What's going on inside the head? Exploring the neurobiology of substance use and addiction

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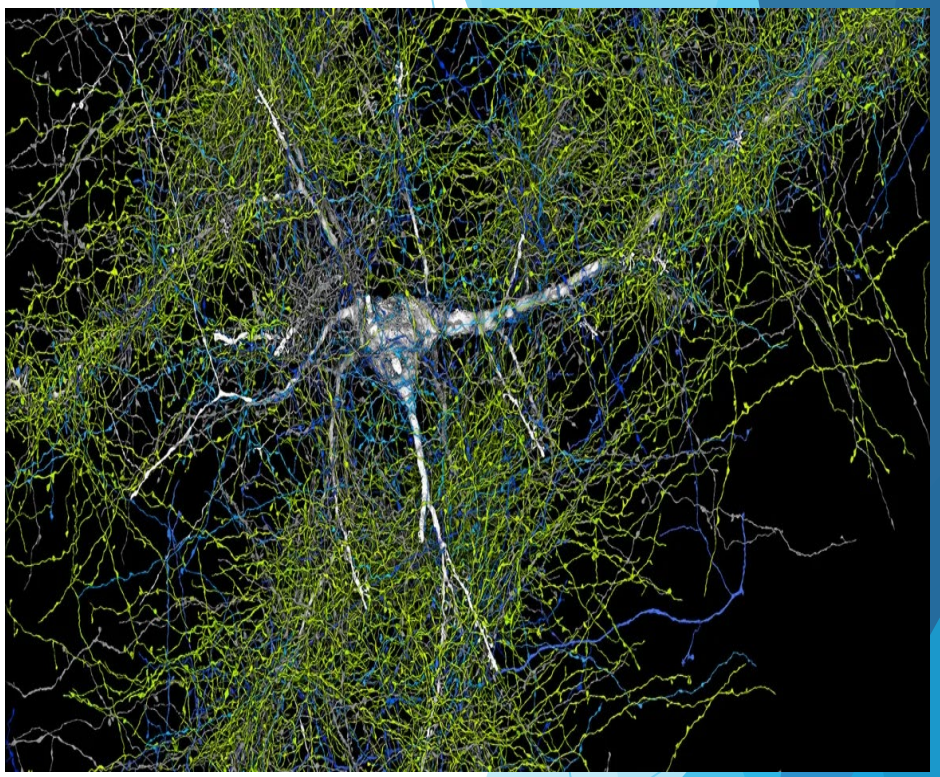
How the brain works

- The brain consists of billions of neurons
- Neurons transmit messages through electrical and chemical signals via neurotransmitters

  → Glutamate, GABA, Acetylcholine, Serotonin, Dopamine
- Neurons for structures which then work together as part of a network/pathway, controlling specific functions

  e.g movement, emotions, attention, physical activation, rest, pain, reward
- The brain seeks to maintain a state of balance (homeostasis)
- Adaptations can occur in response to changes in the internal and external environment (e.g psychoactive substances, injury, learning, experience)



From Google Research & Lichtman Lab/Harvard University (2024)

