Evolution meets biopsychosociality: an analysis of addictive behavior

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ABSTRACT

Evolutionary theory can inform the biopsychosocial approach to addictive behavior through the use of adaptationist thinking, or how natural selection has shaped the mechanisms and processes underlying addiction. Covering how evolutionary theory relates to biology, psychology and sociality, this paper examines three components to drug use and abuse: a biological mechanism (mesolimbic dopamine), a developmental trajectory (attachment) and a social phylogeny (dominance, submission, social dependence). The paper argues for a salience (or wanting) view of the function of dopamine; outlines how attachment affects time perspective, closure of internal models and self-regulation; and examines how inequality affects drug abuse and how social dependence and manipulative behaviors can play a role in relationships with drugs. The article concludes with an analysis of how the adaptive approach applies to interventions against addictive behavior.

KEYWORDS Adaptation, addiction, attachment, biopsychosocial approach, dominance, dopamine, evolutionary psychology, evolutionary theory, individual development, reward, risk and protective factors, salience, self-regulation, social dependence, social inequality, substance abuse, time preference.

AN EVOLUTIONARY FRAMEWORK

In applying evolutionary theory to addictive behavior, a central contradiction is faced: evolutionary arguments generally rely on how a certain trait or behavior benefits an organism, but it is obvious that addictive behavior ends up causing great harm to the individual. One way out of this problem is to use an approach that focuses on evolutionary adaptations (Pittendrigh 1958; Williams 1985; Thornhill 1990; for addiction, see Smith 1999 and Nesse 1994). Simply put, rather than looking at the present costs and benefits of a behavior, one can analyze how certain traits and behaviors have been shaped previously by natural selection.

Evolutionary adaptations have emerged as solutions to how an organism can grow and reproduce successfully in its environment (Lewontin 1978; Rose & Lauder 1996; Cronk, Chagnon & Irons 2000). As solutions, they have been shaped by natural selection to accomplish important functions that improve the organism's fitness—the number of genetic copies (or more generally offspring) one leaves in the next generation. When applied to humans, the adaptationist approach interprets human behavior as the execution of adaptations, rather than simple pursuit of greater fitness (Barkow, Cosmides & Tooby 1992; Cosmides & Tooby 1995; Crawford & Krebs 1998). For humans who abuse drugs, therefore, examining the adaptive mechanisms or processes that underlie addictive behavior will prove more fruitful when applying evolutionary theory than a simple cost–benefit approach.

However, within evolutionary biology, it is clear that adaptive thinking does not provide a complete explanation of any behavior or trait. Rather, as Tinbergen (1963) argued, a complete biological explanation utilizes four types of data: a biological mechanism, an adaptive function, a developmental trajectory and a phylogenetic (or

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evolutionary) history. To strengthen our evolutionary analysis of addiction, we will adapt this approach by: (1) analyzing a central biological mechanism in drug abuse, the mesolimbic dopamine system; (2) examining the development of self-regulation and attachment; and (3) exploring the phylogenetic basis of dominance, social inequality and social dependence. In each area, adaptive considerations will show how the centerpiece of evolutionary theory—the process of natural selection—can help us to build a more complete view of addictive behavior. Moreover, by specifically focusing on a *biological* mechanism, *psychological* development and *social* behavior, this paper aims to incorporate the insight of the biopsychosocial paradigm—that addiction is about more than biology, psychology or sociality on their own (Donovan 1988; Muisener 1994; Pandina & Johnson 1999)—while demonstrating the broad relevance of an evolutionary approach.

DOPAMINE AND ADAPTATION

Dopamine: reward or salience?

As basic biological research progresses, it is becoming increasingly important to move beyond the 'how it works' approach to 'what it does'. In other words, without understanding the adaptive function of biological mechanisms, basic biological research results as very detailed description without sufficient understanding of what a certain system accomplishes and why. The concept of adaptation combines 'how it works' with 'what it does' through focusing on how specific processes and mechanisms solve evolutionary problems.

The mesolimbic dopamine system is a principal neurological system involved in drug abuse, and researchers are now moving to 'what dopamine does' in its role in abuse. Two approaches have emerged—the reward model and the salience model. The difference in these two perspectives is that reward is seen to reinforce directly the stimulus in question, whereas salience imbues the stimulus with 'wanting'.

