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Addiction as a BAD, a Behavioral Allocation Disorder

R. J. Lamb and **Brett C. Ginsburg**

Department of Psychiatry and Pharmacology, University of Texas Health Science Center at San Antonio

Abstract

Addiction is continued drug use despite its harm. As one always has alternatives, addiction can be construed as a decision to allocate behavior to drug use. While decision making is commonly discussed and studied as if it resulted from deliberative, evaluative processes, such processes are actually only rarely involved in behavior allocation. These deliberative processes are too slow, effortful and inefficient to guide behavior other than when necessary. Rather, most actions are guided by faster, more automatic processes, often labeled habits. Habits are mostly adaptive, and result from repeated reinforcement leading to over-learned behavior. Habitual behavior occurs rapidly in response to particular contexts, and the behavior occurring first is that which occurs, *i.e.*, the behavior that is decided upon. Thus, as drug use becomes habitual, drug use is likely to be chosen over other available activities in that particular context. However, while drug use becoming habitual is necessary for addiction to develop, it is not sufficient. Typically, constraints limit even habitual drug use to safer levels. These constraints might include limiting occasions for use; and, almost always, constraints on amount consumed. However, in a minority of individuals, drug use is not sufficiently constrained and addiction develops. This review discusses the nature of these constraints, and how they might fail. These failures do not result from abnormal learning processes, but rather unfortunate interactions between a person and their environment over time. These accumulate in the maladaptive allocation of behavior to drug use. This Behavior Allocation Disorder (BAD) can be reversed; occasionally easily when the environment significantly changes, but more often by the arduous application of deliberative processes generally absent from decision making. These deliberative processes must continue until new more adaptive habits become the most probable behavior in the contexts encountered. As alternatives to drug use become the most probable behavior, relapse risk diminishes.

Keywords

Alcoholism; Choice; Decision Making; Habits; Type I thinking

Corresponding Author: R.J. Lamb, Psychiatry MC 7792, UTHSCSA 7703 Floyd Curl Drive, San Antonio, TX 78229-3900, Tel: 210-567-5483, lamb@uthscsa.edu.

1.0 Introduction

Addiction is a Behavior Allocation Disorder (BAD). This means that instead of some more adaptive behavior, drug seeking and taking occur at rates harmful to the individual or others. This choice is most often not deliberative, but rather results from automatic Type I thinking, just like most of the other decisions each of us make everyday (see Kahnemann 2011 for a discussion of Type I and II thinking). The habitual nature of drug seeking and taking is likely necessary, but it is not sufficient for addiction to occur. Numerous constraints limit even habitual drug use to less dangerous levels, and only when these constraints are surmounted does a BAD occur. While overcoming these constraints is maladaptive, these constraints are overcome as a result of normal learning processes, and BADs like addiction are best understood within this framework.

2.0 Addiction as a Behavioral Allocation Disorder

Addiction is continued drug use despite harm to oneself or others (Lamb et al 2016). This simple definition includes all the essential characteristics of addiction. The harm that results from addiction can take on many faces. Some are stark and clear, like death from opioid overdose (Chen et al 2014). Others are more contextually dependent, such as the legal consequences of marijuana use (Banys, 2016). Still others are not readily apparent until revealed by epidemiologic study, *e.g.*, increased fatalities following a myocardial infarction in smokers (Kaufman et al 1983). Addiction is when use continues despite these consequences to the individual. Addiction can also be characterized by harm to others, *e.g.*, drunk driving deaths, fetal alcohol syndrome, lost productivity and the destructions of families (Bountress & Chassin 2015; NHTSA 2012; Berman et al 2014; Roozen et al 2016;). Continued drug use in the face of such harms is clearly undesirable.

Though sometimes not enticing, alternatives to this continued drug use always exist. Thus, this continued drug use represents a choice of drug use over these alternatives. This choice, like all choices, involves the allocation of behavior among activities: drug seeking and taking instead of other activities. Framing choice as behavior allocation shifts our usual thinking about choice as a deliberative, evaluative process, to a different framework, one concentrating upon identifying the determinants of behavior allocation. This is a useful framework when the allocation is harmful or disordered. It avoids the judgmental attitude that comes when talking about someone’s choices. It also avoids the intellectual missteps that come when viewing this harmful behavior allocation as necessarily the result of deliberative, evaluative choices. Viewing addiction as a Behavior Allocation Disorder, a BAD, thus, provides a useful framework for understanding the behavioral processes operating to cause a maladaptive allocation of behavior and what can be done to correct this.

3.0 Behavior Allocation is more often a function of habit than of deliberation

The role decision-making plays in addiction, is easier to study if we make several admissions we often hesitate to make. First, decision-making is studied by observing the behavior allocation occurring when a particular situation is encountered. This allocation is

the decision resulting from whatever "decision making" happened. Second, this decision making can be usefully discussed as either (1) habitual behavior resulting from a rapid, automatic process that has been called Type I thinking or (2) goal directed behavior resulting from a slower, more deliberative process that has been called Type II thinking[1] (Dickinson 1985; Kahnemann 2011). Third and last, it is almost automatic to assume that what we study when we study decision-making is the slower, more deliberative process, Type II thinking. This is mistaken. and is a result of our Type I, rapid, automatic thinking. When we use our more deliberative Type II thinking, we realize that more often the decisions we study are the result of rapid, automatic, habitual, Type I thinking.