What we know about the brain

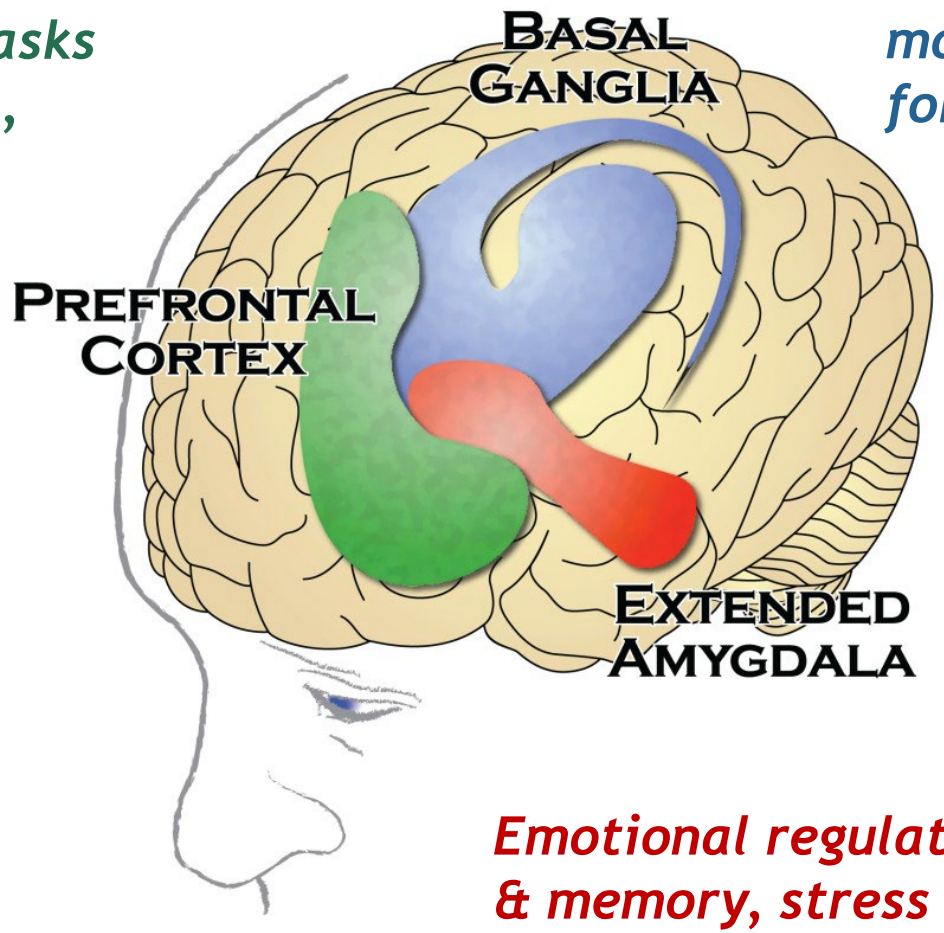
Evolution of FIFA Graphics (1993 - 2017)

From PlayGround Youtube Channel (2017)

