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RESOLVING THE CONTRADICTIONS OF ADDICTION

Gene M. Heyman
Department of Psychology
Harvard University
Cambridge, MA 02138
gmh@wjh12.harvard.edu

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Abstract

Research findings on addiction are contradictory. According to biographical records and widely used diagnostic manuals, addicts use drugs compulsively. These accounts are consistent with genetic research and laboratory experiments in which repeated administration of addictive drugs caused changes in neural substrates associated with reward. However, epidemiological and experimental data show that the consequences of drug consumption can significantly modify drug intake in addicts. The disease model can account for the compulsive features of addiction, but not occasions in which price and punishment reduced drug consumption in addicts. Conversely, learning models of addiction can account for the influence of price and punishment, but not compulsive drug taking. The occasion for this paper is that recent developments in behavioral choice theory resolve the apparent contradictions in the addiction literature. The basic argument includes the following four statements. First, repeated consumption of an addictive drug decreases its future value and the future value of competing activities. Second, the frequency of an activity is a function of its relative (not absolute) value. This implies that an activity that reduces the values of competing behaviors can increase in frequency even if its own value also declines. Third, a recent experiment (Heyman & Tanz, 1995) shows that the effective reinforcement contingencies are relative to a frame of reference, and this frame of reference can change so as to favor optimal or sub-optimal choice. Fourth, if the frame of reference is local,

reinforcement contingencies will favor excessive drug use, but if the frame of reference is global, the reinforcement contingencies will favor controlled drug use. The transition from a global to local frame of reference explains relapse and other compulsive features of addiction.

Virchow: 1849

...disease is only the orderly manifestation of definite phenomena of life (normal in themselves) under abnormal conditions, with deviations which are simply quantitative...

1. Introduction

F. Scott Fitzgerald ordered his hired help to keep him away from liquor and then sneaked drinks when they weren't looking (Goodwin, 1988). Samuel Taylor Coleridge contrived a somewhat more complicated "treatment" for his addiction. He moved into his physician's home under the arrangement that he would not be allowed any opium. During the first few days of his stay, he suffered terribly (apparently from withdrawal), but then suddenly recovered and returned to his writing. Coleridge had persuaded his publisher to smuggle bottles of laudanum into the doctor's house (Weissman, 1989).

Addictive drugs also inspire contradictory and self-defeating behaviors in the general public. Since the Surgeon General's report on the health risks of smoking (US PHS, 1964), a large majority of smokers have tried to quit or to at least smoke less (US DHHS, 1989). Many turned to filtered, low tar and nicotine cigarettes. But like Fitzgerald and Coleridge, health conscious smokers tried to have it both ways. They stuck with the filters, but inhaled more deeply or held the side air vents closed. Nicotine intake in "low" nicotine cigarettes turned out to be about the same as with the unfiltered higher nicotine cigarette (e.g., Ashton, Stepney, & Thompson, 1979; Krogh, 1991).

These stories illustrate an important and unresolved problem in the understanding of human behavior. Drug consumption is a goal oriented act. The behaviors are learned, not reflexive or innate. It requires planning, effort, and in some cases artfulness to secure drugs in the amount necessary for maintaining an addiction. Yet, according to the diagnostic manuals (e.g., DSM-III-R and ICD-10), the feature that defines addiction is drug use which is "out of control" or "compulsive." By these phrases, the manuals mean that addicts "take more drug than they initially intended," that drug use persists despite a wide array of ensuing legal, medical, and social problems, and that after periods of abstinence, however long, addicts relapse. In other words, according to authoritative clinical opinion, addiction is not simply frequent drug use, it is loss of control over drug use.

But how can a behavior be "out of control" or "compulsive" yet require planning? For example, if addiction is interpreted as a compulsive, out of control state, but drug seeking is a coordinated series of directed learned behaviors, then logic yields apparently meaningless statements such as "addicts are those who plan to use drugs in uncontrolled ways." On the other hand, biographical and clinical data show that addicts repeatedly attempt to remain sober, but, despite their efforts, fail to do so (Alcoholics Anonymous, 1976; American Psychiatric Association, 1987; World Health Organization, 1992). These puzzles are at the heart of the long-standing debate as to whether addiction is best classified as an involuntary state, e.g., a disease, or a voluntary state e.g., a preference. (The terms "voluntary" and "involuntary" are discussed more fully in Section 3 of this paper.)

An experimentally based theory of choice, known as the matching law (Herrnstein, 1970), provides a framework for resolving the contradictory features of addiction. In most environments, the matching law equations predict adaptive if not optimal patterns of responding (e.g., Herrnstein & Loveland, 1975; Herrnstein, 1990; Heyman & Luce, 1979). However, when an addictive drug is one of the options, there are conditions under which the matching law and related principles predict increased drug use and patterns of behavior that appear compulsive (see Section 4). In other words, the thesis of this paper is that addiction results from a fundamental behavioral principles, e.g., the matching law, operating under "abnormal" conditions (the biological and behavioral effects of addictive drugs). This theory, in contrast to current disease and learning models, resolves the apparently contradictory features of addiction.

This essay is organized into four major parts. Part 1 (Sections 1 and 2) summarizes the "descriptive" literature, by which I mean diagnostic manuals, biographical sketches, and epidemiological studies. Although these sources are quite different from one another, there is general agreement that the distinguishing feature of addiction is that frequent drug use persists in spite of its aversive consequences. Part 2 (Section 3) evaluates three influential approaches to addiction: the disease model, the incentive-reward model, and the operant reinforcement model. Each theory nicely fits some of the data, but none of the three resolves the contradictory features described in Sections 1 and 2. Part 3 (Section 4) develops a line of reasoning which explains both the compulsive features of addiction and those instances in which addicts are persuaded to abstain or curb their drug intake. The account is based on the matching law and related principles and empirical findings. Part 4 applies the theoretical perspective to two issues: the question of what makes a substance addictive and drug use public policy.

2. The characteristics of addiction

This section of the paper describes the behaviors and relations that a theory of addiction should explain. The observations are well documented and reliable, but, as suggested in Section 1, support contradictory interpretations of whether addiction is a voluntary or involuntary state.

2.1 Loss of control. According to DSM-III-R (APA, 1987) and ICD-10 (WHO, 1992), three characteristics identify addiction: inability to control drug consumption, levels of drug use that adversely affect health, safety, and other conventional pursuits, and tolerance and withdrawal symptoms. The matter of control is most important. The authors of DSM-III-R emphasize that addicts repeatedly consume more drug than they initially intended to take and that they repeatedly try to stop or to curtail drug use, but fail to do so. Similarly, the authors of the WHO manual write that the desire to take drugs is often strong and overpowering and that the "subjective awareness of compulsion to use drugs is most commonly seen during attempts to stop or control use" (p. 76).

2.2 Adverse consequences. Three of the nine primary symptoms listed in DSM-III-R refer to the deleterious influences of drug consumption on conventional activities (pp. 166-167):

(1) Frequent intoxication or withdrawal symptoms when expected to fulfill occupational and other social obligations.

(2) Important social, occupational, or recreational activities given up or reduced because of substance use.

(3) Continued substance use despite knowledge of serious problems caused by substance use.

The theme, which is echoed in autobiographical accounts (e.g., Hamil, 1994; Roth, 1954), is that addiction supplants and interferes with conventional activities.

2.3 Withdrawal. Until relatively recently, it was widely assumed that withdrawal was the defining feature of addiction (Alexander & Schweighofer, 1988; Brecher, 1972). In contrast, the current view, according to both the APA and WHO, is that this symptom is neither necessary nor sufficient for the diagnosis. For example, the writers of the manuals point out that cocaine addiction is not associated with obvious signs of withdrawal (but see Gawin & Kleber, 1986). Conversely, there are numerous examples of drug experiences that lead to withdrawal but not addiction (e.g., following chronic use of cholinergics, opiate pain killers, and steroids (Jaffe 1980, 1992)). However, these comments should not obscure the fact that withdrawal can play an important motivational role in addiction. The symptoms are at the very least irritating and in the case of alcohol can be fatal.

