Chapter

Role of Dopamine Receptors in Olfaction Learning Success

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Abstract

Several biogenic amines neurotransmitters are involved in various social behaviors, including olfaction learning behavior, cast differentiation, generation overlapping and sociability in honeybees. One of the brain's primary functions is remembering and learning the information related to food and odor. Dopamine (DA) is an important signaling molecule derived from the amino acid tyrosine. It is also known as a key neurohormone, neuromodulator and neurotransmitter in vertebrates as well as invertebrates and several studies indicated their important role in olfaction success, rewarding prediction, learning, memory, motor functions, sleep and arousal, aggression, and numerous other behaviors. Evidence suggests that DA plays several roles in honeybees, especially in olfaction success. Three DA receptors, AmDOP1, AmDOP2 and AmDOP3, have been characterized and clones. In this chapter, I focus on the regulation and involvement of the DA in olfactory learning behavior, locomotor function, motivation, and happy memories. This chapter represents an attempt to associate the role of dopamine receptors in olfaction success in honeybees.

Keywords: honeybees, neurotransmitters, dopamine receptors, olfactory learning behavior, olfaction success

1. Introduction

As the population of human grows, habitat loss caused by anthropogenic landscape changes endangers the health and survival of several species. Because of the rising need for food and biofuels due to human population growth, more land must be devoted to agricultural output [1]. To accommodate this need, the usage of land has changed globally, with natural areas and smaller-scale agricultural operations being converted into high-yielding monocultures, but at a cost [2, 3]. Monocultures may significantly affect water, soil, and air quality. When combined with the destruction of natural, noncrop habitats, this type of agriculture has been linked to pollinator population decreases [4]. Concerns have been raised about diminished pollination of crops and wild plants, which might lead to decreased agricultural productivity and ecological service delivery. Honeybees are known as the most economical and important pollinator insects worldwide [5]. Like other pollinating bee species, recently, honeybees faced harsh environmental factors that caused as high as 65% colony losses worldwide. This rate is more significant than apiculturist believes acceptable because of higher expenses for hired pollination services. Several stresses, including genetic, neuroscience, biotic, abiotic, nutritional shortage, and pesticide exposure, are known as potentially interacting stressors, and all are correlated with anthropogenic influence [6].

All social insects interact with our environment for survival through olfactory learning behavior. Among all social insects, Honeybees are important insects of biodiversity on which our planet depends for survival; they provide us with high-quality food and other product such as royal jelly, honey, pollen, beeswax, bee venom and propolis [7]. The honeybee is an essential pollinator for our planet's survival. Honeybees have olfaction behavior for their survival and food seeking. The seeking of food and water resources exposes honeybees to conspecific competition and predation, leading to learning behavior responses to smell, visual cues, specific locations and other relevant stimuli [8, 9]. The olfactory learning behavior is more critical for the survival of the colony and seeking of nectar, pollen and water. This form of learning plays a significant role in foraging and food collection [10].

2. Types of learning behaviors in honeybees

For neuroethological research, insects are considered favorable organisms due to their nervous system and tiny brain. Insects' central nervous system CNS is highly organized, with distinct separations between multisensory neuropils in the brain and sensory-motor neuropils in the ventral cord [11].

The insects have rich behaviors, including visual, space, time, mechanical communication, chemical communication, and complicated motor functioning for olfactory learning walking, flying, nest building, defense, swimming, learning and memory; however, these behaviors are not generally regarded as strengths of insects [12]. After all, genetically designed neural circuitry frequently considers insect behaviors highly standardized and tightly controlled. This viewpoint, however, does not do credit to the insect group Hymenoptera (wasps, bees, ants). Most insect species of Hymenoptera care for their brood either as a female social group or individual females. Subsequently, they return to their nesting site on a daily basis to protect, feed, store food, feed to larvae and defend themself from unfavorable environmental circumstances [13]. Because they seek food (pollen, prey and nectar on blossoms) in unexpected places, they must learn terrestrial and celestial cues that drive their long-distance foraging trips and enable them to locate their nest locations [14]. The forager's bees learn to position of sun and the pattern of the sky of polarized sunlight to the time of day [15] and locations are remembered in connection to the nesting spot using the time-compensated sun compass. The bees communicate the distance and direction of a food place to colony mates by performing waggle dance (a performed body movement). Associative learning is essential to dance communication and bee foraging activity [15]. Colony mates observing a dance show recognize the odor emitted by the dancing bee and seek it out at the designated food location. Flowers' color, shape and odor are remembered when the individual bees learn this stimulus shortly before discovering water and food (pollen, nectar) [16]. This appetitive form of learning behavior in honeybees has several traits of associative learning famous from research on the learning behavior of mammals [17]. It follows the principles of operant and classical conditions, respectively, so behavioral or stimuli acts are related to evaluating motivation. Because associative learning, particularly classical associative learning, is well explained at the operational and phenomenological levels, it offers a promising strategy in the hunt for the neural substrate underpinning learning and memory [18]. The homeostasis, survival and progress of honeybee colonies always rely on the coordination's and contribution of each bee in a hive. Several studies have been conducted on the social behavior response of honeybees and also on other Hymenopteran insects [19].

