Chapter 5

*Elasticity of Demand for Alcohol in Humans and Rats**

Gene M. Heyman

Department of Psychology
Harvard University

Individuals differ in the degree to which alcohol controls their behavior. In extreme cases drinking becomes a dominant—if not the central—activity, determining health, job performance, social relations, and the like (Alcoholics Anonymous, 1976; American Psychiatric Association, 1987; Fingarette, 1988). However, more typically drinking is a relatively circumscribed activity, with but occasional effects on other pursuits. Varying degrees of dependence on alcohol are often described in terms of differences in motivation or need. For instance, some reformed alcoholics report that they were driven by a need for alcohol that superceded all other needs, regardless of the consequences (e.g., Alcoholics Anonymous, 1976; Gardener, 1964; Roth, 1954). The purpose of this chapter is to describe a method that seems especially useful for measuring individual differences in alcohol's capacity to control behavior. The method is based on an elementary economic relationship: the degree to which changes in price affect changes in consumption. This sort of price effect is referred to by economists as *elasticity of demand.* It is a useful measure for several reasons. It is quantitative, and, perhaps most importantly, elasticity of demand differentiates commodities in psychologically important ways. For example, demand for "necessities" is less elastic than is demand for "luxuries" (e.g., Frank, 1991). This chapter addresses the similar idea that differences in elasticity of demand for alcohol correspond to differences in dependence on alcohol.

In the first half of the chapter, econometric data on the relationship between price and consumption of alcohol are reviewed. In the second half, animal studies based on demand elasticity are discussed. In both cases, my goal is to develop a useful, quantitative measure of differences in the strength of an individual's preference for alcohol.

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OWN-PRICE ELASTICITY OF DEMAND

Own-price elasticity of demand is defined as the percentage change in demand that results from a 1% change in price, assuming all other factors that could influence price remain constant. Importantly, change in price and change in consumption are measured relative to current average price and consumption levels. This is made explicit in the mathematical definition of own-price elasticity of demand (oed):

$$\text{oed} = (dq/q)/(dp/p), \quad (1)$$

where p and q are current price and consumption levels, and dq and dp are infinitesimally small changes in each variable.

Figure 1 provides some examples of Equation 1. On the x-axis is price, and on the y-axis is consumption (arbitrary units for both). Following the practice in economics, the curves were drawn under the assumption that consumption declined as a power function of price ($q = aP^{-b}$). This implies that consumption reflects relative rather than absolute changes in price and that a single term, the exponent, quantifies demand. For instance, if the exponent (b) were 0.5 then consumption would decrease by one half for every fourfold increase in price, regardless of the initial price, and the power function relation implies that the solution to Equation 1 is simply the exponent ($-b$).

Figure 1 shows the relationship between price and consumption for four different commodities. The curves also define the relationship between expenditures and price, because expenditure is simply price multiplied by consumption. When b = 1.0, *unitary elasticity*, there is a simple reciprocal relationship between price and consumption. For example, a doubling of price reduces consumption by half. Because the relative changes are the same, expenditures remain the same. Thus, for a good with unitary demand, increases in price decrease consumption, but do not change total expenditures. The curve for b = 1.35 shows *elastic demand.* For this sort of commodity, changes in price result in relatively larger changes in demand. For instance, the curve shows that a fivefold increase in price from 1 to 5 reduced demand by almost a factor of 10 (from 1000 to about 110). For goods with elastic demand, increases in price decrease expenditures as well as consumption. The curve for b = 0.35 represents "inelastic" demand. In this example, consumption is relatively unaffected by price changes. For example, this curve shows that a fivefold increase in price reduced consumption by less than one half. For inelastic goods, price hikes increase expenditures, even though consumption decreases.

According to the economic theory of demand, two mechanisms mediate the effects of price on consumption. First, an increase in the price of one commodity may increase the consumption of another commodity, because it is now relatively cheaper. If this happens then the relatively cheaper commodity has substituted for the relatively more expensive one. For example, if an increase in the

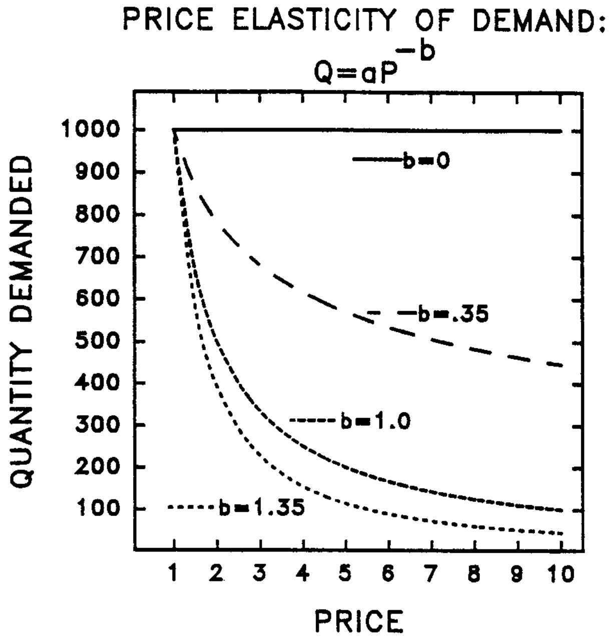

FIGURE 1. Hypothetical demand curves: The curves show the relationship between price and consumption for the case that consumption (Q) is a power function of price (P). The different curves show different degrees of relatedness between the two variables. They were drawn by varying the exponent of the power function. In econometric studies, researchers usually assume a power function relationship.

price of gasoline increased the use of public transportation then public transportation functions as a substitute for private transportation. Second, an increase in price reduces purchasing power (real income). As income decreases, the distribution of income shifts (by definition) in favor of necessities. However, because any particular commodity usually takes up but a small fraction of total income, the substitution effect is usually more important than the income effect.

Table 1 lists demand elasticities for a few familiar commodities. The purpose of this list is to provide some idea of the degree to which commodities can differ in terms of demand and to illustrate substitution and income effects. The examples were drawn from texts and frequently referred-to sources (e.g., Houthakker & Taylor, 1970).

The first three entries in Table 1 show the price elasticity for food (meaning all sources of calories), restaurant meals, and a specific food. The comparison demonstrates the importance of substitutes. There are, of course, substitutes for green peas and restaurant meals, but replacements for food itself are hard to

TABLE 1. Elasticity of Demand for Household Goods

Commodity	Price Elasticity of Demand	Source
Food	0.21	Nicholson, 1985
Restaurant meals	2.3	Houthakker & Taylor, 1970
Green peas	2.8	Frank, 1991
Medical Services	0.20	Nicholson, 1985
Movies	3.70	Mansfield, 1982
Electricity (household utility)	.13 (short-term) 1.94 (long-term)	Houthakker & Taylor, 1970
Intercity bus travel	.17 (short-term) 1.89 (long-term)	Houthakker & Taylor, 1970

come by. The comparison also shows that the more general the specification of the good, the lower the elasticity, all else being equal.

