

Heart-Rate Reactivity and Alcohol Consumption Among Sons of Male Alcoholics and Sons of Non-Alcoholics

J.B. Peterson, Ph.D.¹, R.O. Pihl, Ph.D.¹, J.R. Séguin, B.A.¹, P.R. Finn, Ph.D.², S.H. Stewart, Ph.D.³

¹Departments of Psychology and Psychiatry, McGill University, Montreal, Quebec, ²Department of Psychology, Indiana University, Bloomington, Indiana, ³Department of Psychology, McGill University, Montreal, Quebec

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Recent studies have demonstrated that sons of male alcoholics with multigenerational family histories of male alcoholism are characterized by sober heart-rate hyperreactivity to aversive stimuli, susceptibility to alcohol-induced dampening of that hyperreactivity and by increased resting heart rate while intoxicated. Regression analyses indicate that the magnitude of alcohol-induced change in resting and reactive cardiac response is significantly and powerfully associated with the degree of self-reported voluntary alcohol consumption among 85 non-alcoholic males who are either lacking or who have moderate or extensive family histories of male alcoholism. It appears that heightened sensitivity to alcohol-induced increase in resting and decrease in reactive heart rate might mark or underlie familial risk for developing alcoholism.

Key Words: alcohol abuse, alcohol dependence, alcoholism, genetics, children of alcoholics, risk

INTRODUCTION

Alcohol abuse and dependence are common, costly and serious disorders (Regier et al 1990; Adrian 1984; Harwood et al 1984), characterized by relatively sporadic, ineffective and expensive treatments (Miller and Hester 1986). Alcoholism has severe side-effects, including potentiation of aggression (Pihl et al in press), reduction of general productivity, degeneration of mental and physical health (Adrian 1984; Harwood et al 1984) and destruction of healthy social and familial interaction. Little is known about the processes underlying the development of alcoholism, making the development and application of treatment challenging. However, the fact that alcoholism runs in families has been established (Bohman et al 1981; Cadoret et al 1980; Cloninger et al 1981; Goodwin et al 1973; Cotton 1979; Heath and Martin 1988; Hrubec and Omenn 1981) although the manner in which the familial predisposition manifests itself has not been deter-

mined (Searles 1988). In addition, a large number of studies analyzing animal reactions to alcohol have demonstrated that heritable factors influence the tendency to begin using alcohol (Deminiere et al 1989), susceptibility to alcohol-induced reinforcement (McBride et al 1990; George et al 1991) and development of tolerance, dependence and withdrawal (Crabbe 1989; Keir and Deitrich 1990; Pihl and Peterson in press).

Young sons of male alcoholics (SOMAs) appear to be at particular risk, because of their age (Adrian 1984), sex (Helzer and Pryzbeck 1988) and family history (Cloninger et al 1981; Goodwin 1985), and often have additional characteristics which have been linked independently to alcoholism. SOMAs are more likely to suffer from conduct disorder or hyperactivity during childhood (Pihl et al 1990; Tarter et al 1988). They may also be predisposed to specific cognitive deficits and psychophysiological abnormalities and may react idiosyncratically to alcohol intoxication (Pihl et al 1990; Tarter et al 1988). Furthermore, they drink more alcohol, take more psychoactive drugs, are younger when they begin using alcohol or drugs and suffer from more pathology related to

Address reprint requests to: R.O. Pihl, Ph.D., Department of Psychology, McGill University, 1205 Dr. Penfield Avenue, Montreal, Quebec, Canada H3A 1B1.

alcohol use (McCaul et al 1990). Any or all of these additional characteristics may underlie or mark the tendency to develop alcoholism, in part or in whole.