The dopamine-for-reward (DFR) view is the more prominent and popular view and often emphasizes subjective pleasure: 'the mesolimbic dopamine circuit is a hard-wired system in the brain . . . that provides pleasure in the process of rewarding certain behavior' (Blum *et al.* 1996). Here, the proposed adaptive function is to provide pleasure. As an evolutionary argument, DFR suffers from the problems of 'just-so' stories (Gould & Lewontin 1979). Based on our anthropomorphic view, pleasure is assumed to be necessary for reinforcement, and reinforcement in turn accounts for the complexity of animal behavior. The pleasure of reward acts 'just so'—it is hard-wired and a direct result of processing.

Recent research has refined the DFR paradigm by using a mechanistic approach emphasizing information processing (Schultz 1997; Schultz 1998). The improved-dopamine-for-reward (IDFR) argues that the function of the dopamine system is to signal reward. This reward signal can also provide a teaching error, based on discrepancies between expected and actual patterns of neuronal firing (Schultz *et al.* 1997). While the assumed function of 'pleasure' (a hypothetical adaptive reinforcer) has moved onto research-based functional considerations, there are a number of problems with the IDFR hypothesis. First, dopamine is involved not just in positive reinforcement but also negative reinforcement (Berridge & Robinson 1998). Secondly, dopamine systems appear not to have a unitary function such as reward, but varied impacts on the central nervous system depending on dopamine's neuromodulating role (Redgrave, Prescott & Gurney 1999) and its actual effect on target cells (Jaber *et al.* 1996). Thirdly, the IDFR hypothesis of a dopamine teaching signal has another, alternative interpretation—reallocation of attention (Redgrave *et al.* 1999). Rather than signaling error, this short-latency dopamine signal (which is comparatively stereotyped and occurs in both hemispheres) serves to switch the organism from one behavior to another.

In general, the reward approach also fails to explain several things about drug addiction (Robinson & Berridge 1993). First, there is no clear relationship between subjective pleasure and addictive potential, as is seen with nicotine. Secondly, pleasure alone does not explain why individuals continue to pursue drugs despite severe negative consequences. In the simple contingency of reinforcement, the negative should outweigh the positive. Finally, in experimental paradigms, individuals who have previously used drugs will maintain drug self-administration in the absence of any experience of subjective pleasure.

Given these difficulties, Robinson & Berridge (1993) proposed that dopamine mediates incentive salience (IS). Incentive salience is not about reward, but wanting. Through the action of the dopamine system, stimuli attributed with incentive salience become attractive and demand attention (they are 'important'). Moreover, the activation of dopamine is associated with appetitive and seeking behavior by the organism (as versus consummatory and satiatory behavior). Together, importance and seeking comprise wanting—with the mediation of wanting being the adaptively evolved function of the dopamine system (Nesse & Berridge 1997).

Other researchers are coming to similar conclusions about the role of dopamine in reinforcement (Di Chiara 1995; Pihl & Peterson 1995) and argue that the dopamine system imbues cues for reward with IS which then results in appetitive/approach behavior, but never in

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satiation. Pihl & Peterson's (1995) analogy between salience and money is illuminating in this sense: 'You can't eat it, or drink it, and it will not quell loneliness. However, because it is exchangeable for virtually any satiating agent, it is the (abstract) ultimate in promise'.

Overall, then, IS argues that rather than a hard-wired system, dopamine works within an integrated system and mediates only a part of behavioral decision-making. As an arousal system, the dopamine system has direct effects on attention (Robbins *et al.* 1998), for by imbuing sensations with salience, individuals are motivated to seek them. This part—salience—is crucial to the loss-of-control in drug addiction, for dopamine mediates the compulsive wanting around drug abuse without signaling satiation (stopping). Thus, the IS hypothesis offers a better explanation than either the DFR or the IDFR models in relation to a central risk-factor cluster for drug abuse that involves emotional and behavioral arousal, self-regulation difficulties, impulsivity and sensation seeking (Glantz & Pickens 1992).

