abuse) were combined, these estimates were 36% additive genetic and 51% shared environmental variance. Resemblance for various definitions of alcohol problems was much lower among female than male pairs. For alcohol dependence, the estimated additive genetic effect among 31 MZ and 24 DZ female pairs was 42% with 0%
contribution of shared environment, while for alcohol abuse and/or dependence, estimates were 26% additive genetic and 29% shared environmental variance.

McGue et al. (1992) reported twin resemblance data on alcohol abuse and related behaviors for 85 MZ and 96 DZ male, 44 MZ and 43 DZ female, and 88 opposite-sex DZ twin pairs. This study included subjects reported by Pickens et al. (1991) but was based only on questionnaire data. Substantial heterogeneity across genders was observed, with significant genetic influences present for males but not females. Males with early onset (probands' first symptom by age 20) had evidence of higher heritability (73%) than those with later onset (30%). Shared environmental influences were moderate for early (23%) and late onset (37%) males. Among females, substantial pair resemblance was observed for both MZ and DZ twins, resulting in estimates of 63% shared environment and 0% genetic effect. Resemblance among the opposite-sex pairs suggested that the mechanisms underlying the development of alcohol abuse are shared by males and females. Based on the lack of evidence for genetic transmission among females, the authors attributed these effects to shared environmental influences. The early-onset male twins were most likely to have antisocial behaviors such as delinquency and illicit drug use and the authors suggest that twin similarity for these characteristics may partially mediate the observed resemblance for alcohol problems.

These clinically-based samples are selected for more severe alcohol-related problems, and no doubt many potential subjects with milder problems went undetected. Although such selection would be expected to produce biased estimates of genetic and environmental influences, it is difficult to predict the direction of effect upon these parameter estimates (Martin and Wilson, 1982; Neale et al., 1989).

Population-based samples

Several population-based twin studies have assessed single features of alcohol dependence, such as heavy drinking (Medlund et al., 1977) or frequency of blackouts (Kaprio et al., 1987, 1991). As it is difficult to evaluate how these correspond to clinical diagnoses, we do not review these data here. Only three published studies of alcohol abuse have been based on twin samples unselected for alcohol abuse status.

Partanen et al. (1966) collected data on drinking characteristics from male twins born in Finland between 1920 and 1929. A factor labeled "lack of control" was derived from interview items assessing alcohol consumption quantity and frequency, inability to control intake, and onset ages of hangovers and blackouts. Intraclass correlations for the factor scores were .35 for 172 MZ pairs and .27 for 557 DZ pairs, suggesting small influences of genetic factors and moderate influence of shared environmental sources. Pair resemblance for heavy drinking and arrests for drunkenness were high for both zygosities, suggesting large influences of shared environment but not additive genetic factors.

Grove et al. (1990) reported an 18% prevalence of DSM-III-defined alcohol abuse and/or dependence among 65 members of 32 sets of reared apart MZ twins and triplets. Only two pairs were concordant for alcohol-related problems, resulting in an estimated genetic effect of 11%. Given this unrepresentative and small sample, however, the statistical power and generalizability of this study are very limited.

Kendler et al. (1995) obtained psychiatric histories from 1,033 pairs of female twins from a population-based twin registry in Virginia. The sample included 159 pairs in which at least one twin met DSM-III-R criteria for alcohol dependence. Using several definitions of abuse status, MZ twin concordances were consistently higher than those among DZ pairs, yielding additive genetic estimates ranging from 50% to 61%, with no evidence for contribution of shared environmental influences.

Summary and limitations of past research

The available evidence from twin studies generally supports genetic contributions to variation in alcohol abuse, particularly among males. There is some evidence supporting stronger genetic influences among males with early onset and antisocial traits than among males with later onset and absence of antisocial behavior. The few studies that have included female subjects provide contradictory findings about the role of genetic factors in alcohol abuse among women.

The available research has several limitations, and conclusions about the bases of alcohol abuse and dependence may be premature (Searles, 1990; Stone and Gottesman, 1993). Until recently, nearly all twin studies of alcohol abuse and dependence have been based upon probands ascertained through clinical or legal contact. Since individuals enrolled in treatment programs are likely to differ from alcohol abusers in the community, the results of studies based on clinical samples may provide only a partial view of the mechanisms underlying alcohol abuse. If clinical severity is associated with a single latent dimension of liability, and probands ascertained through clinical contact are more severely affected, the disorder could appear to have greater familiarity than if the disorder is defined more broadly to include less severe forms. Even more problematic is the (likely) possibility that alcohol abuse is a heterogeneous disorder with different underlying mechanisms. If individuals who come to treatment are more likely to have comorbidity for other psychiatric or behavioral disorders, causal mechanisms based on clinical samples may be inappropriate for use with the general population.
Another limitation is the absence of age correction procedures in published reports. Although severe alcohol abuse tends to occur early among men (e.g., Cloninger, 1990), there is great heterogeneity in onset and course. Thus, a significant proportion of potential cases will be missed if results are based on subjects not through the risk period for development of alcohol-related problems.

Other limitations of many twin studies of alcohol abuse are small sample sizes and the predominant use of male samples. Since alcohol abuse is far more common among men, many investigators have confined their studies to males. However, several recent studies (Caldwell and Gottesman, 1991; McGue et al., 1992; Pickens et al., 1991) suggest that the mechanisms underlying the transmission of alcohol abuse may differ for males and females, and underscore the need for further research with female subjects. The apparently contradictory findings for women from studies using clinical ascertainment (e.g., Caldwell and Gottesman, 1991; McGue et al., 1992; Pickens et al., 1991) compared to results from population samples (Kendler et al., 1992) may be because women in treatment are atypical of women with drinking problems in the general population.

Another issue that complicates comparing results of various studies is differing diagnostic definitions. Some archival studies have relied on chart diagnoses from inpatient hospitalizations, leading to severe underascertainment of alcoholism in twins from the general population. More recent studies (e.g., Caldwell and Gottesman, 1991; Kendler et al., 1992; McGue et al., 1992) have provided twin concordance rates for a variety of definitions of abuse and dependence. Although MZ similarity is nearly always higher than that for DZ pairs, point estimates of genetic effects can vary widely depending on the definition employed and the resulting population base rate (e.g., Gottesman and Carey, 1983). Based on the typical sample sizes, it is not possible to determine whether these results are consistent with a continuum of severity or whether they suggest different mechanisms underlying abuse and dependence.

Current research

The current study was undertaken to investigate the patterns, correlates and underlying mechanisms of alcohol abuse and alcohol-related problems among older adults. These data offer many strengths including: (1) a genetically informative design in a community-based sample; (2) large numbers of female and male subjects including opposite-sex twin pairs, allowing investigation of gender and age differences; (3) subjects who essentially have completed the risk period for development of alcohol-related problems; (4) definitions of alcohol abuse based on several sets of research-based criteria; (5) validating information on abuse classifications based on co-twin report; and (6) reports of family history.

In this article we report data on past year and lifetime prevalence of alcohol-associated problems, as well as lifetime prevalence of alcohol abuse criteria based on CAGE items and adapted from Feighner and DSM-III-R criteria. The validity and reliability of these self-report measures of alcohol abuse are addressed by comparison with co-twin report and self-reported history of alcohol consumption, alcohol treatment and diagnosis of alcoholism. We then report correlates of alcohol abuse severity, including demographic variables, family history and onset ages for various drinking milestones. We present pair resemblance for several definitions of alcohol-related problems and address whether resemblance appears to be mediated through pair contact. Finally, we report estimates of genetic and environmental sources of variation based on several definitions of lifetime alcohol abuse.

