Cognitive factors and changes in individual decision making: from drug addiction to natural recovery

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This paper proposes a model of natural recovery, a widespread yet unexplained aspect of addictive behavior consisting on spontaneous cessation of consumption. The model is grounded on the neuroscience and on recent theories regarding addiction as a progressive susceptibility to stochastic environmental cues that can trigger mistaken usage. In order to explain the mechanisms leading to natural recovery, our model introduces a competition between an "implicit cognitive appraisal" process in individual decision making, depending on past addiction experiences as well as on the future expected consequences of addictive consumption, and cue-driven impulses to use. Individual choice is affected in two ways: the reward from use decreases as the decision maker grows older and cognitive and motivational incentives emerge thus reducing the probability of making mistakes. While allowing for cue-triggered mistakes in individual decision making, this model recovers an important role for other factors, such as subjective self evaluations, in explaining natural recovery with relevant implications both for economic and social policy and for the treatment of drug and alcohol dependence.

Key words: Addiction models, natural recovery, behavioral decision making, cognitive policy.

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Introduction

Neuroscience and clinical practice have shown that addictive substances systematically interfere with the proper operation of a process used by the brain to forecast near term hedonic rewards and their repeated use leads to strong impulses towards consumption that may interfere with higher cognitive control. In this case individual consumption choices are sometimes driven by a rational decision making process, sometimes by strong impulses leading to mistakes, i.e. to a divergence between choices and preferences.

Although addiction is defined as a chronic and persistent disease by the scientific community (see e.g. the American Psychological Association's Diagnostic and Statistical Manual of Mental Disorders, known as the DSM-IV), recent longitudinal studies have called into question whether this is an accurate representation (Slutske, 2006). Clinical practice shows that natural recovery characterizes a substantial fraction of individuals with a history of pathological addiction and that this is not an infrequent pattern of behavior in long term addicts. Yet the reasons for it are still to be understood.

This paper tries to suggest what are the main mechanisms involved in solving the interesting puzzle of natural recovery from addiction. Specifically, our main purpose is to identify the main determinants of natural recovery and to highlight its dynamics. The key process involves a mechanism that we call "Implicit Cognitive Appraisal" function incorporating future expected losses as well as the past addiction history. Such process leads to a reduction of the payoff from use as the decision maker grows older and it increases cognitive incentives competing with the basic hedonic forecasting mechanism (HFM henceforth), thus reducing the probability of making mistakes. We also explore the role of other factors, such as learning and individual heterogeneity. Natural recovery is the result of two mechanisms: a physical maturation process combined with increased awareness of the negative consequences of past, current and future substance abuse. As a consequence policy measures should be addressed to the youngest groups of consumers to compensate for the lack of maturity which, at older ages, may spontaneously activate the mechanisms triggering remission from addiction.

Thus our model may have important clinical and policy implications, because it places a high value on measures that increase the likelihood of successful self-regulation without forcing particular choices and eventually leading to natural recovery (Bernheim and Rangel, 2005, p. 136).

The neuroscience of addictive behavior

In human beings drugs produce an increase of dopamine concentration at target-cells' receptor levels, as they stimulate the nigrostriatal (controlling motor coordination) and corticolimbic (controlling emotions and cognitive abilities) dopaminergic systems (Wise, 2004).

Once these systems are engaged by natural rewards (food or sex for example) or by addictive substances (Kelley, 2004; Nestler, 2005) dopamine release in the nucleus accumbens and in other cerebral sites increases causing specific emotional states (for example, euphoria) that are powerful drivers and reinforce that behavior. Addictive substances have an advantage over natural rewards: they produce a higher dopamine concentration by stimulating the (wanting) system more powerfully and for longer periods (Hyman, 2005). The individual is thus induced to repeat such positive experiences (or avoid them when negative), precisely because he associates the specific function to its hedonic responses (Kelley and Berridge, 2002; Bechara, 2005; Kalivas and Volkow, 2005).

However, there is another important difference between natural rewards and drugs of abuse. In the case of natural rewards, a habit develops after repeated use which reduces the importance of the experiential act. In other words the quality and quantity of the gained pleasure diminishes. On the

contrary, addictive substances activate each time a similar hedonic response (Berridge & Robinson, 2003).