2.4. Autobiographical accounts of addiction. There is a large autobiographical literature on the experience of addiction (Agar, 1973; Burroughs, 1961; Carroll, 1987; Hanson, 1985). Although the circumstances of the authors vary widely, their stories reveal several common themes: (1) Imperceptibly to the narrator, recreational drug use slides into addiction. (2) Intoxication and its aftermath repeatedly wreak havoc on family life, friendships, occupation, and health. (3) Attempts to stop or curb drug use have mixed results. There are periods of abstinence, often quite long, followed by periods of renewed, heavy drug use, followed by abstinence, and so on. (4) Drug use becomes the focal point of everyday life or, at least, strongly influences the course of conventional activities. For example, according to ethnographic reports (e.g., Agar, 1973; Stephens, 1991), the street addict's daily routines were organized in terms of getting high. Similarly, alcoholics with "legitimate" occupations (Roth, 1954; Goodwin, 1988; Hamil, 1994) prioritized their social obligations in terms of the amount of alcohol the host was likely to provide. (5) Finally, after "hitting-bottom," or some dramatic event, the addict regains control over his or her drug use. These themes parallel the symptoms emphasized in the diagnostic manuals.

A passage from William Burroughs, the novelist and essayist, provides an especially vivid example of the self-report literature. In the introduction to "Junky," he responds to the question of why he became a drug addict as follows (1977, p. xv):

You become a narcotics addict because you do not have strong motivations in any other direction. Junk wins by default. I tried it as a matter of curiosity. I drifted along, taking shots when I could. I ended up hooked. Most addicts I have talked to report a similar experience. They did not start taking drugs for any reason they could remember.... If you've never been addicted you can not have a clear idea of what it means to need junk with the addict's special need. You don't decide to be an addict. One morning you wake up sick and you're an addict.

The diagnostic manuals and biographical literature emphasize the same patterns of behavior and subjective states: the struggle to abstain is intense and usually ends in failure and addiction is a problem because of the effects it has on health, income, social relations, and general well being.

2.5. Survey reports on addiction. The next two sections selectively sample epidemiological trends in addiction. This research shows that under some conditions, the frequency of addiction varied in an

orderly way as a function of its consequences. For example, the large majority of those who regularly injected heroin while in Vietnam did not continue to do so upon return to the United States (Robins, Davis, & Goodwin, 1974). These and other survey data suggest that addiction is significantly influenced by costs and benefits. This must mean that addicts are persuaded by the consequences of their actions to abstain or reduce their use of drugs. Thus, the survey data and clinical reports lead to conflicting conclusions about the nature of addiction.

2.5.1. Types of drug users. Researchers have found it convenient to distinguish addiction from two, less destructive patterns of consumption. First, many people experiment with illicit drugs or regularly use alcohol without becoming addicted. For example, in the U.S. in 1988, 90% of those who had sampled an illicit drug (e.g., opiates, stimulants, and cannabis) were not addicted. (Thirty-six per cent had at one time sampled an illicit drug (Tables 1 and 5, Kandel, 1992.)) Similarly, according to the Household Survey (Clark & Hilton, 1991), 80% of those who consume one or more alcoholic drinks a year report no adverse effects. Thus, for most people, experience with an addictive drug did not lead to addiction.

Second, there is a population for whom drug use leads to serious problems but not addiction. The technical term for this group is "substance abusers." They use drugs frequently, incur costs for doing so, but do not experience withdrawal symptoms or show signs of compulsive use. In reference to alcohol, Gordis (1990, p. xviii) used the criterion of self-control to distinguish between these two groups. He makes the comparison that alcohol abusers "are responsible for their behavior; they can modify their alcohol consumption patterns in response to simple explanations and warnings," while alcoholics (alcohol addicts) suffer from a "disease."

2.5.2 Epidemiological Trends. Epidemiological trends reflect etiology. For instance, diabetes, cancer, atherosclerosis and other non-infectious diseases became increasingly prevalent as median age, food stores, and leisure time increased (McKeown, 1988). In the case of addiction, some of the variation is correlated with gender, age, marital status, and cohort.

Dependent males outnumber dependent females by about 1.7:1 (Anthony & Helzer, 1991). For both groups, dependency is highest in the twenties and then declines sharply to negligible levels. For instance, the likelihood of dependence for those 65 and over is from 40 to 50 times less than for those in their twenties (Anthony & Helzer, 1991; Kandel, 1992). Marital status is correlated with drug use. For married men who were neither separated nor divorced from their wife, the lifetime prevalence of addiction to an illicit drug was 3.6%. In contrast, for men who lived with a woman but were unmarried, the lifetime prevalence was about 8 times as great, 30.2% (Anthony & Helzer, 1991; Kandel, 1992). Historical factors also influence addiction. In 1978, 10.8% of high school seniors smoked marijuana daily. In 1989, 3.0% of high school seniors smoked marijuana daily (Kandel, 1992).

A variety of sources show that there are also enduring cultural differences in drug usage (e.g., Brecher, 1972; Peele, 1987; Pittman & Snyder, 1962). Asians have relatively low rates of alcoholism (e.g., Sue, 1987), and in an urban Boston neighborhood, ethnic background was the one of the strongest predictors of who would become alcoholic (Vaillant & Milofsky, 1982). These cultural correlations most likely have both biological and experiential roots. For instance, low drinking rates in Asians may be due to metabolic mechanisms (US DHSS, 1993), whereas in Jews, there is a

correlation between drinking practices and religious orthodoxy (e.g., Glassner & Berg, 1980; Schmidt & Popham, 1976).

Although the clinical and biographical materials stressed that addiction is uncontrolled drug use, the epidemiological trends show correlations between drug use and its consequences. For instance, it is plausible that drug use is lower in married than in unmarried men because of differences in available time, the consequences of detection, community ties, and the like.

2.6. Natural experiments. The differences between the clinical reports and epidemiological trends may simply reflect differences in the populations sampled. The clinical data reflect the behavior of addicts, while the population survey data reflect the habits of aggregates, comprised mostly of non-addicts. However, there are also survey data which include measures that index level of drug use. The results for the most frequent users turn out to show much the same pattern as the aggregate data.

2.6.1 The Vietnam experience. American servicemen in Vietnam had easy access to high quality, inexpensive opiates, including heroin. A team of researchers, headed by Robins, interviewed a large number of these men to determine the extent of their drug use while in Vietnam and afterwards (Robins, Davis, & Goodwin, 1974; Robins, Helzer, Hesselbrock, & Wish, 1980). Prior to Vietnam, about 1% of the sample had used opiates regularly. In Vietnam, this number jumped to 20%, with about one-sixth injecting opiates and the rest either sniffing or smoking opiates. However, upon return to the United States, the vast majority (88%) did not resume regular opiate use during a three year follow-up period. Importantly, those who stopped reported withdrawal symptoms and had access to heroin. They stated that they knew where to obtain heroin and had occasionally (but not regularly) resumed use. Rather, what led Vietnam veterans to stop using opiates, according to the interviews, was the "sordid" atmosphere surrounding heroin use, high prices, and the fear of arrest.

Possibly the Vietnam veterans were not really addicts, but drug abusers or simply recreational users. However, highly dependent men, who failed a publicized urine test at departure because they did not stop using, had re-addiction rates of no more than 14% (Robins, Helzer, & Davis, 1975). Similarly, those who injected heroin regularly in Vietnam did not typically resume heavy opiate use at home.

It is informative to compare the Vietnam veteran relapse rates to those of heroin addicts in the United States who either entered treatment voluntarily or were ordered to do so by the courts. In an extensive survey, Brecher (1972) estimated that relapse rates were close to 90%, just about the opposite of what was found for those addicted in Vietnam. Thus, local conditions can have a dramatic effect on both the acquisition and the elimination of addiction.

2.6.2. The price of alcohol and cirrhosis of the liver. Econometric studies typically show that demand for alcohol is somewhat price elastic (Heyman, 1995; US DHHS, 1993). However, these analyses would not accurately reflect the behavior of alcoholics because they are based on aggregate data. To deal with this problem, researchers have used cirrhosis of the liver as a proxy for alcoholism. This strategy is based on the finding that the likelihood of showing clinical signs of cirrhosis of the liver is highly correlated with number of years of heavy drinking. For example, the frequency of cirrhosis for those who have been drinking very large amounts of alcohol daily (180 g/day) for 22-25 years was close to 50%, and about half of this for those who had been drinking heavily for 12 years (Lelbach, 1975; Pequignot, Tuyns, & Berta, 1978). Thus, if price of alcohol influences the frequency of

alcoholism, it should also influence the frequency of cirrhosis of the liver.

Price increases and decreases need to be treated separately. Over the first half of the twentieth century, the real price of alcohol steadily declined and the frequency of cirrhosis of the liver steadily increased ($r > 0.90$, Seeley, 1960). During those few periods that alcohol prices increased, cirrhosis frequencies markedly decreased (Popham, Schmidt, & de Lint, 1976; Terris, 1967). However, these were also periods in which alcohol was restricted (Prohibition and world wars) so that the role of price increases cannot be isolated.