To understand why this is so, consider how many decisions are made in a day. Remember each of these decisions results in emission of one of many possible behaviors, – behavior allocation. So starting to walk down the hall by putting your right foot forward rather than your left is a decision; as is extending it 45 rather than 47 cm; and following this by extending your left foot 45 cm involves more decisions. If much deliberation went into this, the trip to the end of the hall would take a very long time. While most can accept that routine, overlearned everyday acts are habitual and automatic, what is more difficult to accept is that more meaningful and important decisions might also be largely habitual. Yet the boundaries between meaningful and important, and trivial and inconsequential can be difficult to foretell. Further, years of training has often equipped us with a repertoire of habits leading to the correct behavior occurring in the appropriate circumstances: we look left and right when crossing the street, and stop at red traffic lights; we do not cheat or steal; we treat others as we would like to be treated; and we randomize our subjects to treatments. If we do these, we likely do them automatically, without thinking, yet deciding to do otherwise could have important consequences. In these cases, this automaticity is good and adaptive.

When an automatic response is not available, is ineffective, or something alerts us to the desirability of not responding automatically, more deliberative, effortful Type II thinking occurs. However, often when this seems to occur, habits reinforced in other similar circumstances actually occur. For instance, Kahnemann (2011) recounts how instead of answering the question asked, people often answer a similar, but simpler, question they can readily answer. It is not that slower, deliberative, effortful decision-making can not occur, but rather that faster, more automatic and less effortful decision making occurs instead. This is most likely a result of these automatic behaviors occurring more rapidly, *i.e.*, the behavior occurring first is the behavior that occurs.

Kacelnik and colleagues (2011) propose that behavior allocation reflects a race between behaviors rather than a comparison of outcomes because "when two options are simultaneously available, animals do not explicitly deliberate between two options, but instead rely on the same process as when facing independent sequential opportunities. … each option sets in motion a process that would normally generate a latency and then action,

[1]As CP Snow (1959) notes in the *Two Cultures*: "The number 2 is a very dangerous number: that is why the dialectic is a dangerous process. Attempts to divide anything in two ought to be regarded with suspicion." However, like for the purposes of Snow's lectures this dangerous division serves the purpose of this paper.

but the option that generates the shorter latency 'censors' the alternative(s) so that one of them is expressed behaviorally." This view is supported by findings that choices between two options can be predicted from the response latency when each option is available in isolation and that latencies in choice trials tend to actually be shorter than when each option is available in isolation, as would be expected from censored data, but the *opposite* of what would be expected if the subject was to weigh the value of each option (see Kacelnik et al 2011).

Similar to Kacelnik et al's hypothesis that behavioral allocation reflects a race between behaviors, Bickel and colleagues (2000) hypothesize the option with the greater demand when available alone is chosen when both are available simultaneously, a hypothesis supported by several of their earlier studies. In other words, the behavior having the greatest momentary probability, the behavior that would occur most rapidly under the circumstances, is the behavior that occurs, not necessarily the behavior that results in the most valued outcome. This would explain the paradox of preference reversals, *i.e.*, when more behavior is allocated to the consumption of A than B when their price is low, but when their price is high, more behavior is allocated to the consumption of B than A. Such preference reversals would occur when the consumption of A is high at low prices, but falls rapidly as price increases; and the consumption of B is moderate at low prices, but falls slowly as price increases. Thus at low prices the probability of A [P(A)] is greater than P(B) and A is chosen over B. However, at high prices, P(A)<P(B) and B is chosen over A.

4.0 Habitual drug use is necessary, but not sufficient, for development of a BAD

Habits result from overtraining and the reduced variation in behavior that comes with overtraining. Such overtraining can lead to a behavior being the predominant behavior in a context, which results in a tight coupling between the context and the emission of the behavior. This tight coupling of context-response-outcome eventually results in the context reliably leading to the emission of the response. This type of tight control of the stimulus over the response (S-R behavior) can result in a seeming insensitivity of the response to changes in the outcome value. For example, a rat, which has repeatedly earned food for responding when food deprived, will make more responses than a rat with a shorter history of this, when responses no longer result in food delivery and the rats are no longer food deprived (Dickinson et al 1995). In other words, longer training results in habitual behavior that appears insensitive to outcome devaluation when tested in extinction. The relevancy of this type of devaluation insensitivity to the development of a BAD is unclear, as, when responses do result in food delivery, responding between the two groups is more similar (Dickinson et al 1995). However, the rapidity and automaticity of habitual behavior is likely to play an important role in the development of a BAD and a different way in which habitual behavior may seem insensitive to outcome value. The rapidity or high probability of habitual behavior increases the likelihood that habitual behavior occurs first and is chosen. As the most probable behavior may not be the most valued behavior, this can lead to seemingly irrational choice and preference reversals. For instance, at low response costs monkeys respond more for 8% ethanol than 16% ethanol, but this preference reverses as the ratio is

increased (Meisch & Gomez 2016). Such preference reversals are generally considered irrational in normative economics.