Method

Subjects

Subjects are volunteers who responded to a notice appearing in a newsletter published by the American Association of Retired Persons (AARP). They are a subset of twin pairs ascertained for research on tobacco and alcohol use (see Heath et al., in press). The sample is 100% Caucasian and includes 3,049 women and 1,070 men. There are 1,409 pairs with complete questionnaire data and known zyosity including 643 female identical (monozygotic or MZ) twin pairs, 152 male MZ pairs, 320 female fraternal pairs (dizygotic or DZ), 65 male DZ pairs and 229 opposite-sex DZ pairs (DZOS). An additional 63 additional pairs had undetermined zyosity and another 1,175 individuals had co-twins who were deceased, could not be contacted or failed to respond. Detailed demographic information, description of ascertainment procedures, zyosity determination and evidence for possible selection bias appear elsewhere (Prescott et al., 1994).

Measures

Questionnaires covered a variety of domains including general health, history of neurological symptoms, alcohol use, cigarette smoking, social attitudes and various self-report measures of personality. The present research is based on measures of current and lifetime alcohol use and various problems associated with drinking. Respondents rated the presence or absence of 18 signs and symptoms of alcohol abuse during five different time periods (past year, 1-3 years ago, 4-6 years ago, 7-10 years ago and over 10 years previously). The items were adapted from diagnostic criteria for several different diagnostic systems, including Feighner (Feighner et al., 1972), DSM-III-R (American
Psychiatric Association, 1987) and the CAGE items (Ewing and Rouse, 1970; Ewing, 1984). The 18 items cover physical dependence; guilt; complaints by family and friends; loss of control; binge drinking; withdrawal symptoms; engaging in violent, hazardous and irresponsible behavior; and adverse consequences on health, family, social or occupational functioning. A list of these items in the order they appeared on the questionnaire is presented in the Appendix. For the purposes of the current analyses, occurrence of problems was recoded into past year or lifetime (any period, including the past year). Respondents were also asked about parental and co-twin drinking patterns and problems.

The symptom items were based on several classification systems and the wording is not directly analogous to all criteria, particularly those from DSM-III-R diagnoses. We recognize that abuse categories based on these items are not equivalent to diagnoses based on clinical interviews. We use the terms “abuse status” or “abuse classifications” to distinguish these categorizations from diagnostic classifications such as alcoholism and alcohol dependence.

**Feighner-based alcohol abuse criteria.** Feighner et al. (1972) proposed four symptom clusters for use in defining presence of alcohol abuse: (A) excessive use, objections to drinking by others, or negative effects on relationships; (B) legal or job problems or physical violence associated with drinking; (C) physical dependence, as measured by withdrawal symptoms or failed attempts to reduce intake; and (D) binge drinking. These criteria were associated with certainty or severity of alcohol abuse, with three or more criteria indicating “definite alcoholism,” two criteria indicating “probable alcoholism” and presence of one criterion resulting in “suspected alcoholism.” In this article we use the terms “definite abuse,” “probable abuse,” and “drinking problems” or “possible abuse” to correspond to these three categories.

Responses to 15 of the 18 alcohol problem items were used to assess presence or absence of each of the Feighner criteria. The specific items corresponding to each criterion appear in the Appendix. (Two items covering past treatment [item 5] and negative effects on health [item 16] are not directly applicable to the Feighner system and were excluded for the purposes of these classifications. The remaining question [item 1], “Was there ever a time when you drank too much?” was omitted because many subjects apparently misunderstood it to refer to single episodes of overuse rather than the intended meaning of a period of abuse.) Some aspects of the original Feighner criteria are not covered by the current symptom list, including blackouts and several withdrawal symptoms. However, individuals with these symptoms are likely to be positive for milder problems so we assume they will be detected by positive responses to other items. The effect of this would seem to be to diminish our ability to characterize severe alcohol-related problems rather than result in completely missed cases.

Data on the Feighner-based criteria were combined to form abuse classifications based on the maximum number of criteria met during any single reporting interval. For example, if a subject were rated as positive for criteria A and C during the past year, and criterion B for the interval 1-3 years ago, the maximum number of criteria from the same interval would be two. As will be described below, individuals in each category were compared with respect to various drinking related behaviors, including maximum alcohol intake. One hundred twenty-eight women and 25 men classified with “drinking problems” reported maximum intake of fewer than three drinks. Many of these individuals met Feighner criterion A for only one time period and by responding positively to a single item. For example, one subject indicated feeling guilty (Appendix item 2) after being caught drinking as a teenager. It seems likely that similar isolated incidents could result in positive responses to other items contributing to this criterion. To reduce the possibility of false positive errors, an additional criterion was imposed whereby individuals who: (1) met Feighner criterion A for a single time period, (2) were positive for no other criterion at any interval and (3) reported their maximum intake as two drinks or fewer, were excluded from the “drinking problems” classification. Individuals who met other criteria or who met Feighner criterion A for multiple periods were retained, regardless of reported intake. (The maximum intake item followed a series of questions about recent intake and we assume that some of these individuals incorrectly answered the question to refer to past year maximum intake.) Use of this rule resulted in exclusion of 114 women and 20 men from the “drinking problem” designation.

**DSM-III-R-based alcohol abuse criteria.** The DSM-III-R criteria for alcohol dependence require the presence of three of nine criteria as well as symptom duration of at least one month or symptoms occurring repeatedly over longer periods. We did not evaluate four of the most severe criteria: amount of time spent in drinking-related behaviors, reduction of non-alcohol-related activities, physical tolerance and withdrawal symptoms. Absence of this information precludes formation of abuse categories corresponding to DSM-III-R diagnoses of alcohol dependence and abuse.

The remaining five DSM-III-R criteria—(E) excessive intake, (F) intent or effort to reduce intake, (G) impaired performance of role obligations or hazardous behavior, (H) continued use despite negative effects and (I) use to relieve withdrawal symptoms—were indexed using 11 of the 18 alcohol-related questionnaire items (see Appendix). As described above, item 1 (drinking too much) was excluded from the excessive use criterion, leaving only one other item (item 6) directly related to intake. For this reason, the item on history of past treatment (item 5) was
substituted as contributing to this criterion. Although treatment participation reflects characteristics in addition to excess use, it seems a safe assumption that individuals seeking treatment have experienced a period of excessive alcohol intake. The items used to form criterion G are somewhat more restrictive than the wording of the actual criterion, since they assess neglected responsibilities due to binge drinking (rather than due to any drinking or to hangover) and trouble related to drunken driving (rather than engaging in driving while intoxicated regardless of outcome). Only one item was used to assess criterion I, and thus this criterion has less coverage than the description provided in DSM-III-R. The use of items for criteria F and H are self-explanatory. Since the coverage of the DSM-III-R criteria for alcohol dependence is incomplete, we present descriptive information for individual criteria but do not form abuse classifications based on this information.

**CAGE items.** The CAGE items developed by Ewing (1984; Ewing and Rouse, 1970) cover four behaviors proposed as central to alcohol dependence. CAGE is a mnemonic for: need to Cut back, Annoyed by others’ criticisms, Guilt over drinking and Eye openers (morning drinking). Specific wordings of the four items are presented as criteria J through M in the Appendix.