2.7. Laboratory experiments on price increases. Experimental studies support the survey results and suggest that alcoholics are responsive to price increases. The experiments were housed in laboratory settings and "chronic" and "skid-row" alcoholics served as subjects. Increases in the price of alcohol and payment for not-drinking significantly decreased drinking (e.g., Bigelow & Liebson, 1972; Cohen, Liebson, Faillace, & Speers, 1971). In a study which simulated a "happy-hour" (Babor, Mendelson, Greenberg, & Kuehnle, 1978, "heavy" drinkers were as responsive to price manipulations as casual drinkers. Thus, as with the Vietnam data, environmental manipulations reduced drug consumption in addicts.

2.8. Summary of the descriptive literature on addiction. Each of the four literatures revealed a clear and reliable account of addiction. However, across literatures, the findings are at odds. Biographies (e.g., Alcoholics Anonymous, 1976; Roth, 1954) and diagnostic manuals (e.g., APA, 1987; WHO, 1992) report that addiction is "loss of control over drug consumption." This means that if addiction were a matter of choice then the choice would be to abstain or curb use. In other words, "loss of control" means that addiction is involuntary. However, experimental reports and survey data show that factors such as cost, probability of arrest, embarrassment, and other consequences can persuade addicts to curb or even stop drug use. Thus, by one set of data, addicts do not have control, but by another set they do. As is shown in the next two sections of this paper, this puzzle is not solved by conventional explanations of addiction.

3. Perspectives on addiction: disease, operant reinforcement, and conditioned urges.

In order to evaluate theories of addiction it would be useful to say something more about how the terms "disease" and "voluntary behavior" have been used.

There are a number of reasonable criteria for deciding whether a disorder should or should not be called a disease. For example, it is often argued that labelling alcoholism a disease is therapeutically useful for those who drink too much (e.g., Kissin, 1983). However, in scientific discussions of the relationship between addiction and disease (e.g., Lewis, 1991; Maltzman, 1994; Miller & Chappel, 1991), the analysis has typically been limited to three criteria: (1) the degree to which a reliable pattern of signs and symptoms is present, (2) the degree to which such signs and symptoms compromise well-being, and (3) the degree to which the signs and symptoms are involuntary. The first two tests have for the most part gone undisputed (but see Fingarette, 1988). For instance, that clinicians can reliably diagnose addictions (e.g., Anthony & Helzer, 1991) is proof that there is an identifiable syndrome, and that addicts often attempt to become abstinent is a reasonable standard for the statement that addiction threatens well-being. However, historically, the key issue has been whether addiction is voluntary or involuntary, and this question remains controversial (e.g.,

Fingarette, 1988; Peele, 1987; Lewis, 1991; Maltzman, 1994; Miller & Chappel, 1991). Obviously, the problem has at least as much to do with the definitions of voluntary and involuntary behavior as it does with the facts of addiction. The next section reviews B.F. Skinner's criteria for classifying voluntary behavior.

3.1. Voluntary and involuntary behavior. The conventional understanding of voluntary behavior is that it is deliberate and follows conscious free-choice. For example, the dictionary (American Heritage, 1992) identifies voluntary behavior with free will and defines free will as the "mental faculty by which one deliberately decides or chooses upon a course of action; volition." In contrast, behavioral psychologists (e.g., Skinner, 1953) defined voluntary behavior in terms of its environmental determinants. Behavioral consequences (reinforcements) control voluntary acts, and eliciting stimuli control involuntary acts. The contrast between habits and isolated motor reflexes illustrates the difference. The habit of driving on the right side of the road in the United States is governed by legal sanctions, the expectation of an accident, and the like. We could choose to drive on the left side, but consequences, such as those just listed, persuade us not to. In contrast, a puff of air to the eye elicits an eye blink. With repeated trials, the response may habituate, but attempts to eliminate the blink with reinforcement contingencies will have little if any effect. Importantly, the distinction between voluntary and involuntary is not in terms of predictability or biological underpinnings but in the nature of the variables that control action.

3.1.1. Complications. Although the distinction between eliciting stimuli and controlling consequences may be easy to state, in many instances it will prove hard to apply. First, as emphasized in the ethological literature, biologically important behaviors are controlled by both eliciting stimuli and reinforcing consequences. Aggression, sex, food consumption, social interactions, and economic behavior entail a rich interplay of elicited motivational states, stimulus-response like reflex chains, and reinforcement controlled, learned instrumental acts.

Second, since eliciting stimuli and reinforcing consequences act in concert, it is often difficult to determine the relative influences of each. For example, much effort has been spent determining the role of reinforcement contingencies in classical conditioning procedures. Under some conditions, classically conditioned responses vary in frequency as a function of competing reinforced behaviors (e.g., Blackman, 1968; Van Haaren, Kop, & Van der Shoot, 1984), under other conditions, classically conditioned responses are little affected by reinforcement contingencies (e.g., Norris & Grant, 1947). A full understanding of these relations has yet to be realized. For example, Rescorla (1988, p. 158) summarized the situation by saying: "We are badly in need of an adequate theory of performance in Pavlovian conditioning, but the classical notion of a new stimulus taking on the ability to evoke an old response clearly will not do."

Finally, it should be pointed out that the behavioral approach is correlated but not isomorphic with common usage. Those acts that the judicial system classifies as voluntary and punishable fit the behavioral definition of voluntary. But actions that are forced by aversive consequences, e.g., ransom payments to a kidnapper, lead to contrary ways of speaking. In cases in which aversive consequences "force" action, we are likely to say something like, "I acted against my will." However, actions that are motivated by escape or avoidance of harm are controlled by consequences and therefore fit the behavioral meaning of voluntary. In this paper, the question of whether addiction is voluntary will be based on a judgment of the controlling variables, rather than on a judgment of the addict's intentions.

3.2. Disease model of addiction. Until well into the twentieth century, addiction was most often thought of as a vice (Levine, 1978; Room, 1983). It was believed that people got drunk or took laudanum because they liked the effects, not because they had an uncontrollable compulsion to do so. However, during the nineteenth century, physicians and laymen associated with the temperance movement put forward a quite different conception of excessive alcohol consumption. They argued that addiction was a disease and addicts should be treated as victims not as miscreants (Levine, 1978). Over the years, the disease model gained professional and public support, and by many criteria it is now the conventional wisdom. In 1951 the World Health Organization declared alcoholism a disease, in 1956 the American Medical Association did the same (Room, 1983), and in current courtroom proceedings and news reports, addiction is referred to as a disease and an excuse for diminished responsibility (e.g., Parish priest, 1994; Rosenblatt, 1994).

3.2.1 Jellinek and alcoholism. A turning point in the public and scientific understanding of addiction was a series of papers by E.M. Jellinek in which he argued that alcoholism was a disease state (1946, 1952, 1960). His conclusion was based on the same trait emphasized by current diagnostic criteria: "loss of control." In summarizing the conclusions of a World Health Organization conference on alcoholism (1952), Jellinek describes alcohol addiction as follows (p. 674):

The Subcommittee has distinguished two categories of alcoholics, namely "alcohol addicts" and "habitual symptomatic excessive drinkers." ...the latter will be referred to as nonaddictive alcoholics. Strictly speaking, the disease conception attaches to the alcohol addict only...

In both groups the excessive drinking is symptomatic of underlying psychological or social pathology, but in one group after several years of excessive drinking "loss of control" over the alcohol intake occurs, while in the other group this phenomenon never develops. The group with the "loss of control" is designated as "alcohol addicts."

The disease conception of alcohol addiction does not apply to the excessive drinking, but solely to the "loss of control."

3.2.2 Loss of control defines alcoholism. Jellinek's point is that a sub-population of heavy drinkers do not control their alcohol intake and therefore have a disease (alcohol addiction). This line of reasoning remains the basic argument for the interpretation that addiction is a disease. For example, in an article published in 1991, two physicians (Miller & Chappel, 1991) write:

Rarely overtly stated but clearly central to the concept of a disease is the victim state. As a victim, the afflicted has no control over the onset and progression of the disease if left untreated. In the disease concept of alcoholism (and drug addiction), the cardinal feature is loss of control over the use of alcohol, manifested by a preoccupation with acquiring, continued use despite adverse consequences, and a pattern of relapse to alcohol. The loss of control, which can actually be inherited, is the sine qua non for alcoholism (and drug addiction) as qualifying for the disease state. The loss of control signifies a victim state that reflects an alteration of brain function by alcohol or drugs that is not under the conscious volitional control of the individual.