This irrationality and seeming insensitivity to the outcome value makes interpreting addiction as a habit attractive; and almost certainly addiction is maintained by sets of habits facilitating drug seeking and taking. The nature of addiction makes drug seeking and taking likely to be habitual in addiction. Drugs reinforce drug taking. Addiction necessarily involves repeated drug taking that is repeatedly reinforced and strengthened. Drug seeking and the resultant drug taking that reinforces drug seeking often occur under a narrow range of stimulus conditions, which facilitates control over drug seeking by these stimulus conditions. As drug seeking and taking become habitual, they occur more rapidly under the stimulus conditions evoking them, which in turn makes them more likely to be chosen under these stimulus conditions. However, most habitual drug seeking and taking is constrained in ways that minimize their harm and prevent addiction from occurring. Your evening drink with your spouse may be habitual, but likely is not impending alcoholism. My morning two cups of coffee are certainly habitual, but arguably do not represent addiction. Either the stimuli that evoke drug seeking and taking are encountered at rates insufficient for much harm to result and/or the amount taken is constrained to levels producing little harm.

Although, when drug seeking and taking become habitual, their probability of being chosen under particular stimulus conditions increases, addiction is more than just drug seeking and taking becoming habitual. Addiction is a BAD: It is when drug seeking and taking occur so frequently or under inappropriate circumstances such that harm occurs. This requires that drug seeking and taking free themselves from the constraints normally limiting drug intake to levels that are not harmful. While it is likely necessary for drug seeking and taking to become habitual for addiction to ensue, it is not sufficient. Drug seeking and taking must also become unconstrained.

5.0 Constraints on Habitual Drug Use

Multiple processes constrain behavior. Thus, a BAD like addiction can and likely will be multiply determined. Consider a simple situation, a rat pressing a lever 10 times to receive drug injections. The number of injections taken by the rat will depend on at least two things: how many injections the rat would have taken if it didn’t need to press the lever 10 times (Unconstrained Demand), and how much having to press the lever 10 times to get an injection decreases this number (elasticity). So, even in this very simple situation, there are two factors controlling the amount of drug taking (see Hursh & Silberberg 2008; Lamb & Daws 2013). The alternatives to and the consequences of drug taking also influence how much drug is taken (see Lamb et al 2016). Often when other behavior is reinforced, drug taking is decreased. Additionally, when drug-taking is punished drug taking decreases (Grove & Schuster 1974; Johanson 1977). Individual differences will influence how effectively such factors control drug-taking. For example, individuals discounting delayed rewards rapidly may have their drug-taking reduced less by delayed alternatives than individuals’ discounting delayed alternatives less rapidly (see Lamb et al 2016; Maguire et al 2013). The remainder of this section discusses how such factors might constrain drug use.

5.1 Occasions for Use

Occasions for drug use are generally restricted so as to minimize its harms. As the harms of smoking were realized, policies and laws restricted the places where smoking was permitted, and the prevalence of smoking declined at the population level and the number of cigarettes smoked declined at the individual smoker level (USDHHS 2000). Similarly, many of us can observe that our drinking might be greater when on vacation (*e.g.*, Luze et al 2014), when a drink at lunch or in the late afternoon is not precluded by work obligations. Such observations speak both to issues related to the stimulus control of drug use and to constraint by alternatives.

5.2 Amount Consumed on Each Occasion

As the opportunities for drug use increase, the risk of problematic drug use increases, but how much drug is consumed during these opportunities is also crucially important. There are two key determinants of how much drug is consumed on an occasion: how much would be consumed if there were no constraints on consumption (Unconstrained Demand); and the acquisition and opportunity costs of consumption.

5.2.1 Unconstrained Demand—Unconstrained Demand is the maximum that would be consumed in the absence of constraints on availability or lost opportunities (Hursh & Silberberg 2008). Unconstrained Demand is an under-appreciated and important determinant of the amount consumed on a given occasion (Lamb & Daws 2013). Unconstrained Demand is one of the more reliable determinants of whether someone has a drinking problem (McKillop et al 2009, 2010). Thus, understanding what controls Unconstrained Demand may be crucial to understanding how addiction develops.

At very low drug doses, very little drug is self-administered. This could be because the effective price is high or because sufficient drug cannot be taken rapidly enough to effectively reinforce behavior. Be this as it may, as the drug dose increases, the number of drug deliveries earned will increase until at some dose, the number begins to decrease. While the total amount of drug consumed tends to still increase as dose increases, desired (so to speak) consumption appears to be limited by some factor. Two possible factors have been proposed to explain the descending limb of this inverted-U-shaped dose response curve. The first is simply that at a certain level of drug effect, the animal is no longer able to respond to obtain more drug. The second is that high drug levels not only produce reinforcing effects (or perhaps are not reinforcing at all), but also produce aversive effects that punish and limit drug self-administration.

High enough doses of drugs disrupt all behavior. Thus drug self-administration could be limited by the direct suppressive effects of the self-administered drug. Certainly, this hypothesis would also be consistent with observations on monkeys self-administering pentobarbital in which the monkeys self-administered until they were anesthetized and begin again when they started to awaken (Deneau et al 1969). Further, evidence for such a hypothesis comes from a study by Spealman and Kelleher (1979). In this experiment, monkeys responded alternatively for cocaine and electric shock. As the dose of cocaine available increased, responding for shock interposed between opportunities to self-

administer cocaine, at first increased and then decreased. Interestingly, there was good correspondence between doses of cocaine that were on the descending arm of the inverted-U-shaped cocaine self-administration dose-response-curve and the doses of cocaine that decreased responding maintained by shock. This suggests that the response-disruptive effects of the self-administered cocaine were at least partially responsible for the descending limb of the cocaine self-administration dose-response curve. Consistent with this are studies examining the effect of time-out length following drug administration on the dose at which peak responding occurred. For instance, Griffiths and colleagues (1979) found that as the time-out following a cocaine injection increased, the dose of cocaine that maintained peak response rates increased. Again suggesting that drug consumption may be limited by the direct effects of the drug being consumed on the responses needed to obtain the drug.