Brain Structures and Networks Involved in Substance Use and Addiction

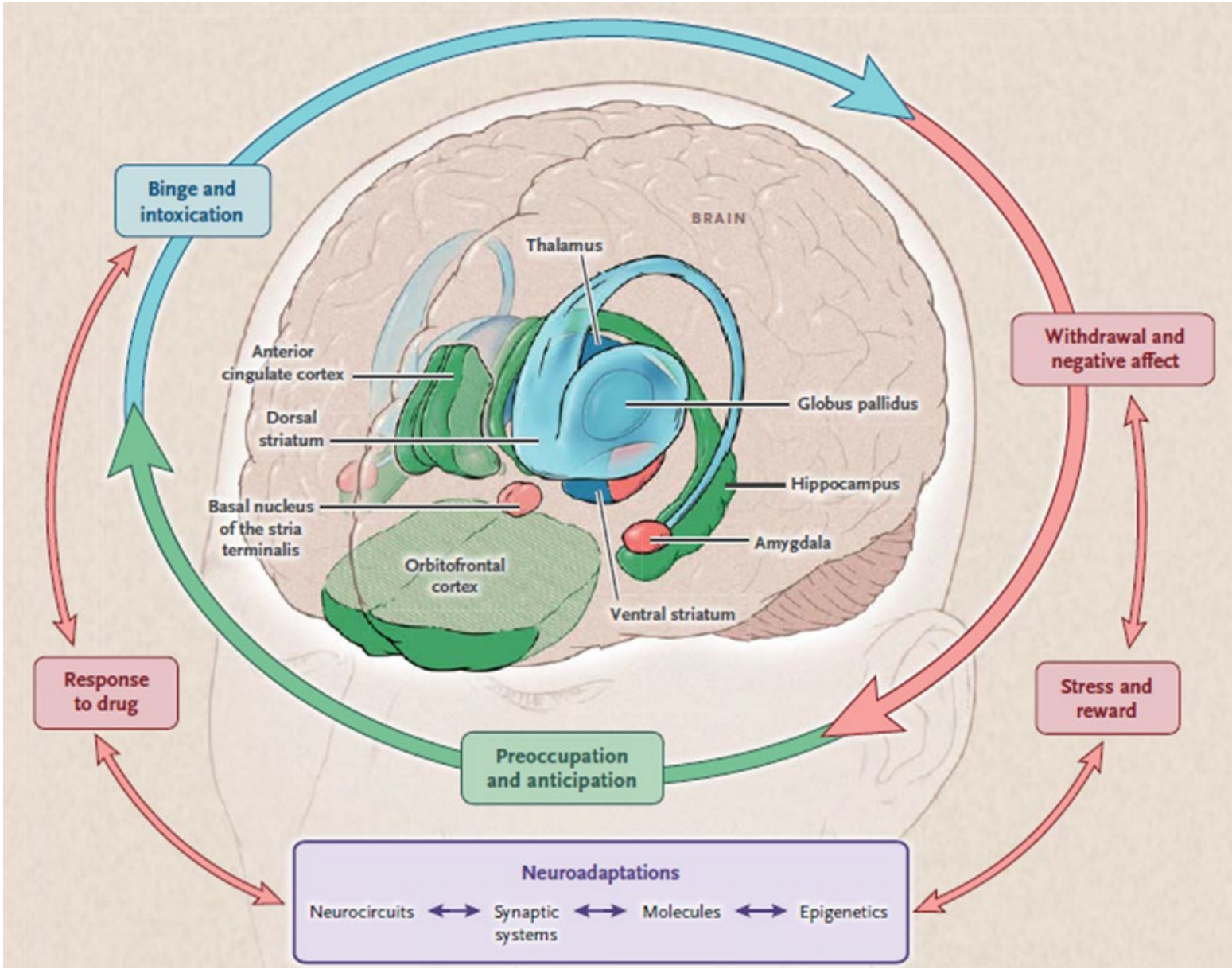
Complex cognitive tasks and decision-making, impulse control

Reward processing, motivation, habit formation/compulsion



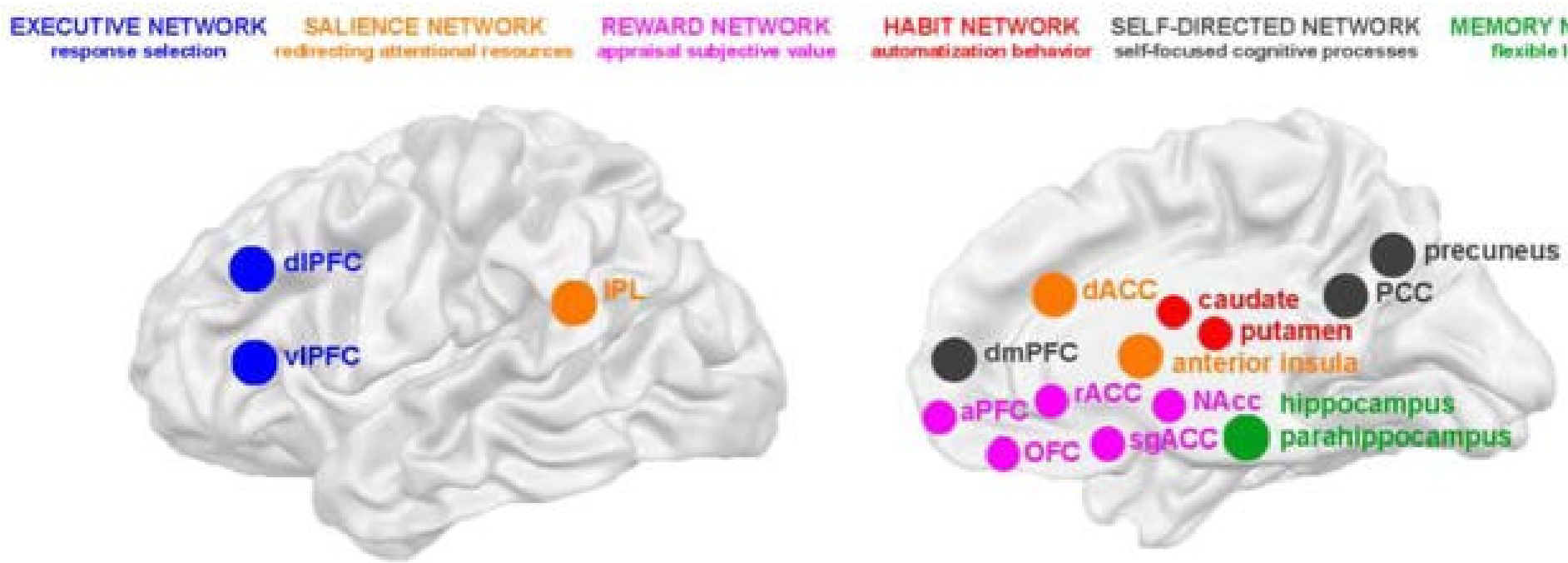
Emotional regulation (stress/fear) & memory, stress response