Miller and Chappel, like Jellinek, equate addiction with disease because both disorders entail loss of control. This logic would be acceptable if disease were the only possible pathway to the behaviors identified as "loss of control." However, as discussed in Section 4 of this paper, the mechanisms that

govern preference can also produce excessive, compulsive-like drug consumption. Therefore, the question as to whether addiction is more like a disease or a preference must be decided on criteria other than the appearance of "loss of control."

3.2.3. Heritability studies. Other evidence in favor of the disease model comes from studies on the heritability of alcoholism. Adoption and twin research reveals a genetic predisposition for at least one population of alcoholics (e.g., Cloninger, 1987; McGue, Pickens & Svikis, 1992). Adopted-away sons of early-onset male alcoholics were more likely to follow their biological father's drinking pattern than that of their adopted father (e.g., Cloninger, 1987). Similarly, among early onset male alcoholics, the concordance rate for drinking problems was 0.7 for monozygotic twins, but 0.5 for dizygotic twins, yielding a heritability of 0.56 (McGue et al., 1992).

However, the relationship between heritability and volition will depend on what is inherited. To see this, consider the traits associated with the heritability of alcoholism and the topography of drinking. Heritability for alcoholism is associated with novelty seeking (Cloninger, 1987) and a dampened response to low doses of alcohol (Schuckit, 1994). These traits increase the likelihood of alcoholism, or are markers for ones that do, but they are not drinking itself. Rather, drinking alcohol is a coordinated set of learned, instrumental behaviors. This suggests that what is inherited are factors that influence the decision to drink, rather than drinking itself.

3.2.4. Drug induced biological changes. Excessive drug consumption can result in aversive withdrawal symptoms and changes in mesolimbic dopaminergic pathways (e.g., Berridge & Robinson, 1995; Hyman, 1994; Nestler, Hope, & Widnell, 1993; Robinson & Berridge, 1993; Wise & Bozarth, 1987). However, as with "novelty seeking" and "dampened response," these changes appear to influence preference for continued drug use rather than elicit an involuntary state of drug seeking.

Withdrawal symptoms indicate that drug consumption has brought about significant biological changes. These changes were once thought to provide a sufficient basis for addiction (see, e.g., discussion by Alexander & Schweighofer, 1988). However, there is now a broad consensus that withdrawal is neither a necessary nor sufficient condition for addiction (e.g., Brecher, 1972; Jaffe, 1992; Kalant, 1989; Stewart, de Wit, & Eikelboom, 1984). This shift in interpretation has been attributed to factual matters (Jaffe, 1992) such as the growing awareness that cocaine was addictive but did not produce dramatic withdrawal symptoms. However, there is also a more theoretical basis for rejecting withdrawal as a sufficient condition for relapse. This is that withdrawal does not elicit the behaviors that comprise addiction. Rather it serves as a negative reinforcer (rewarding behavior that avoids withdrawal). Thus, it is possible, in principle, to create a contingency that counters the motivational effects of withdrawal. Or, put another way, the impact of withdrawal on behavior is mediated by environmental conditions.

There has been much recent interest in the idea that drug- induced neural-sensitization coupled with Pavlovian conditioning provides a sufficient condition for addiction (e.g., Berridge & Robinson, 1995; Wise, 1988). This theory, because of its link with classical conditioning, will be discussed in more detail in the section on learning theories of addiction reinforcement (3.4.2).

3.2.5. Summary of the disease framework. The disease model fits the compulsive-like features of addiction, but is not supported by results which show that factors such as price, reinforcement

contingencies, and fear of arrest persuade addicts to control their drug intake. In addition, in Sections 3.2.3 and 3.2.4 it was argued that the biological factors that are sometimes used as evidence for a disease state are better thought of as factors that influence preference for further drug consumption. Nevertheless, the disease model, despite its shortcomings, is unlikely to be abandoned until there is a replacement that can convincingly explain why addicts will continue to use drugs excessively even after they are well aware of the disastrous consequences of similar episodes in the past (e.g., Alcoholics Anonymous, 1976; Roth, 1954).

3.3. Drugs as reinforcers, drugs as incentives. Learning models of addiction reflect the traditional distinction between operant (Skinner, 1953) and classical (Pavlov, 1927) conditioning. For those in the operant tradition, reinforcers are operationally defined as stimuli or activities that have the capacity to increase the frequency of preceding behavior, and addictive drugs are reinforcers in much the same way as are food, water, etc. (e.g., Falk, Dews, & Schuster, 1983; Young & Herling, 1986). For those in the classical conditioning tradition, addictive drugs elicit states that lead to greater drug taking. The operant approach will be discussed first.

3.3.1. Addiction as operant psychology. The basic premise of operant psychology (e.g., Skinner, 1953) is that behavior is controlled by its consequences. Thus, by the operant approach, addiction should be sensible in terms of its consequences. For example, McKim (1991, p. 68) wrote, "there is no advantage in viewing drug addiction as a disease, it can be understood in terms of operant conditioning theory." However, in operant conditioning, aversive consequences are supposed to decrease behavior. The clinical literature implies that this does not happen in addiction.

As documented in biographical writings and diagnostic manuals, addictive drugs produce a wide array of negative consequences, including hangovers, problems performing conventional activities, toxic reactions, lethal overdoses, and, of course, addiction itself. Importantly, most of these aversive effects do not lessen with continued use. Rather, risks to health, occupation, and social relations increase as drug use continues. In contrast, positive consequences reach some limit and often decrease because of tolerance (Wikler, 1952; Hanson, 1985). Thus, if consequences mattered, as assumed by operant oriented theorists, it is reasonable to suppose that the aversive consequences of addictive drugs would prevent excessive use. That they do not is the problem that needs to be explained, and the empirical generalizations of operant psychology, e.g., patterns of responding under reinforcement schedules, do not seem adequate to this task.

3.3.2 Addiction as a consequence of the positive-incentive properties of drugs. The idea that the incentive properties of addictive drugs explains addiction has been championed by several laboratory research groups (e.g., Stewart, de Wit, & Eikelboom, 1984; Robinson & Berridge, 1993; Wise & Bozarth, 1987). The basic ideas include the following: First, consumption of an addictive drug elicits a motivational state which results in further drug consumption (Stewart, de Wit, & Eikelboom, 1984). Second, the critical incentive effects of addictive drugs increase with repeated drug use (sensitization). Third, drug-induced incentive effects spread to correlated stimuli according to classical conditioning principles. Summarizing these ideas, Berridge and Robinson write (1995, p. 72), "The reason why addicts focus excessive wanting specifically on drug use is primarily this interaction of neural sensitization with associative learning."

However, the evidence for incentive theory is mixed. In laboratory studies with rodents, the predicted

results reliably occur (e.g., de Wit & Stewart, 1981; Lett, 1989; Robinson & Berridge, 1993; Stewart, 1992). But in human studies, the correlations between drug urges, physiological measures of drug use, and relapse are often weak. The basic findings are that relapse was not reliably accompanied by the report of drug cravings (e.g., Marlatt & Gordon, 1980); conversely, drug cravings were not reliably followed by relapse (Tiffany, 1990); physiological correlates of drug effects were not reliably correlated with urges (Kassel & Shiffman, 1992); and priming doses of alcohol typically failed to produce binging in alcoholics (e.g., Cohen et al., 1971; Mello & Mendelson, 1972).

However, the rat and human results may not really be discrepant, and the explanation of why this is so shows the way in which incentive theories of drug addiction are incomplete. The influence of conditioned stimuli on behavior depends on the state of the organism (e.g., Toates, 1995) and current environmental conditions, especially "economic" ones. For instance, level of sodium balance influenced the incentive value of a stimulus paired with salt (Berridge & Schulkin, 1989), and in numerous studies it has been shown that the relative strengths of appetitive and aversive conditioned responses were an inverse function of the frequencies of reinforcement for competing behaviors (e.g., Blackman, 1968; Van Haaren, Kop, Van der Shoot, 1985). In other words, the degree to which conditioned stimuli control behavior is modified by the state of the organism and the reinforcing value of competing interests. This line of reasoning can explain why laboratory animal experiments on incentive motivation have obtained more robust results than have human studies. In the rat experiments, it is likely that competing factors were greatly reduced; in the human studies, it is likely they were not. Alternatively, it may simply be the case that unconditioned and conditioned drug-sensitization is a weaker phenomenon in humans than in rats (see, e.g., Rothman et al., 1984)

3.3.3. Summary of reinforcement theory. Addictive drugs are reinforcing. However, this capacity does not distinguish them from the myriad of activities and substances that influence human behavior. Moreover, conventional activities do not lead to the sorts of problems that addictive drugs present. What is needed is a theory that can predict the persistence or even increase of a voluntary act which yields consequences which are on average aversive. As is shown next, the matching law theory of choice does just this.