While there are individuals whose drinking (or other drug use) ends when they are no longer able to lift their glass to their lips, these are exceptions (see for instance, Cohen & Sokolovsky 1989). Rather, much more often factors other than being so impaired one can no longer obtain and consume drug are at work to limit drug use. One such factor may be the aversive effects of drug consumption. Administration of an abused drug following consumption of a palatable food can reduce future consumption of that food (see Riley 2011 for a discussion). Such Conditioned-Taste-Aversions can be viewed as indicating that abused drugs can produce aversive effects. Riley (2011) has hypothesized that such aversive drug effects can serve to limit the amount of drug that will be self-administered. For example, Wise and colleagues (1976) showed that in the same rats that amphetamine maintained responding, experimenter administered amphetamine also produced a Conditioned-Taste Aversion. Moreover, they showed that when rats ingest a saccharin solution before an apomorphine self-administration session, these rats develop a conditioned taste aversion to the saccharin solution; even though their behavior was being reinforced by apomorphine. This is not an isolated finding. Spealman (1979) showed that monkeys would work to remove their own access to the opportunity to self-administer cocaine. While one might at first be inclined to discard such findings as experimental oddities, a story recounted by Richard Thaler (2015) makes clear how real such actions are even in our own behavior. Thaler recounts hosting a party in which he opened a large can of nuts before dinner and his guests at some point asked him to remove the can so that they would still have an appetite for dinner. It appears that monkeys will take actions limiting their access to cocaine and humans will take similar actions limiting their access to nuts even though in both cases they could simply take less. One way of interpreting these actions are as actions taken to limit the aversive effects of either cocaine or nuts. Another example of such actions comes from studies by Ettenberg & Geist (1991). In these studies, they arranged for rats to receive intravenous injections of cocaine when they finished running down an alleyway. The rats swiftly learned to leave the start box and run toward the goal box. However, after a while rats would start to retreat back toward the start box when approaching the goal box before finally entering the goal box and receiving their cocaine injections. Interestingly, pretreatment with an anxiolytic, diazepam, decreased the frequency of these retreats from the goal box, and Ettenberg & Geist interpret the retreats as resulting from the anxiogenic effects of cocaine. Whatever the interpretation of such effects, psychomotor stimulants

clearly not only reinforce behavior leading to their administration, but also reinforce behavior that limits their administration.

This can be seen with other drug classes as well. To give just one more example, nicotine can have complex stimulus properties that lead to behavior that might limit nicotine self-administration. The same doses of nicotine can reinforce both responses leading to their delivery and responses preventing their delivery (Spealman 1983). Further, these same nicotine injections can also punish behavior maintained by food (Spealman 1983). Interestingly, this punished responding is increased by administration of the anxiolytic chlordiazepoxide: An effect remarkably similar to the decrease in retreats seen following a different anxiolytic in rats running down an alleyway to receive an injection of cocaine. Thus, it is clear that drugs of abuse not only reinforce behavior, but can also suppress behavior, likely including behaviors that result in their delivery.

Another factor that may limit drug intake is habituation. McSweeney and her colleagues (1996; McSweeney & Swindell 1999) argue that habituation works to limit the effectiveness of the repeated delivery of a stimulus to reinforce behavior. McSweeny and colleagues (2005) also argue that such a model is useful when the stimulus reinforcing behavior is a drug, and have presented some data with ethanol-maintained behavior consistent with such an interpretation (Murphy et al 2006). In particular, they argue that a stimulus's decreasing effectiveness at reinforcing behavior with closely spaced repeated delivery can be efficiently and effectively conceptualized as resulting from habituation. This then could explain why consumption can be limited even when there are no other apparent constraints upon behavior. This fairly subtle, complex and nuanced model may explain several important aspects of how consumption is limited without other apparent constraints.

To summarize, Unconstrained Demand is an important and underappreciated determinant of the amount of drug that might be used on any given occasion. Unconstrained Demand might be limited by effects of the drug that directly prevent further drug seeking and drug taking. A heroin user on the nod is likely unable to effectively hustle for his next hit (see Isbell et al 1948 for a description of opioid users on the nod). There may be direct effects of the drug that lead us to emit behaviors that remove ourselves from the situation in which further drug taking would be likely to occur. We remove the can of nuts before we become too full to eat dinner. Finally, the effectiveness of a stimulus at reinforcing behavior declines as we habituate to it. The wine that was so interesting on the first sip is less so after the hundredth. In addition to Unconstrained Demand, the costs of drug consumption may also limit the amount consumed on any given occasion.

5.2.2 Costs—Costs of two types will limit how much is consumed. (1) Acquisition costs will limit consumption. Items whose consumption falls rapidly with increasing acquisition costs are said to have an elastic demand, while items whose consumption falls slowly with increasing acquisition cost are said to have an inelastic demand. (2) Another important cost that limits consumption is opportunity cost: the behaviors that cannot occur because another behavior has occurred. These alternative behaviors can be crucially important in limiting drug use.