**Missing data**

The four Feighner and five DSM-III-R-based criteria were coded as present or absent for each of the five reporting periods. (CAGE items are usually used to assess lifetime abuse so we did not evaluate them by reporting period.) Criteria were considered present if a subject indicated a positive response to at least one of the contributing items, and absent if negative responses were given to all items answered. Criteria were coded as missing if data were missing for all contributing items. Abuse classifications based on the Feighner criteria were coded as missing if subjects lacked sufficient data to exclude a classification of definite or probable abuse. However, if an individual was positive for at least one criterion he or she was retained, no matter how many other criteria were missing. These rules permitted us to use as much data as possible while reducing the possibility of false negative errors. For each item, data were missing for 3-7% of nonabstaining subjects, permitting the great majority of subjects to be assigned positive or negative on all criteria.

**Reliability and validity of abuse classifications**

The primary definition of alcohol abuse used in this article are the classifications adapted from the Feighner criteria. To evaluate the reliability of these designations, abuse categories were compared to various indices of alcohol-related problems including reported history of treatment, past diagnosis of alcoholism (as reported on a previous questionnaire), self-perception of an alcohol-related problem of any duration and excessive alcohol intake (based on maximum single day consumption). Excessive intake was defined a priori as intake at the 90th percentile of the distribution of nonabstainers within each gender. This threshold corresponded to 6 or more drinks for women and 12 or more for men. Validity data on the history of subject drinking problems is available for complete pairs from reports of co-twins. Although informant report does not necessarily correspond to clinical definitions of alcohol abuse, this information does provide evidence of the existence of problems others consider socially significant.

Although these measures are subject to problems of self-report they provide some reliability and construct validity for our classifications. High prevalence of these measures among individuals assigned to the probable and definite abuse classifications can be considered necessary, though not sufficient, for validation of these definitions. If use of these criteria results in categorizing as unaffected many individuals who previously received treatment or diagnoses of alcoholism, we would have to question the usefulness of classification based on such self-report data. Our definition of alcohol abuse is broad and we expect that our criteria will classify as problem drinkers many individuals who have not been identified (by self or others) previously, either due to denial of abuse or lesser severity. For these reasons, we consider it to be a greater error to classify as unaffected individuals who are positive for other indices of abuse than to classify as abusers individuals for whom we lack corroborating information. Thus, we are interested primarily in the sensitivity rates (proportion of those positive for validating criteria who are detected by our abuse classification), and only secondarily concerned with positive predictive power (proportion of those classified as abusers who are positive for validating criteria). (See Gottesman and Prescott, 1989, for discussion of predictive power applied to assessment of alcohol abuse.)

**Statistical techniques and models**

These analyses use standard structural modeling techniques to partition behavioral variation into three sources: additive genetic variation, environmental variation unique to an individual and environmental variation shared by members of a sibship or twin pair (common environment). The three components are assumed to be additive and uncorrelated. The models also assume an absence of assortative mating (i.e., spouses having correlated liability for alcohol abuse). Since this assumption is probably incorrect, some portion of the variance attributed to shared environmental variance may reflect the impact of assortative mating in the parents, resulting in increased sibling re-
TABLE 1. Lifetime and 1-year prevalence of alcohol-related problems

<table>
<thead>
<tr>
<th></th>
<th>Lifetime prevalence</th>
<th></th>
<th>1-year prevalence</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>TOTAL SAMPLE</td>
<td>NONABSTAINERS</td>
<td>CURRENT DRINKERS</td>
</tr>
<tr>
<td></td>
<td>Females (3,049)</td>
<td>Males (1,070)</td>
<td>Females (2,684)</td>
</tr>
<tr>
<td>Alcohol use</td>
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<tr>
<td>Lifetime use</td>
<td>87.7</td>
<td>92.7</td>
<td>100.0</td>
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<tr>
<td>Past year use</td>
<td>63.4</td>
<td>73.3</td>
<td>72.0</td>
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<tr>
<td>Specific problems</td>
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<tr>
<td>Excessive use</td>
<td>32.2</td>
<td>53.4</td>
<td>36.7</td>
</tr>
<tr>
<td>Guilt about use</td>
<td>19.7</td>
<td>32.9</td>
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<tr>
<td>Others objected</td>
<td>10.6</td>
<td>29.4</td>
<td>12.1</td>
</tr>
<tr>
<td>Bothered by criticisms</td>
<td>5.2</td>
<td>16.5</td>
<td>5.9</td>
</tr>
<tr>
<td>Treatment</td>
<td>1.4</td>
<td>3.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Believed should decrease</td>
<td>17.3</td>
<td>35.5</td>
<td>19.8</td>
</tr>
<tr>
<td>Failed to decrease</td>
<td>3.3</td>
<td>10.1</td>
<td>3.8</td>
</tr>
<tr>
<td>Failed to stop</td>
<td>3.5</td>
<td>7.4</td>
<td>4.0</td>
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<tr>
<td>Physical fights</td>
<td>1.3</td>
<td>5.2</td>
<td>1.5</td>
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<td>Binges &gt;1 day</td>
<td>1.1</td>
<td>3.4</td>
<td>1.3</td>
</tr>
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<td>Binged &amp; neglected responsibilities</td>
<td>1.4</td>
<td>4.6</td>
<td>1.7</td>
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<tr>
<td>Drunken driving</td>
<td>0.8</td>
<td>6.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Other legal problems</td>
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<td>2.6</td>
<td>0.4</td>
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<tr>
<td>Morning drinking</td>
<td>1.5</td>
<td>4.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Effects on social life</td>
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<td>8.6</td>
<td>2.6</td>
</tr>
<tr>
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<td>9.4</td>
<td>4.4</td>
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<td>Effects on home life</td>
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<td>12.3</td>
<td>3.7</td>
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<td>Effects on employment</td>
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<td>4.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Personal &amp; family history</td>
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<td></td>
<td></td>
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<tr>
<td>Believed had problem</td>
<td>4.5</td>
<td>12.3</td>
<td>5.0</td>
</tr>
<tr>
<td>Problem lasted &gt;1 month</td>
<td>2.1</td>
<td>3.9</td>
<td>2.3</td>
</tr>
<tr>
<td>Twin said had problem</td>
<td>3.0</td>
<td>6.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Father had problem</td>
<td>10.5</td>
<td>8.6</td>
<td>11.3</td>
</tr>
<tr>
<td>Mother had problem</td>
<td>2.4</td>
<td>1.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Either parent had problem</td>
<td>12.1</td>
<td>9.4</td>
<td>13.0</td>
</tr>
<tr>
<td>Both parents had problem</td>
<td>0.9</td>
<td>0.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

*Data available only for twins from complete pairs responding to item (N = 2,005 females and 607 males)

We evaluate the fit of a model using the probability value associated with the chi-square fit statistic. A small probability value suggests the data are unlikely to have arisen from the proposed model, while larger probability values indicate better fitting models. We compare alternative models using the difference in their chi-square statistics ($\Delta \chi^2$) relative to the difference in degrees of freedom ($\Delta df$), and consider a model to provide significantly better fit than an alternative if the chi-square difference is significant at the .05 level. More details on evaluation of model fit are presented in the companion paper (Prescott et al., 1994). See Fuller and Thompson (1978), Heath et al. (1989) or Neale and Cardon (1992) for more detailed treatments of the twin method, and Muthén (1988) for discussion of latent variable modeling of categorical data.

**Results**

**Lifetime alcohol-related problems**

Frequencies for alcohol-related problems were tabulated separately for males and females. Table 1 presents lifetime prevalence data for various alcohol-related behaviors and
problems. The first two columns present values by gender for the complete sample, including those who report lifetime abstinence. The middle two columns show endorsement values among nonabstainers, reflecting prevalences only among those exposed to alcohol.