Chronic substance abuse induces profound alterations of the cerebral mechanisms just mentioned which ``force'', in a way, the user to make compulsory choices, i.e. choices that diverge from preferences. By powerfully activating dopaminergic transmission drugs reinforce the associated learning process, ending up by constraining the individual's behavioral choices (Berke and Hyman, 2000). In other words, drugs seem to affect the basic forecasting mechanism, a simple system for learning correlations between current conditions, decisions and short term rewards. With repeated use of a substance, the cues associated with past consumption cause the HFM to forecast exaggerated pleasure responses, creating a disproportionate impulse to use leading to mistakes in decision making. The pleasure following use, the excessive and rapid hedonic expectation induced by the HFM, the progressive failing of the frontal cortex to counterbalance with rational choices the more alluring offer of drugs, all portray a process that invariably regenerates itself and seems to have no end (Kelley and Berridge, 2002; Berridge, 2004).

Although drug addiction seems to lead to just one possible result, for still unclear reasons, often the patient stops participating in the ineluctable dynamics of her/his case and ceases to have this insatiable hunger and compulsion for the drug. This may happen as a consequence of psychological, social, pharmacological and individual interactions as well as all other stimuli found inside and around an individual (deterministic or even stochastic events). In more general terms, one could say that the multifactoriality sustaining drug addiction sometimes ceases to offer those profits or conveniences considered up till then as indispensable. When this happens without professional help, it gives rise to the nice puzzle of natural recovery.

Natural Recovery

Epidemiological studies, considering pathways out of alcohol abuse without the utilization of professional help, give evidence that the majority of quitting taking place without professional assistance in various countries reveal rates between 66.7% in Germany to 77% in Canada (Bischof *et al*., 2003). Other studies reveal that although there may be differences in the ways in which it occurs, spontaneous remittance characterizes the whole spectrum of drugs such as alcohol (Cunningham *et al*. 2006; Bischof *et al*. 2000; Weisner *et al*. 2003; Matzger *et al.* 2005; Bischof *et al.*, 2003), marijuana (Copersino *et al.*, 2006), multiple drugs, heroin (Waldorf and Biernacki, 1979), binge eating, smoking, sex and gambling (Hanninen *et al.*, 1999; Nathan, 2003; Slutske, 2006) and that the rate of natural recovery may be much higher than conventional wisdom seems to suggest. Recent longitudinal studies have highlighted that a substantial fraction of individuals with a history of pathological gambling have recovered from their problems without professional help (Slutske, 2006), calling into question the same definition of addiction as a chronic and persistent disorder as given by the DSM-IV.

Despite this evidence, natural recovery remains basically an unexplained phenomenon even though it is of interest to different major disciplines, such as economics, psychology and sociology. It may occur in at least three different ways: (i) cold turkey quitting due to an exogenous shock; (ii) cold turkey quitting happening without an exogenous shock; (iii) gradual quitting occurring after a period of continuous decrease in consumption. We are particularly interested in cases (ii) and (iii) and argue that quitting is the explicit manifestation of an inner process of "self appraisal" that ultimately brings to quitting consumption of the addictive substance. Such process is also the main determinant of quitting in case (i) where the role played by the exogenous shock is that of a strong incentive

accelerating a mechanism that, however, has already begun to develop within the addict. In Table 1 the results of a study evaluating the percentage of recoveries form heroin without treatement are reported (Waldorf & Biernacki, 1979).

Authors **Publication date** **Date of study**	**Type of study**	**Size of N.**	**Percent of completed interviews**	**Percent of heroin addicts**	**Percent of recoveries without treatment**
Robins and Murphy, 1967 1965-1966	Survey of samples of black males born 1930-1934	235	95%	10%	15%
Robins, 1973 1972	Survey of samples of returned Vietnam Veterans	898	95%	21%	90%
Burt associates, 1977	Follow-up survey of treated heroin users	360	81%	98%	29%
Graeven and Graeven, 1976	Survey of samples of high school students	294	149	51%	52%
Brunswick, 1978	Longitudinal study of Black Youth	668	80%	13%	75%

Table 1. Source: Waldorf & Biernacki, 1979.

