Neuroanatomy and neurochemistry of pleasure and fear: are they opposite emotions?

Aina Marcos Puig
Degree in Biomedical Sciences, 2011-2105
Faculty of Biosciences, Universitat Autònoma de Barcelona

Introduction

We experience a variety of emotions every day, and whereas negative emotions such as **fear** usually promote avoidance or defensive behavior, **pleasure** is a positive emotion that encourages exploratory, ingestive, sexual or novel-seeking behavior. Therefore, emotions facilitate adaptive behavior and equilibrium.

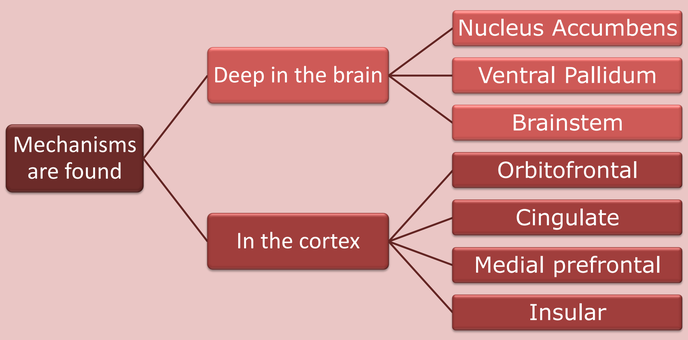
There are several **neuroanatomical** and **neurochemical** substrates involved in both pleasure and fear, but special attention has been paid on the roles of the amygdala, nucleus accumbens and dopamine as they are all involved in these two emotions that may seem opposite at first sight:

- ❖ The **amygdala** has a critical role in emotional expression as it evaluates the emotional valence of each stimulus, and even if it has mainly been associated with negative emotions such as fear, its role in rewarding-stimuli will also be defined.
- ❖ **Nucleus accumbens** (NAc) is the main part of the ventral striatum, and although it is an essential structure for processing positive emotions such as pleasure, its role in negative emotions such as fear will be discussed next.
- ❖ There are diverse chemical neurotransmitters involved in the modulation of emotions, but since **dopamine** (DA) is one of the most important elements in this regulation I aim to define its role in both pleasure and fear.

1. Pleasure

Pleasure itself is generated by a small set of **hedonic hotspots** that enhance liking reactions through interactions between their specific anatomical site and their particular neurochemical.

Distributed system in the brain related to pleasure:



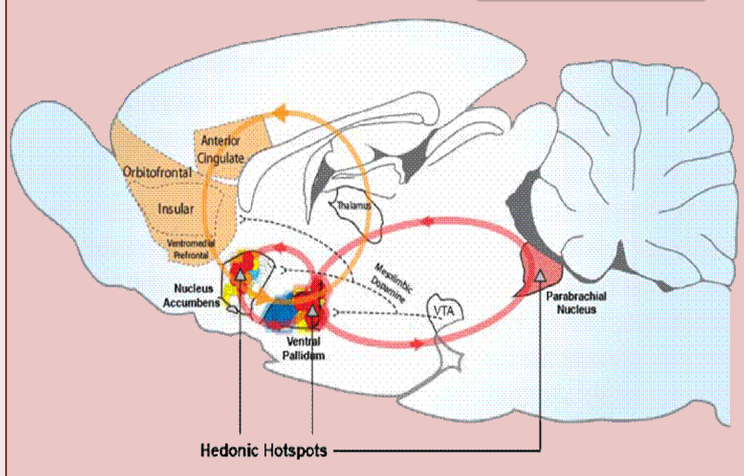


Figure 1. Widespread pleasure coding brain networks. Hedonic hotspots are shown in nucleus accumbens, ventral pallidum, and brainstem parabrachial nucleus. *Ref (1).*

The main **neuroanatomical** structure involved in pleasure is **nucleus accumbens** (NAc), and dopamine neurons from the ventral tegmental area projecting to this structure also play an essential role.