The contingencies of drug availability (their acquisition costs) influence the level of drug consumption, and likely whether a drug is consumed in a given situation. Winger has done extensive studies demonstrating that as the number of responses required to earn an intravenous injection of drug is increased, the number of drug injections decreases systematically (*e.g.*, Wade-Galuska et al 2007). Meisch has shown similar effects with orally delivered drug in monkeys (*e.g.* Lemaire & Meisch 1984; Stewart et al 2002), and for orally delivered methadone and puffs of a cigarette in people (Spiga et al 2005). Thus, the amount of drug consumed in a given situation is a function of how much effort is required. More specifically, the amount consumed is a function of the work required, the elasticity of consumption of the drug and its unconstrained demand.

Opportunity costs, alternative behaviors that directly compete with drug seeking and taking can effectively limit drug consumption. Numerous studies show that when drug and an alternative are available concurrently (Ginsburg et al 2012), available in discrete trial choice procedures (Ginsburg & Lamb 2013a, 2013b; Nader and Woolverton, 1992; Negus 2005), or when the alternative is available after the absence of responding for drug (LeSage 2009) animals will reduce the amount of drug they consume. Similarly, cigarette smoking (Lamb et al 2010, 2007), heavy drinking (Dougherty et al 2015) and other drug use (Higgins et al 1991; Stitzer et al 1992) can be reduced when their absence is reinforced, as well as when the development of alternative behaviors competing with drug use are either explicitly reinforced (Iguchi et al 1997) or shaped by the treatment program (Azrin et al 1982). These findings suggest that normally prevailing environmental contingencies may often be at work to limit drug use to socially acceptable levels.

5.2.3 Summary of the Constraints that may be at work to limit habitual drug use—The interests of society and of the individual are served by making sure that constraints effectively minimize the harms of consumption. Both the individual and society work to create an environment, culture or set of personal rules that limit harm to acceptable levels. Valliant (1995) outlines how Southern European cultures more effectively limit the harms of drinking than Northern European ones. The last 50 years have seen great changes in the law and culture surrounding smoking with a resultant decrease in smoking (Song et al 2015). We keep our kids busy with sports and music hoping that this will reduce their opportunities to use drugs and increase the opportunity costs of using drugs (Andrabi et al 2017). Both societies and individuals act to constrain drug use so as to minimize its harm.

Thus, there exist many factors constraining drug use to levels not harmful to the individual or to society, and for most people these factors adequately constrain drug use. In fact, it has been estimated that for most drugs, cigarette smoking being the notable exception, only around 10–20% of those with more than marginal drug use exposure end up having sustained problematic drug use (Lopez-Quintero et al 2011). In other words, the factors that act to constrain drug use do a remarkable job at constraining drug use for the overwhelming majority of individuals. However, for some individuals these factors are ineffective.

Likely, this broad success at constraining drug use relates to the multiplicity of factors and their redundancy, so that if one factor is ineffective, another factor might still constrain drug use. This suggests two things. First, often multiple constraints are circumvented when

addiction occurs, and second, there are multiple routes to the development of addiction, *i.e.*, there is no single cause. A complimentary notion suggested by this is that when problematic drug use is the result of a single cause, then this problematic use may be more easily addressed than when problematic drug use is the result of multiple constraint failures.

6.0 Beyond Constraint

While the great majority of those who use drugs at one time or another do not go on to develop a drug problem (*e.g.*, Anthony et al 1994, 2005) because of the constraints that limit drug use, some do go on to develop drug problems. Examining how the multiplicity of constraints that have just been outlined might be overcome could be instructive to understanding how addiction develops in this subset of individuals. Fundamentally, there are two variables that determine the amount of drug that is used: The frequency of drug use (the number of occasions for drug use) and the amount of drug used on any given occasion. Arguably, it is possible to use a drug frequently, but in small amounts, without developing problematic use. However, infrequent use of large amounts is most often problematic, and sometimes fatal.

6.1 Increasing Occasions

If drug use reinforces our behavior, we may change our environment to provide increased opportunities for use; and one of the things that we may change is our peer network. The importance of peer networks in the extent and pattern of drug use has long been recognized. Drug using friends are a clear determinant of the propensity to use drugs in youth (e.g., Roberts et al 2015). Similarly, in adults the likelihood of an individual's drug use correlates with the drug use in his or her peers (e.g., Meisel & Goodie 2015). The converse is also true, for instance as the number of peers who smoke decreases the likelihood of quitting increases (e.g., Hitchman et al 2014). This is not to imply our peers cause our increased use: We choose peers who do as we do (see Mundt et al 2012; our interactions are mutually reinforcing), and the actions of our network facilitate our actions. Peers provide access (see Becker 1963 for discussion of this and other aspects of peer networks in developing a drug habit). If peers use, the opportunity costs of using might be less (our friends approve; *e.g.*, Sutter 1966). Meeting with peers provides an occasion for use. Thus, we will often unintentionally allocate more of our time to peers whose use supports our increased use. We may also change our rituals to provide increased opportunities for use: Instead of an evening walk when we get home, a before dinner cocktail; Instead of reading a chapter before bed, a nightcap; and so on. Instead of restricting the occasions on which drug use occurs in a way that limits use, as drug use expands the opportunities to use also expands.