The discovery of a genuine risk factor or marker may aid in the early, premorbid identification of those at great risk of developing alcoholism and abet attempts to prevent the development of the full-blown syndrome. The ideal indicator might be easily assessed and linked to the development of alcoholism in a theoretically plausible manner — and may be associated with greater use of alcohol among individuals who are currently not alcoholics. It seems reasonable to search for such a marker among those who are at particularly high risk for alcoholism, for known but non-specific reasons. The Douglas Hospital-McGill Alcohol Research Project was designed with this aim in mind. Subjects participating in this program are young non-alcoholic SOMAs with extensive multigenerational family histories (MFH) of severe paternal-line male alcohol dependence or abuse. These specific criteria were established for subject selection, in part because individual risk for polygenetically mediated disorders, such as alcoholism, clearly increases as a function of the number of that individual's affected relatives (Gottesman and Shields 1982).

Adolescent SOMAs with multigenerational family histories of alcoholism appear comparatively deficient in their ability to abstract and plan and are more likely to suffer from hyperactivity or conduct disorder than control subjects matched for age, IQ and socioeconomic status, free from familial alcoholism (Harden and Pihl in press). This relative lack of cognitive capacity is also evident in adulthood (Peterson et al 1992). In addition, MFH SOMAs manifest an idiosyncratic pattern of cardiovascular response to various challenges. As pre-adolescents, they are characterized by increased heart rate when sober and vasoconstriction while completing mental arithmetic tasks (Harden and Pihl in press). As young adults, they manifest a similar pattern of sober cardiovascular hyperreactivity to threat of and signalled electric shock (Finn and Pihl 1987; 1988; Finn et al 1990; Stewart et al 1992). Consumption of a legally intoxicating dose of alcohol appears to virtually eliminate or dampen this cued shock reactivity (Finn and Pihl 1987 1988; Finn et al 1990; Stewart et al 1992). Young adult MFH SOMAs also clearly display a comparatively heightened increase in, or stimulation of, resting baseline heart rate while they are acutely and legally intoxicated (Finn and Pihl 1987 1988; Finn et al 1990).

These patterns of cardiovascular response may constitute a marker or risk factor for alcoholism. For example, they may be in some way related to the quantity of alcohol consumed — which necessarily increases before the onset of alcohol abuse or dependence. However, the nature of the relationship between sober hyperreactivity, alcohol-induced dampening, alcohol-induced stimulation of heart rate and drinking behavior as such has yet to be explored. The data analyses described in this paper were conducted in an attempt to redress this

omission — to determine the nature of the association, if any exists, between the cardiovascular response patterns characteristic of SOMAs with multigenerational family histories of alcoholism and their non-alcoholic drinking behavior.

METHOD

Data were collected during a continuous project sponsored by the Douglas Hospital-McGill University Alcohol Research Project. Various aspects of this project have been described elsewhere, and the data included here were drawn from these studies (Finn and Pihl 1987; 1988; Finn et al 1990; Stewart et al 1992). However, the analyses described in this paper, conducted on a cumulative data sample, were not completed, nor have they been reported previously.

Subjects

Data were gathered on 85 non-alcoholic non-abstinent males between the ages of 18 and 40. Thirty-six of the subjects had an extensive multigenerational history of severe male alcoholism — at minimum, an alcohol-dependent biological father, alcohol-abusing or alcohol-dependent paternal grandfather and alcohol-abusing or dependent paternal uncle or brother. In the authors' experience, three-quarters of the paternal male relatives of the subjects with multigenerational family histories selected in this manner have diagnosable alcohol dependence or abuse. Sixteen additional subjects had a unigenerational family history (UFH) of alcohol dependence, limited in the past two generations to the biological father. The remaining 33 subjects had no family history (FH-) of alcohol abuse or dependence among their siblings or among relatives in the previous two generations.

The subjects were recruited through newspaper and posted advertisements, screened initially by telephone (for provisional determination of their drinking behavior and family history of alcoholism) and interviewed to screen for psychiatric disorders by a qualified clinician, using the DSM-III criteria (American Psychiatric Association 1980). In the case of the subjects with an MFH or UFH of alcoholism, who were difficult to find and were selected with the idea of long-term participation in mind, available family members were interviewed, also using the DSM-III criteria. Family members who were unavailable were diagnosed using the Family History Research (FHR) diagnostic criteria (Endicott et al 1975). In the case of FH- subjects, who were relatively easy to find, family members were diagnosed solely using the FHR diagnostic criteria. The large number of subjects meant that any FH- subject whose family history was questionable in any relevant manner was immediately excluded from the study.

