A model of the initial stages of drug abuse: From reinforcement learning to social contagion

Gilly Koritzky, Adi Luria, and Eldad Yechiam

Technion – Israel Institute of Technology

A great deal has been written about the antecedents of drug use and abuse. The importance of the issue is of course incontestable: drug use and abuse carry severe consequences for the individuals themselves as well as society as a whole. For individuals, drug abuse affects mood and cognitive processes (Adams et al., 1990), is a factor in contracting various diseases such as lung cancer (Blum, 1987), coronary heart disease (Blum, 1987) and AIDS (see e.g., Beyrer et al. 2000; Chu & Levy, 2005), and is related to various negative situations such as child abuse, violent crime, unemployment (Hawkins, Catalano & Miller, 1992), and adolescent and adult delinquency (Brook, Whiteman, Finch & Cohen, 1996). For society in general, drug abuse has consequences for the cost of health care and mental health services, crime rates, educational systems and more (Adams et al., 1990).

The issue has been studied from many different perspectives and approaches, and an array of risk factors - biological predisposition, societal and cultural variables and personality variables (such as impulsiveness or sensation seeking) - has been suggested. It is important to note that various definitions of substance or drug use and abuse have been utilized in the literature. In the current chapter, we will rely on the definition of substance abuse adopted by Hawkins et al. (1992), and that is the frequent use of alcohol, drugs or other substances in a

manner that is associated with problems and dysfunctions. Taking this perspective, drug abuse is a habit which certain individuals acquire despite its detrimental consequences. In the current chapter we suggest that drug use acquisition is adequately described as the product of individual learning and decision-making impairments, along with certain social and environmental influences.

In the next sections we will summarize several factors contributing to drug abuse. These findings show the influence of individuals' decision characteristics and their social environment (peer and family influence) on drug abuse risk, but most current theories present these factors as separate mechanisms. Further in the chapter we will present a model which integrates the effect of these factors.

1. Individual factors leading to risk of addiction

It has been found that certain individual characteristics, such as sensation seeking and impulsivity, are related to drug use (Cloninger, Sigvardsson, & Bohman 1988; Shedler & Block, 1990). In a series of studies on alcohol use, Donohew and colleagues found the use of alcohol to be twice as high among individuals high in sensation seeking than those low in the measure (Donohew, Palmgreen & Lorch, 1994; Donohew, Lorch, & Palmgreen, 1991; Donohew, Helm, Lawrence, & Shatzer, 1990). Findings such as these lend support to the idea that individual traits such as sensation seeking and impulsivity may be related to risk taking and poor decision making in real-world situations. Furthermore, impulsivity and sensation seeking have been linked to neurotransmitter activity in certain brain structures, suggesting that some drug related behavior may in part be affected by biological characteristics (see Hawkins et al., 1992, for a review). For example, there is some research to suggest that sensation seeking is linked biochemically to platelet monoamine oxidase (MAO) activity (Zukerman, 1987), which has also been found to be associated with early-onset alcoholism (see Hawkins et al., 1992). The enzyme

ALDH (aldehyde dehydrogenase) has also been linked to alcoholism. Studies on Asian populations showed that Asians lacking the ALDH enzyme drink less and have lower rates of alcoholism than controls (in Hawkins et al., 1992).

Studies of individual decision making also lend support to the idea that drug abusers may be adopting different decision making patterns than those of non-users. Such studies usually have subjects complete an abstract decision making task and then compare performance between different subject groups. The differences between choice alternatives along with the subjects' choice patterns allow the researchers to reach different conclusions about the emphasis subjects place on variables such as the relative magnitude of winning or losing, the immediacy of the payoff, and its probability. For example, in Grant, Contoreggi and London (2000) and in Bechara, Dolan, Denburg, Hindes, Anderson and Nathan (2001), groups of substance abusers and controls completed the decision making task known as the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994). The drug abusers demonstrated impaired decision making compared to controls, preferring choices that yielded high immediate gains but warranted higher future losses. We will return to the Iowa Gambling Task later in the chapter and elaborate on its potential in telling drug abusers from non-abusers.