Salience and context: maladaptive possibilities

If the IS system is adapted, why then can there be such maladaptive outcomes? In an adaptationist argument, it is important to look at the component processes of a single evolutionary function (e.g. vision, where eye, nerve connections and brain come together (Marr 1988)), with the corollary that one cannot place too many functions on any single component. The mesolimbic dopamine system does not support all the functions that go into reinforcement and decision-making (Rodriguez & Navarro 1998). However, through its role in salience attribution, dopamine affects other neurological processes such as attention and memory (Wilson & Gottman 1996; Izquierdo & Medina 1997; Cahill & McGaugh 1998; Robbins *et al.* 1998). This combination of specific function and broad effects on other neurological processes sets the stage for possible maladaptive outcomes under the influence of drugs.

Classical conditioning offers a conceptual framework to understand how the brain can be 'tricked' by ingestion of psychoactive drugs. In this framework, unconditioned stimuli are those that occur through reflexive, natural responses (i.e. are not affected by conditioning). As argued by Ramsay & Woods (1997), this implies that it is wrong to label the drug itself as the unconditioned stimulus. Rather, the drug effects—the disturbances at some level of the nervous system—form the unconditioned stimuli, for these result in automatic or reflexive responses. Psychoactive drugs, through their action on the mesolimbic dopamine system, produce an unconditioned stimulus—a salience signal. This drug-induced signal, since it is internally and reflexively generated within the brain, then appears normal to other brain systems of the brain, and results in the expression of behavioral patterns that are often considered adaptive.

In conjunction with the implicit and automatic functioning of the dopamine system, one neurological process—provision of associative context—has a powerful role in shaping the expression of seeking behavior (Robinson & Berridge 1993). Associative context is the internal configuration of situational stimuli (the brain's representation of relevant environmental information), and shapes salience attribution through its gating/selective role. For example, associative context can match salience to representations of external stimuli related to drug intake such as drug paraphernalia and past environments, and even internal states that both precede (e.g. boredom, anxiety) and follow (e.g. reward, pleasure) drug ingestion.

The prefrontal cortex is a central neurological area mediating associative context, and can exert top-down control through its multimodal representation of context (or information needed to direct behavior), thus directly affecting selection and attention processes (Miller 1999). The prefrontal context embodies somatic markers that are 'acquired by experience . . . and are under the influence of an external set of circumstances which include not only entities and events with which the organism most interacts, but also social conventions and ethical rules' (Damasio 1994). Thus, the prefrontal cortices indirectly regulate the mesolimbic dopamine system through the directives of associative context that integrate salience into behavior. These contexts, through top-down control, enhance the reflexive provisioning of salience, and can thus prompt the 'heightened want'—or craving—a sensitized dopamine system can be produced.

In contrast to this functional argument, some argue that the maintenance of homeostasis through down-regulation and cellular adaptation provides an explanation of drug abuse (Nestler & Aghajanian 1997). Indeed, these changes are part of the explanation, but need to be coupled with the impact of drugs on the *adaptive* function of the dopamine system. With heavy drug exposure, dopamine cells downregulate their activity, building tolerance. However, these same cells continue to automatically fulfill their evolved function and, given prefrontal control of context, the same salience signal is expected. Thus, the dopamine system is caught in conflicting demands: excessive activation by exogenous drugs leads to down-regulation of cellular sensitivity, yet at the same time the dopamine cells tend to activate themselves more to maintain the expected signal. This twofold process (changes in cellular functioning, maintenance of adaptive signal) provides a powerful explanation for the common observation that more and more drugs need to be taken to produce the same subjective effect. Often

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thought to depend entirely on pharmacological tolerance, the loss-of-subjective-effect seen with continued drug use depends on both the cellular and adaptive functioning of the dopamine system.

Salience and design

Given the possibilities for maladaptive outcomes, why did evolution fail to provide some sort of precise regulation of the dopamine system, much as has happened with other systems like level of oxygen in the blood or rate of blood flow through the heart? Why is there not some 'maladaptive salience detection device' hard-wired into the dopamine system?

The answer is found in our evolutionary history. The natural distribution of resources in past environments provided three regular outcomes. First, psychoactive drugs were available in small quantities (e.g. fermented fruit), and thus their effects on the mesolimbic dopamine system were short-lived, intermittent and of low intensity—not effects likely to have an evolutionary impact. Secondly, there was simple limitation of general resources in the environment. Thirdly, when exploiting a resource patch, an organism reached a point of diminishing returns. In other words, at some point environmental resources became depleted and continued approach behavior no longer made cost-benefit sense. Therefore, given resource limitation in the ancestral environment (drug or otherwise), there was little pressure on the mesolimbic system to have an in-built regulator because excessive signaling of salience was rarely a problem.

