Neuropsychology, Cognition and Behavior of Drug Addiction: a Non-monotonic Multiscale Computational Model.

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Drug addiction has a significant impact on our lives. The United Nations Office on Drugs and Crime estimated that in 2006 about 16 million people used cocaine and 12 million people used heroin at least once during the previous year. The World Health Organization estimated that there were about 76.3 million people worldwide with diagnosed alcohol use disorders in 2004 and about 1 billion smokers in 2002.

The present paper is concerned with computational modeling of addiction. Current models describe addiction as a monotonic process with positive feedback, a non-reversible process which cannot be overcome. But significant evidence indicates that addiction can be defeated. In 1962, Charles Winick reported on a large number of former addicts who ceased to take drugs. He called this phenomenon "a process of maturing out of narcotic addiction". Other evidence was subsequently reported which documented that addiction is reversible. Nowadays these are called "natural recoveries".

The current study presents a non-monotonic and reversible computational viewpoint of addiction, which is based upon studies involving mouse, rat, and human animal models. The techniques employed in these studies include cell culture, gene knockout, electrophysiology, MRI, and statistical surveys. A computational model is developed which combines neuropsychological, cognitive, and behavioral scales to characterize the behavior trajectories of an animal that becomes addicted, stays addicted, or overcomes addiction. The neuropsychological scale represents the effects of the neural activity on the animal addiction related stimuli perception. These encompass both internal and the external processes, which describe continuous and discrete events, respectively. The internal processes include the health-related pain, the negative emotional state, the dopamine-related craving, and the saliency of drug-associated cues. External processes include the painful traumas, the stressful episodes, the drug priming occasions, and the drug-associated cues. The cognitive scale represents the mediation between low and high level controls of addiction-related behavior by integrating and weighing the ongoing activity of the neuronal pattern. The behavioral scale consists of two different strategies of behavior, compulsion and inhibition, which work in parallel and compete for dominance in selecting the behavioral action.

Two experimental evaluations are presented and validated. The first simulation describes the profile of a college-age student, who becomes an addict, fails to overcome this maladaptive behavioral state, and shows relapse patterns. The second simulation is for a mature adult who, after a period with a high likelihood of drug-seeking behavior, succeeds to overcome addiction and return to a healthy and stable behavioral state.

The present model for addiction allows for both relapse and reversibility of the addictive state. Future work will include an additional step in the validation of the model, a more detailed dynamic analysis of its properties, and the integration of a further scale describing the processes of dopamine and glutamate receptors in the brain.

References

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