2. Social factor leading to risk of addiction

The most prominent antecedent of drug use, however, is simply the exposure to drugs being used. Among the factors associated with drug use and abuse are the prevalence of drug use in one's social environment and the general availability of drugs in one's surroundings, as well as social norms favoring drug related behaviors.

Social learning theory (Bandura, 1977) suggests that behavior is primarily learned through a process of operant conditioning, in which behavior is shaped by consequences that follow it. The social aspect of the theory stems from the assumption that behavior is learned

through this direct process of conditioning, but also through the imitation or modeling of others'

behaviors. Social groups are so significant because they affect the individual's main sources of

reinforcement and punishment, expose the individual to behavioral models and help form

conceptualizations of normative behavior. This suggests, for example, that individuals who are

raised in a home where alcohol is frequently consumed without major punishment come to see

frequent drinking as normative. According to reviews of the literature, the most important of

these social groups with which one is associated are the peer-friendship groups and the family

(Akers, Krohn, Lanza-Kaduce, & Radosevich, 1979).

Social learning theory proposes that drug use and abuse develop through a process of

observation of and experience with the associated problematic behaviors and their

consequences. In brief, individuals form a sense of belonging to a social group, which influences

their definitions of norms and expectations, and also provides models for imitation. From this

perspective, Akers and his colleagues (1979) suggest that individuals both experience and

observe reinforcement or punishment for drug use, and their norms and expectations with regard

to drug use are shaped accordingly. The interaction of these variables leads either to abstinence

from, or to initial use of, various substances. After the initial use, consequences (also partially

influenced by the social group) determine whether or not this behavior will continue, and to

what extent. Notice that the effect of social norms implies that in environments in which drug

use is generally accepted, abstinence from drugs may bear aversive consequences, just as much

as drug use does in environments which condemn the behavior.

Indeed, strong support for social learning theory in the context of drug abuse has been

reported. In their classic investigation of social learning theory and deviant behavior, Akers and

colleagues (1979) found that social group association variables explain the largest amount of

variance for marijuana and alcohol use, and specifically, that peer association was the single

most important predictor. The researchers also indicated that modeling of peer behavior was

considered to have its greatest effect on first use and in the initial stages of behavior acquisition, suggesting that social learning effects may be particularly important in early stages of drug abuse.

The social learning aspect of drug abuse is also related to parental modeling of drug-related behaviors. A large body of literature has shown that parental use of alcohol and drugs is strongly related to juvenile use and misuse of substances (see Hawkins et al., 1992, for a review). Parental drug use has been shown to predict initiation of drug use by adolescents, frequency of adolescent marijuana use, and adolescent use of additional illegal drugs, such as cocaine and barbiturates. In a study examining the effects of parental modeling of drug related behavior, Ahmed, Bush, Davidson, and Iannotti (1984) investigated children's expectations to use drugs as well as their actual drug use. The researchers found that the strongest predictors of children's expectations to use alcohol and of their actual alcohol use were the number of household drug users and the degree of the child's involvement in parental drug-taking. Parental modeling of drug related behavior is assumed to influence children and adolescent's behavior indirectly as well. Several studies have found that parental substance abuse is related to friends' use of drugs, which in turn is related to adolescent substance abuse (e.g. Hansen et al., 1987 in Hawkins et al., 1992).

Still, of the various drug abuse antecedents, the single strongest predictor of drug use in youth remains drug abuse by peers. A substantial body of research has consistently shown that the influence of peers on adolescent drug use is robust for different ethnic groups and surmounts the effect of parental drug modeling (Brook et al., 1988; Hawkins et al., 1992). In some drugs of abuse, often referred to as social drugs, this situation is particularly striking. Certain drugs of abuse such as alcohol and cannabis are more often than not consumed in groups (Skog, 2006; Wilkins et al., 2002; WDR, 2006), and their use is positively associated with the amount of time spent with friends (Duncan, Duncanm & Strycker, 2000; McMorris & Uggen, 2000; Peretti-

Watel & Lorente, 2004; Svenson, 2000). These findings support the key role that social learning processes play in drug use and abuse.