Environmental self-limitation had an impact on the evolutionary design of the salience system that helps to explain why the salience system can signal continual approach behavior. To produce a more effective design, it often makes sense to take advantage of regular aspects of the environment, such as how information is provided or the environment is patterned (Clark 1997). First, this results in a closer coupling between environment and organism through an expectant design (one that expects a specific type of environmental input to enhance its own functioning). Moreover, by not programming everything into the 'design', selection builds a cheaper (incomplete) design (Dennett 1995; Dawkins & Dennett 1999).

Through expectant and incomplete design, the dopamine system can rely on the environment to moderate its signaling. When the environment no longer provides the same resource return (either through resource exhaustion for high-quality resources, or resource depletion to a point of diminishing returns for low-quality resources), the dopamine system no longer provides 'stay-engaged' and 'keep-seeking' signals. This is particularly true for organisms that have evolved in patchy environments, where resources are not continually distributed (such as sunlight for plants or plant material for some herbivores), but rather vary in quality, ease of access and amount. Our hunter-gatherer ancestors evolved in this type of environment, where determining how long to stay in a particular patch of resources versus seeking a new one was a crucial problem. The implication is that humans, along with many organisms, do not engage systematically in explicit consideration of behavioral options (i.e. a rational cost–benefit approach), but rely at times on the environment to be the limiting factor for approach behavior.

However, in today's abundant environment, this evolutionary design appears to be no longer fully adaptive. Yet this design appears to have significant heritability (as seen in drug abuse: Vanyukov & Tarter 2000; Anthenelli & Schuckit 1998) and can be particularly damaging for those individuals who have more sensitive dopamine systems due to natural variation (Cravchik & Goldman 2000). In these individuals, the pharmacological impact of the drug will produce a larger reaction in the dopamine system, thus imbuing drugs—as cues—with greater salience and seeking. When this is coupled with an environment that is not self-limiting, and indeed can favor maladaptive outcomes, the overall effect can be highly damaging.

The impact of environment

To understand how this happens, it is important to recognize that today's environment is vastly different from the environment we evolved in—generally called the environment of evolutionary adaptedness (EEA) (Foley 1995; Irons 1998). Since adaptations evolve through the slow, generational process of selection, they do not always match an organism's environment, especially one changing as rapidly as our modern one. Thus, today, psychoactive drugs come in concentrations far beyond those seen over our evolutionary history, and are generally used in environments vastly different from those of our hunter-gatherer past. Given cultural environments that reinforce the local benefits of drugs use (including lifestyles based on use) (Zinberg 1984; Stephens 1991; Alasuutari 1992) and environments that promote adjunctive behavior (the abuse of one substance due to regular limitation of another) (Falk 1998), the modern world provides a 'configuration of situational stimuli' that provides a positive associative context for the salience signals produced by drugs.

To understand this process better in today's environment, the IS model (including context and incomplete design) can be coupled with early biopsychosocial arguments. Peele (1985) stressed that addiction is to an experience constructed jointly from pharmacological,

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individual and socio-cultural sources—an experience that is the interactive product of social learning involving physiological events as they are interpreted, labeled and given meaning by the individual (Lindesmith 1968). Rather than inherently rewarding physiological events based on subjective pleasure, the IS model brings unconditioned physiological events (salience) together with context—the interpretation, labeling and meaning-making—in the construction of what individuals want. Social and cultural factors then become operative in the way they construct and pattern the environment. Given wide drug availability and cultural situations which favor drug involvement, the environment often promotes continued approach behavior. In this way, other experiences such as sex and gambling can become addictive, since the environment itself can provoke stimulation of the dopamine system through the way environmental regularities tap into the expectant design of the brain.

Unconventionality provides an example of how this happens. Individuals involved with traditional value-oriented institutions (e.g. religious institutions, school) are at lower risk for drug use, while 'the most powerful predictors of more frequent drug use are the unconventionality variables, namely sensation seeking, rebelliousness, tolerance of deviance and low school achievement' (Brook & Brook 1996). A crucial distinction between conventionality and unconventionality is between present and future—something that context mediates. Traditional institutions emphasize restraint, long-term investment and security. These offer few immediately available resources, thus 'conventionality' has few benefits in the short term. For many (e.g. those with low attachment), the world is not a secure place, and it makes more sense to maximize short-term benefits. The short term is highlighted through salience—immediate commodities such as drugs seize attention, they are desired.

