

NEUROSCIENCE AND ADDICTION

Brains, environments, and policy responses to addiction

Reward and decision-making circuitry are critical

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With 1 in 8 deaths globally due to the use of tobacco, alcohol, and other drugs, the director-general of the World Health Organization (1) recently called for more scientifically informed public policies regarding addiction. In the United States, where an average of 91 people per day die of opioid overdose, a presidential task force is to present, on 27 June, policy recommendations to combat opioid addiction, although the House of Representatives passed an Affordable Care Act repeal bill that would withdraw health insurance from two million people with addictions. Despite these urgent challenges, research on the brain and its interactions with the environment, which can help policy-makers advance more effective and humane policies than some traditional approaches to addiction, has only occasionally been applied in public policy.

Neuroscientific research validates the centuries-old hypothesis that addiction lasts beyond acute intoxication, which suggests an enduring adaptation (2). Repeated addictive drug use can induce long-term changes in the brain's motivational and reward circuits, as well as in the ability of the prefrontal cortex to influence circuits that guide decision-making. The widespread practice of treating addiction only with short-term medical "detoxification" to help addicted patients cope with withdrawal symptoms—a policy reinforced by U.S. health insurance providers—serves only to remove the acute effects of the addictive substance rather than treat the disorder (and may also increase risk of future overdose by inducing loss of tolerance). Treating addiction more commonly requires longer-term in-

tervention, such as Alcoholics Anonymous, methadone-buprenorphine maintenance, "sober living" residential facilities, and extended case monitoring (3).

Motivational circuit alterations in addiction must be accounted for in health care-system design. Treatment programs that require people to "prove they are motivated" by abstaining for weeks or months before entry will fail most of the population, who relapse before that point. By contrast, contingency management programs that change behavior through the use of immediate, small rewards (e.g., a meal voucher for a negative urine test) have demonstrated impressive efficacy (3). Individuals with prefrontal cortex impairment can exert control over their substance use for short periods and for defined rewards as long as the clinical environment is properly structured.

Within the criminal justice system, the threat or experience of a long prison term does not remove addiction, but offender monitoring programs that directly and repeatedly offer modest rewards or penalties in response to cessation or continuation of substance use

can be effective (3). A good example is South Dakota's "24/7 Sobriety" program for individuals convicted of repeated drunk driving and other alcohol-involved offenses. Rather than being imprisoned for a lengthy period as was the norm before the program's initiation, offenders are sentenced to regular monitoring of their alcohol use, with modest but certain, immediate consequences for drinking (e.g., one night in jail). The human brain is more sensitive to swift and certain environment responses to behavior than to distant and probabilistic ones, which suggests why this program has significantly reduced alcohol-related arrests and population mortality in the state while simultaneously reducing the number of individuals being sent to prison for long terms (3).

SHAPED BY THE ENVIRONMENT

Explaining the rise of addiction in modern societies requires looking beyond the brain to the environments that shape it (2). Addiction can only occur if a person engages in certain behavior (drug consumption) within certain environments (those with an available drug). The worldwide challenge of rising substance addiction (3) reflects how the past two centuries have ushered in technology to produce ubiquitous, addictive substances. For example, in the mid-19th century, it took a factory worker about 1 minute to roll a cigarette, and the resulting product was so harsh that few people could inhale it deeply enough to become addicted to nicotine, presuming a person even lived in a region where cigarettes were available. A modern cigarette-rolling machine (see photo) can roll 20,000 cigarettes a minute. These are expertly sweetened and blended to allow deep inhalation that promotes nicotine addiction, and they are available almost everywhere on Earth (4).

Exposing the human brain's reward circuitry, which evolved over tens of thousands of years, to this relatively new and variegated stew of addictive substances has produced addiction on a scale that we have never before experienced. Now that these substances are among the most widely produced and traded commodities in the global economy, there is a strong financial incentive for both illegal and legal sellers to produce and market these substances ever more effectively. In an unfettered free market, availability will increase, which translates into increased exposure and addiction. These trends may be fueled by economic development, because as humans gain resources, they commonly allocate them to



Advances in technology, such as this cigarette-rolling machine, have helped make addictive substances ubiquitous, fueling rising addiction.

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psychoactive substances, as surging use of alcohol, tobacco, and other drugs in developing countries (e.g., China, India, South Africa, and Brazil) attests (5).