3. A unified model for the joint effect of individual sensitivity and social exposure

The current chapter proposes a unified model for the joint effect of individual learning and social influence on drug abuse. Under this model social experience acts as a substitute to individual learning that facilitates choice of alternatives with rare (or delayed) negative outcomes, by increasing the salience of the immediate positive outcomes as a result of drug consumption. Social experiences, therefore, accelerate risky behavior under certain conditions. The current model further suggests that there is a particular decision making style which prompts the acquisition of drug use in certain individuals. It therefore indicates an interaction between a particular decision style and environmental factors implicated in addiction. We first present the models' main assumptions verbally, and follow in the next section with a quantitative summary.

3.1. Observing what could have been - social influence and risk taking in the laboratory

Since drug use is learned from experience - acquired through repeated encounters of initially unknown consequences – we consider the most suitable experimental environment for simulating drug use acquisition to be experience-based decision tasks. These tasks involve repeated selection between alternatives while receiving little or no initial information as to the nature of the payoffs associated with them. As the task proceeds, the accumulated knowledge of past outcomes gradually shapes one's pattern of responses. Since their phrasing and interface do not reveal what traits or tendencies they measure, experience-based tasks are also relatively immune to response biases, such as attempts to impress observers favorably (Koritzky &

Yechiam, in press). This contributes to their capability of capturing real-world behavior in the laboratory.

Laboratory settings of this kind can be made further suitable for modeling the initial acquisition of drug use if social influence is taken into account, for instance, by letting decision makers observe the outcomes of others' choices. The effect of observing others' behavior in decisions from experience has been studied by Yechiam, Druyan and Ert (2008). They used decision tasks which included a safe alternative (yielding a constant payoff) and a risky one (yielding payoffs with some variance). In one task, labeled 1/2, the safe alternative produced superior outcomes in half of the trials, and in the other task, labeled 1/20, the safe alternative was superior in only 5% of the trials. However, the safe alternative was always the advantageous one in terms of expectancy, as described below:

Task 1/20
S (Safe)	Lose 2 Ag. [1]
R (Risky)	Lose 30 Ag with a probability of 0.05 (1 in 20).
	Lose 1 Ag otherwise.

Task 1/2
S (Safe)	Lose 2 Ag.
R (Risky)	Lose 4 Ag with a probability of 0.5 (1 in 2).
	Lose 1 Ag otherwise.

Participants performed the tasks on a computer, with the two alternatives displayed as two unmarked buttons that could be selected by mouse clicking (see Figure 1). Participants were encouraged to maximize their earnings, which were converted into real money at the end of the experiment.

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[1] Ag.- abbreviation for "Agora", an Israeli currency. 1 NIS = 100 Ag. 1 Ag = approx. 0.24 US Cents.

Social influence came into play as follows. For half of the participants, the display was twofold: while they were performing the tasks, their monitors also displayed the course of the same task as simultaneously performed by another, independent participant. As shown in Figure 2, these participants made more risky choices than control participants, who did not have the opportunity to observe others. However, this difference was larger in the 1/20 task in which the risky alternative was superior most of the time, indicating that exposure to others' behavior prompts risky choices especially in the case of seemingly attractive alternatives with rare – but severe – negative consequences (see Figure 2).

This pattern is consistent with the effect of social exposure on drug use. Evidently, the exposure to the outcomes experienced by others as they act and make decisions influences the behavior of the observers. This influence is stronger when the behavior displayed by the social models (which could be risky) yields better outcomes than its alternative most of the time. This can explain why effects such as that of social drugs are only seen in certain risky behaviors and not in others: Social exposure will enhance risk taking in contexts where the risky alternative is better most of the time. In other contexts, social exposure may have a negative effect, or no effect at all, on risk taking.

For example, some behaviors associated with risk, such as Internet gambling, tend to be solitary activities, and were found to be negatively associated with time spent with friends (Wood, Griffiths, & Parke, 2007; see also Miltenberger, Fuqua, & Woods, 1998). One possible contributor for the difference between these behaviors and the consumption of the so called social drugs may lie in the frequent penalties associated with Internet gambling and similar activities. When a behavior often yields negative outcomes, this effect would only be emphasized if one is exposed to others performing that same behavior. Therefore, frequent punishments may make the social context less conducive of risky behavior.