All the subjects had scores of 5 or less on the Michigan Alcoholism Screening Test (Selzer 1971) and were neither dependent upon nor abused alcohol, according to the DSM-III criteria. The subjects whose mothers (currently or previously) had one or more symptom of alcohol abuse or

dependence, according to the DSM-III or FHR diagnostic criteria, were excluded from the study, to control for the potentially confounding effects of fetal alcohol syndrome. Subjects undergoing treatment for any active physical or psychiatric condition were excluded, as were those with a schizophrenic disorder (active or in remission) or who had first- or second-degree relatives with schizophrenia.

All the subjects refrained from consuming alcohol for 24 hours and from consuming food and beverages for four hours prior to testing. They were not allowed to smoke during the testing period. Since testing required approximately six hours (including recovery time), the subjects were assessed in the morning. The subjects were paid \$5.00 an hour for their participation.

Procedure

Upon arrival at the laboratory, all the subjects were required to read and sign an informed consent form, were weighed and were asked to complete a questionnaire on their age, education and the frequency and quantity of their alcohol consumption. Frequency was measured as the number of occasions alcohol was consumed per week, on average, within the last six months. Those who drank alcohol less than once weekly were asked to estimate their monthly or yearly frequency. Quantity was measured as estimated average number of drinks (one beer = one mixed drink = one glass of wine) consumed per drinking occasion. A simple, easy to understand composite measure of drinking behavior was calculated by multiplying the average weekly frequency by the average quantity of alcohol consumed.

After the interview, each subject was seated in a reclining chair, in a quiet, darkened, comfortable room, attached to a polygraph and asked to relax. Baseline measures of heart rate were taken during the following ten minutes. After baseline measures were established, a small concentric shock electrode was attached to the inside of the subject's right elbow, and stereo headphones were placed on the subject's head. Three countdown and signalled shock trials were conducted and recorded. The countdown, presented through stereo headphones, consisted of the taped presentation of a low-frequency 1 s tone, followed by an oral count from ten to one and the presentation of a second 1 s tone. A 1.85 mA 0.25 s electric shock, delivered through the concentric electrode, was administered at the same time as the second tone. Initial tone onset to shock offset took 14 s. Each subject was then unhooked from the shock electrode and administered three beverages consisting of 95% pure USP ethanol mixed with orange juice (five parts to one). Each subject was required to consume these beverages within 20 minutes (random across-group distribution of actual drinking rate was assumed, within this formal time constraint). Fifteen minutes later, each subject was asked to relax, and the physiological recording procedure was repeated.

The subjects who participated in the Douglas Hospital-McGill Alcohol Research Project were tested under the influence of five doses of alcohol: 0.132 mL (active placebo), 0.50 mL, 0.75 mL, 1.00 mL and 1.32 mL of 95% alcohol per kg of body weight. The latter three doses are generally sufficient to produce blood alcohol levels between 0.08 and 0.11 (Stewart et al 1992). Doses of alcohol of this magnitude are rarely used in studies of this type. Nonetheless, research has indicated that alcohol must be administered in such quantities to produce substantive effects among young social drinking males. It is not until blood alcohol levels of 0.08 to 0.11 are reached that subjects with multigenerational family histories have reliable and significant alterations in their cardiovascular functioning (Stewart et al 1992). Furthermore, male university students with blood alcohol levels in the same range have clinically significant reductions in their ability to plan and for the longer-term consolidation of memory (Peterson et al 1990). Data for these analyses were therefore drawn only from those subjects who had been administered alcohol at doses of 0.75 mL/kg, 1.00 mL/kg and 1.32 mL/kg. Statistical measures designed to control for this variability in alcohol dose are described in detail below.