4. Behavioral choice theory.

In the 1940s and 1950s, the standard dependent measure in operant psychology was an analogue, moment-to-moment representation of response rate, known as a "cumulative record." However, in a paper published in 1961, Herrnstein plotted relative response rate as a function of relative reinforcement rate in cartesian coordinates. Both the dependent and independent variables were quantities, and, instead of cumulative records, an equation was fit to the data. This change in emphasis opened the way for a new, quantitative theory of behavior and choice. The central principle in this theory is a simple mathematical rule, referred to as the "matching law" (Herrnstein, 1970). Recently, the matching law and related concepts have been applied to questions in psychopathology (e.g., Ainslie, 1992), economics (e.g., Herrnstein, Loewenstein, Prelec & Vaughan, 1993), and addiction (Herrnstein & Prelec, 1992). I will introduce the theory and key findings with a simple thought problem that I use in undergraduate courses. (The problem is based on one first described by Herrnstein (1990).) In this example and throughout this paper, "reinforcer" and "commodity" are used interchangeably.

4.1. A thought experiment. Consider the following situation: You are trying to decide which of two restaurants to eat at, one is Chinese, the other is Italian. You know from past experience that your preference for each restaurant declines as a function of how many times you have chosen it in the recent past (assume that your memory goes back 10 meals). How should you choose which restaurant to go to tonight?

The standard response is something like this: "Choose the Chinese (Italian) restaurant until its value decreases below that of the Italian (Chinese) restaurant. Then reverse choices, and choose the other restaurant. In this way, you will always go to the restaurant you like best."

The students are saying that the current relative value of each meal would dictate their choice. This strategy is local or molecular in the sense that the governing variable is the value of each meal taken separately. (It will prove convenient to express the current expected values of each meal with the notation: v_1/v_2 , where the subscripts refer to the type of restaurant.)

However, there are other ways of looking at the restaurant problem. For example, consider the idea that meals should be chosen so that the experience of "eating out" is maximized. That is, instead of choosing the type of restaurant which at the moment seems best, go to the restaurant that will lead to the best meal experience (counting both restaurants). This is equivalent to saying that the choice is between different combinations of Chinese plus Italian meals. For instance, should a week of eating out consist of two Chinese meals and five Italian meals, or would some other combination be better? The relevance of this perspective is that it is the one assumed in economics. For example, consider the classic problem in consumer demand theory.

The consumer has a limited budget and must divide his or her scarce funds between two or more commodities. Combinations of different goods are referred to as bundles, and the fundamental and universal assumption is that the consumer chooses bundles so as to maximize their subjective effects (their utility). For example, applying this approach to the restaurant problem, the consumer would weigh the subjective value of all possible combinations of Chinese and Italian meals. Using the notation introduced above, the independent variable would be $(pv_1 + (1-p)v_2)$, or some function of this expression, where v_i is the expected value of a meal given that preference for the meal is p or $(1 - p)$. Although the difference between a sum and ratio (v_1/v_2) may seem minor, it proves to be quite important.

4.2. Melioration theory. Herrnstein and Vaughan (1980) introduced the term "melioration" to describe the local strategy that the students used. In a series of papers, they argued that melioration, not overall maximization, is the elementary process governing choice (e.g., Herrnstein, 1990; Vaughan & Herrnstein, 1987). The difference between melioration and overall maximization has been described as a difference between an empirical principle and rationality. However, the contrast between the two models of behavior can be put more concretely, in terms of how choices are aggregated, or in what has been called "bookkeeping" schemes (Herrnstein, 1990).

According to melioration theory, options are not aggregated but compete against one another. That is, the consumer chooses between "A" or "B," depending on which one is at that moment best. In contrast, in order to maximize overall returns in settings like the restaurant example, it is necessary to order the choices as competing aggregates (so as to take into consideration the effect of the present

consumption on future value). That is, the consumer must choose the combination of "A" and "B" which is best. Thus, the functional distinction between melioration and maximizing is in the manner in which the choice problem is framed, not in the choice rule (which is simply to choose the best option).

Although economists routinely assume that consumers combine rather than compare options, over the past two years, only one student out of several hundred has suggested comparing different combinations of Chinese and Italian meals. Instead, the students say that choices should be defined as the current expected value of each meal taken separately, as assumed in melioration theory.

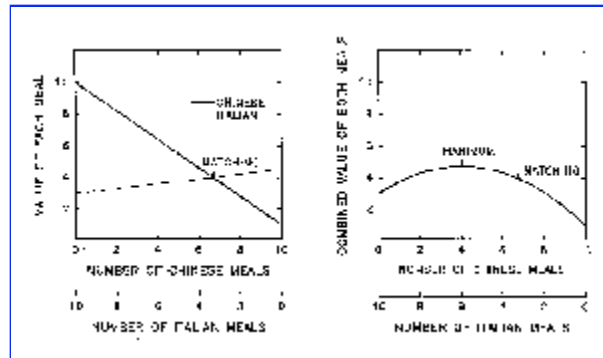


Figure 1: The restaurant problem

4.2.1. Melioration and the matching law. The left panel of [Figure 1](#) provides a graph of the local strategy. Let the solid line represent the current expected value of a Chinese meal, and let the dashed line represent the current expected value of an Italian meal. These lines will be referred to as "local value functions," where "local" refers to the fact that the y-axis measures the value of each activity as a function of how much time is spent at the activity. (For example, if time spent at an activity increased at a greater rate than did the returns paid by the activity then local value would decrease.) On the x-axes are the number of choices out of the last 10 for each type of restaurant, and there are two axes for each panel so that the complementary relationship between the two choices is explicit.

Under the conditions of this graph (left panel only), the local strategy predicts that the consumer will go to the Chinese restaurant 7 times in a row, then the Italian restaurant 4 times in a row, then the Chinese 7 times in a row, and so on. Consequently, there is a stable, overall equilibrium, which falls at about 63% preference for the Chinese restaurant. This result, although highly intuitive, has a number of surprising implications. (The basic argument does not depend on such issues as order of choices.)

First, at the equilibrium point (indicated by the asterisk), the overall ratio of choices between the two meals matches the overall ratio of values the two types of meals provided. This relationship is given by the equation:

$$B1/(B1 + B2) = V1/(V1 + V2), \text{ (Eq. 1)}$$

where B_i is a measure of behavior, either the total number of choices or total amount of time spent at each restaurant, and V_i is the overall value provided by each meal (e.g., $V_i = B_i v_i$). This relationship is apparent from the definitions: Since $V_i = B_i v_i$, Equation 1 can only be true when $v_1 = v_2$, the equilibrium point, according to melioration.

4.2.2. The generality of the matching law. Equation 1 was based on the students' intuitions about their choices. However, it is also a widely established laboratory result. For example, in an experiment in which college students served as subjects, Equation 1 described the relationship between "attention" and "verbal approval" (Conger & Killeen, 1974) about as well as it did in experiments in which the subjects were hungry laboratory animals and the reinforcers were food. Equation 1 also holds in non-laboratory settings (e.g., Baum, 1974; Houston, 1986), and in all of these experiments, as in the restaurant problem, there were many logically possible outcomes other than matching. That is, matching reflects something about the nature of behavior, not particular procedures. Because of this generality, Equation 1 is often referred to as the "matching law" (for reviews, see Davison & McCarthy, 1988; Williams, 1988).

4.3. Matching and overall reinforcement rate maximizing. The second point to be made about [Figure 1](#) has to do with the relationship between matching and the predictions of rational choice theory. To calculate the maximum possible return, it is necessary to take into account both options. The simplest equation for this is $(pv_1 + (1-p)v_2)$, where p is the overall proportion of choices for the Chinese restaurant, and v_i is the expected value of a meal for a given choice proportion. The right panel of [Figure 1](#) shows the result. The x-axis is the same as in the left panel, but the y-axis represents the total value associated with each choice, rather than the value of each option taken separately. The curve, therefore, represents the overall hedonic consequences for every choice ratio (e.g., $pv_1 + (1-p)v_2$). The maximum is not at matching. Instead, a choice distribution which favors the Italian dinner maximized overall subjective value of eating out. Since the Chinese meal had the highest local value, this point may require some explaining.