Another related phenomenon involves the difference between drugs of abuse. In a nation-wide Canadian study the use of drugs such as heroin and hallucinogens was not found to be associated with the amount of time spent with friends (HBSC, 2004). Possibly, social exposure in a situation where drugs have common negative consequences, along with their positive impact on affect, does not increase consumption to the extent it does when the outcomes are typically favorable (e.g., in marijuana).

It could be argued that in the experimental model of Yechiam et al. (2008) being observed by others, rather than the observation of the payoffs others received, accounts for an elevated tendency to take risk in social contexts. However, in a second study (Yechiam et al., 2008) no similar pattern emerged for individuals who were simply observed by others. We assert that the same logic applies to the issue of social influence in initial drug use: Drug use is prompted by observing others who use.

Next we will consider whether individual differences in drug abuse are indeed associated with a tendency to pick an alternative that is pertinently better most of the time.

3.2. Sensitivity to favorable outcomes and drug abuse

The reward learning of drug abusers can be studied using experience-based decision tasks, such as the commonly used Iowa Gambling Task (Bechara et al., 1994). In this task, respondents choose repeatedly between four decks of cards without initial information as to the payoffs they yield, and with the goal of maximizing their profit. Each card selection yields a gain, but occasionally losses occur too (gains and losses are given in points, which are converted into real money when the task ends). Two of the decks are disadvantageous in that they yield relatively high gains along with losses that are even higher, resulting in net loss. The two advantageous decks yield smaller gains but also much smaller losses, resulting in net gain (see Table 1). In order to perform well in this task, one must learn to avoid the disadvantageous decks and prefer

the advantageous ones. Indeed, such a pattern of learning is usually found in normal samples of task performers.

Another distinction between the decks that is less commonly made (see Yechiam, Stout, Busemeyer, Rock & Finn, 2005) is between decks that accrue positive outcomes most of the time (B and D, where outcomes are gains 90% of the time) and those that accrue positive outcomes only half of the time (A and C). This distinction can allow the assessment of the sensitivity of performers to a typically favorable event.

The IGT was originally proposed to provide insight into the real-world maladaptive decision making of persons with lesions in a particular area of the forebrain – the ventromedial prefrontal cortex (VMPFC). Despite having their intellectual skills intact, these individuals are known to be reckless and impulsive in their daily lives. Bechara et al. (1994) conjectured that it takes more than cognitive ability for successful decision making. As VMPFC lesion patients perform poorly on the IGT, these authors suggested that motivational and affective factors are involved in responding to losses and gains, and in learning to avoid needless risk and prefer the alternatives that would be better in the long run (Bechara et al., 1994).

When applying the IGT as a means of distinction between drug abusers and non-abusers in terms of decision making style, a noteworthy pattern is observed. While *chronic* drug abusers tend to perform poorly on the task (Bechara et al., 2001; Stout, Busemeyer, Lin, Grant & Bonson, 2004; Yechiam, Busemeyer, Stout & Bechara, 2005), *high-functioning* drug abusers are hardly any different from controls (Stout, Rock, Campbel, Busemeyer, & Finn., 2005; Yechiam et al., 2005a, b). High-functioning drug abusers are "individuals with high substance use levels and/or substance use problems identified by self-report on substance use questionnaires, but who have not received a formal substance abuse diagnosis, have not been treated, and who remain either employed or in school" (Yechiam et al., 2005b). It may not sound surprising if indeed these individuals demonstrated adaptive decision making. After all, by definition they are

individuals whose use of drugs does not hinder their coping with the demands of everyday life, and this may suggest that their decision making style is just as adaptive as any healthy non-user's. However, this does not appear to be the case.

Notice that in half of the trials of the task, disadvantageous deck A is superior to the advantageous decks (see Table 1), and disadvantageous deck B is superior in as much as 90% of the trials. This misleading, apparent advantage is sufficient to attract chronic drug abusers. It may be, though, that high-functioning drug abusers are not immune to these effects either. Rather, it might simply take a higher salience of the bogus rewards to lead these individuals astray.