Demand for movie tickets was more elastic than was demand for medical service or food. Presumably, there were relatively more substitutes for movies. In addition, introductory texts (e.g., Nicholson, 1985; Baumol & Blinder, 1988) point out that the price elasticities for necessities (e.g., food and medical service) are lower than those for luxuries (e.g., movies).

Elasticity may also depend on such factors as the time frame over which it is measured (long-term or short-term), the fraction of the consumer's budget devoted to the commodity in question, and whether price increased or decreased. The evidence for the temporal dimension is the strongest. In general, the longer the period of measurement, the greater the elasticity (e.g., Houthakker & Taylor, 1970). However, this may also be seen as evidence for the importance of substitute commodities because the longer a price change is in effect, the greater the opportunity to find substitutes. Thus, there is wide support for the principle that price elasticity of demand varies as a function of the availability of substitutes.

If economic principles apply to the purchase of alcohol, then the examples in Table 1 imply that elasticity of demand for alcohol will depend primarily on the availability of substitutes. However, it should be pointed out that the availability of substitutes does not simply reflect environmental factors. Individuals differ widely in the degree to which they respond to alcohol and the degree to which they exploit alternatives to alcohol. Thus, differences in biology and experience will determine whether a given environment provides substitutes for alcohol. In addition, as described later, level of drinking is likely to be inversely related with the degree to which consumers can extract value from nonalcoholic activities. As individuals drink more, they are less able to participate and enjoy activities that require sobriety. This means that drinking itself will affect the availability of substitutes. The economic framework, then, should not be seen as a statement about the relative weight of biological and environmental factors in the development of alcoholism; rather, it is simply a convenient method for quantifying biological and environmental determinants of drinking.

ALCOHOLISM AND THE CLASSIFICATION OF DRINKING PATTERNS

The most recent report to the United States Congress from the National Institute of Alcohol Abuse and Alcoholism (USDH&HS, 1990), identified three types of drinkers: moderate or social drinkers, alcohol abusers, and alcoholics. These distinctions are correlated with level and pattern of drinking, but are described in terms of a behavioral relationship, which seems best described as the degree to which alcohol controls the drinker's activities.

Moderate drinkers drink within socially sanctioned boundaries. They rarely drink enough to experience the aversive consequences that alcohol can produce and are more likely to experience alcohol's positive psychological and social effects. Importantly, for moderate drinkers, alcohol does not cause problems; its consumption is not out of control. In contrast, alcohol abusers often drink amounts that lead to negative consequences. These effects may be direct, such as drunken driving arrests, or indirect, such as poor job performance due to hangovers. Alcohol abusers show less control over their drinking than do moderate drinkers by the criterion that their drinking interferes with other activities (e.g., loss of driving license, fights with family, and the like). Alcoholics also drink heavily and frequently but, according to the NIAAA and other experts (e.g., Jellinek, 1952), they can be distinguished from alcohol abusers. Alcoholics are usually not able to stop drinking, even though their drinking led to serious problems in the past (also see American Psychiatric Association, 1987 for a discussion of this issue). For example, the authors of the NIAAA report point out that problem drinkers, with counseling and other forms of support, can curtail their drinking (e.g., USDH&HS, 1990). In contrast, alcoholics have a craving for alcohol that they cannot control. They continue to drink, despite attempts to stop (Alcoholics Anonymous, 1976; American Psychiatric Association, 1987; USDH&HS, 1990). Thus, an important criterion in current thinking about the health consequences of drinking is the degree to which alcohol's aversive effects influence behavior.

Other symptoms of alcoholism include marked tolerance to the behavioral and physiological effects of alcohol and withdrawal symptoms on cessation of drinking. However, problem drinkers (alcohol abusers) and, to some extent, social drinkers show these symptoms as well (e.g., Vogel-Sprott, 1992). Thus, the feature that distinguishes alcoholics from other drinkers, according to current views, is the inability to control excessive drinking. The authors of the NIAAA (USDH&HS, 1990) report summarized these definitional issues by stating (p. xvii) that problem drinkers are not dependent on alcohol and are responsible for their behavior, whereas alcoholics have a disease, characterized by an uncontrollable craving for alcohol. (The parallel implication that alcoholics are not responsible for their behavior does not appear, but, presumably, this is the intent of the contrast.)

That alcoholics differ in their capacity to control excessive drinking implies that drinking has aversive (as well as reinforcing) consequences (otherwise, why try to stop?). By definition, price increases are aversive. Thus, changes in the price of alcohol should differentially affect alcohol consumption in moderate drinkers, problem drinkers, and alcoholics. For example, if alcoholics continue drinking despite the attendant health, social, and financial problems then they should also ignore price increases.

However, there is no straightforward way of determining whether those who are more dependent on alcohol are also more insensitive to changes in the price of alcohol. The problem is that the econometric data are based on aggregate survey techniques—heavy drinkers are not separated from moderate drinkers. I dealt with this problem by comparing per capita price elasticities of alcohol with the relationship between price and a symptom of heavy drinking—the frequency of cirrhosis of the liver. Although the average or per capita elasticity estimate is based on aggregate data, it should be most representative of the drinking habits of moderate drinkers, as they form the majority of those surveyed (Clark & Hilton, 1991). In contrast, the frequency of cirrhosis of the liver should primarily reflect the drinking habits of alcoholics (e.g., Lelbach, 1974). Thus, changes in price should have a bigger impact on average consumption level than on the frequency of cirrhosis (all else being equal).

DEMAND FOR ALCOHOL: ECONOMETRIC STUDIES

In the experiments discussed in the second part of this chapter, elasticity of demand for alcohol was estimated by experimentally manipulating price. In econometric studies, elasticity of demand is determined analytically. The data are obtained by survey methods, and the relationship between price and consumption is estimated by fitting a quantitative model to the data. The model is in effect a theory of the determinants of consumption.[1] For instance, in alcohol studies, the predictor variables included such factors as legal drinking age, statewide sales regulations, consumption in previous years, the frequency of labor strikes, etc. Sales and price data were based on industry and government records; they were not directly measured (which turns out to be a serious drawback). In addition, as mentioned earlier, consumers were treated as a single aggregate group, despite large and well-known individual variation in drinking habits (e.g., Clark & Hilton, 1991). A study by McCornac and Filante (1984) provides an example of the econometric approach.