Aside from the “drank too much” item discussed previously, endorsements of alcohol-related problems ranged from 0.3% (legal problems) to 19.7% (guilt) among women, and from 2.6% (legal problems) to 35.5% (believed should cut down) among men. As is typical of other samples, the reported prevalences of alcohol-related problems among males were 2-3 times higher than among females.

Among individuals who had ever used alcohol, 5.0% of women and 12.9% of men indicated they considered themselves to have had problems with alcohol during their lifetimes. About half of these women (2.3%) and a third of these men (4.1%) indicated their drinking problems lasted more than one month. Co-twin reports, available for 2,612 twins, indicate 3.4% of female and 6.8% of male subjects who drank are considered by their twin to have had a drinking problem lasting more than one month. A small proportion of subjects acknowledged they had received treatment for alcohol-related problems, with 45 (1.6%) of female drinkers and 39 (4.1%) of male drinkers reporting involvement in Alcoholics Anonymous or other treatment.

**Current alcohol use and associated problems**

The right side of Table 1 presents frequencies of past year alcohol-related problems among the 63% of women and 73% of men who used alcohol during the year prior to questionnaire completion. Overall, the prevalences of current alcohol-related problems are much lower than those reported for lifetime problems. The great majority of subjects (89%) reported no current problems, with an additional 7% acknowledging one or two problems, 3% having three to five and only 1% reporting six or more alcohol-related problems. These low values probably reflect several factors, including a general decrease in alcohol consumption in older age, the shorter reporting period, selective survival of non-problem drinkers and greater response bias toward underreporting current problems. As was true for lifetime problems, prevalence of current alcohol-related problems was about 2-3 times greater among males compared with females.

Greater prevalence of recent problems was significantly \( p < .001 \) associated with higher frequency and quantity of alcohol intake. Items covering treatment, binging, drunken driving, legal problems and negative effects on social life and employment had cell sizes too small to provide reliable chi-square tests of association with intake, but the observed relations were in the expected direction. Individuals who endorsed multiple problems were much more likely than others to report frequent alcohol intake during the past year. Among 136 subjects reporting at least three drinking-related problems, 46% of women and 47% of men used alcohol daily compared to 11% of women and 13% of men who endorsed fewer problems. Fifteen percent of females and 19% of males with three or more problems reported consuming at least 25 drinks weekly, compared to 1% of females and 2% of males with fewer reported problems.

**CAGE items**

Response rates for the individual CAGE items appear in Table 1. Among women, the most commonly endorsed item was guilt over drinking, followed by believed should cut down, annoyed by criticisms and morning drinking. About one-third of male respondents reported guilt over drinking and believing they should cut down, followed by annoyed by criticisms and morning drinking. Based on a cutting score of three or more items, 3.6% of women and 12.1% of men would be classified as alcohol abusers. Using the commonly employed criterion (Ewing and Rouse, 1970) of two or more items, 12.6% of women and 26.7% of men would be classified as having suspected alcohol abuse.

**DSM-III-R-based abuse criteria**

Lifetime prevalence estimates were also complied for the five available DSM-III-R-based criteria. The most frequently met criterion was excessive intake. One-sixth (16.8%) of female and 35.3% of male respondents reported a period during their lifetime when they believed they should reduce their drinking or had entered treatment for a drinking problem. Among women, the next most commonly met criteria were negative social, family, occupational or health effects (5.7%); failed attempts to cut back (4.7%); irresponsible behavior (1.8%); and morning drinking (1.5%). Prevalences among men were again two to four times greater than among women but in the same relative ordering with negative psychosocial and health effects experienced by 14.4%, failed attempts to cut back by 11.5%, irresponsible behavior by 8.8% and morning drinking by 4.6%.

Relatively few subjects acknowledged having alcohol-related problems of sufficient length to meet the DSM-III-R 1-month duration criterion for alcohol dependence. Only 2.1% of female and 3.9% of male respondents specifically reported problems lasting longer than 1 month. However, it seems likely these responses underestimate the actual numbers of subjects experiencing persistent alcohol-related problems. Many subjects responded negatively to items that explicitly asked about “drinking problems” despite giving positive responses to several of the 18 alcohol problem items. Furthermore, nearly the same proportions of subjects (1.5% and 3.6%) reported enter-
ing treatment for drinking problems. Unless one believes that all subjects with even briefly enduring problems seek treatment, it seems likely that many more subjects experienced problems for longer than 1 month.

Feighner-based abuse criteria and classifications

As detailed in the Method section, questionnaire items were used to form four criteria for alcohol abuse adapted from Feighner criteria. As with the individual symptoms, men were between two and four times as likely as women to meet thresholds for these criteria. As can be seen from Figure 1, the ordering of criteria was the same for males and females. Criterion A (excessive intake, criticism by others of one's drinking, and negative social or health effects) was met by 26.0% of female respondents and 46.7% of males. Less common were legal or work problems (criterion B; 2.3% of women, 11.8% of men), physical dependence (C; 5.1% of women, 12.3% of men), and binge drinking (D; 1.7% of women, 5.3% of men).

The maximum number of criteria met during a single reporting interval was used to form abuse classifications. The proportions of subjects in each category are displayed by gender in the right side of Figure 1. The threshold for definite alcohol abuse (3 or 4 criteria) was met by 1.5% of female and 6.4% of male respondents. Using the broader definition of definite plus probable abuse (at least two criteria), 5.4% of female and 16.3% of males were classified as positive for alcohol abuse. The values for the broadest category of drinking problems plus probable or definite abuse were 22.6% among women and 45.8% among men. (These values were obtained after screening out low volume drinkers; see Method section.) For the remaining description and analyses, the term "abuse classifications" (unless specified otherwise) will refer to those adapted from the Feighner criteria.

Table 2. Lifetime prevalence of abuse classification by abuse indices (entries are percentage of individuals positive for criterion classified within each abuse category)

<table>
<thead>
<tr>
<th>External criterion</th>
<th>n</th>
<th>No abuse</th>
<th>Possible</th>
<th>Probable</th>
<th>Definite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>84</td>
<td>1.2</td>
<td>4.8</td>
<td>21.4</td>
<td>72.6</td>
</tr>
<tr>
<td>Previous diagnosis</td>
<td>53</td>
<td>1.9</td>
<td>9.4</td>
<td>15.1</td>
<td>73.6</td>
</tr>
<tr>
<td>Twin-reported problem</td>
<td>98</td>
<td>10.2</td>
<td>30.6</td>
<td>23.5</td>
<td>35.7</td>
</tr>
<tr>
<td>Self-reported problem</td>
<td>242</td>
<td>6.2</td>
<td>28.9</td>
<td>29.8</td>
<td>35.1</td>
</tr>
<tr>
<td>Excess intake</td>
<td>418</td>
<td>27.0</td>
<td>38.0</td>
<td>20.6</td>
<td>14.4</td>
</tr>
<tr>
<td>None of above</td>
<td>3,391</td>
<td>79.8</td>
<td>17.5</td>
<td>2.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Base rate</td>
<td>3,972</td>
<td>71.3</td>
<td>20.4</td>
<td>5.5</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Evidence for abuse classifications

Table 2 presents the lifetime prevalence of abuse classifications among individuals positive for each of the five indices. Strong trends were found for treatment and previous diagnosis, with individuals in the definite and probable classifications accounting for the large majority of cases. Similar, but less dramatic, trends were also present for twin- and self-report of alcohol problems and high maximum intake. When evaluating these proportions it is important to compare them to the base rates for the abuse classifications. These values, portrayed in the bottom row of Table 2, represent the expected values for each column. The 8.3% of individuals who comprise the definite and probable categories account for 94% of those reporting treatment, over 88% of those with diagnosed alcoholism, nearly 60% of those reported by their co-twins to have drinking problems, 65% of those who self-report drinking problems and 35% of those having excessive intake levels. Males and females had similar patterns for treatment, prior diagnosis and self-reported problems but women in the drinking problems category accounted for relatively more of the co-twin report and excess intake cases than their male counterparts.