Yechiam et al. (2005b) hypothesized that high-functioning drug abusers would differ from non-abusers when favorable outcomes are more saliently presented in the form of *foregone payoffs*: knowledge of the outcomes of alternatives that were not selected by the participant. In order to test the effects of foregone payoffs, the IGT can be modified so that with each card selection, all decks will be revealed, and decision makers will see not only the payoff for their choice, but also the payoffs they could have obtained if they had chosen differently. This addition of foregone payoffs provides that regardless of one's last choice, most of the time larger payoffs will be displayed by the disadvantageous decks. This state of affairs may increase temptation to choose from these decks, despite the bad consequences.

Indeed, this was the finding in Yechiam et al. (2005b): High-functioning drug abusers and non-abusers performed about equally in the standard version of the IGT, but the high-functioning drug abusers made significantly more disadvantageous choices when foregone payoffs were presented. Of the two disadvantageous decks, the deck most sensitive to the addition of foregone payoffs was deck B, which yielded favorable outcomes in the vast majority of trials (see Table 1). High functioning drug abusers chose from this deck more frequently, and this effect lasted as the task proceeded, in contrast to the decrease in deck B choices found

without foregone payoffs (in fact, in the standard task drug abusers showed a much more rapid decrease than controls). Non-abusers were also affected by the addition of foregone payoffs in the same direction, though to a much smaller extent (Yechiam et al. 2005b).

It appears therefore that however well-adjusted they are, high-functioning drug abusers are more easily distracted by seemingly attractive (yet hazardous) alternatives, when these are made salient enough. Notice the similarity of these results to the findings of Yechiam et al. (2008) regarding the effect of observing others' behavior. As described in the first sections of this chapter, drug use is almost always acquired upon observing others in one's environment consume drugs and obtain desired outcomes. We suggest that the social experience functions as foregone payoffs, which increase the salience of commonly favorable outcomes from risky alternatives.

4. Accounting for drug abuse in formulae: the Expectancy-Valence model

Drug abuse is acquired through learning, and so it can be described with a quantitative learning model, i.e., a set of equations representing the stages of learning. An appropriate model should encompass the initial exposure to drugs (or to the possibility of using them), the evaluation of the pros and cons of this action in comparison to its alternatives, the principle determining what choice will be made, and the influence of accumulated experience on future choices made. All these features can be implemented in reinforcement learning models (e.g., Busemeyer & Myung, 1992; Erev & Roth, 1998; Sarin & Vahid, 1999), which explain the behavior of a person who makes a series of choices from a set of alternatives. For instance, a reinforcement learning model called the Expectancy Valence model (Busemeyer & Stout. 2002; Yechiam et al., 2005a) was proposed to account for the decision making of individuals taking the Iowa Gambling Task. In this section we examine its suitability for the process of drug use acquisition.

Upon encountering the available alternatives, choices lead to outcomes. These are modeled as gains if they are favorable, and as losses if they are aversive. Each alternative may convey either gains, losses, or both. In an analogy to drug use, this simulates a situation where positive and negative outcomes can follow either from using the drug or from not using it. Though the decision maker is not informed in advance about the exact magnitudes of gains and losses and probabilities of obtaining them, he or she can rely on their subjective experience when making the next choice. According to the model, each experienced outcome evokes an affective reaction, referred to as *valence*. As valences are experienced, individual *expectancie*s are formed with respect to each alternative, and in turn they may affect following choices. These expectancies are constantly updated as further choices are made, and so forth, shaping one's behavior through a process of reinforcement learning. Adaptive learning will take place if the subjective expectancies are closely related to the objective ones, as the individual will then tend to select the more beneficial alternatives. In decisions regarding drug use, learning to stay away from drugs is usually adaptive and desired. However – as described earlier in this chapter – several individual and social factors might stand in the way of such learning.

The updating of the expectancy of an alternative is not determined only by the outcomes it has produced, but also by individual properties of the person making the decision. As suggested by the Expectancy Valence model, these are: weighting of losses vs. gains, weighting of recent outcomes, and consistency of choosing according to expectancy. These three properties appear in the model as parameters that are assessed through computation. Next we will consider these components and the roles they are assumed to play in drug use acquisition.