As drug use is occasioned by more and more different contexts, fewer and fewer stimuli are reliably associated with the absence of drug use. This creates a positive feedback loop in which even more contexts have a non-zero probability of drug use. In time, drug seeking occurs in these new contexts, is reinforced by drug taking, resulting in an increased probability of future drug use in that context and fewer and fewer stimuli inhibiting drug use. Further, the relatively more recent drug use in those additional contexts (relative to other activities that had previously occurred) further increases the relative likelihood of drug use

over temporally more distant behavior (see Devenport & Devenport 1994). Drug use may eventually become habitual in these new contexts, as drug seeking is repeatedly reinforced with drug taking in them. As drug use becomes habitual in these new contexts, drug use may become the most rapidly occurring behavior in them, thus becoming the most likely behavior in a context in which drug use had once been unlikely.

Alternatively, drug use occurring in many contexts may not reflect the broadening of stimulus control over drug use, but rather a failure of stimulus control to ever develop. Stimulus control develops from behavior being reinforced in some contexts and not being reinforced or punished in other contexts (see Terrace 1966). Reinforcement strengthens behavior while extinction and punishment narrow the range of contexts in which the behavior occurs. If drug seeking is seldom in extinction and seldom effectively punished, then the contexts occasioning drug use might be expected not to narrow and limit use to a safer level. Two examples might make this clearer. Consider a young man transitioning from high school to college. While in high school he had little contact with those able to purchase alcohol, he has been working hard on college applications and finishing his high school courses which preclude drinking and he lives with his parents who further limit his opportunities to drink and punish him if they find him drinking. Suddenly, he is living on his college campus, away from parental oversight, old enough to purchase alcohol (or in daily contact with others who can), and with few obligations interfering with his drinking that cannot be delayed till another time. The removal of these constraints is likely responsible for the high rates of problematic drinking observed among college-age males (Weitzman et al 2003). In this case, the environment provided the constraints. Now consider a second case in which the individual's sensitivity to the constraints in the environment is the problem, the sociopath. He is insensitive to and isolated from social constraints (*e.g.* Mokros et al 2008), self-selecting for like-minded peers and often migrating to environments in which drugs are readily available. A high frequency of drug use in this population is not unexpected.

The constraints that limit the frequency of occasions for drug use may be defeated in several ways. Changes in peers and rituals may provide more opportunities for use and decrease the costs of use. Greater use in one context may generalize into use in other contexts. Finally, when one is isolated from or insensitive to the contingencies that generally limit the occasions for use, then use is likely to occur under conditions that it would not occur in for others. All these factors may increase the range of conditions under which drug use might occur.

6.2 Increasing Demand

While frequent drug use can facilitate the development of addiction, it is neither necessary nor sufficient. Drinking every day is not alcoholism. Drinking a couple dozen beers every day, however, likely represents a drinking problem. Drinking once or twice a year is likely not alcoholism, but drinking two or three liters of vodka in a day once or twice a year is certainly problematic and potentially lethal. As argued earlier, amount consumed on any occasion is a function of Unconstrained Demand, and sensitivity to the costs of consumption.

6.2.1 Increasing Unconstrained Demand—Unconstrained Demand might be at least temporarily increased by several manipulations. One way is by combining discriminative stimuli that each independently signal drug availability. For example, Panillio and coworkers (2000) trained rats to respond for heroin when either a tone or a light was present, but did not reinforce responding when neither was present. When they presented both the tone and light, heroin intake increased two-fold. So, individuals may, for instance, drink more when confront with two situations that independently in the past had occasioned drinking. A person might drink when at a party and a person might drink when at a bar, in which case a party at a bar might result in greater drink than either being at bar or at party.

Another way unconstrained demand might be increased is by decreasing habituation. As discussed earlier, habituation may serve to limit Unconstrained Demand, thus reducing habituation should increase unconstrained demand. Habituation is typically specific to the sensory properties of the item being consumed and to the environment in which it is being consumed (McSweeney et al 1996; McSweeney & Swindell 1999). Changing either should decrease habituation. For instance in a multi-course meal in which the sensory properties of each course are distinct from the preceding course, one will often consume more food than otherwise would be the case. The same may be true of drinking at that meal, if the wine available with each course changes. Similarly, alcohol consumption would be expected to be less if drinking occurs at a single venue than when bar hoping and consumption is spread among several venues. Switching between drugs not sharing similar discriminative properties will change the sensory properties, and thus reduce habituation and presumably increase drug use. So there are many ways to possibly reduce habituation and thus increase reinforcement density.

Reduced sensitivity to the impairing or adverse effects of a drug could increase unconstrained demand by allowing greater levels of drug consumption before these are encountered. This reduced sensitivity could either be innate or acquired. For instance, individuals whose father was an alcoholic are generally less sensitive to some of the effects of alcohol than are individuals whose father was not an alcoholic (Schuckit 1988; Schuckit & Smith 1996). This effect can be seen even before differences in drinking develop in the two groups. Such differences could reflect either a shift in the alcohol dose-response curve to the right or greater acute tolerance to the effects of alcohol in offspring of alcoholics. In either case, this reduced sensitivity may permit more problematic levels of consumption, and may represent a risk factor for the development of alcoholism (King et al 2011). Consistent with this is the demonstrated genetic control of sensitivity to many of ethanol’s effects in mice (e.g., Browman et al 2000).