Self-Reports of Reasons to Quit Using Cocaine, by Treated and Untreated: Percentage Answering Yes

			Subsamples			
Reasons to quit	*Total Quitters (N=106)*	*Rank Order*	*Treated (N=30)*	*Untreated (N=76)*	*Chi Square*	*Significance*
Health problems	(50) 47.2%	1	(15) 50.0%	(35) 46.1%	0.92	n.s.
Financial problems	(43) 40.6	2	(19) 63.3	(24) 31.6	7.45	0.006
Work problems	(38) 35.8	3	(20) 66.7	(18) 23.7	14.73	0.0001
Pressure from spouse and/or lover	(35) 33.0	4	(16) 53.3	(19) 25.0	6.35	0.01
Decision to stop selling	(31) 29.2	5				
Fear for arrest for possession or sales	(30) 28.3	6				
Pressure from friends	(29) 27.3	7				
Pressure from family	(28) 26.4	8				
Decline in quality cocaine	(18) 17.0	9				
Difficulties obtaining cocaine	(13) 12.3	10				
Pressures from fellow users	(12) 11.3	11				
Other	(8) 7.5	12				
Arrest for possession	(6) 5.7	13				
Arrest fro drug sales	(1) 0.9	14				

Note: After the fourth most frequent reasons to quit, the number of responses was too small for meaningful comparisons between treated and untreated groups or for tests of statistical significance. Percentages do not totally exactly 100 because of multiple responses. Degrees of freedom=1; n.s.=not

Table 2. Source: Waldorf, Reinarman and Murphy, 1992.

Clinical and experimental research has studied natural recovery from substance abuse since the mid-1970s (Vaillant, 1982; Klingemann, 1991) focusing on triggering mechanisms, maintenance

factors and on trying to identify common reasons for change in substance use (Prochaska, Di Clemente and Norcross, 1992). To our knowledge, however, there are very few studies describing pathways to natural recovery in an economic model of addiction.

Matzger *et al.* (2005), in a study of the reasons for drinking less, assess that triggering mechanisms, the interpersonal and environmental influences that cause a person to move from problematic alcohol use to sustained abstinence or non-problematic use, can be varied and multidimensional and often involve a combination of both short and long term pressures. Results showed that the two most frequently endorsed reasons for cutting down were self-evaluation, i.e. weighing the pros and cons of drinking and not drinking and experiencing a major change in lifestyle. Self-evaluation implies that recovery is not necessarily triggered by negative or traumatic events, but alternatively comes about through a period of self-reflection. Interventions by medical personnel and family members were either non-significant predictors or significantly negatively related to sustained improvement for both the general population and treated drinkers.

Cunningham *et al*. (2005) give support to both the "cognitive appraisal" and the "life events" motivations for quitting. They noted that individuals who recovered without treatment went through a process of cognitive appraisal (also known as the motivational explanation for quitting) in which they weighed the pros and cons of drinking and not drinking and decided that the pros outweighed the cons. Anticipated costs and benefits of change is thus one means of measuring the respondents' motivational explanation for quitting.

The "life events" motivation is instead based on past life events. It is hypothesized that addicts' life events prior to and after their quit attempt are related to successful quitting attempts. Reasons for quitting may vary according to the substance of abuse and the addict's age. Copersino *et al*. (2006) report that reasons for quitting marijuana by the adults are different from those reported by adolescents. Table 2 reports the main reasons to spontaneous quit using cocain (Waldorf et al., 1992).

The Model

Our model of natural recovery is grounded on the Bernheim and Rangel (2004), B&R henceforth, addiction theory. This is based on the following premises: a) consumption among addicts is frequently a mistake; b) previous experience with an addictive good sensitizes an individual to environmental cues that trigger mistaken usage; c) awareness of sensitivity to cue-triggered mistakes produces attempts to manage the process with some degree of sophistication. While the second and third premises are also present in other recent models of addictive consumption, such as Laibson's Cue-Theory of Consumption (2001) for instance, the perception of consumption of addictive substances as mistakes is an original feature of the B&R model. This stems from recent advances in neurosciences stressing that addictive substances are different from others in the way they interfere with the normal operation of the brain.