The general context of the study was the question of whether an increase in tax on alcohol would reduce the federal deficit. If demand for alcohol was elastic (coefficient greater than −1.0) then the loss in sales would offset the price increases, and the tax would decrease rather than increase government revenues. Alternatively, if demand was inelastic, the same logic implies that revenues would increase. McCornac and Filante's model had the following general form:

[1]See the chapters by Chaloupka (this volume) and by Brito and Strain (this volume) for examples of this approach in the areas of cigarette smoking and alcohol consumption, respectively.

$$APC = a + b_1DSP + b_2BEER + b_3DIF + b_4LIS + b_5CONT + b_6AGE + b_7INC + b_8UN + u, \quad (2)$$

where *APC* was consumption of distilled spirits in the 50 states plus the District of Columbia (based on data from the Distilled Spirits Council of the United States), *DSP* was the real retail price of a four-fifths quart of Seagram Seven Crown whisky (nominal price divided by state consumer price index), *BEER* was real state excise tax rate (a proxy for beer price), *DIF* was price relative to border states, *CONT* was type of state control, *LIS* was number of liquor licenses per capita, *AGE* was minimum legal age for purchasing distilled spirits, *INC* was median real per capita income (deflated by consumer price index), and *UN* was unemployment level. They assumed that a power function described the relationship between distilled liquor sales and each of the explanatory factors so that the left side of the equation should read log (*APC*) and similarly the right side should read log a + log b_l ... log u. Finally, the data were pooled over the time period 1970 to 1976.

McCornac and Filante found that spirits were somewhat price inelastic. The best-fitting coefficient for data pooled over the period 1970 to 1976 (across all 50 states) was –0.89 (–1.0 defines unitary elasticity, see Figure 1). Thus, they concluded that tax increases would result in greater government revenues.

However, other investigators report that spirits are price elastic. Table 2 provides a sampling of the literature. Most of the citations are from Ornstein's (1980) comprehensive review. The estimates for a given form of alcohol often vary widely. This may reflect real differences in demand as well as spurious differences due to problems in collecting reliable data.

Demand for beer was usually lower than that of wine and spirits, and may be inelastic in Western countries. In support of this point, Ornstein and Levy (1983) stated that the best estimate for price elasticity of beer in the United States is about –0.30. If this is a valid estimate, beer consumption should decrease by about 20% for every doubling in price.

However, the alcohol in beer is the same as that in spirits and wine; why, then, should demand be different? Possibly beer serves quite different functions than spirits or wine. For instance, because it has a lower alcohol content than either wine or spirits, it is a safer drink. Alternatively, there may be an economic reason. Beer was taxed less than were wine and spirits (e.g., Cook, 1981) so that the unit price of alcohol in beer may be lower. Second, the price of beer may vary over a narrower range than the price of other alcoholic beverages. Third, for many commodities, demand elasticity is not constant, as implied by Figure 1, but increases as price increases (e.g., Lea, 1978). Thus, demand for beer may have been inelastic because the prices varied little and were usually cheap.

Demand for wine varied widely as a function of national culture. In France and Spain demand was inelastic, whereas in North America it was elastic. These differences may reflect differences in function. Wine is often at the table for lunch and dinner in France, and per capita wine consumption is several times

TABLE 2. Elasticity of Demand for Alcohol

Type of Study	Author	Elasticity
Place and Time		
Beer		
UK: 1870–1938	Ornstein, 1980	−0.66
UK: 1920–1948	Ornstein	−0.69
USA: 1934–1954	Ornstein	−0.33
USA: 1946–1970	Ornstein	−0.87
USA: 1956–1959	Ornstein	−0.89
Canada: 1955–1971	Johnson & Oksanen, 1977	−0.27
USA: 1971–1975	Nelson, 1990	−0.61
Spirits		
UK: 1870–1938	Ornstein, 1980	−0.57
UK: 1920–1948	Ornstein	−0.57
USA: 1934–1954	Ornstein	−0.93
Canada: 1949–1969	Ornstein	−1.45
USA: 1971–1975	Nelson, 1990	−0.83
USA: 1970–1975	McCornac & Filante, 1984	−0.89
USA: 1970–1975	Ornstein	−1.06
Canada: 1955–1971	Johnson & Oksanen, 1977	−1.14
USA: 1960–1975	Cook & Tauchen, 1982	−1.8
USA: 1970	Ornstein	−1.95
Wine		
UK: 1920–1948	Ornstein, 1980	−1.17
Canada: 1949–1969	Ornstein	−1.65
France: 1954–1971	Ornstein	−0.06
Spain: 1954–1971	Ornstein	−0.37
Germany: 1954–1971	Ornstein	−0.38
Italy: 1954–1971	Ornstein	−1.0
Canada: 1955–1971	Johnson & Oksanen, 1977	−0.67
USA: 1971–1975	Nelson, 1990	−1.23

greater in France (Terris, 1967) than in either Canada or the United States. Possibly, as wine is more widely used, the number of goods that can substitute for it decreases.

With the exceptions of wine in France, Spain, and Germany and beer in North America, Table 2 suggests that demand for alcohol tends to be elastic (that is, elasticity values greater than −1.0). However, studies on demand for alcohol are usually introduced with a list of caveats. Econometric researchers caution that there is no single model of alcohol consumption and that there is good reason to question the validity of the data. Some investigators included terms for out-of-state purchases, degree of advertising, previous level of use (habit), unemployment rates, demographic data, and retail store density, whereas others omitted some or all of these variables. Moreover, regardless of the investigators' assumptions, the elasticity estimates may be subject to systematic error. As price goes up, retailers are more likely to underestimate sales in order to avoid taxes, and consumers are more likely to buy alcohol illegally or out-of-state. This suggests that estimates based on price increases may lead to different results than estimates based on price decreases, and, more generally, no investigator undertook a detailed, brand-by-brand analysis of true sales and consumption levels. Thus, the results shown in Table 2 require some qualification: Although they show elastic demand for spirits and wine in the average consumer, they may be misleading because of problems in estimating the true changes in price and consumption.

However, even if the results summarized in Table 2 prove perfectly valid, they may not reflect the habits of consumers who are dependent on alcohol. Researchers interested in problem drinking have dealt with this issue by assessing the relationship between price of alcohol and symptoms of drinking, such as hospitalizations, arrests, automobile accidents, and cirrhosis of the liver (e.g., Cook, 1981). Of these markers, cirrhosis of the liver has been studied most.

Cirrhosis of the Liver and the Price of Alcohol

Long-term heavy drinking can result in fibrous cell growth in the liver, referred to as cirrhosis of the liver (*cirrhosis* means scarring). Cirrhotic cells are not able to perform their normal metabolic functions. As a result, toxins build up that can be fatal. According to clinical evidence, the overall frequency of cirrhosis in alcoholics is approximately 10% to 30% (Grant, Dufour, & Harford, 1988; Lelbach, 1975). However, these figures may underestimate the true frequencies. Autopsies of alcoholics suggest that a large number of cases, perhaps 40% or more, go undetected (e.g., Lieber, 1976), and, as emphasized by Lelbach (1975), cirrhotic symptoms are sometimes masked by other pathological consequences of heavy drinking. Although the frequency of cirrhosis has decreased over the last 20 years, it remains one of the major fatal diseases. For instance, it was listed as the 9th leading cause of death in the United States (about the same as current estimates for AIDS), and in New York City it was the 4th leading cause of death for men between the ages of 25 and 65 in 1992 (Brody, 1992).