Dopamine is the main **neurochemical** related to pleasure through its interaction with NAc, but the role of this structure is also controlled by glutamatergic, serotoninergic and noradrenergic afferents from diverse areas of the brain.

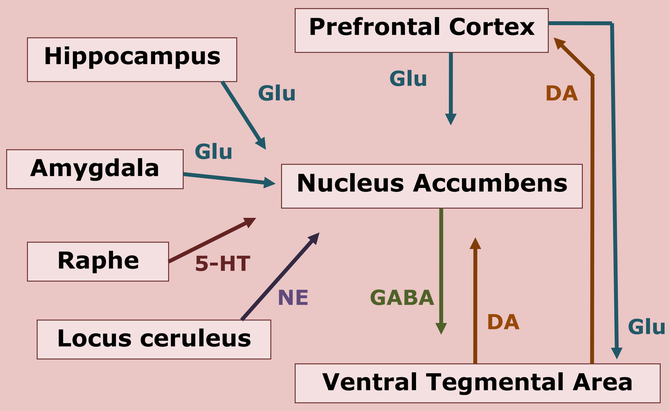
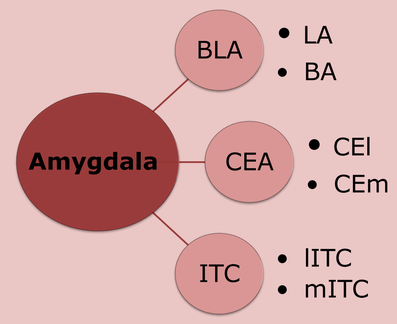


Figure 2. NAc is mainly regulated by dopamine (DA) but also glutamate (Glu), serotonine (5-HT) and norepinephrine (NE). *Adapted from ref (2).*

Nucleus accumbens and dopamine: main components of **pleasure**

2. Fear

Fear functions as an internal signal to alert the organism to potential danger, and the **amygdala** is a structure critically important for processing this emotion. It is composed of distinct nuclei:



1. **Basolateral amygdala** (BLA):
   Lateral (LA) + basal amygdala (BA).
2. **Central nucleus of the amygdala** (CEA):
   Lateral (CEl) + medial nucleus (CEm).
3. **Intercalated cell masses** (ITCs):
   Lateral (lITC) + medial ITC (mITC).

Diverse biogenic amines such as serotonine and norepinpehrine are related to this emotion, but **dopamine** (DA) is the main **neurochemical** involved since it is important in the controls of inhibitory circuits and fear responses.

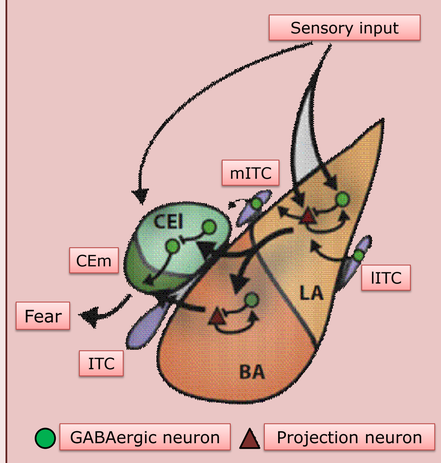


Figure 3. Simplified scheme of the organization and function of inhibitory interneurons in amygdaloid nuclei. The majority of cells composing the BLA are glutamatergic excitatory projection neurons, and only few cells are GABAergic interneurons that form local inhibitory circuits.
CEA mostly consists of GABAergic neurons.
ITCs are composed of GABAergic interneurons that provide feedforward inhibition and control expression of fear responses. *Adapted from ref (3).*

Amygdala and dopamine: main components of **fear**

3. Pleasure and fear: common features

N**ucleus accumbens** is mainly known for its role in pleasure while the **amygdala** is known for fear processing, but these two neuroanatomical structures are actually involved in **both types of emotions.**

Dopamine neurons come in multiple types and through their connections with distinct brain networks they modulate fear and pleasure.