Their model involves a decision maker (DM) living for an infinite number of discrete periods who can operate either in a cold (involving rationality) or hot (where decisions and preferences may diverge) mode. In each time period, the DM makes two decisions in succession. First, he selects a lifestyle from a set including "exposure", "avoidance" and "rehabilitation" states. Second, he allocates resources between a potentially addictive good/substance, and a non addictive good. Each period is entered in cold mode and the DM chooses his lifestyle rationally. This choice, along with the addictive state determines the probability with which he encounters cues that trigger the hot mode (see

below). Consumption of the addictive substance in each time period moves the individual to a higher addictive state in the subsequent period, while abstention moves him to a lower addictive state.
Since people become sensitized to cues through repeated use, when the volume of substance related environmental cues encountered exceeds some exogenous given intensity threshold M^T, the decision maker is induced by the Hedonic Forecasting Mechanism (HFM) to enter the hot mode and he is forced, in a way, to consume the addictive substance. The "power" assigned to the drug by the HFM-generated impulses is modeled as a function M that, on average, has a logistic shape, in line with the literature in neurosciences and pharmacology.

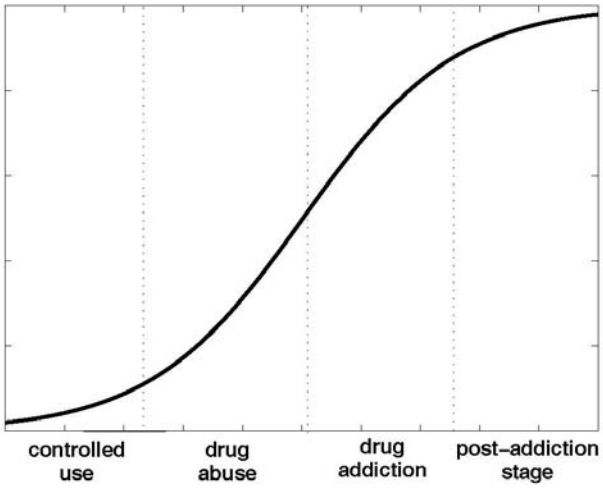

Figure 1: The deterministic portion of the M function.

Di Chiara (2002), for example, defines four different phases of addiction, delimited in Figure 1 by vertical dotted lines: controlled drug use, drug abuse, drug addiction, post-addiction stage. In the first stage, as a result of curiosity, peer pressure, social factors, personality traits, the DM comes into contact with a drug. Sensitization facilitates further experimentation and increases the power of the HFM (M weakly increasing). At this stage the subject responds to the drug-related stimuli in a controlled manner. With repeated drug exposure the DM progressively enters the stage of drug abuse. At this stage sensitization becomes very powerful and drug-related stimuli are associated to craving (M strongly increasing). The stage of drug addiction is characterized by the preceding stage to which is added that of tolerance and physical dependence (the slope of the M function starts decreasing). In the post-addiction stage abstinence, as well as sensitization, progressively disappear but the HFM-generated impulses remain active (saturating M function).

The DM disposes of a flow of income (resources) in each period. These resources decline with the addictive state due to deterioration of health and increased medical expenses. Both the addictive and non addictive goods produce pleasure, but the incremental pleasure from consuming the addicitve substance rises with the addictive state, whereas the incremental pleasure from consuming the other goods decreases with the addictive state. When evaluating the pleasure of any possible set of current and future choices, the individual discounts future hedonic payoffs at a fixed rate. In summary, the chosen consumption set corresponds to the solution of an intertemporal stochastic maximization problem, in which the stochastic component depends on the effect of the exogenous

cues described above. This model generates a number of addiction patterns.

In order to model natural recovery, we introduce mechanisms that decrease the probability of entering the hot mode and the convenience to use when in cold mode so that the DM is inclined to abstain from consumption for a reasonably long period of time [1]. This implies building a more complete model of cognitive control where such mechanisms influence the likelihood of overriding the HFM-generated impulses by increasing the threshold M^T.

Accounting for Future Expected Losses and past Addiction Histories

We assume that consumption of addictive substances has negative effects as the addictive state s increases. Our model conceives a loss function which accounts for past experiences with addictive goods and for the future negative effects of current addiction. We assume that, due to increasing awareness of both, the DM may experience a change of perspective as he grows older sufficient to induce quitting even without an exogenous shock or a stressful event occurring to generate this outcome. Future losses from current addictive consumption are evaluated by calculating the present discounted value of expected reductions in the length of life. Such future losses increase with the addictive state. Higher addictive states eliminate the expected benefits of the final moments of life. Moreover, they rise with age as one gets older, because the discount factor used to weight end-of-life utility rises as aging draws one closer to the terminal date. Stated differently, due to discounting, end-of-life utilities are given more weight as one gets closer to the terminal date, because they are closer to the present. On the other hand, at a younger age, end-of-life utilities are given much less weight because they are far away in the future.