From Substance Abuse and Mental Health Services Administration (2016)



Conceptual Framework for Neurobiology of Addiction

From Volkow, Koob & McLellan, 2016



Aberrant brain networks in in individuals with addiction

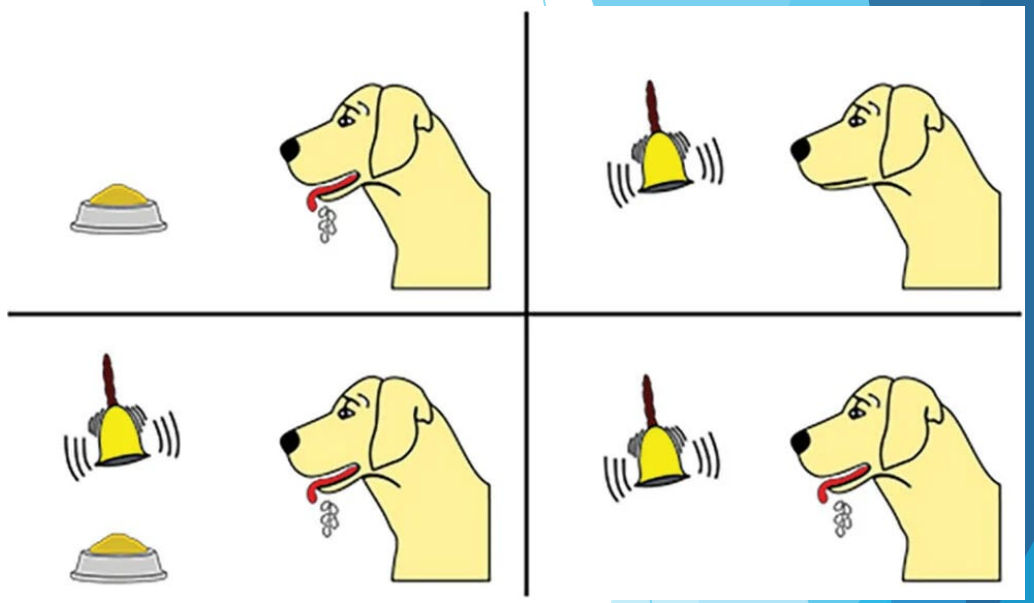
From Zilverstand, Huang et al (2019)

Binge/Intoxication

- Addictive substance act on receptors in the brain, which ↑ neurotransmitters (e.g dopamine) and leads to intoxication
- Continued use of substances reinforces this reward (+ve reinforcement)
- Activation of brain reward pathways via dopamine strengthens substance-seeking and substance taking

  = results in compulsion and habit formation
- Repeated substance use can condition the reward pathways to be activated in response to cues (conditioned response/ incentive salience)
- But not all people develop addiction even with regular use