3. Olfactory learning behavior

The appetitive associative behavior type is crucial in foragers' honeybee's species. The foragers' bees quickly learn to associate olfactory and visual stimuli with sugar solution/food reward, establishing a long-lasting remembrance of this association. Under controlled laboratory conditions, the worker bees can also remember/learn to respond to odor stimuli. In what has known as PER paradigm or proboscis extension response [20]. Usually, A bee harnessed in a metal or plastic tube learns to link a sucrose reward with an odor stimulation presented directly before the reward is given. Memory formation is evidenced when the harnessed bee extends its proboscis in response to the learned odor in anticipation of the sucrose reward. This form of classical conditioning has been successfully used to characterize multiple characteristics of associative learning and has shown potential in *Apis florea* and *Apis cerana* [21, 22].

4. Role of biogenic amines in the olfaction success of honeybee

Natural selection has shaped the brain to learn to associate cues that predict the occurrence of nutritious food. Sensory input is organized to produce memory traces for food stored for retrieval when animals are hungry so that animals can identify signals associated with nutritional rewards and avoid irrelevant or intoxication signals. Numerous biogenic amines receptors play a significant role in different types of behavior, such as social behavior [7]; among all biogenic amine receptors, dopamine, octopamine and serotonin receptors are considered primary biogenic amine receptors. The biogenic amines (BAs) neurotransmitters are key modulators and perform biological activities in animals, plants and microorganisms, BAs are responsible for executing and regulating the multiple behavioral and physiological activities in the body of honeybees as neurotransmitters, neurohormones and neuromodulators (**Figure 1**).

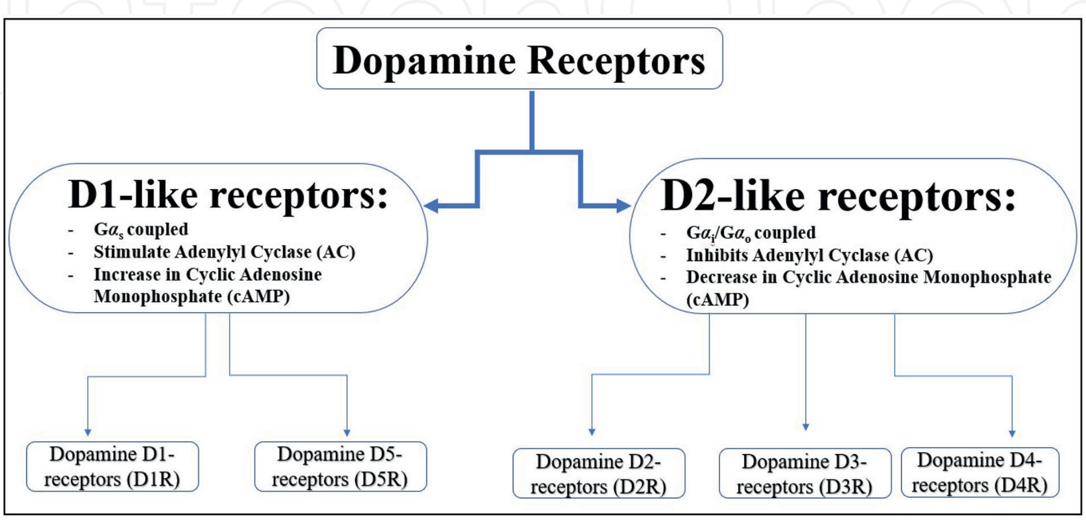

Figure 1.
Schematic diagram of dopamine receptor subtypes.