Future expected losses may affect behavior in three distinct ways:

(i) they increase the threshold M^T thus reducing the probability of entering the hot mode. In our model the Mesolimbic Dopamine System (or wanting system) plays an important role in determining the choice to consume an addictive good at each point in time. Even though with age the wanting system declines inducing also a reduction in drugs use (Badanich, Adlich and Kirstein, 2006) this is not enough to generate Natural Recovery in young consumers, as empirical evidence suggests. Therefore other factors must be involved, besides Dopamine decline with age, in explaining spontaneous remittance. We assume that structures in the frontal cortex may activate competing "cognitive incentives" by identifying alternative courses of action or projecting the future consequences of choices (B&R, 2004, p. 1563). These higher cognitive incentives triggered by future expected losses from addiction could even override HFM-generated impulses.

(ii) They affect the decision process through the decreased probability of use.

(iii) They erode the marginal instantaneous benefit from use as they enter the cold mode of operating.

The process leading to natural recovery is conceived as a competition between HFM-generated impulses to use and other impulses which may be dubbed cognitive control impulses. Such competition can be thought of as similar to an internal game. Economists are not new to interpreting conflicts between different parts of a person as an internal game and this interpretation is particularly suitable to the case of addiction (Frank, 1996).

Berridge and Robinson (2003, p. 508) explain that the motivational component of reward can

[1] Clinical practice suggests that we can speak of recovery after about at least two years of sustained abstinence from use.

be parsed into two different psychological components: an implicit and an explicit one. Explicit processes are consciously experienced whereas implicit psychological processes may not operate at a conscious level. They also stress that additional psychological processes of cognitive awareness can transform the products of implicit processes into explicit representations. This is also consistent with recent advances in the neurosciences that strive to bridge the gap between moral and biological lines and allow the addiction treatment ``*to reduce the rewarding properties of drugs while enhancing those of alternative reinforcers, inhibit conditioned memories and strengthen cognitive control.*'' (see Baler *et al.*, 2006).

Drawing from these insights we introduce an ``Implicit Cognitive Appraisal'' process I, with initial condition I_0 representing the a priori level of cognitive control, competing with the HFM's generated impulses to use M, with initial condition M_0. The I function incorporates future expected losses from addiction representing an additional psychological drive that may transform the implicit cognitive mechanism into the dominant one thus overriding the HFM generated impulses.

We let the population of DMs consist of two distinct groups: *non addicts* and *potential addicts*. For *non addicts* $I_0 \geq M_0$ and for *potential addicts* $I_0 < M_0$. A *non addict* DM may never become an addict, because its level of competing cognitive incentives is high enough to decrease the probability of entering the hot mode. On the other hand, $I_0 < M_0$ represents the case of a DM who has not yet gained experience with the addictive good and is thus less aware of its potential consequences. We focus on this class of DMs.

The I function for potential addicts is related to the loss function through the initial condition $\bar{I}_0$ which is now defined as

$$\bar{I}_0 = I_0 + \gamma L ,$$

where L is a loss function and γ indicates the presence of learning processes related to past history of consumption, age and awareness of future expected losses. We assume $0 \leq \gamma \leq 1$, where $\gamma = 1$ implies perfect learning and $\gamma = 0$ signals absence of learning. Given I_0, the presence of learning may drive the implicit cognitive incentives to override the HFM impulses to use. Since different individuals have different learning capacities and histories I_0 and γ account for DMs heterogeneity.

For a given γ, the I function shifts upwards as time t and the addictive state s increase, so that different values of I may be associated with the same s reached at different time periods. Such process may continue until the I function overrides the HFM and the probability of entering the hot mode may even decline to zero. An analogous process arises when the a priori level of cognitive control I_0 increases.