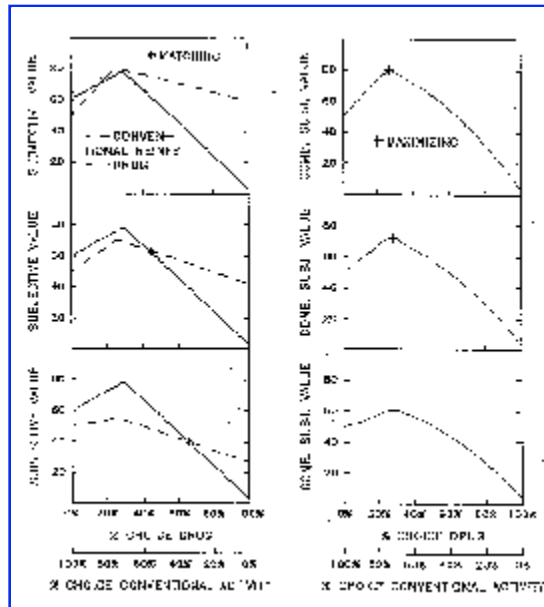
The problem was set up so that current choices influenced present as well as future consequences: each meal decreased the future value of the type of meal just chosen and increased the future value of the meal not chosen (which is to say, v_1 and v_2 , changed as a function of p). In addition, the habituation rate for Chinese food was greater than for Italian food. Consequently, there was an overall benefit for not eating Chinese food. Put another way, economic rationality in this situation required factoring in the future and resisting the present. (Indeed, this is what makes economic rationality easier to prescribe than to follow.)

The restaurant problem is hypothetical. Possibly, if choices really mattered, matching would give way to economic maximizing. Numerous studies with hungry pigeons, hungry rats, and college students working for money show that this is not the case (Williams, 1988). For instance, in one experiment (Heyman & Herrnstein, 1986), subjects (hungry pigeons) persisted in matching even though this choice ratio provided the lowest possible overall reinforcement rate.

4.3.1. Matching, maximizing, and bookkeeping. One of the implications of [Figure 1](#) is that whether an individual behaves in an economically rational way depends on the bookkeeping scheme that is in effect. Under conditions in which the future value of a commodity is strongly influenced by present consumption patterns, bookkeeping schemes which aggregate across commodity categories, for example, "eating out" rather than "Chinese meal" versus "Italian meal," will lead the consumer toward the optimal choice distribution. In contrast, when the bookkeeping scheme respects the commodity categories and cross-commodity aggregation does not occur, choice proportions will tend toward the matching law equilibrium. In laboratory and natural settings, both humans and infra-humans almost always match (e.g., Baum, 1974; Conger & Killeen, 1974; Houston, 1986). Thus, a theory of choice

should assume the bookkeeping scheme that corresponds to matching, unless special circumstances dictate otherwise. (In some environments, matching and maximizing will predict the same outcomes (e.g., Herrnstein & Loveland, 1975), but that does not alter any of the conclusions presented in this paper.)

4.4. Addiction as melioration. Melioration is a consequence-driven mechanism, yet it can result in overall choice proportions that fall short of economic rationality. Addiction is irrational in the sense that it is not curtailed by the aversive effects of drugs. Possibly, then, the matching and melioration principles can be fruitfully applied to the paradoxes of addiction.



[Figure 2: The progression toward excessive drug use](#)

[Figure 2](#) provides a schematic account of a history of drug consumption that ends up as addiction. In the left column of panels, the solid and dashed lines are the local value functions for drug consumption and a set of conventional activities, such as work, family life, recreational pursuits, etc. For each panel, the first x-axis stands for the percentage of days, say of the last 10, in which an addictive drug was consumed to the point of intoxication. The second x-axis is the percentage of days in which conventional activities occurred. The two axes are complements, adding to 100%. (The activities are mutually exclusive, and it was assumed that order in which the choices occurred did not matter.) In the right column of panels, the dotted lines plot the overall or combined value of each choice ratio. Thus, the left column represents the way consequences control choice according to melioration theory, and the right panel represents the way consequences control choice according to economic theory.

The local value function for drug consumption is bitonic (left panels). For choice proportions of 0 to 30%, the value of drug taking increases, whereas for preferences greater than 30%, the local value of drug use decreases. The upward swing represents the common report that there is a learning curve for the enjoyment of addictive drugs. For example, addicts often refer to pre-addiction drug use as a "honeymoon period" (e.g., Agar, 1973; Hanson, 1985; Stephens, 1991). This may be due to reward sensitization, as discussed in Section 3, tolerance to aversive effects, or both.

The downward swing of the curve was meant to represent the effects of tolerance. It is commonly reported that as use continues, the subjective effects of addictive drugs attenuate (e.g., Hanson, 1985). For example, in a study conducted in a hospital setting (Wikler, 1952), an addict with free access to intra-venous morphine increased his daily dosage by a factor of about 10 over a 100 day period. Tolerance also occurs with alcohol, psychomotor-stimulants and nicotine (e.g., Goudie & Emmett-Oglesby, 1989; McKim, 1991), but not to the degree found with opiates.

The local value function for conventional activities is also bitonic. As with drug use, it was assumed that the future value of most ordinary activities varies as a function of how frequently they are engaged in. The shape of these interactions must differ as a function of the activity. However, the conclusions discussed in this section of the paper hold for a wide range of local value functions.

Under the conditions of the top panels, matching and economic rationality predict nearly the same outcome---about an 18% choice proportion for drugs and an 82% choice proportion for conventional alternatives. For these value functions, then, melioration yields rational behavior.

However, under the conditions of the middle panels, the matching law equilibrium shifted to 45%, thereby doubling drug intake. In contrast, the optimal distribution of behavior (overall maximization) remained at about an 18% drug preference (right panel). This shift occurred because the equations that generated the curves were written so that an increase in drug consumption would decrease the value of conventional activities. In other words, drug consumption increased because other activities worsened.

The assumption that drug use would undermine the value of conventional pursuits is based on the descriptive literature reviewed in Section 2. Recall that both the diagnostic manuals and biographies stressed the indirect costs exacted by addiction. In addition, even addicts with few conventional responsibilities are likely to fall victim to the relations shown in [Figure 2](#). Heavy drug use results in withdrawal symptoms. By definition these occur during periods of abstinence. Thus, heavy drug use has unfavorable indirect effects even for those who have little left to sacrifice.

The third panel repeats the themes of the second panel. It was assumed that continued heavy drug use would drive the value of conventional activities down even further. As a result, the relative value of drug consumption increased. Importantly, this occurred even though it was also assumed that the absolute value of drug use decreased because of tolerance. Eventually this process should drive drug consumption to an upper limit, constrained not by preference but by the sheer physical inability to take any more drug.

Also note that the relations displayed in these three panels mimic laboratory findings. In these experiments, the contingencies were like those in [Figure 2](#): preference for the higher local reinforcement rate (food or money) decreased its future value and also the future value of the competing reward. Nevertheless, the subjects (pigeons and college students) shifted to the alternative with the higher local rate, thereby decreasing overall returns, as predicted by the matching law (e.g., Herrnstein et al, 1993; Heyman & Herrnstein, 1986).

4.5. Melioration, the paradoxes of addiction, and self- defeating preferences. [Figure 2](#) resolves the fundamental paradox of addiction. It demonstrates conditions under which an increase in the frequency of a voluntary act is correlated with a decrease in the value of that act's consequences and a

decrease in the value of the consequences of the competing choices. That is, by choosing the best local rate of reward, both the local and global rates of reward go down. The critical factors for this perverse situation are the melioration bookkeeping scheme, the matching law equilibrium, and a commodity whose consumption undermines its own future value and the future value of competing commodities. These relationships are not limited to the specific equations that generated the value functions shown in [Figure 2](#). Melioration and matching predict a suboptimal outcome for any setting in which consumption of one commodity decreases its own future value and the future value of competing activities (Herrnstein & Prelec, 1992).

[Figure 2](#) also helps resolve the contradictory features of the descriptive literature on addiction discussed in Section 2. Recall that the biographical and clinical data support the view that addicts cannot stop using drugs, whereas the experimental and survey data showed that various penalties persuaded addicts to moderate their drug intake. Both outcomes are possible if Equation 1 describes the relationship between drug consumption and its consequences. First, [Figure 2](#) provides the theoretical basis for those cases in which drug use is excessive and not reined in by its negative consequences. Now, imagine that an external factor is introduced which selectively penalized drug use. The local value function for the drug curve would decrease, and as a result preference would shift in favor of conventional activities. This is a rough approximation of what happened during Prohibition, and during this period, cirrhosis of the liver and other signs of heavy drinking markedly decreased. (Alcohol was not unavailable. However, experts estimate that its price had markedly increased.)