Another example where salience, context and design come together is relapse. Three situations relate to relapse: (1) negative emotional states like anxiety, (2) interpersonal conflicts with related feelings of frustration and anger and (3) social pressure and being in a context where addictive behavior previously occurred (Marlatt & Gordon 1985). In each situation, the context emphasizes movement towards something believed to be positive—amelioration of negative internal and interpersonal feelings and a once highly desired behavioral sequence. Given this context, the person desires the state drugs seem to provide, even if the resultant state is actually not rewarding. Thus, the immediate determinant is not rational consideration of the situation—indeed, relapse is often dreaded—but the sudden surge in 'wanting' that results from the context. Without a reflexive way to manage this, relapse can result.

DEVELOPMENT AND REGULATION

Given the in-built risks due to the functional design of the dopamine system, environmental impacts that heighten risk deserve special attention. One of the major developmental risks is suboptimal care from parents. For example, parental attachment, parental monitoring, substance abuse by parents and abusive behavior directed at the child have been shown to impact the development of substance abuse (Brook *et al.* 1990; Hawke, Jainchill & De Leon 2000; Hops *et al.* 2000). In applying the adaptive approach to what happens in development, it is important to pay attention to possible mechanisms and processes that have been shaped by natural selection. In this section, the focus will be on how parental care and attachment influence the development of time perspective, internal models and self regulation. These largely cognitive processes appear to be localized in the prefrontal cortex, precisely the site that provides contextual information to the dopamine system (Davidson 2000; Schore 2000, 1996), and they can all play a role in 'executive cognitive function' (cognitive constructs involved in the self-regulation of goal-directed behavior) that significantly affects substance abuse (Giancola & Tarter 1999).

Attachment and context: time preference and closed models

Attachment affects the internalization of environmental context. For example, a strong parent–child relationship is associated with the child's internalization of parental norms and values—thus mediating unconventionality (Brook & Brook 1996). Moreover, attachment provides 'design-for-free'—the parental relationship provides information about the environment. Chisholm (1996) has argued that children's attachment strategies have been shaped by natural selection so that when irregular care is being received, children become insecurely attached because it makes more sense to focus on short-term growth and survival than to engage in resource solicitation from non-responsive and potentially dangerous parents. Chisholm (1999) then argues that time perspective—mediated by internal working models derived from attachment—is a major proximate mechanism mediating this shift in life-history strategy.

Time preference is the degree to which an individual 'expects or prefers (consciously or not) to receive benefits, rewards, or consequences of action now, immediately—or later, sometime in the future' (Chisholm 1999). In suboptimal environments (especially those characterized by poor attachment), developing children will emphasize short-term strategies and risk-taking, as this proved adaptive in the past: 'When the future is dangerous or unpredictable the optimal strategy is (or was in the EEA)

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to discount it or devalue it at a high rate. Doing so makes immediate, short-term payoffs more attractive (because they are relatively more valuable). This in turn means that it would take impossibly high and guaranteed fertility (or success) in the future to compensate for foregoing some immediate opportunity (which, simply by virtue of its immediacy, becomes more attractive)' (Chisholm 1999). What outlines the virtue of immediacy is how children derive internal working models through attachment (Bowlby 1969; Shaver, Collins & Clark 1996), in particular how inconsistent, insensitive parenting leads to models that emphasize risk and uncertainty—or immediate time preference. In turn, an immediate time preference is significantly related to drug use (Keough, Zimbardo & Boyd 1999).

Attachment has another proximate effect through its impact on the receptivity of internal models. Crittenden (1990) proposes that open models are receptive to new information, while closed models rely on existing interpretations, precluding cognitive exploration of behavioral alternatives. Securely attached children generally have open models, while maltreated children have closed models (Cicchetti 1996a). Closure, here, has the adaptive effect of protecting against high stress which can significantly damage biological systems (De Kloet, Oitzl & Joels 1999; Markowitsch 1999). However, this closure can also lead to psychological problems—as closure is incorporated into development, it can result in the emergence of repetitive behavioral patterns based on rigid interpretation of incoming signals or their association with specific responses (Basch 1988; Pollack, Cicchetti & Klorman 1999; Miller, Green & Vales 1999).