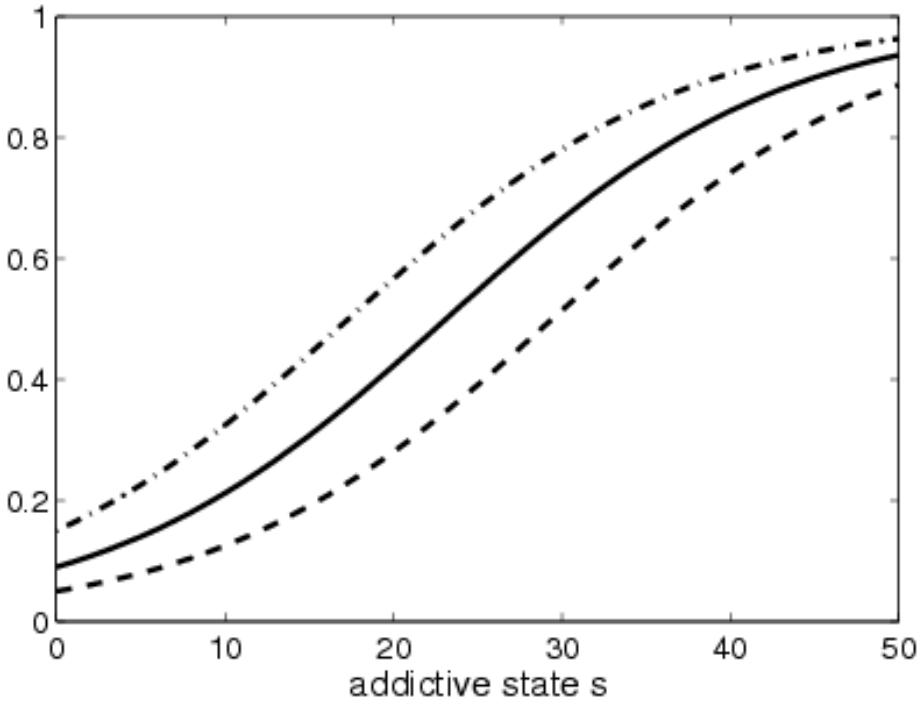

Figure 2: M and I functions corresponding to different assumptions on $\bar{I}_0$.
Dashed line: $\bar{I}_0 < M_0$ (for $\gamma L_{Y,H} < M_0 - I_0$), solid line: $\bar{I}_0 = M_0$ (for $\gamma L_{Y,H} = M_0 - I_0$), dashdot line: $\bar{I}_0 > M_0$ (for $\gamma L_{Y,H} > M_0 - I_0$).

Results and discussion

Our main results are the following:

- ✓ Higher values of I_0 decrease the probabilities of entering the hot mode;
- ✓ higher values of γ decrease the probability of entering the hot mode;
- ✓ on average, an increase in I_0 lengthens the time interval between the initial use and the maximum addictive state and shortens the interval between it and natural recovery.
- ✓ on average, an increase in I_0 lowers the maximum addictive state.
- ✓ an increase in γ shorthens the interval between the initial use and the maximum addictive state and anticipates natural recovery.

Finally, we show that the equilibrium solution $s = 1$ of the dynamical system describing the evolution of addiction, corresponding to natural recovery, is globally asymptotically stable. This is shown in Figure 3.