In order to use cirrhosis as a proxy for heavy drinking, it is first necessary to establish the relationship between these two variables. Lelbach (1974, 1975) published the most detailed clinical account. The sample was consecutive admissions to an alcoholic treatment center in West Germany over the period 1960–1963. Admission was voluntary, and the treatment lasted for 6 months. Patients were described as "alcoholics" but not "end-stage skid row types." Drinking histories were based on self report and interviews with family members and health-care providers. Of 526 males, 417 provided what were described as reliable accounts of their previous drinking. From this sample, 334 liver biopsies were obtained. Figure 2 shows the relationship between the biopsy results and drinking history.

On the x-axis is number of years of heavy drinking and average grams of

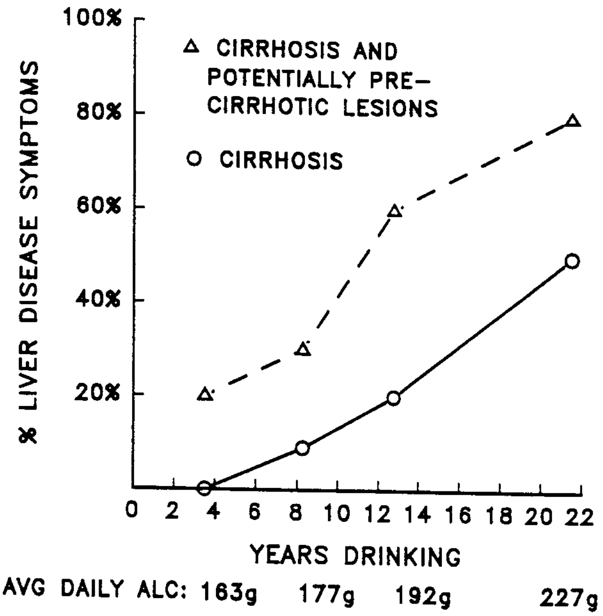

FIGURE 2. The relationship between drinking history and cirrhosis of the liver. The first x-axis gives the number of years of heavy drinking; the second x-axis gives the average daily intake as a function of years drinking. Average intake level increased as a function of drinking history. The graph was adapted from data presented by Lelbach (1974, 1975).

alcohol consumed/day. On the y-axis is the percentage of patients that showed signs of cirrhosis. To provide some idea of the amounts, 163 grams of alcohol is equivalent to approximately 14 cans of beer (4% alcohol) or 14 one-ounce shots (100 proof). These figures represent daily intake. About 88% of the patients were daily imbibers, leaving just a small number of binge drinkers.

Figure 2 shows that cirrhosis was strongly correlated with duration and amount of drinking. In this sample, those who drank for less than 4 years showed no signs of cirrhosis, whereas 50% of those who had been drinking for 22 years showed cirrhotic lesions. In an attempt to dissociate the contribution of amount and duration, Lelbach (1974, 1975) segregated the population into two groups of heavy drinkers, using a 160 g/day cut off and selecting subjects so that average duration of drinking for the two groups was the same. Those who drank relatively larger amounts of alcohol (227 g/day versus 126 g/day) were about twice as likely to develop cirrhosis, and the heavier drinking group had a 14% cirrhosis morbidity rate, whereas the lighter drinking group had no incidence of cirrhosis death.

Lelbach's results are consistent with similar studies. A survey conducted in the United States (in Schmidt, 1977) showed a linear relationship between wine consumption and cirrhosis mortality, and a study conducted in France (Pequignot, Tuyns, & Berta, 1978) showed a 50% cirrhosis rate for drinkers who consumed about 180 g of alcohol/day for 25 years. This figure is nearly identical to that found by Lelbach. Cirrhosis, then, is a good proxy for heavy drinking: there is an orderly, quantitative relationship between drinking history and symptoms, and moderate drinkers show no apparent signs (e.g., Lelbach, 1975; Pequignot et al., 1978).

Figure 3 shows the relationship between price of alcohol, consumption of alcohol, and deaths due to cirrhosis for the Province of Ontario between 1929 and 1956 (Seeley, 1960). The data were derived from government records and studies. The solid line shows the "price" of a gallon of pure alcohol, where price is the ratio of real price to available disposable income. (Real price is nominal price divided by consumer price index, and disposable income is income after taxes.) Thus, this index changes as a function of both price and income. The broken line shows the average number of gallons of pure alcohol purchased each year by individuals 15 years and older. This measure was calculated on the basis of purchases of beer, wine, and spirits and the alcoholic content of each liquor. The dotted line shows the rate of cirrhosis fatalities for individuals 20 years old and over.

Over the time period 1933–1956, the real price of a gallon of alcohol de-

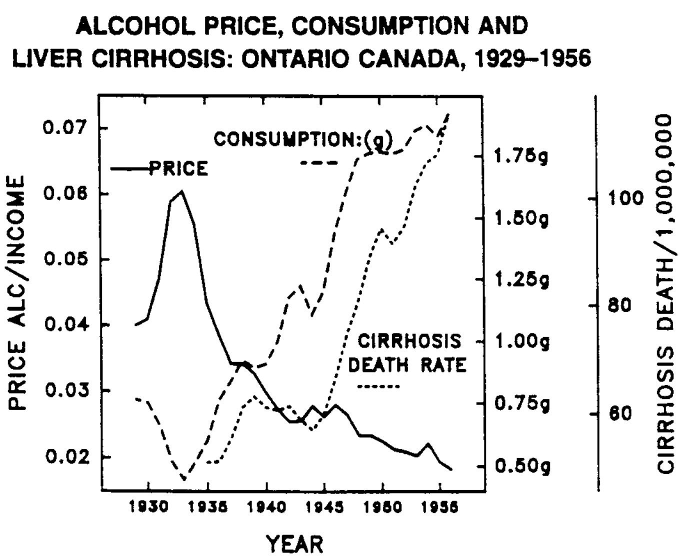

FIGURE 3. The relationships between price of alcohol, yearly alcohol consumption in gallons (g), and cirrhosis death rate in Ontario, Canada. The graph is based on a similar graph presented by Seeley (1960). The data were collected by Canadian government agencies.

creased by about a factor of three (from a little more than about 0.06 to a little less than 0.02 of a year's disposable income). As in the United States, real price of alcohol did not keep pace with inflation and increases in income. Over this same period, per capita alcohol consumption increased by almost a factor of four. For instance, in 1933, during prohibition, consumption sank to about 0.50 gallons a year, and in 1956, the last year of the survey, consumption had increased to more than 1.80 gallons/year.

The dotted line shows that changes in the frequency of death due to cirrhosis usually lagged somewhat behind changes in consumption, but otherwise the two measures followed much the same course. Cirrhosis mortality increased about threefold, from about 40 to 120/1,000,000, and the increase began about 4 years after the start of the increase in consumption. The correlation between price and consumption was –0.96, and the correlation between consumption of alcohol and cirrhosis was just as strong, 0.97.

Along with the overall trends, the graph shows year-by-year correspondences between changes in price and consumption. Prohibition was accompanied by a sharp increase in price of alcohol and a sharp decrease in alcohol consumption. Similarly, during periods in which price was relatively constant (e.g., 1942–1947), the level of alcohol consumption changed little. These data suggest that the relationship between changes in price and alcohol consumption was relatively direct.