Determination of cardiovascular variables

Each subject's heart rate was assessed while they were sober and while intoxicated by alcohol. Resting baseline measures were calculated as average heart rate during the last 90 seconds of the ten-minute pre-stimulus relaxation period, during both non-drug and drug conditions. Reactive measures, in contrast, were calculated as the mean heart rate during signalled shock exposures (from the initial tone onset to 7 s after the shock was administered), averaged over three trials, during both non-drug and drug conditions. The following variables were calculated from these basic measurements: 1. sober reactivity — percentage of change in heart rate from sober baseline to sober signalled shock; 2. post-alcohol reactivity — percentage of change in heart rate from post-alcohol baseline to post-alcohol signalled shock; 3. post-alcohol dampening — alcohol-induced change in signalled shock reactivity, calculated as sober reactivity minus post-alcohol reactivity; and 4. post-alcohol stimulation — percentage of change in baseline heart rate, from sober to post-alcohol conditions. These variables (change scores) were used because they could be entered easily into multiple regression analyses, as described below. Arithmetic scores (change from baseline) were used because the groups did not differ in sober resting baseline heart rate, as described below. Percentage change scores were used because they account in part for proportion of change, in contrast to standard difference scores.

Table 1

Means and standard deviations of age, education, blood alcohol level and number of alcoholic beverages per week by group according to self-reports

Group	n	Age (years)		Education (years completed)		Blood alcohol level (%)		Number of alcoholic beverages per week	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
FH-	33	22.06	4.07	14.33	1.69	0.90	0.020	5.76	4.72
UFH	16	24.31	4.94	13.38	3.12	0.87	0.012	6.00	3.78
MFH	36	23.58	4.70	13.75	2.13	0.93	0.018	8.97	7.07
All	85	23.13	4.54	13.90	2.20	0.91	0.018	7.16	5.85

RESULTS

Demographics, blood alcohol levels and alcoholic beverages per week

One-way analyses of variance revealed that the subjects in the three groups did not differ significantly in mean age, years of schooling or blood alcohol level but did differ in the number of alcoholic beverages they consumed per week ($F(2,82) = 3.13, p < 0.0488$). Post-hoc Fisher's Least Significant Difference test indicated that subjects with multigenerational family histories consumed significantly more alcohol than the FH- controls ($p < 0.05$). Means and standard deviations for all these variables are presented in Table 1.

Heart-rate response and familial status

Table 2 presents the heart-rate measures (means and standard deviations) by group for sober and post-alcohol resting baseline and signalled shock conditions and the derived (percentage of change) measures (means and standard deviations) for sober and post-alcohol reactivity. Table 3 presents the means and standard deviations of the derived variables post-alcohol dampening (sober reactivity minus post-alcohol reactivity) and post-alcohol stimulation (percentage of change in baseline heart rate from sobriety to intoxication). Figures for post-alcohol stimulation and post-alcohol damp-

ening are presented with the potentially confounding effect of dose variation covaried out. One-way ANOVAs revealed no significant differences between the groups in sober resting baseline heart rate ($F(2,82) = 1.74, p < 0.18$). In contrast, one-way ANCOVAs revealed that subjects in the three groups differed significantly in sober reactivity ($F(2,82) = 7.94, p < 0.0007$), post-alcohol dampening ($F(2,82) = 16.73, p < 0.00001$) when the insignificant effect of dose variability ($F(1,81) = 0.11, p < 0.75$) was covaried out, and in post-alcohol stimulation ($F(2,82) = 9.99, p < 0.0001$) when the insignificant effect of dose variability ($F(1,81) = 0.93, p < 0.34$) was covaried out. Post-hoc Fisher's LSD indicated that: 1. the subjects with multigenerational family histories were more susceptible to sober reactivity ($p < 0.0001$), post-alcohol dampening ($p < 0.0001$) and post-alcohol stimulation ($p < 0.001$) than the UFH and FH- subjects; and 2. the FH- subjects were more prone to sober reactivity ($p < 0.05$) and post-alcohol dampening ($p < 0.05$) than the UFH subjects.