Table 3 presents the prevalence of each of the indices among the subjects in each classification. A clear positive association was found between increasing severity of abuse and endorsement of other alcohol-related criteria. Among the 111 individuals classified in the definite abuse category, 55% had received treatment, 35% previously had been diagnosed with alcoholism, 81% reported a history of drinking problems and 54% had excessive single-day consumption. Among the 70 subjects in the definite abuse category for whom co-twin reports were available, 50% were reported by their co-twin as having had alcohol-related problems lasting more than 1 month. In contrast, fewer than 1% of individuals classified in the no-abuse category had been in treatment, received a diagnosis of alcoholism, perceived themselves as having had a drinking problem or been reported by their co-twin as having had a drinking problem of at least 1 month's dura-
tion, and only 4% met our definition of excessive intake. Prevalences for the drinking problems and probable abuse categories were intermediate between those for no abuse and definite abuse, with a classification of probable abuse always associated with a higher affected proportion than those observed for the drinking problem category. These values are similar across genders (Figure 2) except among women classified as having definite alcohol abuse who were more likely than men to have entered treatment (73% vs 43%).

**Correlates of abuse status**

Age, marital status, educational level, employment status, family income, onset ages for drinking milestones and problem drinking, and family history of alcohol abuse were studied separately by gender for association with abuse classification. Because of the relatively few individuals in the definite abuse classification, the definite and probable categories were grouped together for these analyses.

As we found previously in our analyses of alcohol use (Prescott et al., 1994), age differences existed for alcohol abuse, with individuals in the probable and definite abuse classifications significantly younger than subjects in the drinking problems and no-abuse groups ($F = 4.3, 1/3,978$ df, $p < .05$). There was a trend toward an interaction with gender ($F = 3.1, 1/3,978$ df, $p < .08$), with females showing a stronger effect of age on abuse.

Abuse status was significantly associated with educational attainment among men ($\chi^2 = 13.6, p < .01$), with males who had education beyond high school less likely to be classified as having alcohol abuse problems. There was also a tendency for males in lower income levels to be classified as abusers ($\chi^2 = 11.0, p < .1$). No association was found between alcohol abuse classification and educational attainment or family income among subjects. Marital status and employment status were not significantly associated with abuse level for either males or females.

Age of attaining each of five drinking milestones was significantly associated with severity of lifetime alcohol-related problems. Males and females classified as non-abusers reported trying alcohol an average of 3 years later than respondents classified in the probable/definite category, and 2 years later than those in the drinking problem classification. Similar patterns were observed for other milestones, including age of first drink with friends and

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**TABLE 3. Prevalence of abuse indices by Feighner abuse classification (entries are individuals within each abuse category positive for criterion)**

<table>
<thead>
<tr>
<th>Feighner abuse classification</th>
<th>Previous treatment</th>
<th>Previous diagnosis</th>
<th>Twin report</th>
<th>Self-report</th>
<th>Excess intake</th>
<th>Any</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n$</td>
<td>$n$</td>
<td>$n$</td>
<td>$n$</td>
<td>$n$</td>
<td>$n$</td>
</tr>
<tr>
<td>No abuse</td>
<td>2,840</td>
<td>1</td>
<td>0.04</td>
<td>10</td>
<td>0.5</td>
<td>113</td>
</tr>
<tr>
<td>Possible</td>
<td>813</td>
<td>4</td>
<td>0.5</td>
<td>30</td>
<td>5.8</td>
<td>159</td>
</tr>
<tr>
<td>Probable</td>
<td>218</td>
<td>18</td>
<td>8.3</td>
<td>23</td>
<td>18.1</td>
<td>72</td>
</tr>
<tr>
<td>Definite</td>
<td>111</td>
<td>61</td>
<td>55.0</td>
<td>35</td>
<td>50.0</td>
<td>85</td>
</tr>
<tr>
<td>Criterion base rate$^a$</td>
<td>2.1</td>
<td>1.3</td>
<td>3.8</td>
<td>6.6</td>
<td>13.3</td>
<td>14.8</td>
</tr>
</tbody>
</table>
drinking milestones: first drink, first intoxication, and regular drinking. Although great variability was present in both groups, the mean intervals were significantly shorter for the definite abuse classification. Definite abusers reported an average interval of 17.8 ± 12.6 years (range = 0.56) between their first drink and on the onset of problem drinking, compared to 23.2 ± 13.2 years (range = 0.47) among probable abusers ($F = 7.1, 1/154$ df, $p < .01$). The average lag between first intoxication and problem drinking was 13.2 ± 12.1 years (range = 0.56) among definite abusers compared to 18.5 ± 12.7 years (range = 0.54) among probable abusers ($F = 7.6, 1/144$ df, $p < .01$). Similarly, the mean interval between regular drinking and problem drinking was 12.2 ± 11.5 years (range = 0.52) among definite abusers compared to 16.2 ± 12.7 years (range = 0.47) among probable abusers ($F = 5.2, 1/131$ df, $p < .05$). Gender differences and the interaction of gender and abuse severity were not significant for any of the three measures, although females tended to have shorter intervals than males.

Figure 4 shows the relation between severity of alcohol abuse and presence of parental alcohol abuse as reported by subjects and their co-twins. Greater abuse severity was associated with probability of having an affected father ($\chi^2 = 25.2, p < .001$), mother ($\chi^2 = 39.7, p < .001$) or both parents ($\chi^2 = 37.5, p < .001$). Trends were similar across genders but were somewhat stronger for female subjects.

Factors mediating pair similarity

We found little evidence for the influence of past or current social contact on pair resemblance for alcohol abuse. A wide range of ages of separation were reported for pairs in all abuse levels and these distributions differed little across groups. Among pairs concordant for any level of abuse (drinking problem, probable abuse or definite
abuse), 45% did not begin living apart until age 21 or later, and among pairs “concordant” for no abuse, 48% lived together past age 21. This proportion was only slightly lower, 39%, among those twins discordant for alcohol abuse, suggesting that more intense interaction in young adulthood probably does not explain similarity for lifetime alcohol abuse.

The frequency of in-person or telephone contact between twins was assessed on a questionnaire administered 4 years prior to the current study. Among pairs with neither twin affected, 31% had daily or weekly contact, another 31% communicated once or twice monthly, and the remaining 38% were in contact only a few times yearly. Among pairs with both members positive for alcohol abuse, 28% were in contact at least weekly and 20% communicated monthly. Values among pairs discordant for abuse were similar (25% at least weekly and 28% monthly contact). Since MZ twins were more similar for abuse, the association between contact and abuse concordance was examined separately by zygosity. Among pairs with neither member affected, a large proportion of MZ twins had frequent contact, with 39% communicating daily or weekly compared to 23% of same-sex DZ twins and 15% of opposite-sex pairs. These values were virtually the same among same-sex pairs discordant for abuse (36% for MZs, 22% for DZs), but lower among opposite-sex pairs (4%). Pairs concordant for alcohol abuse were most likely to have infrequent contact, with 45% of MZ pairs, 51% of DZ same-sex pairs, and 81% of DZ opposite-sex pairs in touch less than monthly. These results suggest frequency of pair contact in later adulthood does not explain similarity for lifetime alcohol abuse.