Closed models affect drug use and abuse in three ways. Firstly, by being closed, an individual is at greater risk for unconventional behavior because the conventions of others (especially parents) are not internalized. This closure, conversely, increases the risk for drug use, for the powerful effects of drugs *internally* are exactly those stimuli that prove operative in a system closed to the outside. Secondly, as the individual begins to engage in drug use, closed models lead to an emphasis on repetition, heightening the risk of going from use to abuse. Thirdly, once abuse has started, closed systems severely affect an individual's ability to both clearly evaluate drug consumption and to explore other behavioral options.

Attachment and regulation

Problems in parent–child attachment are also related to drug use and abuse through the developmental impact on self-regulation (Brook, Whiteman & Finch 1993). Parents help children to modulate emotional states and reduce internal tension (Cicchetti *et al.* 1996b), due in prt to how the incomplete, expectant design produced by evolution provides for 'open' homeostasis sytems that permit partial parental regulation (Hofer 1994). This is adaptive because it allows closer matching—through the parent—of environmental patterns by the developing individual, as well as buffering against possible malfunctions in an immature system (Hofer 1994). However, some parents lack sensitivity and responsivity, failing to help with state modulation and tension reduction (Cicchetti 1996b). In these suboptimal attachment situations, emotional regulation involves inherent trade-offs and 'makes nonoptimal strategies of managing emotion expectable, perhaps inevitable, in a context of difficult environmental demands and conflicting emotional goals' (Thompson & Calkins 1996).

Worse, if trauma such as sexual abuse and maltreatment accompanies poor parental care, the effect on the child's ability to regulate arousal and emotion can be tremendous, due to both the disorganizing effects of overwhelming stress and the fear provoked by such terrible events (Cicchetti & Lynch 1993). For example, an abused child tries to withdraw from possible threat and overwhelming emotions, and also to be hypervigilant for the risk of further abuse.

Thus, when confronted by insensitive and damaging care, children will generally manage homeostasis and regulation on their own, rather than with the extra emotional support that parents can provide. This results in a fragile regulatory system, which is a major risk factor for substance abuse (Brown 1998). This can happen through poor emotion and attention regulation (Wilson & Gottman 1996) as well as difficulties in behavioral inhibition (Polivy 1998; Iacono *et al.* 1999). Moreover, this developmental approach is relevant to homeostatic theories of drug abuse (Koob & Le Moal 1997). The addictive experience provides regular, stimulating and controlling effects (Peele 1985), and compromised homeostatic systems can reorient around drug consumption. Thus, a person with compromised self-regulation due to poor parental care can find in drugs what has been missing but none the less was evolutionarily expected.

Life-history theory, deviance and adolescent drug abuse

Within evolution, life history theory predicts that children at higher risk of morbidity and mortality or with relatively less access to resources (i.e. at a relative evolutionary disadvantage) will mature more rapidly (Belsky, Steinberg & Draper 1991a,b), while adolescents facing these suboptimal conditions will take greater risks to gain an immediate evolutionary advantage (Wilson & Daly 1985). Often this risk-taking can consist of expensive or dangerous adult-like behavior such as early reproduction, high-risk resource acquisition (theft), fighting

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and competitions for status such as auto racing or gambling—in other words, general deviance.

Early attachment problems can set up this developmental trajectory. Poor attachment leads to an emphasis on uncertainty and risk, failure in maintaining open systems and less sophisticated cognitive strategies. Trauma places greater emphasis on immediate gains, further closure of models and compromised emotional regulation. These problems lead to adolescents adopting short-term facultative strategies and involvement in more mature (i.e., adult) and untraditional behaviors for resource acquisition and mating—while being compromised in the ability to handle these high-risk behaviors. Adolescents in these conditions often demonstrate a time preference focused on immediate issues, regulation that is internally fragile and susceptible to drugs and models of behavior that are closed to outside influences (such as teachers and law-enforcement officials). The result is high vulnerability to deviance and drug use and abuse.