Heart-rate response: correlations

Further analyses, conducted to assess the nature of the relationship between each measure of heart rate, demonstrated significant correlations between sober reactivity and post-alcohol stimulation ($r = 0.2320, s = 0.0326$), post-alcohol dampening and post-alcohol stimulation ($r = 0.3929$,

Table 2

Measures of heart rate by group for sober and post-alcohol resting baseline and signalled shock conditions and derived percentage change measures for sober and post-alcohol reactivity

Group	Sober baseline		Sober shock		Sober reactivity		Post-alcohol baseline		Post-alcohol shock		Post-alcohol reactivity	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
FH-	69.40	10.60	73.95	10.77	7.02	9.15	72.01	11.17	74.41	10.47	3.76	6.17
UFH	71.77	12.13	71.97	12.54	0.42	7.44	71.40	9.55	74.10	10.79	3.71	5.76
MFH	66.10	10.39	74.06	10.23	13.07	13.24	74.56	12.01	73.82	11.96	-0.93	5.22
All	68.44	10.90	73.62	10.80	8.34	11.70	73.00	11.22	74.10	11.05	1.76	6.10

Table 3

Derived measures (means and standard deviations) for post-alcohol dampening^a and post-alcohol stimulation^b

Group	Post-alcohol dampening		Post-alcohol stimulation	
	Mean	SD	Mean	SD
FH-	3.26	8.36	4.14	9.77
UFH	-3.30	4.10	0.48	10.72
MFH	14.00	13.45	13.46	12.76
All	6.58	12.31	7.40	12.40

^asober reactivity minus post-alcohol reactivity

^bpercentage change in baseline heart rate from sobriety to alcohol intoxication

$s = 0.0002$), and sober reactivity and post-alcohol dampening ($r = 0.87$, $s = 0.00001$). The strong correlation evident in the latter case indicates that cardiovascular reactivity to signalled shock is reduced to zero among intoxicated individuals in these risk groups, regardless of its magnitude in the sober condition. This correlation is so strong that there is no point in treating the two variables independently. Post-alcohol dampening was therefore retained in the course of the remaining analyses, in preference to sober reactivity. This preference was determined on theoretical grounds: post-alcohol dampening is an alcohol effect, and it appears reasonable to posit that it is the consequences of the effect of alcohol on reactivity, rather than the reactivity itself, that influences drinking behavior. This issue is detailed in the discussion below.

Heart-rate response, family status and number of alcoholic beverages per week

Four additional statistics were calculated to help clarify the nature of the relationship between risk, heart-rate response and voluntary weekly alcohol consumption. A one-way ANCOVA demonstrated that subjects in the three groups no longer differed in the number of alcoholic beverages consumed per week (FH- = 6.23, UFH = 7.39, MFH = 7.92; $F(2,81) = 0.73$, $p < 0.49$) when the significant effect of post-alcohol dampening ($F(1,81) = 5.70$, $p < 0.05$) was covaried out. Similarly, a one-way ANCOVA revealed that the three groups no longer differed in number of alcoholic beverages consumed per week (FH- = 6.18, UFH = 6.90, MFH = 8.18; $F(2,81) = 0.98$, $p < 0.3807$) when the significant effect of post-alcohol stimulation ($F(1,81) = 5.78$, $p < 0.0185$) was covaried out.

However, a one-way ANCOVA demonstrated that family history remained significantly associated with post-alcohol dampening (FH- = 3.91, UFH = -2.75, MFH = 13.16; $F(2,81) = 14.76$, $p < 0.00001$) when the significant effect of the number of alcoholic beverages per week ($F(1,81) = 5.70$, $p < 0.0193$) was covaried out. Post-hoc Fisher's LSD indicated that the subjects with multigenerational family histories

remained more susceptible to post-alcohol dampening ($p < 0.0001$) than the UFH and FH- subjects and that the FH- subjects remained more prone to post-alcohol dampening ($p < 0.05$) than the UFH subjects. Likewise, a one-way ANCOVA revealed that risk remained significantly associated with post-alcohol stimulation (FH- = 4.86, UFH = 1.08, MFH = 12.54; $F(2,81) = 7.00$, $p < 0.0016$) when the significant effect of alcoholic beverages per week ($F(1,81) = 5.78$, $p < 0.0185$) was covaried out. Post-hoc Fisher's LSD indicated that subjects with multigenerational family histories remained more susceptible to post-alcohol stimulation ($p < 0.001$) than the UFH and FH- subjects.