The results in Figure 3 are representative of other studies and are consistent with clinical data on treatment of cirrhosis. First, epidemiological studies conducted in Europe and North America show that cirrhosis fatalities covaried with per-capita alcohol consumption (e.g., Grant et al., 1988; Schmidt, 1977). The correlations usually fell within a range of about 0.40 and 0.90 (Smart & Mann, 1991) and were stronger when data were lagged so as to take into account the time course of cirrhosis (Skog, 1980). Second, the results for Ontario, Canada, shown in Figure 3, were replicated in a larger study that included all 10 Canadian provinces (Seeley, 1960) as well as in a study conducted in the United States (Cook, 1981; Cook & Tauchen, 1982) that used quite different methods. (However, the results of the American study are difficult to interpret. I reanalyzed the data and did not find a significant negative correlation between tax increases and percent change in cirrhosis fatalities, whereas Cook's econometric model, based on the same data set, predicts that tax increases will lead to decreases in cirrhosis of the liver.) Third, and most important, the relationship between price of alcohol and cirrhosis is consistent with the course of clinical treatment.

The progression of cirrhosis depends on whether drinking continues. Patients who stop drinking have significantly higher survival rates. In a Danish study (described in Crabb & Lumeng, 1989), the 5-year survival rate for patients with a diagnosis of cirrhosis was 35% for those who abstained and 20% for those who continued drinking. Others have reported similar results (summarized in

Parrish, Higuchi, & Dufour, 1991). Imagine, then, that there is a pool of heavy drinkers with cirrhosis. If they cut down or stop drinking, damage to the liver is arrested and chances of survival increase. Thus, if the levels of heavy drinking have remained stable or increased over the recent past, a sudden decrease in drinking can result in a sharp and relatively immediate decrease in fatalities. Conversely, if there is an increase in the number of cirrhosis patients that continue drinking, fatalities can show a relatively immediate increase.

The simplest (but not sole) interpretation of Figure 3 is that price had a significant influence on alcohol consumption in alcoholics. The basis for this interpretation is Lelbach's study (Figure 2). According to his report, long-term, heavy drinking was a necessary condition for alcoholic cirrhosis. Short-term, heavy drinking did not lead to cirrhosis, and there appears to be no reason to believe that moderate drinking provides any risk. Although alcoholism is not defined in terms of drinking level per se, it seems unlikely that individuals who drank enough to develop cirrhosis (about 20 ounces of pure alcohol a day for 10 years or more) would fail to meet the criteria for alcoholism. Thus, Figure 3 provides evidence that decreases in the price of alcohol promoted alcoholism. Whether or not the data suggest the converse, that is, a correlation between price increases and alcoholism decreases, is discussed next.

Low Prices May Invite Heavy Drinking, But Do High Prices Curb It?

Although the epidemiological evidence clearly shows that the frequency of cirrhosis of the liver is inversely correlated with the price of alcohol, clinical and biographical reports (e.g., Alcoholics Anonymous, 1976; American Psychiatric Association, 1987; Goodwin, 1988; Orford, 1985) provide no support for the idea that the price of alcohol contributes to the frequency of excessive drinking. Rather, clinical and biographical accounts foster the view that alcoholic drinking is undeterred by the constraints that affect social drinkers. How can clinical accounts ignore economic factors, when the frequency of cirrhosis of the liver shows such a strong correlation with price of alcohol?

One possibility is that there are really two groups of heavy drinkers who develop cirrhosis: those who drink excessively regardless of price ("true alcoholics") and those who become heavy drinkers when the price of alcohol is low. The following scenario suggests how price-dependent heavy drinkers may have gone undetected.

First, assume that the relatively low price of alcohol influences the acquisition of drinking. For instance, it is plausible that some people began to drink heavily in part because alcohol was an inexpensive way to have fun or pass the time. If alcohol had been more expensive, they would have done something else and drunk less. Second, although alcohol is relatively cheap, heavy drinking results in continually mounting indirect costs. Frequent intoxication compromises performance at work, health, and social relations (e.g., Alcoholics Anonymous, 1976; American Psychiatric Association. 1987; Orford, 1985; Vaillant & Milofsky, 1982). These economic factors should now curtail drinking (especially if economic factors contributed to the initiation of drinking). However, the process may not be reversible. The secondary effects of drinking limit the range of activities that can be effectively pursued. Drunks loose their friends, family, and jobs. Under these conditions, drinking might continue despite the mounting costs, because drinking itself has removed compelling nonalcoholic alternatives. Thus, there may be an asymmetry in how economic factors influence drinking: Low prices may recruit heavy drinkers, but high prices or rising indirect costs may, unfortunately, not have the opposite effects.[2] To my knowledge, this dynamic has not been discussed in the clinical literature.

If low prices entice but high prices fail to cure then there should be an asymmetry in the relationship between price change and frequency of cirrhosis. Unfortunately, the data to test this hypothesis are not available. There has not been an extended period during which the price of alcohol increased independent of other factors. For example, during prohibition price increases were accompanied by legal sanctions and a decrease in the availability of alcohol. Thus, the decrease in cirrhosis during this era may have been primarily due to decreased availability of alcohol rather than to an increase in its price. Given the great personal and financial costs associated with alcoholism, it is unfortunate that the best data are on price decreases rather than on price increases. (Cook, 1981, concluded that price increases decreased cirrhosis but, as noted earlier, the tabulated data do not show a negative correlation between changes in cirrhosis frequency and price increases.)

Thus, there are at least two interpretations of the strong inverse correlation between price of alcohol and cirrhosis of the liver. It may mean that alcoholics are as influenced by price as are moderate and problem drinkers. If so then the hypothesis that motivated this chapter, that alcoholics show inelastic demand for alcohol, is wrong. Alternatively, the correlation between price and cirrhosis is misleading because it is restricted to decreasing prices. That is, if the data sets included both price increases and price decreases, the correlation would weaken. However, uncertainty about whether increases in the price of alcohol would curb drinking in those already alcoholic should not obscure what has been learned. As the price of alcohol decreased, the frequency of heavy drinking and cirrhosis of the liver increased. At the very least, this suggests that if the price of alcohol had kept pace with inflation and increases in real income, many individuals would not have become alcoholics.

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[2]This analysis is consistent with the implications presented in Bickel and DeGrandpre (this volume) with regard to cigarette smoking. They suggest that increases in price lead to less initiation but have much less effect on decreasing smoking in heavy users. (See, also, the chapter by Chaloupka, this volume.)

DEMAND FOR ALCOHOL IN RATS: BACKGROUND

For over 50 years researchers have used rats to assess the biological and behavioral effects of alcohol (e.g., Richter & Campbell, 1940). These studies show that many of the important features of human alcohol consumption are also found in rats. Rats become intoxicated, as measured by loss of balance (Shegog, 1991); with chronic heavy drinking, they develop tolerance (e.g., Kalant, 1985); and on cessation of heavy drinking, they go into withdrawal (e.g., Falk, Samson, & Winger, 1972).