Fear and pleasure are not as opposite as it may seem at first sight since they share several features.

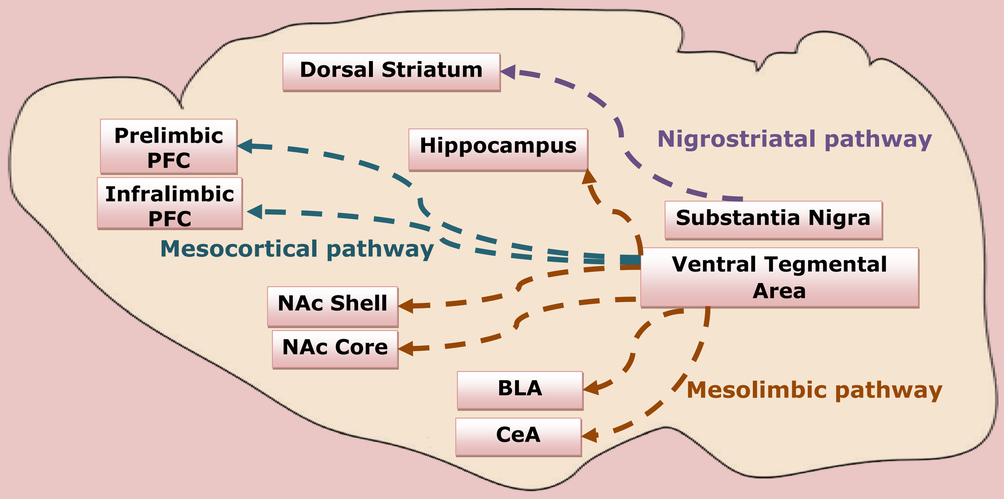
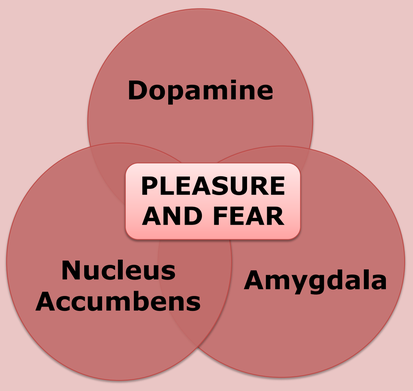


Figure 4. Dopamine neurons project to several structures such as the amygdala, NAc, prefrontal cortex, and hippocampus. *Adapted from ref (4).*



Nucleus accumbens, amygdala and dopamine are all involved in pleasure and fear

Conclusions

Nucleus Accumbens

- Nucleus accumbens is the main structure involved in causing pleasure, but evidence from anatomical, neurochemical and behavioral studies implicate it also in processing fear.
- Activity in this nucleus allows the assignment of a particular value to a stimulus depending on the distribution (D1R vs. D2R) and location (core vs. shell) of receptors that are activated by a burst of dopamine, and it is thus important for both pleasure and fear.

Amygdala

- The amygdala is particularly important for its role in processing fear memories, but its role in positive emotions such as pleasure has also been described.
- This structure processes the valence of a stimuli and bias behavior in an adaptive manner.
- Important problem ➡ studies have just recently began to define amygdala's circuits that contribute to reward, and these analysis are not as far along for reward as they are for fear.

Dopamine

- In spite of the mixed effects found in several studies, it is clear that dopamine is important for learning and memory in most terminal fields of nigrostriatal, mesolimbic and mesocortical dopamine systems.
- It has a role in both fear and pleasure through its interactions with several neuroanatomical structures such as nucleus accumbens and amygdala.

Methodology

In order to do this review the bibliographic research has been focused on the most recent and relevant articles.

- The most used Data Base has been PubMed
- Amongst the several prestigious journals consulted are *Discovery Medicine, Nature, Neuron and Trends in Neurosciences.*
- A total of **20** articles have been cited but the number of documents consulted is a bit higher.

References

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