Multiple regression analyses indicated that familial history, post-alcohol dampening and post-alcohol stimulation cumulatively accounted for a significant proportion of the variance in self-reported number of alcoholic beverages consumed per week ($R^2 = 17.00$, $F(3,84) = 5.53$, $p < 0.002$) and that the independent contribution of each variable, with the exception of risk, approached significance. Additional multiple regression analyses revealed that risk and number of alcoholic beverages consumed per week independently and cumulatively accounted for a significant proportion of the variance in post-alcohol dampening ($R^2 = 22.4$, $F(2,84) = 11.81$, $p < 0.001$) and post-alcohol stimulation ($R^2 = 18.49$, $F(2,84) = 9.30$, $p < 0.001$). Table 4 shows the T-values, probability levels and sequential and simple R^2 s for the risk rate and alcohol consumption variables for each of these analyses.

DISCUSSION

The analyses described in this paper demonstrate that: 1. sons of male alcoholics with extensive multigenerational family histories of male alcoholism consume significantly more alcohol on a weekly basis (according to self-reports) than males with no familial alcoholism, even when they were specifically selected because they were not alcoholic; 2. SOMAs with multigenerational family histories are characterized by heightened heart-rate response to signalled shock when sober (but not when intoxicated) and by heightened resting heart rate when intoxicated; 3. the relationship between a familial history of alcoholism and drinking is subsumed by the relationship between alcohol-induced reduction (post-alcohol dampening) in reactive heart rate, or by alcohol-induced (post-alcohol) stimulation of the resting heart rate, but the reverse is not true; and 4. post-alcohol dampening and post-alcohol stimulation account for a large and significant proportion of the variance in drinking behavior among subjects categorized according to their family history of alcohol abuse and dependence.

What does this pattern of results mean? The association between extensive familial male alcoholism and an increase in alcohol consumption may be considered predictable, given that a family history of alcoholism is currently the best single marker of a risk of developing alcoholism (with the possible

Table 4
Regression analyses: T-values, probability levels and sequential and simple R²s. Interrelation of alcoholic beverages per week, risk, post-alcohol dampening and post-alcohol stimulation

	Independent variable			
	T-value	Probability	Sequential R ²	Simple R ²
Number of alcoholic beverages per week by risk, post-alcohol dampening, post-alcohol stimulation				
• intercept	3.10	0.003		
• risk	0.76	0.450	0.063	0.063
• post-alcohol dampening	1.91	0.060	0.132	0.117
• post-alcohol stimulation	1.93	0.057	0.170	0.112
Post-alcohol dampening by risk, number of alcoholic beverages per week				
• intercept	-2.18	0.033		
• risk	3.36	0.001	0.162	0.162
• number of alcoholic beverages per week	2.55	0.013	0.244	0.117
Post-alcohol stimulation by risk, number of alcoholic beverages per week				
• intercept	-1.39	0.167		
• risk	2.71	0.008	0.119	0.119
• number of alcoholic beverages per week	2.57	0.012	0.185	0.111

exception of conduct disorder). It is evident that increased alcohol consumption constitutes a necessary, although not sufficient, precondition for the development of alcohol abuse or dependence. It is precisely for this reason that it is worthwhile to search for factors that are associated with, or even predate, increases in alcohol consumption.

Demonstrating that alcohol dampens the increased shock-induced heart-rate reactivity characteristic of SOMAs with multigenerational family histories of alcoholism may be more relevant, in part because it is less predictable *prima facie*, and in part because it has interesting theoretical implications. The sober cardiovascular hyperreactivity of SOMAs with multigenerational family histories has been associated with inappropriately exaggerated physiological and psychological preparation for activity, in keeping with Obrist's idea of cardiac-somatic coupling (Obrist 1976), and as a potential consequence of abnormal cognitive/linguistic processing (Peterson and Pihl 1990). Such reactivity may be a physiological concomitant of activity in the limbic and prefrontal centers responsible for the processing of novel and/or threatening stimuli (Harden and Pihl in press; Peterson et al 1992). Activity in these centers has been associated with animal and human behavior indicative of anxiety (Gray 1982; 1987). The consumption of a relatively large dose of alcohol reduces or dampens this reactivity (Finn and Pihl 1987; 1988; Finn et al 1990; Stewart et al 1992). Levenson et al (1987) and Peterson