SOCIALITY: ENVIRONMENT AND PHYLOGENY

Evolutionary theory and sociality

Group living occurs regularly when the individual fitness benefits of group living outweigh those of living alone. In these social groups, relationships are a principal source of benefits (e.g. gaining resources, lowering morbidity and mortality and increasing reproduction). One specific way that relationships increase fitness is through kin selection—helping individuals closely related to oneself (Hamilton 1964). Supporting family members in dominance interactions is an example of this. A second way in which social relationships increase evolutionary gain is through reciprocal altruism, where unrelated individuals exchange altruistic behaviors whose benefit outweighs the cost to each individual (Trivers 1971).

Group living is also important because local patterns of behavior (1) serve as a reference point, (2) strongly shape individual behavior and (3) are significant forces on biological systems. First, one's group is the local and determining scale of reference. Evolutionary success is not absolute but occurs relative to one's local group (Trivers 1985). For example, being successful with a group of ex-addicts or with one's family is different from being successful with friends down at the bar. Secondly, group living can provide local expertise and knowledge about adaptive traditions in one's local environment. For modern humans, local expertise is often transmitted through language and culture (Dunbar 1995). However, there is a negative side to social learning, seen in its impact on biological systems. For example, research on monkeys has shown that stressful events such as a hurricane have significant effects on the offspring of those individuals that experienced the event—thus, stress can have a transgenerational effect in animals and humans (Abrams 1999; Suomi & Levine 1998).

Families, peers and neighborhoods

The family, by acting as a local frame of reference and significant source of social learning for the developing child, has a large impact on the internalization of context. Early exposure to parental drug use can create a context that highlights the positive aspects of drug use, the importance of immediate payoffs and the inhibition of regulatory mechanisms, which helps to explain the significant link between parent and offspring substance abuse (Kilpatrick *et al.* 2000; Pickens *et al.* 2001). Moreover, social inequality has an impact on the quality of child care (Chisholm 1999). Parents with fewer resources in more stressful environments generally provide less consistent and sensitive care, with the subsequent detrimental effects on the child.

'Bad' friends and friends who use drugs are both risk factors for drug use (Glantz & Pickens 1992) because they place drug use in a normal and attractive context. Peer drug use also impacts individual drug use through choice of peers (Brook & Brook 1996). This peer selection acts as a form of niche selection. By occupying niches, individuals and groups create trajectories through the social landscape where competition is lower and/or locally successful strategies are monopolized (Thalhofer 1993; Sulloway 1995). Environmental niches then have a powerful reciprocal effect on individual development and behavior (Gottlieb 1991; Odling-Smee 1988), especially for adolescent drug use which generally takes place in peer clusters consisting of good or best friends (Oetting & Beauvais 1987).

The phylogeny of dependence: implications for addiction

With the evolution of social groups, some individuals quickly took advantage of the benefits of being dominant (e.g. high reproductive success, disproportionate access to resources). Others became subordinate to avoid engaging in aggressive behavior and its resultant injuries while still keeping the benefits of group membership (e.g. protection from predators). Thus, with the evolution of dominance and submission, dominant individuals and groups could exclude others from valued resources, monopolize relationships with other successful individuals and by direct and indirect aggression heighten morbidity and mortality for subordinates (Trivers 1985). The inequality of these living conditions—through both

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general stress and through favoring short-term strategies by nondominant individuals—can have a significant impact on drug abuse. For example, this is seen in the high rates of drug use and abuse in disadvantaged and marginalized communities (Kamien 1986; Currie 1993; Smyth & Kost 1998).

Besides general stress and favored short-term strategies, there is another way being non-dominant can affect drug abuse. To understand how, it is important to examine the evolutionary history of social behavior in groups. In past social groups, subordinate individuals faced reduced reproductive success in comparison to dominant individuals (Ellis 1995; Smith 1993). Thus, strong selection pressure emerged to find ways to ameliorate the costs and increase the benefits of being non-dominant. To pose the selection pressure as a question, what could the non-dominant animal do to turn this situation to its advantage?