We also examined the influence of age heterogeneity on pair resemblance for abuse. As noted previously, older subjects were less likely to have been classified in any of the abuse categories. After excluding lifetime abstainers (who were overrepresented in the oldest age groups) this difference was no longer significant for males ($\chi^2_{10} = 14.5, p > .1$), but remained so for female pairs aged 75 and older ($\chi^2_{10} = 33.1, p < .01$). Of greater concern for the present analyses, however, is homogeneity of pair resemblance over age groups. For both males and females, equivalence of tetrachoric correlations between younger and older cohorts could not be rejected. Subsequent analyses are based on zygosity groups combined over age.

**Pair resemblance for alcohol abuse**

The proportion of positive concordant pairs for the CAGE items and Feighner and DSM-III-R–based criteria other than excessive use was low, ranging from 0% to 8%. Due to such low base rates and the resulting instability of the tetrachoric correlations, we did not conduct model-fitting analyses on individual diagnostic criteria.

Table 4 presents pair resemblance data by zygosity for seven different definitions of alcohol abuse. The first definition considers as affected only those subjects receiving a definite abuse classification, whereas all others are considered negative. The second employs a broader definition of definite plus probable abuse, and the third uses the broadest definition of considering as affected anyone positive for at least one of the criteria. The fourth definition uses a three-category classification of no symptoms, problem drinking and definite plus probable abuse. Next is a three-category classification based on CAGE item scores of 0, 1 or 2, and 3 or 4. The sixth definition uses the subject's response to the single item, “Have you ever had an alcohol problem?” The final definition is a continuous index based on lifetime total problems. This was obtained by summing the number of problems endorsed (out of 18), then transforming (by taking the fourth root) to correct for the marked positive skewness of the distribution.

For the first three measures, Table 4 also displays the proportions of pairs concordant for presence and absence of abuse. For example, 7 of 512 female MZ twin pairs (1.4%) were concordant for a definition of probable plus definite abuse and 449 (87.7%) were similar for nonabuse under this definition. The remaining 56 pairs were discordant, with one twin classified as an abuser and the other not (see Table 4, definition 2). Twins from same-sex pairs are randomly ordered within pairs so we expect the proportions in the two discordant cells to be equal and make no distinction between these groups. The exception to this is for opposite-sex twin pairs, for whom it is expected (because of base rate differences between genders) that the proportion of pairs with affected males and unaffected females will be greater than that of pairs with affected females and unaffected males.

As can be seen by these proportions, the numbers of pairs concordant for abuse are small for all but the broadest definition. The standard errors for the tetrachoric correlations based on these classifications are large, reflecting the small sample sizes and instability of these estimates. Such results are common for estimation of tetrachoric correlations, particularly for conditions with low base rates. We thus conducted several tests to assess our power for biometric modeling.

The results of these tests are displayed in the final three columns of Table 4. The first of these represents a test of the assumptions of bivariate normality and whether the thresholds are equivalent for males or females across all zygosity groups. (For the continuous index of total problems, this test statistic represents a test of equivalence of score variance and means for males and females of different zygosity groups.) Based on an alpha level of .05, this assumption is supported for four of the seven definitions. However, definitions based on the broadest Feighner-based classification, the CAGE items and self-report are rejected at this level. Inspection of the fit separately by
zygosity group revealed this misfit is primarily attributable to threshold differences between groups. Thus, within the constraints of the available power, these data are consistent with the distributional assumption of bivariate normality.

The correlations based on the dichotomous classifications show some male-female differences, whereas those based on the multiple threshold and continuous measures provide little evidence of gender differences. We next fit models to test whether these data supported the presence of gender differences in pair resemblance for lifetime alcohol-related problems. This model required equivalence of male and female MZ correlations and equivalence of male, female and opposite-sex DZ correlations, resulting in a 3 degrees of freedom difference relative to the previous model. For all seven definitions, the chi-square difference was small and could not be rejected at the .05 level. Thus, these data do not support the presence of significant differences between male and female groups in degree of resemblance for any of these measures.

Finally, we fit models to test for differences in resemblance across MZ and DZ groups. Equality of zygosity could be rejected for only one measure, the broadest dichotomous definition of problem drinker plus probable and definite abuse. Thus, although the estimates of MZ pair resemblance are consistently higher than those for DZ pairs, the data are generally of insufficient power to make strong conclusions about genetic or environmental sources of resemblance.

Results of biometrical genetic models

Given the limited power of these data, the results of biometric model fitting are provided in a descriptive mode. A series of models were fit for five definitions of lifetime alcohol abuse. The definitions of definite abuse only and self-reported problem were excluded due to the absence of concordant pairs in the DZ male group. For all five definitions, a model of no pair resemblance was clearly rejected ($p<.001$), strongly supporting the exist-
ence of familiality for lifetime alcohol-related problems, however defined. The fit of a model constraining all resemblance to be due to additive genetic sources did not differ significantly from that for the model requiring all familiality to be due to common environment. We thus report parameter estimates based on the full model, allowing for the contribution of all three sources of variation.

The top portion of Table 5 displays the chi-square fit statistic, degrees of freedom and associated probability value for each definition. Other than the CAGE items, the models fit well, but as noted above, there is limited power to test group heterogeneity for characteristics other than threshold differences.

The middle portion of Table 5 presents the standardized proportions of variance attributable to each source along with parameter estimates and associated standard errors. Standard-error estimates are not available with the Mx program, so we estimated them as the parameter loading divided by the square root of the difference between the chi squares for the full model and the model with the parameter fixed to zero. Thus, if a parameter estimate is more than 1.96 times its standard error (i.e., the square root of the .05 critical value for a chi-square statistic with 1 degree of freedom), the parameter is significantly different from zero at the .05 level. These estimates are larger than those obtained when modeling tetrachoric and polyarchic correlations in conventional software packages (e.g., LISREL-7, Joreskog and Sorbom, 1989; LISCOMP, Muthen, 1988), but have a more clear interpretation. Standard error estimates are not presented for the unique environment parameter since it merely represents the non-shared or residual variance, and the hypothesis of 0% residual is untenable.

Estimates of genetic variation range from 20% to 48% across the five definitions, with a median of 32%. Estimates for common environmental proportions of variance range from 7% to 22% with a median of 16%. The parameter estimates for additive genetic effects for four of the five definitions are significant at the .05 level (based on the definitions above), but the common environmental parameters do not meet this criterion for any of the definitions.

The lower portion of Table 5 displays the estimated proportion of individuals in each severity level (for the four categorical measures) and the mean scores (for the index of total problems) by gender.

Discussion

This investigation differs from prior twin studies of alcohol abuse in several important ways. Unlike most other population-based twin studies, we collected extensive data on current and lifetime history of alcohol-related problems as well as consumption variables. To our knowledge, this is the only study of alcohol-related problems in a large sample of male and female twins who have completed the conventional risk period for alcohol dependence. Our sample of 1,409 pairs of male, female and opposite-sex twins provides greater power to test for age and gender differences in genetic and environmental contributions to alcohol-related problems.