and Pihl (1990) have proposed that such dampening may prove anxiolytic, and therefore negatively reinforcing. The anxiolytic effects of alcohol, comparable to those produced by barbiturates or benzodiazepines (Gray 1982; 1987), appear to be manifested through pharmacological effects on the functioning of the anxiolytic-sensitive septal/hippocampal novelty/threat detection system (Gray 1982; 1987). It is possible that anxiolysis emerges, in part, as a consequence of the effect of alcohol on GABA, the brain's major inhibitory neurotransmitter (Gray 1982; 1987). Alcohol enhances the ability of GABA to open the CL⁻ ion channel, at the GABA-benzodiazepine-CL-receptor complex and directly potentiates CL⁻ ion intake (Gray 1982; 1987; Warneke 1991; Zorumski and Isenberg 1991). These two actions increase the firing rate of GABA neurons and enhance their inhibitory action (Warneke 1991). The hippocampus contains a high concentration of GABAergic neurons, arranged in "recurrent inhibitory circuits" (Gray 1987), and alcohol may serve an anxiolytic role by enhancing their functioning.

Individuals characterized by substantially elevated sober reactivity, such as SOMAs with multigenerational family histories, may find the reactivity-dampening effects of alcohol comparatively reinforcing, because of the increased contrast they may experience between their sober and intoxicated psychophysiological states. Such individuals may consume alcohol in greater amounts or with greater regularity over

time, once they have experienced alcohol's reactivity-dampening effects during the course of normal experimentation with drinking (Peterson and Pihl 1990). The fact that alcohol reactivity-dampening is strongly associated with level of alcohol consumption provides general support for this hypothesis.

SOMAs with multigenerational family histories of alcoholism are also differentially susceptible to alcohol-induced resting baseline heart-rate acceleration. This phenomena is equally interesting from theoretical and practical viewpoints. Ethanol administration produces an increase in resting heart rate consistently (Sher 1987) and reliably (Newlin and Thomson 1990). Similar forms of increases in heart rate have been associated with excitation of the behavioral activation (Gray 1982; Fowles 1980; 1983) or psychomotor exploratory system. Such excitation may constitute the biological basis for increased incentive and/or reward (Gray 1982; Fowles 1980; 1983). Many, if not all, drugs with the potential for abuse share psychomotor-stimulant and associated rewarding properties (Wise and Bozarth 1987; Wise 1988). Alcoholics, in fact, have comparatively pronounced baseline heart-rate increases while acutely intoxicated (Kaplan et al 1985; McCaul et al 1989), and such increases may be predictive of craving for alcohol (Kaplan et al 1985; Laberg and Ellertsen 1987) and preference for alcohol reward (Kaplan et al 1983). Pihl and Peterson (in press) have hypothesized that a dopamine-mediated, psychomotor-stimulant-like response to alcohol may underlie this heart-rate increase. Alcohol is certainly capable of stimulating the dopaminergic system (Pihl et al in press). The firing rate of ventral tegmental dopaminergic neurons increases upon exposure to non-sedating doses of alcohol, and these neurons appear to mediate theoretically rewarding behavioral activation induced by psychomotor stimulant drugs (Gessa et al 1985). Various rat strains bred for differential response to alcohol (including preference) have distinctive patterns of sober and intoxicated dopaminergic function (Deminiere et al 1989; McBride et al 1990) and vary greatly in sensitivity to the psychomotor stimulant properties of alcohol (Ehlers et al 1991). Such sensitivity appears to be strongly influenced by genetic factors (Dudek et al 1991). People with high heart rates after alcohol consumption (such as SOMAs with multigenerational family histories) may, in fact, be more sensitive to ethanol-induced reward. This increased reward, attendant upon intoxication, may provide powerful reinforcement for alcohol consumption and lead to increases in such consumption over time. This study, in fact, demonstrates that increased heart rate is associated with increased alcohol consumption, at least among certain (non-alcoholic) individuals.