Despite these important similarities, it is not clear whether rats provide a reasonable model for human alcohol preference (e.g., Dole, 1986; Lester & Freed, 1973). In humans, alcohol can become a potent if not the prepotent reinforcer, outweighing health, family, and job. But, in rats, the reinforcing power of alcohol was eclipsed by relatively weak, palatable foods. For example, in two-lever, choice procedures, rats strongly preferred alcohol mixed with water to water (e.g. Meisch & Thompson, 1973; Samson, 1986). However, preference for alcohol markedly decreased when the control solution was 1% and 5% sucrose (e.g., Samson, Roehrs, & Tolliver, 1982; Schwarz-Stevens, Samson, Tolliver, Lumeng, & Li, 1991). This is notable for two reasons. The rats were selectively bred to prefer alcohol (Li, Lumeng, McBride, & Murphy, 1987), and 1% sucrose is a rather weak reinforcer when presented by itself in food deprived rats (Heyman & Monaghan, 1994).

Rats Readily Consume Sweetened Alcohol (Even When Sucrose is Available)

But in the rat experiments in which sucrose displaced alcohol, alcohol was mixed with water. This is, of course, at odds with how humans usually drink alcohol. Distillers, brewers, vintners, and advertisers have invested countless hours and dollars to the purpose of making alcohol more palatable. This effort is prima facie evidence that there is something to hide. Most of us do not like the taste of "lab alcohol," especially if we are new to alcohol and sober. Possibly, then, the rats were more influenced by alcohol's aversive taste than by its positive pharmacological effects. This is especially likely because taste is the most immediate consequence of ingestion, and rats are strongly governed by the relative immediacy of reward (e.g., Mazur, Stellar, & Waraczynski, 1987). To test the importance of taste, a procedure was arranged in which rats were served alcohol flavored with sucrose or saccharin (e.g., Heyman, 1993; Heyman, 1995; Heyman & Oldfather, 1992).

The experimental chamber housed two dippers: one provided sucrose and the other alcohol mixed with sucrose or saccharin. The sweeteners masked the aversive taste of alcohol. Once baseline preference was established, access to the alcohol mixture was challenged. If the mixture is simply a source of calories then limiting its availability should increase preference for the concurrently available sucrose solution. Alternatively, if sucrose is a poor substitute for alcohol, then manipulations that make alcohol more difficult to obtain should increase (not decrease) responding maintained by alcohol. Thus, the experiments measured (a) the degree to which preference for alcohol changed in response to changes in schedule requirements, and (b) the degree to which sucrose substituted for alcohol solutions.

Experiment 1: Concurrent Ratio Schedules

The purpose of this experiment was to measure the price elasticity of demand for an alcoholic drink in rats. The sessions were conducted in conventional, two-lever chambers, equipped with two dippers. One dipper served a 0.1 ml mixture of 10% alcohol plus 10% sucrose. The other dipper served a 0.1 ml solution of 10% sucrose. This concentration was selected because it is generally highly reinforcing. For example, in a study in which rats were allowed to reach weights of 115% of their initial free-feeding values and were also given large presession meals of sucrose and rat chow, 10% sucrose solutions maintained response rates ranging from 10 to 30/min (Heyman, 1993). Thus, the rats had a choice between sweetened alcohol and a highly reinforcing sucrose solution.

At each lever, responses were reinforced according to variable-ratio (VR) schedules. In the initial condition, the response requirement was on average four responses for both reinforcers. In subsequent conditions, the response requirement for the alcohol mixture was increased. For example, in the final condition of the study, the requirement for the alcohol mixture was on average 20 responses (with a range of about 2 to 60 responses), whereas the requirement for the sucrose solution remained four responses (with a range of 1 to 12 responses).

Session length was initially 45 minutes. However, because the point of the experiment was to determine if the rats would defend baseline intake levels, session length was increased so that it was possible for subjects to maintain baseline consumption levels, despite the response requirement increases. This was done by providing the rats with a response budget. The budget was determined by the ratio requirement and average number of responses in a 45-minute session when each reinforcer was available on a VR 4 schedule. For example, if there was a 50% increase in the response requirement for the alcohol solution (from VR 4 to VR 6) and no increase in the response requirement for sucrose, then the budget was increased by 25% ((50% + 0%)/2). The rat could allot the extra responses to either the alcohol solution (VR 6) or the sucrose solution (VR 4). However, in order to maintain baseline levels of alcohol, the preference for alcohol solution, relative to baseline, would have to increase. For instance, if preference for alcohol solution was exclusive in baseline then all the extra responses would have to be allotted to alcohol in order to maintain baseline levels when the ratio was increased. The budgets were tailored individually for each rat, but for all subjects a sizeable majority of the extra responses had to be allotted to the alcohol lever in order to maintain baseline levels of alcohol intake.

Eight rats served as subjects. Prior to the experiment, they had a long history of alcohol mixture consumption. Figure 4 summarizes the results in terms of group averages.

Results

The bottom panel of Figure 4 shows that increases in the ratio requirement for the alcohol mixture had little influence on total alcohol consumption. From VR 4 to VR 8, alcohol consumption remained at about 1.8 ml/session (approximately 4.0 g/kg), and with larger increases in schedule requirement there was about a 10 to 15% decrease in consumption. The coefficient of elasticity was estimated by fitting a line to the logarithms of prices and consumption levels, as in Figure 1. The best fitting slope was nearly –.09. However, this was not significantly different than 0.0.

Because alcohol consumption remained approximately constant despite increases in price, response output at the alcohol lever must have increased. For schedule increases of 50% and 100% (VR 6 and VR 8), there were comparable increases in response output (middle panel). For larger schedule requirements, response output also increased, although not in strict proportion to the change in schedule values. Nevertheless, in the final condition, response output for the alcohol drink had increased by 333% (whereas the schedule requirement was 400% greater).

The top panel shows the overall distribution of responses between the two levers. Responding maintained by alcohol mixture increased from about 40% to 60%. The increase was not greater because responding maintained by sucrose also increased. For example, in the VR 20 condition there was a 50% increase in responses at the sucrose lever and a 333% increase in responses at the alcohol mixture lever.

Discussion

As described in the section on demand theory, the effects of price on demand are mediated by changes in income and the availability of substitutes. Because income was compensated, the results shown in Figure 4 imply that sucrose did not substitute for alcohol. This is an unusual result. Caloric reinforcement sources typically substitute for one another. In experiments with rats, sucrose was a relatively good substitute for chow (Lea & Roper, 1977) and root beer was a relatively good substitute for Tom Collins Mix (Kagel et al., 1975). In experiments with pigeons, different feeds were virtually perfectly substitutable for one another (Miller, 1976). Indeed, the only reinforcers that have not substituted for one another in animal experiments are chow and water (e.g., Green & Rachlin, 1991). Because alcohol provides calories as well as pharmacological effects, it is surprising that water and food are the closest comparison.