As is typical of studies of alcohol-related behaviors (e.g., Barnes et al., 1980; Schuckit, 1985), we found striking gender differences, with males having higher prevalence of current and lifetime signs and symptoms of alcohol abuse. These findings are similar to our findings for alcohol use with this sample (Prescott et al., 1994), in which
males began drinking at younger ages, drank more often and consumed more when drinking than did females.

Our finding of a 16.3% lifetime prevalence of probable plus definite abuse among males is very similar to the lifetime prevalence estimate of 16.8% for DSM-III alcohol abuse plus dependence among males 45 and older from the Epidemiologic Catchment Area project (ECA; Eaton and Kessler, 1985; see also Helzer et al., 1991; Robins and Regier, 1991), and of 14.0% from the 1988 National Health Interview Survey (NHIS) among Caucasian males using DSM-III-R criteria (National Institute on Alcohol Abuse and Alcoholism, 1992). Our prevalence of 5.4% among women is higher than ECA findings of 2.1% among women over 45, but similar to the 4.7% reported for Caucasian females from the NHIS.

We have treated drinking problems as part of an abuse continuum, rather than considering individuals with alcohol dependence to differ categorically from those with less severe drinking problems. This conceptualization is somewhat speculative, but is supported by longitudinal studies of the development of alcohol abuse (e.g., Clark and Cahalan, 1976; Vaillant, 1983), by our finding of increased prevalence of self- and twin-reported alcohol problems among individuals with "drinking problems" relative to values among nonabusers and by the good fit of the multiple threshold baseline model.

Our lifetime prevalences for any classification of drinking problems (problem drinking and probable or definite abuse) were 23% for women and 46% for men. These values, although higher than what we might have expected for these older, economically advantaged subjects, are consistent with those found in other national samples. For example, 30% of current drinkers over age 35 (combined across gender) from the National Household Survey endorsed at least one symptom of dependence for the year prior to interview (National Institute on Drug Abuse, 1989), suggesting even higher levels for lifetime alcohol-related problems.

As is common in other studies (e.g., Helzer et al., 1991; Mishara and Kastenbaum, 1980), severity of lifetime alcohol problems was associated with a variety of other characteristics, including demographic variables, positive family history and age at various drinking milestones such as first drink, first time intoxicated and regular drinking. We found significant age cohort effects, with individuals born prior to 1918 having lower prevalence of alcohol abuse than individuals born subsequently. These effects were similar to those observed in the ECA study (Helzer et al., 1991), in which prevalence of lifetime DSM-III-based alcohol abuse/dependence was 21.1% among males aged 45 to 64 compared to 13.5% among males over 64. Prevalence estimates for women were 3.1% in the 45 to 64 age group and 1.5% among women 65 and older.

A number of factors may contribute to the observed lower prevalence among older groups, including higher mortality among individuals with alcohol abuse histories, a greater reporting bias among older respondents toward denying alcohol abuse and actual cohort differences such as individuals born more recently have higher prevalence of disorder (e.g., Helzer et al., 1991). We cannot resolve these issues based on our data. However, we found that younger subjects had higher prevalence of abuse even after controlling for cohort differences in alcohol use and abstinence, suggesting increased prevalence among individuals (particularly women) born more recently. Provocative findings from a study of familial transmission of alcohol abuse suggest that increased prevalence among younger subjects is not due to an increase of sporadic cases but from more cases among individuals with familial liability (Reich et al., 1988).

Males with a history of alcohol-related problems tended to have lower levels of current family income and lower educational attainment. Neither of these characteristics was associated with lifetime drinking problems for women, perhaps because regular drinking among women tended not to begin until their mid-20s, by which time their education would be complete. In addition, for many of the women in this study, family income is likely to depend on husband's employment and would be less affected by their own disability from alcohol problems. Individuals with a history of alcohol-related problems did not differ from other subjects on current marital or employment status, probably reflecting the long interval for most subjects between occurrence of these problems and study participation. Increased severity also was associated with younger age at drinking milestones and earlier onset of drinking problems. Individuals in the definite abuse classification also experienced shorter intervals between problem onset and ages of first drink, beginning regular drinking and first intoxication than those with probable abuse. These intervals did not differ significantly across males and females.

Using several overlapping definitions of alcohol abuse, we found strong evidence for family resemblance for liability to lifetime alcohol abuse and alcohol-related problems, with about 50% of the variance estimated as familial. There was a significant additive genetic contribution to this variation with estimates ranging from 20% to 48% (median = 32%) depending on the definition employed. We were unable to resolve whether the observed familiality was due entirely to genetic contributions or to a combination of genetic and shared environmental influences. Obtained estimates of common environmental variation ranged from 7% to 22% with a median of 16%.

As noted previously, we did not incorporate data on parental assortative mating for alcohol abuse in our models. To the extent that parents of these twins had positively
correlated liability for abuse, the obtained estimates would be biased toward overestimating shared environmental effects and underestimating the role of genetic influence. Based on twin's reports of whether their parents had an alcohol-related problem lasting at least one month, the phenotypic parental correlation (± SE) for alcohol problems is \( p = .48 \pm .06 \). Combining this value with the median estimates (32% additive genetic and 16% common environment) and assuming absence of vertical cultural transmission would increase the genetic estimate to approximately 37% and decrease that for common environment to 11%. Thus, the impact of a moderate level of parental resemblance for alcohol abuse would be expected to have only slight impact on the obtained estimates.

Our median additive genetic estimate of 32% is similar to estimates reported by Pickens et al. (1991) for the combined category of alcohol abuse plus dependence (36% among males, 26% for females), but our value for shared environmental influences is lower than they obtained (51% male, 29% female). Based on a model of only additive genetic and unique environment influences we obtain genetic estimates ranging from 29% to 66% with a median of 53%, very similar to the 58% estimate obtained by Kendler et al. (1992).

In our data, evidence of gender differences in causes of alcohol abuse was limited and we could not reject a model of gender invariance. Unlike the results of clinically-based studies (Caldwell and Gottesman, 1991; McGue et al., 1992; Pickens et al., 1991), the evidence reported here and by Kendler et al. (1992) suggests equally strong familial resemblance among women as for men. These discrepancies suggest that there may be important differences between samples ascertainment using the two methods, and indicate the need for caution in applying results from studies using clinical ascertainment to the general population.

Unlike findings for social alcohol use (e.g., Clifford et al., 1984; Kaprio et al., 1987; Prescott et al., 1994; Rose and Kaprio, 1988; Rose et al., 1990), we did not find a strong association between twin similarity for alcohol abuse and frequency of social contact. Pairs discordant for abuse status were slightly more likely to begin living apart prior to age 21 relative to pairs without abuse but had the same frequency of contact in later adulthood. Interestingly, pairs in which both twins had histories of alcohol-related problems tended to have infrequent contact, indicating twins with alcohol problems are more likely to be estranged from one another. This observation suggests that the relation between contact frequency and alcohol abuse is not a simple one. We interpret these data to be more consistent with the hypothesis that contact frequency is a consequence, rather than a cause, of within-pair differences in abuse status (e.g., Lykken et al., 1990). However, it could also be argued that close contact with one's twin may be a protective factor in preventing the development of abuse behaviors. Longitudinal studies of the development of alcohol abuse and pair contact are needed to resolve this question.