4.1. The motivation parameter: Weight to losses and/or gains

When people make choices they experience gains and losses, which they do not necessarily weigh equally. If an environmental stimulus leads to gains and losses of high magnitudes (and

hence is *risky* according to the classic economic definition of the variance of outcomes; see Pratt, 1964; Markowitz, 1952; Sharpe, 1964), then individuals who tend to assign a heavier weight to gains can be tempted to take the risk despite potential losses.[2] This appears to be relevant to the situation of a person deciding whether or not to use a drug, since taking drugs can lead to exhilaration and pleasurable experiences but it can also be harmful in many ways.

In formal terms, the evaluation of the gains and losses results in a cognitive-affective response called a valence, and is represented by a utility function that allows for gains and losses to be weighted differently (see Kahneman & Tversky, 1979). The valence is denoted $v(t)$, and is calculated as a weighted average of gains and losses for the chosen alternative in trial t.

$$v(t) = W \cdot gain(t) \ - \ (1-W) \cdot loss(t) \tag{1}$$

Where $win(t)$ is the gain on trial t; $loss(t)$ is the loss on trial t; and W is a parameter indicating the weight given to gains versus losses. This parameter varies between decision makers, hence reflecting individual differences in the weight assigned to different outcomes. The parameter ranges from 0, denoting complete focus on losses, to 1, denoting complete focus on gains. Values between 0 and 1 indicate the comparative weight of gains versus losses.

Chronic drug abuse is associated with high weighting to gains compared to losses (Stout et al., 2004; Yechiam et al., 2005a) – a motivation bias which is consistent with the attraction to the enjoyment the drug provides while ignoring the damages it causes. We assert that in high functioning individual drug use may also be prompted by attraction to gains and lower sensitivity to losses. Yet, in the case of high functioning this bias is only activated in certain conditions.

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[2] Ert and Yechiam (2009) have shown that the weighting of gains and losses is not a construct independent from risk taking. Consistent individual differences in this parameter only appear when the individual has clear signals that it faces a risky alternative containing gains and losses, and an alternative where risk can be avoided.

These conditions, as shown by the reviewed above, occur when the gains are made to be more salient by a) their being the typical outcome b) such means as foregone payoffs and social exposure. This suggestion is consistent with the results of studies of self-control showing the influence of salient temptations. For example, in the classic study of Mischel (1974), children were asked to wait and not take a prize (a small teddy bear) in order to receive a larger prize (e.g., a larger teddy bear). Waiting was more difficult when the smaller prize was in front of the children, compared to when it was covered.

In real life, the enjoyment and popularity of drug users in one's environment can serve as salient temptations. By attracting attention to the advantages associated with drug use, they might weaken self control while one makes his or her decisions. The result is an increased tendency to choose badly, which can be modeled as an increase in the weight assigned to gains in the presence of foregone payoffs. We suggest that this tendency is a most influential factor in the initial stages of drug abuse acquisition.

4.2. The recency parameter: weighting recent versus distant valences

In the course of repeated decisions, individuals can rely on previous experience by making choices based on recent outcomes, on outcomes observed over longer periods of time (within memory limitations), or both. The balance between recent and distant experiences (or prior information) is highly relevant to the decision of whether to use drugs, because drugs typically produce outcomes that are better in the immediate range than in the long run. Moreover, seeing others use drugs vicariously demonstrates their immediate positive effect. In order to make the "right" decision, the individual must balance this positive information with previously experienced negative consequences of drug use, or with her commitment not to use.

In the EV model, the expectancy term E_j denotes the accumulated expected utility for alternative j, i.e., the experience one has with this alternative. High relative expectancy implies

high propensity to select the corresponding alternative. Expectancies are updated as a function of both the new valence and the old expectancy from previous trials. A delta learning rule (see e.g., Busemeyer & Myung, 1992; Sarin & Vahid, 1999) is used for updating the expectancy after each choice, as follows:

$$E_j(t) = E_j(t\text{-}1) + \phi \cdot [u(t) - E_j(t\text{-}1)] \cdot \delta_j(t) \tag{2}$$

The term $\delta_j(t)$, which denotes the weight associated with the chosen alternative, equals 1 if alternative j is chosen on trial t, and 0 otherwise. On any trial t, the present expectancy $E_j(t)$ is equal to the preceding expectancy $E_j(t\text{-}1)$, unless this alternative has been chosen on that trial. In such a case the expectancy is updated according to the outcomes newly obtained, and the change occurs in the direction of the prediction error given by $[u(t) - E_j(t)]$. That is, if the new outcome from alternative j is higher than the preceding outcome (i.e., the old expectancy) this increases the expectancy as well as the propensity to select the alternative again. If the new outcome is lower, then the new expectancy is lower, and the propensity of choosing the alternative again decreases.