  - genetic, neurodevelopment, social influences



Pavlov's Dogs Experiment and Pavlovian Conditioning Response

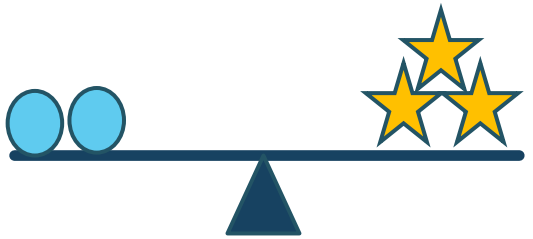
Fromwww.simplypsychology.org/pavlov.html

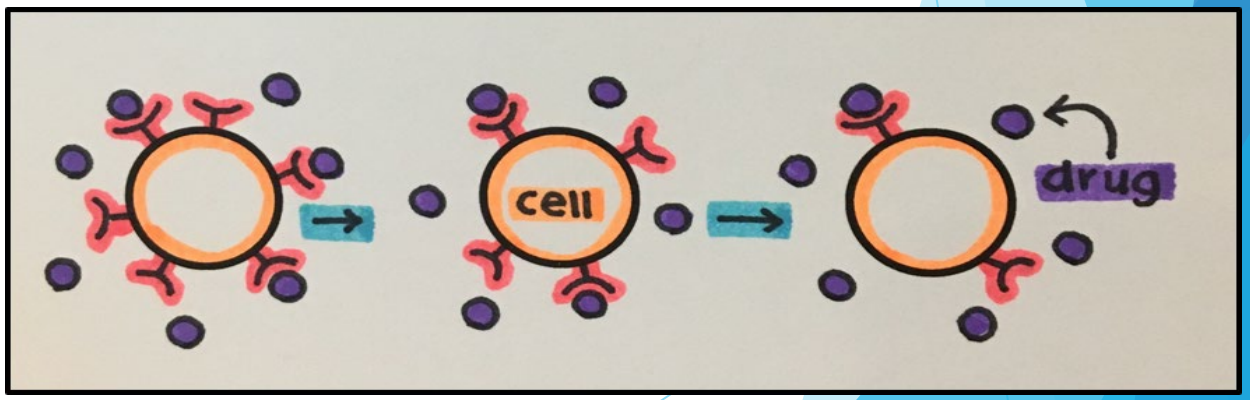
Tolerance

- Regular use of substances disrupts the neurochemical balance
- Brain adapts to imbalance by reducing the number and sensitivity of brain receptors (neuroadaptation)
- Tolerance develops

→ Need to take more substances to achieve the same effect

→ Reduced experience of pleasure/rewards from non-drug related activities





Downregulation of neuro-receptors with increased presence of drugs

From Principles of Pharmacology - Study Guide
Edited by Dr. Esam El-Fakahany and Becky Merkey

Withdrawals

- Resulting dopamine deficiency results in negative affect, anhedonia, amotivation
- Activation of Amygdala results in release of stress hormones from pituitary gland
- Cessation of drugs leads to a further neurochemical imbalance which results in physical withdrawal symptoms

Need to continue using substances to minimize withdrawal symptoms and reduce stress

→ Substances used compulsively to reduce –ve experiences (rather than impulsively use to achieve +ve experience)

Credit: colorfuelstudio // Depositphotos

Pre-occupation and Anticipation

Addiction results in alterations to brain networks → thoughts/urges to use. These can even persist during abstinence

- ***Memory and habit network***

Anticipation/learned response to substances. Cues/reminders of substance use result in strong cravings