Several investigations have reported greater familiality for alcohol abuse among pairs with early ages of onset. We had onset information for fewer than half of subjects classified as probable or definite abusers, so we were unable to divide the sample into early versus late onset. Among 24 concordant pairs for whom we had age of onset data on both twins, the mean (± SD) within-pair difference in onset ages was 13.3 ± 10.6 years (range=0, 38), suggesting it may be difficult to assign pairs to one category or the other. This observation also underscores the need for long-term follow-up of unaffected subjects in twin and family studies of alcohol abuse.

**Interpretation**

What is the nature of this liability that is transmitted? Although our models assume a single latent dimension of alcohol abuse, it is not our intent to endorse the idea that there exists a single entity of “alcoholism” or that drinking-related problems have the same sources for all individuals at all points in the lifespan. Rather, alcohol dependence appears to be characterized by both phenotypic and etiologic heterogeneity. As a number of writers have discussed (e.g., Cloninger, 1990; Grove and Cadoret, 1983; McGue et al., 1992), the phenotype of alcohol abuse may be associated with several distinct patterns of personality and affective characteristics. To the extent that antisocial traits or depression are genetically transmitted, they may partially mediate the apparent genetic basis for alcohol abuse. This underscores the need for genetically informative studies of the associations among alcohol abuse, personality characteristics, and affective and anxiety disorders. Such research has been conducted using family studies (e.g., Merikangas et al., 1985), but only limited evidence is available from the more powerful designs employing adoptees (e.g., Bohman et al., 1987) or twins (e.g., Mullan et al., 1986).

What do these results tell us about the opportunities for prevention and treatment of alcohol abuse? The findings from this study and others suggest about half the measured variation in the liability for alcohol abuse is attributable to experiential factors unique to individuals. The remaining variation appears to be largely genetic in origin, but this does not imply these aspects are predestined or immutable. All behavior develops in an environmental context and altering the environment in which genetically influenced behavior unfolds can change the course of that development. Estimations of genetic and environmental proportions of variance are dependent upon the amount of relevant genetic and environmental variation in the sample. Thus, introduction of new environments may reduce
the relative importance of genetic influences. By studying the interactions between genetic predisposition and alternative environments, behavior genetic approaches can be an important tool in the search for environmental influences and interventions in alcohol abuse.

**Study limitations**

As is common with volunteer samples, our subjects tended to have higher education and income levels than would a random sample of the U.S. population in this age range. Comparisons of these subjects with those who dropped out since originally ascertained in 1987 suggest members of the current sample are less likely to have been diagnosed with alcoholism during their lifetime. Despite this, these subjects endorsed a broad range of alcohol-related problems and substantial proportions met our criteria for alcohol abuse and problem drinking.

The validity of these results depends on the accuracy of the questionnaire responses and the degree to which such measures correspond to clinical constructs of alcohol abuse. Self-report data require retrospective reporting on lifetime behaviors and could be affected by memory limitations. Few of our subjects reported current alcohol-related problems, and most classifications of alcohol abuse were based on earlier experiences. Although temporal distance from an event is likely to increase recall problems, it may be associated also with an increased willingness to report socially undesirable behaviors. Furthermore, studies comparing accuracy and completion of health questionnaires collected by various methods suggest individuals who are unwilling to reveal sensitive personal information during an interview may report it by mail (e.g., Siemiatycki, 1979). Studies comparing self-report and interview derived measures of alcohol abuse have demonstrated the potential reliability and validity of self-report data (e.g., Bacon et al., 1991; Perkins et al., 1991).

The available data on alcoholism treatment, physician diagnosis, co-twin report and self-perception of alcohol-related problems strongly support the probable and definite abuse classifications as indices of significant alcohol problems. Our use of a problem drinker category as part of the abuse continuum had less empirical support but the available data are consistent with higher prevalence of these abuse indices relative to subjects reporting no alcohol-related problems. A test of the multiple threshold model for this continuum obtained good fit, but the low prevalence of the probable and definite abuse cases means this test had limited power. Subsequent research with this sample is aimed at further investigating the validity of this classification system.

For the probable and definite abuse categories we required symptoms to have been experienced during the same reporting interval. However, this does not insure that they actually occurred simultaneously and may have produced inflated prevalence estimates for these classifications. It should be noted, however, that the definitions of lifetime abuse and dependence used in the ECA project were based on lifetime prevalence of individual criteria and did not require that they be experienced simultaneously (Helzer et al., 1991).

Results from structural modeling analyses provide broad indications of the relative contributions of genetic and environmental sources, and should not be viewed as precise estimates. Reliable estimation of polychoric correlations requires very large sample sizes and when smaller samples are used estimates may vary with the placement of the threshold for abuse status. The values in Table 5 demonstrate how genetic and environmental estimates vary with the definition of abuse even though six of these definitions represent differing subsets of the same items. Even with a sample of more than 1,100 nonabstinent twin pairs, we lacked sufficient power to determine the contribution of common environmental influences and we had limited power to detect gender differences in the sources of alcohol abuse.

**Extensions**

This study represents a first step in our effort to investigate the sources of variation in problem alcohol use in a large sample of older twins. The twin design is a potentially powerful method for studying etiologic heterogeneity in alcohol abuse as well as for investigating the sources of covariation with other characteristics. In this report we studied age and gender as two potential sources of heterogeneity. In future reports we plan to investigate the contributions of personality style, health behaviors, nicotine intake, and presence of depressive and anxiety symptoms to heterogeneity in alcohol abuse.

**Appendix:**

**Items Used for Alcohol Abuse Classification**

<table>
<thead>
<tr>
<th>Questionnaire item</th>
<th>Feighner-based criterion</th>
<th>DSM-III-R-based criterion</th>
<th>CAGE items</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. You drank too much?</td>
<td>A</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>2. You felt bad or guilty about your drinking?</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Someone else objected to your drinking?</td>
<td>A</td>
<td></td>
<td>K</td>
</tr>
<tr>
<td>4. People annoyed you by criticizing your drinking?</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. You were treated for an alcohol problem?</td>
<td>A</td>
<td></td>
<td>E</td>
</tr>
<tr>
<td>6. You felt you should cut down on your drinking?</td>
<td>A</td>
<td></td>
<td>E</td>
</tr>
<tr>
<td>7. You deliberately tried to cut down on your drinking, but were unable to?</td>
<td>C</td>
<td></td>
<td>F</td>
</tr>
<tr>
<td>Questionnaire item</td>
<td>Feighner-based criterion</td>
<td>DSM-III-R-based criterion</td>
<td>CAGE items</td>
</tr>
<tr>
<td>--------------------</td>
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<td>---------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>8. You planned to stop drinking completely, but then failed to stick to your plan?</td>
<td>C</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>9. You got into physical fights while drinking?</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. You went on binges where you kept drinking for a day or more without sobering up?</td>
<td>D</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>11. You went on binges and neglected some of your usual responsibilities?</td>
<td>D</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>12. You got into trouble driving an automobile after drinking?</td>
<td>B</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>13. Your drinking led to other legal problems?</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. You had a drink first thing in the morning to steady your nerves or get rid of a hangover?</td>
<td>C</td>
<td>I</td>
<td>M</td>
</tr>
<tr>
<td>15. Your drinking had a harmful effect on your friendships and social life?</td>
<td>A</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>16. Your drinking had a harmful effect on your health?</td>
<td>A</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>17. Your drinking had a harmful effect on your marriage or home life?</td>
<td>A</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>18. Your drinking had a harmful effect on your work, or employment opportunities?</td>
<td>B</td>
<td>H</td>
<td></td>
</tr>
</tbody>
</table>

*Items denoted by same letter contribute to the same criterion.

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References