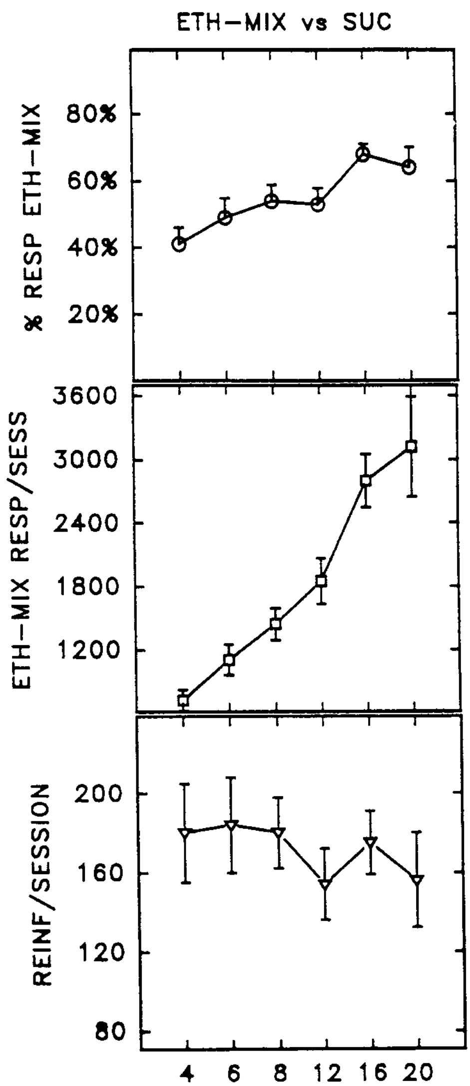

FIGURE 4. The relationship between response requirement and responding maintained by a mixture of alcohol and sucrose in rats (see text). On the x-axis is the average number of responses required for access to the alcohol mixture. Throughout the experiment, a second dipper provided sucrose. The sucrose response requirement was four responses. The bottom panel shows the average number of 0.1 ml alcohol drinks/session. The middle panel shows the average number of responses at the lever that operated the dipper that served alcohol. This panel shows that increasing the response requirement increased (rather than decreased) responding. This is the predicted result if sucrose did not substitute for the alcohol mixture. The top panel shows the proportion of responses allotted to the lever that operated the alcohol mixture dipper. Choice proportions did not increase as much as absolute response rates, because responding also increased at the lever that operated the sucrose dipper. The data points show group (8 rats) averages.

Experiment 2: Concurrent Interval Schedules

A study with interval rather than ratio schedules leads to the same conclusion as did the ratio experiment. Heyman and Oldfather (1992) provided rats with a choice between alcohol mixture and 10% sucrose on a concurrent variable-interval schedule. In the initial condition, the average interval values were 5 sec for both the sucrose solution and the alcohol mixture. In subsequent conditions, the interval requirement for the alcohol mixture was increased. Unlike the ratio experiment (Figure 4), the session length was held constant (30 min). Thus, in most conditions it was not possible for the subjects to retain baseline levels of alcohol. There was also a control condition in which both dippers served sucrose, and the schedule requirement for the dipper that had previously served alcohol was increased. Otherwise the experiment was the same as the ratio study. Figure 5 summarizes the results.

Results

The data shown in Figure 5 are the average of four subjects (individual data in Heyman & Oldfather, 1992). The filled circles show response proportions in terms of the alcohol mixture. In the initial condition, when the average time to the next reinforcer was 5 sec for both the sucrose solution and alcohol drink, three of four subjects preferred the sucrose solution, and the mean preference for the alcohol drink was about 38%. However, increases in the interreinforcement intervals for the alcohol drink did not shift preference to the more readily available sucrose solution. In fact, preference for alcohol drink increased somewhat. Each rat showed this pattern.

The purpose of the sucrose control condition was to measure the relationship between preference and schedule requirement when the two reinforcers were identical and presumably highly substitutable. The predicted outcome was based on the matching law (Herrnstein, 1970). This is an empirically based choice rule that describes the relationship between reinforcement frequencies and response frequencies. When the reinforcers are perfectly substitutable and only the nominal reinforcement frequencies control behavior, the matching law equation takes the form of a simple, parameter-free equality:

$$B_1/(B_1 + B_2) = R_1/(R_1 + R_2), \tag{3}$$

where B_i refers to response frequencies and R_i refers to reinforcement frequencies. For example, Equation 3 says that relative frequencies of behavior match relative frequencies of reinforcement. However, Equation 3 does not fit the data when the competing reinforcers are not perfectly substitutable and when factors other than the nominal frequencies of reinforcement control behavior. Thus, the equation provides a second technique for measuring the degree to which two reinforcers substitute for one another (see discussion by Green & Rachlin, 1991; Herrnstein, 1970; Williams, 1988).

The filled triangles show the response proportions when both dippers served

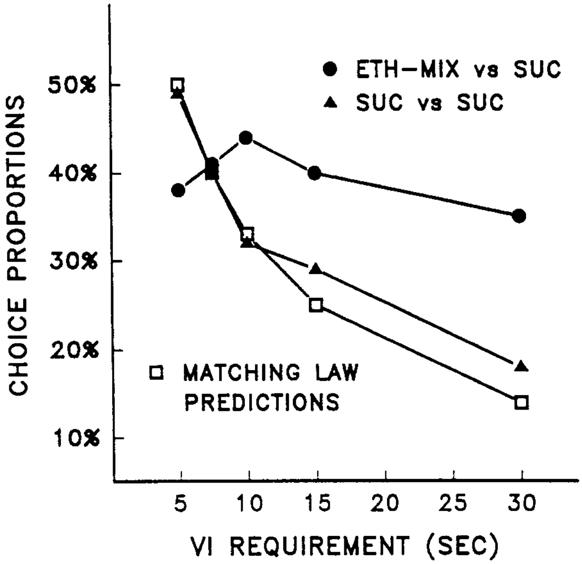

FIGURE 5. The effects of increases in variable-interval requirement on responding. The filled circles are from a study in which one of the reinforcers was alcohol mixture and the other was sucrose. Under these conditions, increasing the interval requirement for the alcohol mixture had little influence on the allocation of responding. That is, alcohol mixture continued to maintain responding even though it had become less available. The filled triangles are from a study in which both dippers served sucrose. Under these conditions, an increase in the interval requirement for one of the sucrose solutions resulted in a shift in preference to the other sucrose solution. The magnitude of the changes in preference were predicted by the matching law (see text). The data points represent the average of four subjects (Heyman & Oldfather, 1992).

sucrose, and the open squares show the predicted values according to Equation 3 (with R_i set to $1/VI_i$, the programmed reinforcement rate). In contrast to the results when one of the reinforcers was alcohol, increases in the schedule requirement for one sucrose solution resulted in increases in preference for the other sucrose solution. As expected, the rats simply shifted to the lever that provided reinforcement more frequently. Moreover, the magnitude of the change was consistent with calculations based on the matching law (see Figure 5). For increases from VI 5 to VI 10 sec, the predicted and obtained values were nearly identical, and for the VI 15 sec and VI 30 sec conditions the rats shifted somewhat less than predicted. However, the pattern of findings was clearly different than when the schedule requirement for the alcohol solution was increased.