- ***Reward network***

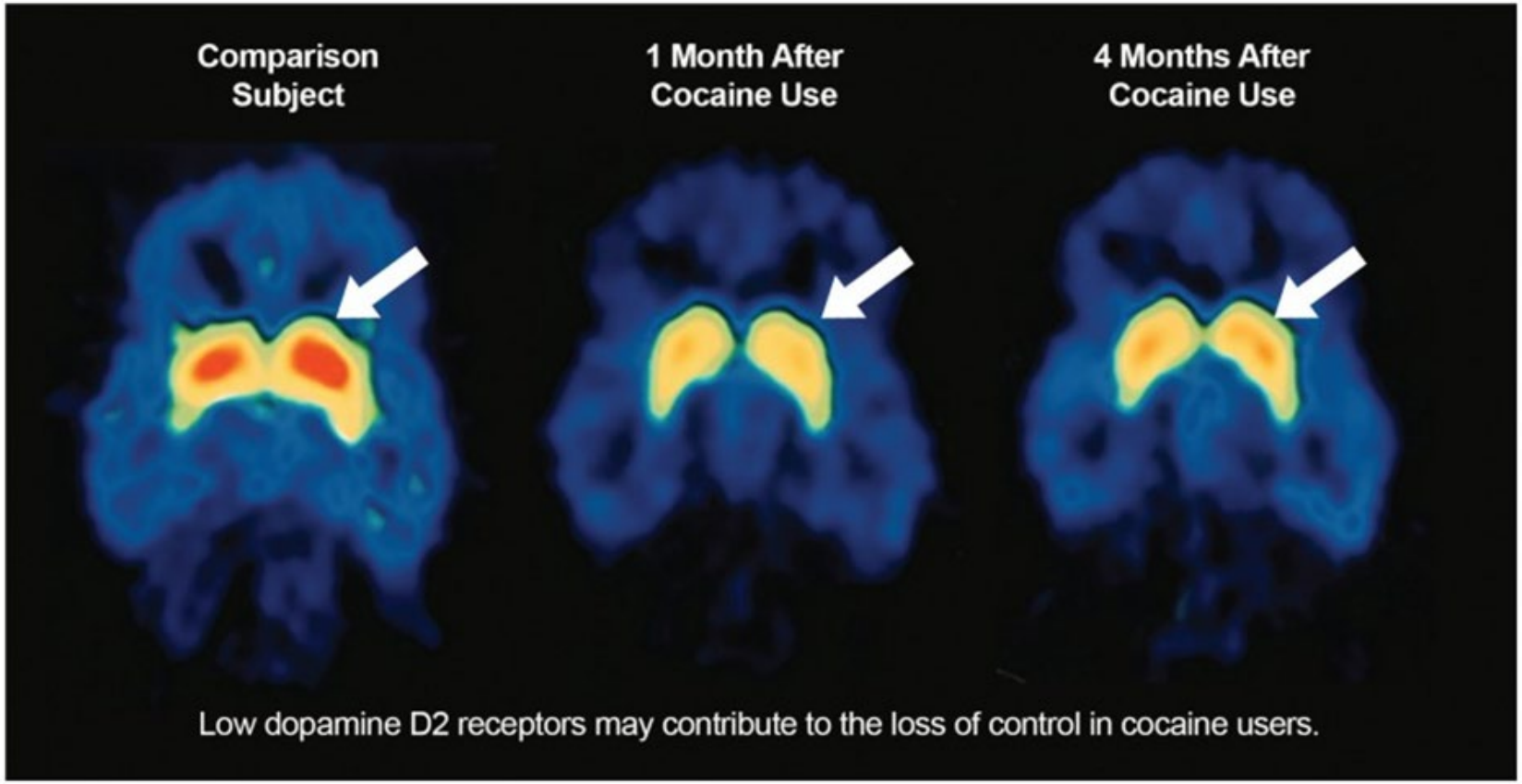
Reduced sensitivity of dopamine receptors. Less pleasure from social and emotional experiences.

- ***Executive and self-directed network***

Impaired decision-making/impulse control

Reduced self-awareness and self-control

Impaired cognition (concentration, memory)



fMRI findings showing the lower levels of the D2 dopamine receptor (depicted in red) in an individuals with regular cocaine use

Volkow et al., (1993)

Neurobiology of treatment

Therapeutic interventions can target the impairments to brain networks

- Medications → Reward & Habit Networks
- CBT → Executive & Self-directed Networks
- Motivational Interviewing → Memory Networks
- Contingency Management → Reward Networks
- Lifestyle Interventions → Reward & Habit Networks

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