Individuals may also engage in behaviors that minimize aversive drug effects and allow greater drug consumption before contacting these aversive effects. For instance, rules like drinking a glass of water for each alcoholic drink consumed may increase the amount of alcohol that may be consumed before encountering a hangover (webMD). Perhaps more speculative is that drugs with antipunishement effects like alcohol and benzodiazepines may increase the unconstrained demand for other drugs by decreasing one’s sensitivity to the aversive effects of the other drug encountered at higher doses. Interestingly, acute doses of

alcohol are frequently and reliably observed to increase cigarette consumption (e.g., Griffiths et al 1976).

These manipulations that acutely increase Unconstrained Demand at least on occasion may have long-lasting effects on Unconstrained Demand by facilitating tolerance development. Tolerance development is greater following exposure to higher doses (Dumas and Pollack, 2008; Hammer Jr. et al., 1997; Yoburn et al., 1993), which is more likely to occur with increased Unconstrained Demand. Greater tolerance development would in turn lead to longer lasting increases in Unconstrained Demand by increasing the doses of drug at which impairing or aversive effects would be encountered.

6.2.2 Decreasing Sensitivity to Costs—A history of repeated drug exposure may result not only in increased tolerance, which might increase Unconstrained Demand, but also in physical dependence and/or allostasis (Koob et al 1989), which may result in decreased elasticity, *i.e.*, consumption would be reduced less by increases in work requirements. While physical dependence is clearly not needed for addiction to occur, physical dependence is common in problematic opioid use, cigarette smoking and some forms of problematic drinking (Benyamin et al., 2008; DiFranza, 2015; Goldstein, 1979; Okamoto et al., 1981), and physical dependence is thought to make each of these less tractable. For instance physical dependence on opioids increases the amount of work an animal will emit to earn an injection of an opioid (Wade-Galuska et al 2007), and chronic ethanol exposure increases the amount of work an animal will make to earn a delivery of ethanol (Walker & Koob 2007). These effects are generally interpreted as physical dependence or allostasis increasing drug value. However, whether these increased breakpoints result from decreased elasticity or increased Unconstrained Demand is unclear, as an increase in breakpoint could result from either (see Lamb & Daws 2013). In an effort to address this issue, Winger and colleagues (Wade-Galuska et al 2007) examined how the demand curves for opioids changed in animals that had received chronic opioid treatments that would produce physical dependence. Chronic opioid treatment appeared to make demand more inelastic. However, the way the data were analyzed precluded seeing changes in Unconstrained Demand, and if the data are analyzed in a way that allows Unconstrained Demand to vary then Unconstrained Demand appears to increase while the elasticity of demand is unchanged. In either case, it is clear that repeated drug administration can result in increased drug consumption that in turn would increase the likelihood of the development of problematic drug use.

Certainly, studies on the effects of price on cigarette and alcohol consumption have reached similar conclusions. Increases in the prices of cigarettes can produce larger decreases in the uptake of smoking than in the amount smoked by established smokers (USDHHS 2000). Similarly, increases in the costs of alcoholic beverages decreases drinking by moderate drinkers more than drinking of heavy drinkers (Manning et al 1995). Thus, heavier or more regular drug use appears to be less sensitive to increases in acquisition costs than lighter or less regular drug use. So, while increases in acquisition costs will decrease drug use in individuals with heavier more regular drug use, this decrease will be less in these individuals.

While alternatives to drug use can effectively compete with and reduce drug use to non-problematic levels, when these alternatives are ineffective at competing with drug use or the environment supports behavior facilitating drug use, problematic levels of drug use can result. How alternatives affect drug use is more nuanced than generally appreciated, and this nuance has important practical implications. The same environment may affect two individuals differently. Rewards provided by the environment are always delayed: Sometimes by only milliseconds or seconds; sometimes by years. Individuals differ greatly in the how the effectiveness of rewards decreases with delay to their receipt. As drug use offers relatively swift rewards compared to rewards available for other achievements, the delay of these alternative rewards may foster greater allocation of behavior to drug seeking and taking in those who more rapidly discount delayed rewards (see Lamb et al 2016), a trait that appears to be at least partially under genetic control (Anokhin et al 2011, 2015). This greater allocation of behavior to rewards offering more rapid delivery like drugs may explain why those with drug problems tend to discount delayed rewards more rapidly than those without drug problems (*e.g.*, Kirby et al 1999; Mitchell 1999; Petry 2002; Baker et al 2003).

Thus, individual differences that are apparent at a very early age (e.g. Caspi et al 1996) may influence how effective a given environment will be in shaping normative behavior in an individual. The history the individual has will also shape how the individual interacts with that environment (see Nader & Reboussin 1994) and the resulting rewards that the individual obtains from that environment. This history is shaped by many things, including early predispositions. The point here is that it is the interaction between the individual and the environment that determines how alternatives change the probability of problematic drug use.

The potential actions a person has available at a given moment results from their experiences. It is not what consequences the person's environment had available in the past, but rather the consequences that the person experienced in that environment that shape the individuals repertoire.

A repertoire consisting mainly of skills for drug acquisition will be more difficult to redirect than a repertoire that also includes a number of more socially adaptive behaviors. The behavior that the individual has available, and the consequences the individual has experienced in their environment define how they experience the opportunity costs of their drug use. It is by bringing those costs into contact with the actions of the individual that change can happen. For instance, the costs to the individual of severe alcoholism are enormous. However, these costs are all too often ineffective at changing behavior. Yet, when Cohen et al (1971) brought very heavy drinking individuals onto a research ward and alternated periods when drinking could occur without consequences and when ward privileges were contingent on the absence of excessive drinking, excessive drinking occurred under the first, but not the second condition.