The major finding was that increases in the schedule requirement did not decrease preference for alcohol solution. Thus, under both ratio and interval schedules, preference for alcohol was inelastic. In contrast, when both reinforcers were sucrose, preference was controlled by the schedule requirements and was elastic.

General Discussion

According to the econometric data, per capita consumption of alcohol was often strongly influenced by price (e.g., Table 2). According to Seeley's (1960) study, the frequency of cirrhosis fatalities increased as the price of alcohol decreased. Thus, many heavy drinkers were as influenced by price as were moderate drinkers. In contrast, rats in the mixed-drink procedure showed inelastic demand for alcohol. What accounts for this difference? To answer this question, it is first necessary to understand why the rats defended baseline alcohol consumption levels against price increases.

Why did Sucrose Fail to Substitute for Alcohol in the Rat Studies? The alcohol mixture and sucrose solution differ in terms of caloric density, pharmacological effects, taste, and, most likely, other factors as well. Some researchers have maintained that rats and other animals appear to consume alcohol primarily for its calories (e.g., Dole, 1986). Several recent experiments tested the importance of calories and pharmacological consequences in maintaining preference for the alcohol mixture relative to sucrose.

Alcohol provides about 7.1 kcal/g, and there are 0.81 grams of alcohol in each milliliter of alcohol (5.75 kcal/ml). In contrast, sucrose supplies about 3.95 kcal/g. Possibly this difference in density, even though it is quantitative, explains the failure of sucrose to substitute for alcohol. This was tested as follows.

First, feeding conditions were varied (Heyman, 1993). The basic idea was that if the alcohol plus sucrose mixture functioned primarily as a form of food, then presession meals or increases in body weight should decrease its value. As in the elasticity experiments, one dipper served 10% sucrose and the other dipper served 10% sucrose plus 10% alcohol. Responses at the two levers were reinforced according to variable-interval 5-sec schedules. In one experiment, the subjects were given presession meals of sucrose. The meals systematically decreased responding maintained by sucrose, but failed to decrease responding maintained by the alcohol mixture. In another study, body weight was manipulated. Over a wide range of body weights (85% to 115% of the initial free-feeding values), responding maintained by the alcohol mixture remained relatively constant, whereas responding maintained by sucrose tended to decrease. In a third study, the rats were pre-fed both sucrose and laboratory chow while at 115% of their free-feeding weight. Again, responding maintained by sucrose decreased, whereas responding maintained by the alcohol mixture was more or less constant. These results provide no support for the view that alcohol's reinforcing efficacy depended on its calories.

If caloric differences do not explain preference for alcohol in the rat studies then pharmacological ones might. Some recent studies, in which rats were injected with a benzodiazepine compound support this hypothesis (Petry, in press). The background for this experiment includes the following findings. In vitro and in vivo studies suggest that alcohol and benzodiazepines (e.g., valium, librium) act on common receptor sites (Tabakoff & Hoffman, 1987). The compound Ro15–4513 binds to benzodiazepine (GABAergic) receptors, but it is not sedating, and in many preparations it blocks the effects of benzodiazepines (e.g., Suzdak et al., 1986). This suggests that Ro15–4513 may also block some of the effects of alcohol (e.g., McBride, Murphy, Lumeng, & Li, 1988; Samson, Haraguchi, Tolliver, & Sadeghi, 1989). As expected, in a choice procedure in which one dipper served alcohol plus sucrose and the other dipper served sucrose, Ro15–4513 decreased responding maintained by the alcohol mixture but not responding maintained by sucrose (Petry, in press). The procedure was identical to that used in the experiments in which rats defended baseline alcohol consumption levels (e.g., Heyman, 1993). Thus, the simplest summary of the sweetened alcohol (mixed-drink) experiments is that alcohol's pharmacological effects were highly reinforcing, and, importantly, the consequences of sucrose and chow consumption did not substitute for these pharmacological effects. This second point is emphasized, because the failure of basic foods to substitute for alcohol's pharmacological effects explains why demand for alcohol mixture was inelastic in the mixed-drink rat experiments.

DEMAND FOR ALCOHOL IN HUMANS AND RATS

The econometric studies showed that demand for wine and spirits was often elastic. Assuming that these findings are reliable, this means that the average consumer found substitutes for alcohol. This is not a surprising result, because by definition moderate drinking is drinking that is constrained by other activities. In contrast, sucrose was not a substitute for alcohol in the rat studies that used the mixed-drink procedure. This apparent discrepancy may be due to differences in drinking history.

The rats in the sweetened-alcohol procedure had a history of heavy drinking (relative to their body weight), whereas the average consumer does not. This suggests that demand for alcohol became increasingly inelastic as alcohol consumption increased. The available data are consistent with this idea. The degree to which rats defended baseline alcohol consumption against response requirement increases was correlated with the amount of alcohol consumed (e.g., compare Heyman & Oldfather, 1992 with Schwarz-Stevens et al., 1991). However, it should be pointed out that this comparison does not control for taste. For example, sucrose was a relatively good substitute for alcohol when alcohol was mixed with water, but a relatively poor substitute when alcohol was sweetened.

SYNTHESIS AND SUMMARY

This chapter was motivated by the idea that "own-price elasticity of demand" provided a useful operational measure of drug dependence. The econometric findings suggested that demand for alcohol in the average consumer was price elastic. However, the elasticity estimates sometimes varied widely, and there are well known methodological problems in estimating demand for alcohol. In contrast, there was agreement that cirrhosis of the liver increased when price of alcohol decreased (Schmidt, 1977; Seeley, 1960). One interpretation of this finding is that changes in price of alcohol influenced alcohol consumption in alcoholics. However, a more reasonable interpretation is that the correlation was strong because it was based largely if not entirely on price decreases. This interpretation is compatible with the clinical impression that increases in the price of alcohol would not decrease drinking in someone who was an alcoholic. Put in more general terms, the clinical and econometric data are consonant given the assumption that elasticity of demand for alcohol varies inversely with alcohol consumption. This hypothesis predicts that an increase in alcohol prices would have much more influence on the frequency with which individuals graduated from moderate to heavy drinking than it would on drinking in someone who had already become alcoholic.

In the sweetened alcohol procedure, rats defended baseline alcohol consumption levels against increases in response requirements. In contrast, when alcohol was mixed with water, sucrose substituted for alcohol. Because the rats in the sweetened alcohol procedure drank more than did rats in experiments that used a water vehicle, the experimental results are consistent with the hypothesis that increases in alcohol consumption decreased elasticity of demand for alcohol. Finally, that rats would drink large amounts of alcohol when they also had access to sucrose is a promising finding for those interested in developing an animal model of human alcohol consumption. Problem drinkers and alcoholics choose alcohol over other normally reinforcing activities. Thus, an important component of an animal model of human drinking should be that alcohol maintains its reinforcing strength in the presence of other potent reinforcers.

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