4.6. Compulsive drug use as ambivalent preferences. The author of a recent text for clinicians (Thombs, 1994, p. 125) writes.

[Relapse] is probably the most significant issue in treating chemically dependent clients. It is often puzzling that individuals who seem to recognize the seriousness of their addiction, who appear committed to recovery, and who have gained some mastery over their drinking or drug-taking behavior often have tremendous difficulty remaining abstinent.

Relapse and "taking more drug than initially intended" are the signs of compulsive drug use and loss of control. However, both these signs can also be explained as behavior under the control of its consequences. The basic idea is that excess and relapse reflect competing or ambivalent preferences. When preference is under the control of the overall value functions, as in the right side of [Figure 2](#), just the right amount of drug will be consumed, which may be moderate amounts or none, depending on the shape of the value functions. However, when preference is under the control of local value functions, drug use will increase by the standards of the overall value functions. Thus, a switch from overall to local value functions, in someone with a history of heavy drug use, will trigger a relapse or an increase in drug consumption beyond that which was intended.

This re-interpretation of compulsion as a problem of competing bookkeeping schemes does not do violence to logic. However, as was described in Section 4.4, experimental studies repeatedly reveal that the local rather than overall value functions predict preference (assuming matching). The few exceptions to this generalization therefore become quite important. As is shown next, they support the idea that relapse and excessive drug use entail the transfer of behavioral control from overall to local value functions.

4.6.1. Conditions in which overall rather than local value functions control preference. The first example comes from the analysis of choice, rather than choice itself. When economists describe how people should behave, they assume that choice is controlled by its overall consequences. Similarly, in theoretical analyses of operant behavior, psychologists often assume that overall reinforcement rate controls responding (e.g., Baum, 1981; Rachlin, Green, Kagel, & Battalio, 1976). These two examples may reveal a general principle. They show that when the consequences of choice are under scrutiny but not immediately present (as when an economist computes the expected value of a set of options), overall value functions dominate. For similar reasons, it is plausible that overall value functions also are likely to become more salient in therapy sessions or any analytic and dispassionate discussion of one's behavior.

The second case is from a recent experiment in my laboratory (Heyman and Tanz, 1995). The purpose of the experiment was to arrange conditions in which overall value functions would control preference. The subjects were pigeons, and a contingency was arranged such that matching provided the lowest possible overall reinforcement rate. To help the pigeons learn what was "good" for them, a stimulus light turned from blue to white whenever relative response rates deviated from relative reinforcement rates, that is, whenever Equation 1 was violated. This meant that when the light was white, overall reinforcement rate was higher. Under these conditions, the pigeons learned to deviate from matching, and the overall rather than local value functions predicted preference. In contrast, pigeons and college students failed to learn to maximize in experiments which were similar except for the signal that indicated the change in overall reinforcement rates (Herrnstein, Loewenstein, Prelec, & Vaughan, 1993; Heyman & Herrnstein, 1986). Thus, conditions can be arranged so that overall rather than local value functions control choice. (However, this sort of setting seems to be less "natural." For example, the Heyman and Tanz experiment was the first in which an external cue was correlated with overall reinforcement rate.)

4.6.2. Context-dependent preference reversals. These two examples show that under some circumstances, choice is correlated with the overall rather than local consequences of behavior. This is an important finding; it means that the contingencies governing choice can vary, which, in turn, allows for context-dependent reversals in preference, independent of the properties of the competing choices.

Little is known about the conditions that influence whether contingencies operate at a local or overall level (and it is probably the case that "local" and "overall" are points along a continuum). However, the examples given in this paper suggest that as behavioral consequences become more remote, the effectiveness of the overall value functions increase, and, conversely, as behavioral consequences become more immediate, the effectiveness of local value functions increase. This means that when drugs are inaccessible and choices are under scrutiny, an addict is more likely to favor not using them, but when they are available, he will reverse himself. This is just the pattern of behavior that has been interpreted as a sign of loss of control and compulsive drug use.

This argument can be taken one step further: If the factors that determine whether overall or local value functions control preference are difficult to detect, then relapse will likely be attributed entirely to individual variables, such as disease or failure of will. However, from the perspective of the matching law and melioration principle, relapse occurs because conditions that favored control by the overall value functions changed so as to favor control by the local value functions.

4.7. Relationships to other theories. The matching law describes how behavior is distributed between reinforcers; it does not describe the origins of these motives or the processes by which motives vary in strength. This is a matter of biology, conditioning, socialization, etc. For example, from the perspective of the matching law, heritability studies show that there is biological variation in preference for addictive drugs. Similarly, preference may also vary as a function of conditioning histories. In contrast, the theory presented in this paper is not compatible with theories that imply that addiction is an involuntary state or that imply a choice rule that violates matching.

5. What makes a substance or activity addictive?

Melioration and matching typically do not result in excessive behavior when the options are conventional substances and activities. However, when one of the options is an opiate, psychomotor stimulant, alcoholic drink, or tobacco, addiction becomes a possibility. This implies that addictive drugs differ in important ways from conventional reinforcers. According to the logic of matching and melioration, the primary difference should be in the way in which drug consumption influences the future value of the drug and competing options. In support of this idea, a common theme in clinical and biographical accounts of addiction is that drug consumption subverts the value of competing activities (APA, 1987; WHO, 1992). In contrast, food consumption, work, and recreation usually increase the value of competing activities. For example, to the extent that a meal reduces hunger, it must increase the relative value of those activities which were competing with hunger. Similarly, it is likely that one of the purposes of holidays and weekends is to rejuvenate the motivational value of work. However, there are no obvious complementary benefits for frequent intoxication. Rather, as has been emphasized in this paper, frequent intoxication is likely to subvert the value of competing activities. Other differences between conventional pursuits and addictive drugs are discussed next.

5.1 Immediacy and magnitude of reward. Over a wide range of conditions, individuals will reliably choose smaller but sooner rewards over larger but later rewards (e.g., Ainslie, 1992; Rachlin, 1990). This has been explained in terms of the impact of delay on reward value. Laboratory research shows that preference for a reinforcer is a positively accelerated (hyperbolic) function of its immediacy, where immediacy is defined as the interval from instrumental response to consumption (e.g., Ainslie, 1974; Mazur, 1987). Addictive drugs act rapidly, usually much more so than conventional rewards, especially non-essential ones. For example, onset of action takes place within seconds for cigarette delivered nicotine, injected heroin, and crack cocaine. Thus, to the extent that immediacy of action determines choice, addictive drugs will hold an advantage over many conventional rewards. (It should be remembered, however, that the sensory properties of essential rewards like food and water are reinforcing and also immediate, and that, in general, the reward value of immediacy will be tempered by learned associations that signal the availability of temporally distant events.)

5.2. Intoxication. Addictive drugs alter perception, self-regard, and mood. Heroin, especially in the early stages of use, often produces dramatic feelings of euphoria and well-being (Agar, 1973; Stephens, 1991); alcohol increases self-regard and sociality (Babor, Berglas, Mendelson, Ellingboe, & Miller, 1983; Steele & Josephs, 1990), and nicotine, while not intoxicating, produces subtle sensations of relief, calm, and, under some circumstances, stimulation (e.g., Krogh, 1991). Importantly, these effects are highly reliable and, as noted above, immediate. Of course, conventional activities alter mood in positive ways too. But there is reason to believe that these effects are not as intense, immediate, or dependable as those produced by addictive drugs. For example, religious ecstasy and

"runner's high" require much effort and are not usually described in as vivid or concrete terms as is a heroin rush (e.g., "like an orgasm"). Thus, for many users addictive drugs are a unique commodity; they cheaply and immediately enhance mood. In contrast, to the extent that conventional activities can produce similar feelings, much more effort is required.

5.3. Satiating. Drugs and conventional reinforcers differ in terms of the mechanisms that inhibit on-going use. Consumption of many if not most conventional reinforcers is self-limiting because of satiation. Of course, it is possible to overindulge basic appetites, but it takes some effort since the negative feedback mechanisms are concrete and immediate. For example, with a stuffed gut, one more bite of banana split is aversive, and past the age of 18, sexual fantasy begins to outstrip capacity, at least for males. In contrast, evolution has not arranged mechanisms for limiting psychoactive drug intake. With the exception of alcohol, addictive drugs are not filling, and, even in the case of alcohol, highly concentrated solutions can get you quite drunk before they get you quite full. Consequently, moderate use of an addictive drug depends more on judgment than it does on sheer physical limits.