The recency parameter, ϕ, describes the effect of recent outcomes relative to the overall past experience with the associated alternative. This parameter is also limited from 0 to 1. Large values of ϕ indicate strong recency effects such that the most recent trials are more prominent when updating the expectancy, whereas past outcomes are discounted. In contrast, small values of ϕ indicate the persistence prior outcomes in memory over longer spans of selections and slower incorporation of new outcomes into expectancies. [3]

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[3] According to some approaches, if foregone payoffs are assumed to be weighted differently than obtained payoffs, the delta rule should be modified, and a parameter denoting the weight of foregone payoffs should be assessed separately (see Yechiam & Busemeyer, 2005).

In drug use, some outcomes are more frequent than others and have a better chance of having been recently experienced. For instance, a "high" feeling can come with every use, but aversive aftereffects – pain, failure, or the consequences of neglecting other causes while under influence – may only appear once in a while. On the other hand, refraining from the drug may not be tempting in the short run, but would be beneficial over time.

The effect of the individuals' predispositions to use drugs can also be implemented formally. It can be assumed that the expectancies in the initial learning period are not neutral and favor a certain alternative (e.g., not using a certain drugs) over others. Again, high recency would be expected to be associated with a greater tendency to succumb to addiction due to the positive weight of average recent experiences.

Indeed, chronic drug abusers display a high level of recency when assessed by the EV model. For instance, Yechiam et al. (2005a) found that chronic cannabis and cocaine abusers were highly affected by recent outcomes in the Iowa Gambling Task. However, such an effect was not found for high-functioning users of drugs and alcohol, and hence it does not seem that high recency is a major risk factor in the initial stages of drug abuse.

4.3. The choice consistency parameter: Reliability of choice behavior

Another possible factor involved in decisions regarding drug use is the ability to follow one's resolves and opinions consistently, rather than choose randomly. Under the Expectancy-Valence model, the expectancies formed in the learning process do not have a deterministic effect on the next choice of the decision maker. Rather, in the Expectancy-Valence Model, the probability of choosing an alternative is a strength ratio of that alternative's expectancy relative to the sum of strengths of all alternatives' expectancies. The formula yields a probability for choosing each alternative, and the probabilities sum up to one (these probabilities can be later examined for their predictive value).

$$\Pr[G_j(t)] = \frac{e^{\theta(t) \cdot E_j(t)}}{\sum_k e^{\theta(t) \cdot E_k(t)}} \qquad (3)$$

The parameter θ denotes the choice consistency of the decision maker. Low values (close to zero) are associated with erratic patterns of choice, while high values induce choosing according to maximal expectancy. With regard to drugs, we expect that low consistency – making choices unrelated to updated expectancies – will hinder the convergence to beneficial alternatives (the learning pattern usually found in the general population) and will bring to more incidences of drug use.

Indeed, low consistency was found among chronic abusers of cocaine (Stout et al., 2004; Stout et al., 2005) and cannabis (Yechiam et al., 2005a). However, as in the case of the recency parameter, consistency does not seem to be exceptionally low among regular, high functioning drug users (Yechiam et al., 2005a). Therefore, it does not seem that consistency is a major factor in the initial formation of drug abuse.

The recency and low consistency effects in chronic cocaine and marijuana abusers may be due to the impact of drugs of abuse or may constitute an important selection bias which predisposes individuals to abuse these drugs. A study by Lane, Yechiam and Busemeyer (2006) supports the former view, at least with respect to marijuana. These authors showed that an acute administration of marijuana led to increased recency and decreased consistency while being intoxicated, compared with a placebo condition. This suggests that the pattern of high recency in marijuana abusers may be due to memory problems that result from cannabanoid administration (e.g., Bolla et al., 2005).