The answer is social dependence. Similar to a child benefiting from parental dependence, a subordinate individual can attempt to establish a socially dependent relationship with a dominant. This relationship is marked by non-confrontational interactions with the dominant partner where one supports (or appears to support) the dominant individual while working to extract greater benefits from the relationship (Western & Strum 1983; van Hoof 1994). Social dependence provides four types of benefits: (1) manipulating the dominant individual; (2) creating an ally and further reducing aggressive behaviors; (3) promoting close interaction between the two individuals, thus favoring reciprocal altruism; and (4) using other types of evolved behaviors (e.g. appeasement, parent–offspring interactions) to engage in a sort of social parasitism through resource extraction. Thus, dependence behavior draws on deception and social manipulation which are significant parts of social behavior in many animals (Whiten & Byrne 1997, 1988).

In ways similar to arguments relating 'yielding' (submissive) behavior by subordinates to depression (Price & Sloman 1987; Price *et al.* 1994), dependence behavior can relate to certain types of addictive behavior—most clearly those involving the emergence of abuse later in the life-time and often accompanied by depressive-like symptoms (versus an earlier, more sensation-seeking type) (Cloninger 1987; Zucker, Fitzgerald & Moses 1996). In these individuals, drugs often offer an escape, generally from negative and depressive feelings and/or difficult, frustrating and stressful situations (Cooper *et al.* 1995; Kreek & Koob 1998). In general, these individuals do not engage consciously in dependent behavior with drugs, but rather fall into it as they personalize the relationship with the drug and project learned dependent patterns onto it. As addicts build a close association with a drug, rather than recognize the negative effects of their relationship, they will focus on the personal benefits of drug use—such as the release from depressive feelings.

The argument is bolstered by the three types of evidence: first, in some cases, drug abuse is related to unequal social and economic conditions (Currie 1993; Bourgois 1995); secondly, humans have the ability to displace patterns derived from interpersonal behavior onto objects (Krystal 1994; Smith 1990); and thirdly, addicts tend to personalize their relationships with drugs, often through symbolism (Alasuutari 1992; Anderson 1994). Thus, as addicts lend human qualities to drugs and project patterns of behavior from other areas of their life onto this object, their behavior will tend to build off the evolved foundation of social dependence.

An example of this can be derived from Bateson's (1972) classic paper on alcoholics' struggle to alternatively assert their dominance over alcohol or submit to its power. Bateson saw only the dominance–submission dynamic, whereas in the phylogenetic framework developed here, individuals can also engage in dependent behavior. With dependence, manipulative and proximity behaviors (rather than avoidance and appeasement in submission) offer greater individual benefits than straight submission and its total loss of control, for example, by having an ally in drugs to help deal with everyday problems. Statements like 'I can control the drug' and 'I know when to stop' can be seen to reflect this dependent dynamic. Alcoholics Anonymous's emphasis on giving up control—first, struggling for dominance over the drug, then reverting to the evolutionary dependent relationship with alcohol—might actually be a powerful cognitive strategy to subvert this reliance on an ancient and evolved pattern of social behavior by concretely demonstrating that this type of behavioral pattern is not relevant to the situation with alcohol.

CONCLUSION

The adaptive approach taken in this paper illustrates several important things. First, the significant heritability seen in drug abuse can relate to diverse processes in different areas, from tolerance to specific drugs and individual sensitivity in the dopamine system to the effect of attachment on life history strategies and the role of evolutionary dependence in certain types of addictive behavior. Secondly, the adaptive approach provides a useful analytical framework when examining the specific function and effects of the mechanisms and processes underlying addiction. For example, with the dopamine system, the difference between cellular and adaptive functioning and the importance of the environment in shaping the functional design of the system both emerge from the use of adaptationist thinking.

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Finally, an evolutionary approach can help in the development of therapeutic and intervention efforts. Given the possibility for identification and prevention of early onset substance abuse (Anthenelli & Schuckit 1998), environmental interventions that improve general conditions for the developing child (both in the family and the larger local environment) are central to reducing the short-term and deviant strategies that early onset substance abusers often display. For therapy, tactics that deal with initial resistance due to deviance and psychological closure, such as motivational interviewing (Miller & Rollnick 1991), are likely to be effective, followed by more focused interventions to develop better self-regulation and longer-term behavioral and life strategies. Indeed, the strongest and most specific *evolutionary* suggestion this paper can make is that until interventions deal with the adaptive nature of the short-term life strategies individuals have developed, risk for substance abuse—given how drugs signal immediate salience—will remain high as individuals continue to seek short-term pay-offs.

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