But judgments are easy to circumvent. Moreover, one of the effects of addictive drugs is to compromise judgment (e.g., Steele & Josephs, 1990). Intoxication weakens inhibitions. Thus, with addictive drugs, consumption undercuts the very mechanisms that promote moderate use. This sort of positive feedback loop does not exist for most conventional reinforcers.

5.4. Withdrawal. Food deprivation produces hunger, and hunger is more deadly and its pangs more intense than any drug withdrawal state. Similarly, it is not possible to survive without water and sleep. However, deprivation from most if not all conventional recreational and non-essential reinforcers does not result in sharp physical discomfort. In contrast, most addictive drugs produce distinct and aversive withdrawal symptoms. The discomfort should decrease the value of sobriety and directly augment the value of the drug. For example, the best cure for withdrawal is the drug itself.

5.5. Intoxication, withdrawal, and substitutability. Many addictive drugs are potent reinforcers. For example, in a frequently cited experiment (Aigner & Balster, 1978), monkeys strongly preferred cocaine to food and would have starved themselves to death if the experimenters had not intervened. The discussion of intoxication and withdrawal suggests another important dimension of comparison. Drugs are unique sources of reward. An implication of this point is that as drug use proceeds, the number of competing reinforcers that can substitute for the drug decreases. (Where "substitute" is used in the sense of filling a similar psychological function.) Thus, if the price or costs of the drug increased, the user would not have cheaper alternatives to turn to and would be more likely to absorb the increased expenses. In contrast, for a conventional commodity with many substitutes, an increase in price would simply reduce preference in favor of a cheaper substitute. (This last point is admittedly circular. The best measure of whether two commodities served "similar functions" would be the degree to which an increase in the price of one increased preference for the other, what economists call "demand elasticity.")

5.6. Predicted changes in the biological substrates of reward. One of the main points of this paper is that the degree to which a commodity or activity will be addictive depends in part on the degree to which its consumption undermines its future value and the future value of competing goods. The mechanisms could be indirect, as with the social sanctions that accompany illegal drug use, or direct, as with changes in the neural substrates of reward (Koob & Bloom, 1988). Possibly, repeated

administration of addictive drugs compromises brain mechanisms that mediate reward (e.g., Hyman, 1994). In support of this idea, Wise and Munn (1995) recently reported that repeated administration of amphetamine increased the threshold for rewarding brain stimulation, and in a similar, unpublished study in my laboratory, repeated injections of cocaine reduced the rewarding value of food. These laboratory results support Gawin and Kleber's (1986) theory that cocaine binges have residual, dysphoric effects which eventually lead to another period of binging. In contrast, there is no reason to expect that repeated consumption of conventional rewards has deleterious effects on brain reward circuits.

5.6. Summary of differences. This brief overview reveals three themes: Inhibitory, negative feedback relations are often weaker for drugs than for conventional commodities (e.g., see discussion of satiation); strengthening, positive feedback relations are often stronger for drugs (e.g., see discussion of immediacy or reward); and addictive drugs have fewer substitutes than do conventional reinforcers. However, these differences would not lead to addiction if choice were based on the net, overall consequences of consumption (as assumed in economics). For instance, even though the positive effects of cigarettes and intra-venous heroin and cocaine may be more immediate than those of conventional reinforcers, the net value of these drugs must be negative (or else addiction would not be considered a problem). Put another way, if reinforcing strength or preference were based on the long-run or aggregated consequences of behavior, addiction would not exist. However, consequences influence choice in the way described by the matching law and melioration principle. Thus, substances which subvert the value of competing commodities can be over-consumed.

6. Policy and treatment.

A discussion of drug control policy treatment for addiction is beyond the scope of this paper. However, in an attempt to avoid misunderstandings, a few basic points will be made.

6.1. Drug availability. If addiction depends on elementary choice mechanisms then everyone is a potential addict. This in turn suggests that differences in prevalence rates will depend importantly on exposure to drugs. Epidemiological data support this inference. In Vietnam, strong, cheap heroin was readily available, and heroin addiction increased by about a factor of twenty. Among professionals, physicians have the greatest exposure and easiest access to opiates, and their addiction rates are higher than those of most if not all other professional groups (e.g., Winick, 1961). Among the middle class, addiction rates were considerably higher during the late 19th century when opiates were legal and readily available from pharmacies and mail order companies (Courtwright, 1982). Thus, as suggested by the theory presented in this paper, it seems likely that increasing the availability of addictive drugs would substantially increase the frequency of addiction.

6.2. Enhance overall value functions. Second, the ideas presented here indicate that treatment should attempt to bring drug consumption under the control of overall rather than local value functions. A recent anti-smoking television commercial provides a nice example of this approach. It begins with a middle aged man holding a pack of cigarettes. He explains that information about the health risks of smoking, although believable, has failed to curtail his smoking. He knows he is endangering his health, but he still smokes. The ad provides a handy solution. The man places a picture of his daughter beneath the outer cellophane wrapper. The picture brings the statistics to life. The ad links smoking with fatherhood and the welfare of loved ones, especially children. Put another way, according to the

matching law approach, addiction is a question of whether the overall or local value functions control drug consumption; thus, methods that increase the salience of distant behavioral consequences should move individuals towards more rational use of drugs. This point suggests that persuasion is a potentially powerful weapon in altering people's behavior. (The recent changes in the frequencies of smoking support this idea. Over half of those who have ever smoked have quit, and the fundamental force behind the anti-smoking campaign is the scientific research on the health risks of smoking. On the other hand, teenagers are smoking at about the same rates as before, and they are probably the population least influenced by research on future behavioral consequences.)

6.3. Provide alternatives. Third, the idea that addiction is a choice, albeit a less than optimal one, implies that addicts should be helped to make better decisions and not excused as helpless victims of a disease. An example of this approach is a recent program for treating cocaine abuse (Higgins et al., in press). The basic strategy was to provide a market in which "clean" urines could be exchanged for gifts and recreational activities. As the authors emphasize, drug consumption decreased when the environment provided a valued alternative. Notice also that the contingency insured that drug effects would not interfere with the ability to "consume" the competing reinforcers.

6.3.1 Are local value functions easier to overcome than diseases? The idea that addiction is a disease earns at least some of its appeal from the extreme difficulties that many addicts encounter when trying to stay abstinent (Alcoholics Anonymous, 1976; Burroughs, 1961; Roth, 1954). The idea that addiction is voluntary, albeit self-destructive, is not incompatible with these difficulties, nor does it suggest that addicts can "just say no." Rather, as has been emphasized, the choice to continue to use an addictive drug is governed by the matching law principle and a wide array of conditions. These conditions have proved hard to change, but the matching law approach should help target efforts as to where to apply pressure.

7. Summary.

The key ideas of this paper are: (1) The behaviors that comprise addiction are voluntary even though their net consequences are aversive. (2) A voluntary aversive state can exist because the amount of behavior devoted to an activity is a function of its relative (rather than absolute) reinforcement rate (the matching law). (3) Local rather than overall value functions typically determine drug preference. (4) But there are occasions in which the overall values functions determine preference, as when the drugs are not immediately available and options are under scrutiny. These ideas have the logical power to explain relapse, compulsive-like behavior, and the apparent contradictions in the descriptive data, such as the influence of economic factors on drug use in addicts. In contrast, the explanatory power of the other approaches discussed in this paper are limited. The disease model can explain the persistence of an aversive state, but not the voluntary aspects of addiction; the reinforcement model does just the reverse, and incentive- sensitization theory leaves out the manner in which conditioned urges interact with other factors to influence the directed acts that comprise drug consumption.

At a more general level the theme of this paper is that addiction is the result of natural behavioral processes under the unusual and perverse conditions created by substances that, when consumed in large amounts, decrease their own future value and the future value of other activities. This analysis is parallel to the view of disease that emerged in the second half of the nineteenth century as basic physiological mechanisms functioning under abnormal circumstances, (e.g., the work of Claude

Bernard), except that behavioral mechanisms have been substituted for physiological ones. Finally, since addiction is but one of many voluntary behaviors that is not attenuated by its negative consequences, the analysis used in this paper may also prove useful in other areas of human psychology.

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