Altogether, the EV model embeds cognitive and affective elements and has the potential to account for different phenomena occurring in adaptive as well as maladaptive reinforcement learning in complex environments.

5. Conclusions and implications

This chapter proposed a decision making model of sensitivity to drug abuse among high functioning individuals. The model suggests that individuals at risk for drug abuse have an increased tendency to respond to gains when they are salient. We presented two factors that increase this salience, both of which have ecological similarity to features of typical drug use situations: 1. Risky alternatives that produce favorable outcomes for the majority of the time. 2. Foregone payoffs that highlight the positive counterfactuals of such risky alternatives. These factors are involved in situations of social exposure to drug use, where individuals observe salient gains that are favorable in the immediate range. Either alone or interactively, they increase individuals' propensity to use drugs.

Social exposure is therefore suggested as a replacement process by which a person receives information about the consequences of drug use even if he or she has sufficient resolution to avoid the particular drug. This is consistent with the effect of the drugs that are commonly consumed in the company of other people. The most popular explanation for why certain drugs are "social" involves their low price (WDR, 2006). We propose an alternative explanation based on the fact that the typical outcomes from social drugs, such as cocaine and marijuana, tend to be rewarding. Furthermore, notice that unlike other drugs, these drugs do not involve negative effects that are immediately observable (e.g., skin abrasion or pain). Hence social drugs fall into the category of behaviors that, while risky and maladaptive, result in favorable outcomes most of the time. According to the model presented in this chapter, these are the behaviors most prone to being induced by observing others.

In terms of cognitive processes, results using the Iowa Gambling task and the quantitative Expectancy valence model show that high functioning drug users are described as having heightened sensitivity to gains (compared to losses), which is triggered in situations

where potential gains have relatively high salience. Thus, individual tendencies are triggered in contexts that are typically induced by the social environment.

The current model implies that an effective way to reduce drug use, at least among high-functioning users, is to prevent them from socializing frequently with drug using individuals. Indeed, this implication is consistent with the observations of sociologists on the effect of social exposure to drug use in American universities. A survey conducted by NIDA showed that marijuana is used by about 30 to 35 percent of college students (USDE, 2008). An interesting phenomenon however is that many students who use drugs in college stop doing so afterwards (Merline et al., 2004). For instance, the rate of marijuana use among college graduates is reported to be only 7% for those who finished college and 11% for those who dropped out (Merline et al., 2004). A simple explanation for this effect is that marijuana smoking drops when one is no longer frequently surrounded by other users.

More specifically, we assert that social exposure facilitates the use of drugs that bear favorable outcomes most of the time, since the benefit of using these drugs gains salience as one witnesses them being used. Since drugs such as marijuana are prohibited in most countries, one potential way of reducing the effect of social exposure on drug use is by higher levels of enforcement. This is in line with certain law enforcement policies, which proclaim that extended presence of police forces in public places reduces crime. Under the current model such enforcement has added value since it reduces the contagious effect of drug using; yet it should focus not on single and isolated users but on hubs of social activity where many individuals are exposed to the use of drugs by their peers.

The negative consequences of drug use can also be made more salient by drawing attention to them as consistently and as often as possible. Extended presence of authorized officials in venues of social gathering can be helpful in itself, as it can serve as a salient reminder of the possibility of getting caught. From another perspective, the idea of elevated

enforcement can be applied in intervention programs and other methods of education:

According to our suggested model, such endeavors will be more effective if they take place

frequently rather than once in a while.

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Table 1. The distribution of payoffs in the Iowa Gambling Task

Deck	Type	Gains	Losses
A	Disadvantageous	100 for sure	50% to lose 250
B	Disadvantageous	100 for sure	10% to lose 1250
C	Advantageous	50 for sure	50% to lose 50
D	Advantageous	50 for sure	10% to lose 250

Figure 1. A schematic image of the experimental display in an experience-based decision task with two alternatives.

A	B
	-1

You got: **-1**
Total: **-4**

Figure 2. Proportion of Risky choices in two decision tasks (1/20 and 1/2), by social exposure condition (Yechiam, Druyan & Ert, 2008).