It is crucial that such contingencies are experienced, not just programmed. Smokers not readily achieving the one day abstinence period that was the target of a contingency management program did very poorly in this program, but if successively lower levels of smoking that occurred in these individuals were reinforced, then success rates were

substantially increased (Lamb et al 2010). Thus, if the environment is such that the opportunity costs of drug use are not realized, these opportunity costs are unlikely to constrain drug use; but if individuals can be brought into contact with these opportunity, costs changes in behavior allocation are likely to occur.

7.0 Conclusion

The allocation of behavior is the crux of addiction. In addiction, behavior is allocated to drug seeking and taking at levels that result in harm to the individual and/or harm to others. While this allocation of behavior can be viewed as a choice, this choice is generally not a result of the deliberative, evaluative processes usually thought of when discussing choice. In other words, while a drug problem may be the result of many bad decisions, these decisions probably did not involve listing out and evaluating the consequences of drug use versus that of the alternatives, and based upon that evaluation, deciding on drug use instead of the alternatives. Little of what any of us does depends upon such deliberative decision-making. Such decision-making is arduous and time consuming; typically it is inefficient and often not any more effective than the decision-making that occurs by more rapid habitual Type I thinking that some would hesitate to call thinking or decision-making. Yet the results of this Type I thinking, of our habits, are generally fast, efficient and adaptive. This is because these behaviors are selected by their consequences (see Skinner 1981), *i.e.*, these behaviors are the result of repeated reinforcement. Normally, the consequences of our behavior constrain our behavior into patterns that are adaptive. However, sometimes the constraints are insufficient to prevent a BAD like addiction from occurring. In these cases, our behavior allocation is no longer adaptive. Yet, even in these pathological cases there is no reason to believe that behavioral processes guiding our behavior are other than those processes that normally guide our behavior. Rather, the cumulative interactions between our actions and the environment resulted in a BAD.

Correcting this BAD involves changing our allocation of behavior. Sometimes this will be easy when all that is needed is insertion into the more normative environment that constrains drug use. An example of this might be the great success seen when service men with drug problems in the Vietnam War were detoxified before returning to the mainland United States. The great majority of these individuals did not have drug problems before their service and were successful in avoiding drug problems upon their return (Robbins 1993; Robbins et al 1974). Another example might be the great number of young males who develop problems with drug and alcohol use in college, but upon undertaking vocational and family roles that compete with this problematic use appear to simply mature out of their problematic use (Kandel & Logan 1984; Moffitt 1993).

Often though, changing a BAD, like addiction, is difficult. The difficulties involve at least the following three factors: (1) the frequent need to engage in Type II thinking; (2) arranging an environment that facilitates sobriety; and (3) maintaining change long enough so that new habits replace the old maladaptive habits. At the early stages of recovery, the most likely action in too many contexts will be drug use. In order to avoid drug use, deliberative, evaluative Type II goal-directed thinking must intervene, and this behavior (as thinking is a behavior) must reshape our environment such that it supports other activities that reinforce

our actions. As one's new actions are repeatedly reinforced, they become habitual and the actions that occur most rapidly. As these new actions are reinforced across different contexts the probability of relapse decreases, as one attends less and less to the stimuli previously occasioning drug use.

This might become a bit clearer upon examining the results of some recent studies (Ginsburg & Lamb 2013a,b). In these studies, rats were trained to press a lever five times to earn ethanol in the presence of two stimuli. In the presence of the one stimulus, presses on the other lever resulted in food after 150 presses, and responses occurred mainly on the ethanol lever. During the other stimulus presses on the other lever resulted in food delivery after five presses and most responses occurred on the food lever during this stimulus. Rats were then exposed to this stimulus for various numbers of daily sessions. Following these sessions in which the rats responded almost exclusively on the food lever, rats were given a test session. During the test session, responding was in extinction and the stimulus normally occasioning responding for ethanol was present. As the number of sessions preceding the test session in which responding had been predominantly on the food lever increased, the number of responses made on the food lever before responding on the ethanol lever increased. This finding was interpreted as representing a decrease in attention to the stimuli signaling the contingences for responding on the food lever, *i.e.*, that food responding had become more contextually controlled or habitual. Further, supporting this assertion, the generalization gradient for the stimulus occasioning responding on the food lever had broadened with increased training under this condition (Ginsburg & Lamb 2013c).

In summary, the behavior that occurs first is the behavior that occurs; habits are rapidly occurring behaviors and thus are likely to be the behavior that occurs first; being habitual, however, is not sufficient for the development of a BAD like addiction; for a BAD to develop, the constraints that limit habits to adaptive levels need to be surmounted; while overcoming these constraints is pathological, the means by which these constraints are overcome are those that occur normally in learning; similarly, changing a BAD will also be the result of normal learning processes that may be easier when only the return to a more normative environment is needed, but difficult when the development of new habits replacing older BAD habits requires the prolonged application of arduous Type II deliberative, evaluative goal-directed behavior.

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Highlights

- Addiction is a behavioral allocation disorder, a BAD
- BADs result from learning, the cumulative experiences of a person with an environment
- Of the behaviors that could occur, the most probable, the fastest one occurs
- Habitual behavior is rapid; thus as drug use becomes habitual, it becomes more likely
- Habits are naturally constrained, when habits escape constraints a BAD may occur