Receptors	Function	Location	Mechanism	Type	Selective agonist	Selective antagonist
D2	Reproductive behavior, Locomotion, Sleep, Attention	VTA, Olfactory bulb, Striatum, Cerebral cortex	Increased level of cAMP intracellular by activating adenylate cyclase	Gi-coupled	• Bromocriptine • Pergolide • Cabergoline • Ropinirole	• Haloperidol • Raclopride • Sulpiride • Spiperone • Risperidone
D3	Locomotion, Regulation of food intake, Impulse control, Cognition	Cortex Islands of Calleja Striatum		Gi-coupled	• Nafadotride • GR-103691 • GR-218231 • SB-277011A NGB-2904 • PG-01037ABT-127	• 7-OH-DPAT • Pramipexole • Rotigotine • PD-128907
D4	• Attention • Impulse control • Reproductive behavior	• Hypothalamus • Amygdala • Frontal cortex • Nucleus accumbens		Gi-coupled	• A-381393 • FAUC213L-745,870 • L-750667	• A-412997 • ABT-670 • PD-168077
D1	• Attention • Learning • Locomotion • Sleep • Impulse control • Regulation of renal function • Memory	• Olfactory bulb • Nucleus accumbens • Striatum • Amygdala • Hippocampus • Frontal cortex • Substantia nigra • Hypothalamus	Enhanced intracellular cAMP through activated adenylate cyclase	Gs-coupled	• KF-81297 • SKF-38393Fenoldopa • (SKF-82526)	• SCH-39166 • SKF-83566 • SCH-23390

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Receptors	Function	Location	Mechanism	Type	Selective agonist	Selective antagonist
D5	• Motor • Learning • Cognition • Decision • Making • Renin • Secretion	• Hypothalamus • Substantia nigra • Cortex	Adenylate cyclase	Gs-coupled		

Table 1.
Functional and physiological knowledge of dopamine receptors.

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Several BAs, such as dopamine, serotonin, octopamine and tyramine, are crucial for olfactory learning behavior in honeybees [23]. Among all these BAs, dopamine is the major receptor and performs a vital role in the olfaction success of honeybees. In both vertebrates and invertebrates of the animal kingdom, dopamine receptors are present in the central nervous system and regulate multiple tasks. The dopamine receptors are divided into two families D1-like family and D2-like families. The D1-like family (D1, D5) and D2-like family (D2, D3, D4) actively regulate and modulate cell proliferation, differentiation, the release of cyclic adenosine monophosphate (cAMP) and other neurotransmitters also [24]. In this chapter, we focused on the learning behaviors of honeybees, especially olfactory learning behavior. Our focus is the practical functions of dopamine receptors, including olfactory learning, motivation, social behaviors, reward system, cognition, movement, emotion, etc., for forming appetitive and aversive learning [25]. Dopamine receptors catecholamine neurotransmitters work as catecholamine release, vascular tone, cardiovascular function, gastrointestinal motility, hormone secretion and renal function. The scientific community has been investigating over four decades that several diseases like schizophrenia, hyperprolactinemia, Tourette's syndrome and Parkinson's disease have been associated with dysregulation (erratic breathing, heart rate, thinking and behavior) of transmission of dopamine neurotransmitters [26].

D1-like receptors (D1 and D5) are located in different body parts. Dopamine D1 receptors are usually located at the Olfactory bulb, nucleus accumbens, striatum, amygdala, hippocampus, frontal cortex, substantia nigra, and hypothalamus and perform various functions, including Attention, learning, locomotion, sleep, impulse control, regulation of renal function and memory. **Table 1** shows the details and knowledge of the function, location, mechanism, type, selective agonist and selective antagonist of all dopamine receptors.

Dopamine receptors control olfactory learning behaviors and insect reproduction [27]. These receptors are responsible for various bodily functions, but dopamine receptors' major functions are reward-seeking, learning and other physiological properties. These receptors have distinct patterns and functional properties to compose the learning and memory in the brain. In insects like honeybees, *Drosophila melanogaster* and rodents, dopamine receptors and the basolateral amygdala are critically important for learning behavior. The mushroom bodies (MB) of *Drosophila melanogaster* and honeybees have a rich center for dopamine for olfactory learning and olfaction success and also provide a tractable mechanism to investigate the interaction between olfactory learning and dopamine receptors [28, 29]. This chapter will provide the basic interaction of dopamine receptors and olfactory learning behavior; olfactory learning behavior is important for colony survival. The functions of dopamine provide concrete evidence of how dopamine receptors are crucial and contribute to honeybees' olfactory behavior. Further study is required to investigate the role of dopamine receptors in managing the pest *varroa* mites of honeybees by using grooming behavior.

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