It might be argued that differences in post-alcohol dampening and post-alcohol stimulation are a consequence of initial differences in alcohol consumption — that it is in fact the increased alcohol intake of the SOMAs with multigenerational family histories that accounts for their characteristic pattern of heart-rate response. However, controlling for vari-

ability in post-alcohol dampening or post-alcohol stimulation virtually eliminates the relationship between familial risk and the level of alcohol consumption. In contrast, controlling for variability in alcohol consumption significantly reduces the degree of relationship between post-alcohol dampening or post-alcohol stimulation and familial risk, but comes nowhere near eliminating it. This pattern of results means that there is little relationship between familial risk and alcohol consumption in the absence of variability in cardiac response, and that there is still a profound relationship between familial risk and cardiac response, in the absence of variability in alcohol consumption. This does not prove that there is a causal connection between post-alcohol dampening or post-alcohol stimulation and level of alcohol consumption, but it moves the idea beyond the level of pure speculation. In addition, it is evident that relevant variability in cardiac response is not merely a consequence of drinking behavior.

Furthermore, the multiple regression analyses presented in this paper not only demonstrate that post-alcohol dampening and post-alcohol stimulation are powerful predictors of alcohol consumption, but that they are better predictors than family history — one of the two best predictors of alcoholism known to date (Pihl et al 1990) — even when the potential predictive power of a family history of alcoholism has been purposefully exaggerated through extremely careful subject selection. This means that post-alcohol dampening and post-alcohol stimulation may be used to successfully identify individuals within a known risk group who are most likely to engage in the one form of behavior — the consumption of alcohol — which necessarily precedes development of alcoholism. In addition, post-alcohol dampening and post-alcohol stimulation are easy to measure and play a theoretically plausible role in marking susceptibility to alcohol-induced negative reinforcement and reward.

The influence of various methodological problems potentially complicate interpretation of the familial risk/cardiac reactivity/alcohol consumption relationship, as described in this study, contributing what might be substantial non-systematic error to the data. Data from self-reports on alcohol use, for example, have been criticized for their susceptibility to social desirability bias (Babor et al 1990). This criticism is based on the assumption that those who abuse substances, in particular, may under-report the degree of their substance use. However, there is no compelling evidence to support this view. A recent review of the literature by Sobell and Sobell (1990) concludes that self-reports generally provide accurate estimates of alcohol use, even among alcohol abusers, who may be considered motivated to falsify their responses to conform with social demand. Subjects in this study, in contrast, were selected for their relative sobriety and had no reason to be ashamed of their essentially normative patterns of alcohol use. Furthermore, all the subjects were questioned while sober, under laboratory conditions, and answered questions regarding alcohol use in a non-threatening context: in a brief questionnaire for assessing demographic information.

The validity of self-report data is demonstrably enhanced under such circumstances (Babor et al 1990; Sobell and Sobell 1990; Baker and Brandon 1990). The use of change scores also inevitably adds error to the analyses. A variable constructed from the arithmetic combination of two variables retains the error of both. It is possible, therefore, that relatively imprecise measures of cardiac response were used to predict inexact self-reports of alcohol consumption. In addition, three different doses of alcohol were used to induce changes in cardiac response, and the post-hoc statistical control (ANCOVA) instituted to restrict the effect of this *a priori* dose differential is imperfect.

These methodological shortcomings undoubtedly reduce the accuracy of these findings by adding potentially controllable random error. However, it is important to note that the addition of such error in fact reduces, rather than increases, the probability of detecting statistically significant relationships of the nature described above. It is therefore reasonable to conclude that post-alcohol dampening and post-alcohol stimulation are strongly associated with levels of alcohol consumption (although they cannot be attributed to that consumption), even when imperfectly assessed and correlated with relatively inaccurate estimates of drinking behavior.

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