The policy implication is clear. Addiction will do massive and increasing damage to humanity if drugs with addictive liability are treated as ordinary commodities, with a lightly regulated free market left to sort out supply and demand (5). The “invisible hand” on which successful markets depend will fail if the organ upon which putatively wise consumer decision-making relies—the brain—becomes unreliable. The liability of the human brain to overvaluing addictive drugs relative to their adaptive worth is precisely what makes them attractive products to sell and is equally what gives society an interest in using as many policy tools as possible to make them less available and attractive (e.g., high taxes or constraints on industry).

For example, consider that all eight U.S. states that have legalized the sale of marijuana for recreational use tax it without regard to product content. Neuroscience research indicates that marijuana that is higher in δ^9 -tetrahydrocannabinol (THC) potency and lower in cannabidiol (CBD) is more harmful to the brain (6). A graduated tax based on THC:CBD ratios rather than sales price might encourage safer marijuana use.

Neuroscientific work on cue exposure suggests further regulatory strategies for protecting public health. With repeated use of addictive substances, previously neutral cues associated with the drug experience grow attractive in their own right, often generating powerful memories of and craving for another drug experience. Multiple sensory modes can activate the motivational circuits that stimulate appetitive behavior, and commercial marketing campaigns often seek to leverage this interplay of sensory and motivational circuits (7). Saturation of environments with rich multisensory cues (e.g., advertising campaigns for beer and cigarettes) raises the risk of continued drug use by addicted individuals. Conversely, drug use can be reduced by curbing promotion of products with addictive liability, including legal pharmaceuticals. Policy-makers might also consider regulating the combination of drugs with other already attractive sensory compounds, such as sugared cannabis-infused confections designed to look or taste like cookies or candies (8).

The highest period of vulnerability for development of addiction is when neuroplasticity is high and the prefrontal cortex has not fully developed, which neuroimaging research suggests is characteristic of humans before their early 20s (9). The resulting vulnerability is typically unimportant in early development (e.g., before age 12) when exposure to addictive substances is rare. However,

in modern industrial societies, adolescence tends to be associated with increased access to addictive substances, in part due to diminished contact with parents coupled with participation in a robust, free-standing peer culture (10). Adolescents are thus subject to two converging risks for addiction: the physiological reality of high neuroplasticity in motivational circuits and immaturity of control circuits combined with a social reality of expanded access to drugs of abuse (for some youth, genetic factors may add yet a third converging risk). This could explain why the incidence for substance-use problems clusters in adolescence and early adulthood (10). Policies that reduce access to substances and associated cues (e.g., advertising) during adolescence are thus of paramount importance.

Fortunately, adolescence is also charac-

“...as humans gain resources, they...allocate them to psychoactive substances...”

terized by emergence of reliable and valid neural measures that can help track not only brain changes due to drug intake but also predictors of vulnerability (11). This raises hope that in the future, neuroscience will inform policy-makers on how prevention and early intervention efforts can be targeted toward young people at particularly high risk for addiction.

Policies focused on reducing addiction need not all be substance-focused (1). Iceland has achieved a sustained drop in adolescent substance use in part through a national policy of expanding access to competing rewards, including recreational and cultural activities, as well as programs that strengthen family and civic ties (12). Primate and rat research suggests that positive social interactions may provide potent competition for the neural rewards of drug use and may be protective for adolescents and other vulnerable groups (13, 14).

TRANSLATING SCIENCE FOR POLICY

For neuroscience to make an impact on public policy, an active education and translation effort must occur. Translation efforts must involve active and tailored communication, as well as spell out implications (i.e., describe alternative policy options and their impact). Industries that are successful at translating science into policy and practice (e.g., pharmaceutical companies) rarely send their scientists into the political fray unaided and alone. They have dedicated staff whose job explicitly involves translation and who are resourced to adopt specialized tactics for so do-

ing. Resources for such activities are harder to find in efforts to translate neuroscience to drug policy, because federal government research funding focuses mainly on pure research, whereas private funders often are interested in a predetermined policy outcome (e.g., legalizing marijuana).

That said, some funders are willing to bring scientists, science translators, and policy-makers together. The MacArthur Foundation generously supported such an initiative for years in mental health, and the authors of this paper are part of a 5-year policy-maker-scientist network focused on addiction (Neurochoice). More efforts of this type are needed, with the most likely source of support coming from scientific societies, which are well positioned to serve as credible, non-partisan suppliers of information that make the personal contacts and translation efforts to put useful science in policy-makers' hands.

Even for some purely scientific policy-relevant questions, the relevant body of neuroscience may be less well developed or useful than is research in a different field, for example, genetics, psychology, or economics (15). But those realities in no way minimize neuroscience's potential to guide domestic and international leaders as they strive to tackle the addictions that afflict their populations. ■

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