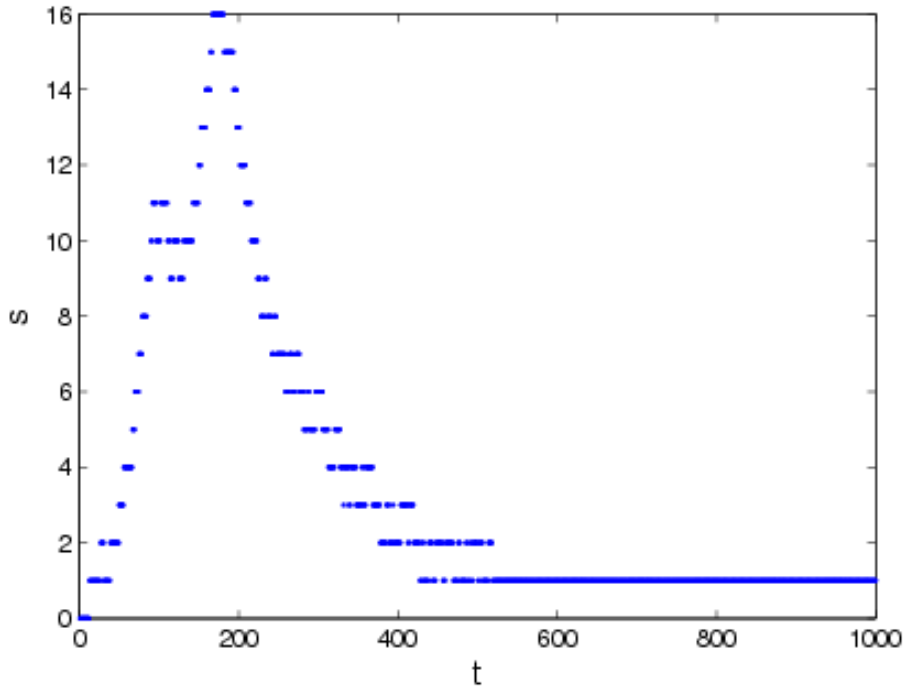

Figure 3: Evolution of the addictive state s when a self-evaluation process is introduced in decision making leading to natural recovery.

The results discussed in this Section have also been produced via numerical simulations which are available upon request to the interested reader.

Public policies towards addictive substances are targeted at reducing negative externalities (e.g. second hand smoke, social or familial discomfort connected to the addictive state) and social costs (e.g. alcohol related violence and crime, road accidents and extra costs to the health and social security system) that may occur as a consequence of addiction.

If consumers are sometimes rational and sometimes driven by cue-triggered mistakes, traditional public policy approaches, i.e. regulation *versus* incentives, may produce undesirable results. While strict regulation or prohibition may be mostly effective and discourage consumption in rational individuals by raising the monetary and non-monetary costs of consumption, they are not effective if addiction is induced by cue-triggered mistakes. In this case such measures only raise the costs of consumption without reaching the target of reducing it. Similar considerations apply to tax policies. While price increases of legal addictive substances (such as alcohol and tobacco) may induce a reduction of demand in rational people, they only raise the costs of consumption if this is driven by compulsive choices. Thus both criminalization and taxation may be socially counterproductive and ineffective at reaching their goals, because those who become addicted incur higher monetary costs, but do not reduce consumption.

Such conclusions, however, are modified if spontaneous remittance, i.e. spontaneous cessation of consumption, occurs through increased awareness of future expected costs and through learning from past experiences. In this case cognitive policies, education and information campaigns or a combination of them may be best suited to activate cognitive control mechanisms, but more

traditional approaches such as regulation and taxation still play an important role.

Cognitive therapies may help consumers to activate a process of self evaluation that raises the value of the future negative consequences of addiction thus reinforcing the motivation to change habits. Education may also help identifying the social, health and psychological consequences of substance abuse increasing the present value of uncertain and remote future costs. As Trosclair *et al.* (2002) have emphasized, more educated individuals are far more likely to quit smoking successfully, for instance, as education helps activating the competing "cognitive incentives" necessary to override the HFM. Therefore, we believe that education campaigns may be effective, to some extent, in reducing consumption even among those already addicted and not only as a prevention policy to discourage initial experimentation. Even though education and information campaigns may not alter the mechanism through which individuals engage in compulsive use (i.e. the HFM), they may help activating the competing cognitive incentive mechanisms which trigger a process of self evaluation.

Regulation and/or taxation may also play this role, because they increase the monetary and non monetary costs of future consumption as well as of current one. Once a process of self evaluation has been activated, even more traditional policy measures may be of help in carrying out the mechanisms of self appraisal which may lead to spontaneous quitting.

Policy strategies could be differentiated according to the age profile of addicts. If natural recovery is the result of two mechanisms: a physical maturation process combined with increased awareness of the negative consequences of past, current and future substance abuse, then those policy measures that may have a positive impact on I_0 and γ should be addressed to the youngest groups of consumers to compensate for the lack of maturity which, at older ages, may spontaneously activate the mechanisms triggering remission from addiction.

Allowing for cue-triggered mistakes greatly improves our understanding of the phenomenon of addiction and also leads to counter intuitive policy implications. However, our explanation of spontaneous remittance recovers an important role for cognitive processes and rational decision making, because when the DM becomes increasingly aware of the costs and benefits of addiction he may start a process of self-appraisal that, eventually, can successfully overcome its hedonic impulses to use.

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