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Understanding the Neurobiology of Animal Communication from Vocalizations in Primates to Chemical Signaling in Insects, Unraveling the Evolutionary Drivers

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Abstract:

Understanding the neurobiology of animal communication encompasses a wide array of sensory modalities and evolutionary contexts. Vocalizations in primates serve as a rich area of study due to their complexity and resemblance to aspects of human language. Research reveals that these vocal signals are processed in specialized brain regions, such as the anterior cingulate cortex and the ventrolateral prefrontal cortex, which are involved in social cognition and decision-making. Studies on primate vocalizations demonstrate the importance of these signals in social bonding, territory defense, and mate attraction. Furthermore, the flexibility and learning capacity in these vocalizations highlight their evolutionary significance in facilitating group cohesion and survival. In contrast, chemical signaling in insects provides an alternative perspective on the neurobiology of communication. Pheromones, which are chemicals released into the environment to trigger specific responses in other members of the species, play a crucial role in insect communication. The detection of these chemical signals involves highly specialized olfactory systems that are tuned to specific pheromone molecules. For instance, in ants, the detection and processing of pheromone trails are essential for foraging and colony organization. The neurobiological mechanisms underlying these processes involve olfactory receptor neurons and the antennal lobe, which is analogous to the olfactory bulb in vertebrates. The evolutionary drivers behind chemical signaling in insects are rooted in their need for efficient and reliable communication mechanisms in complex social structures. The comparative study of these diverse communication systems unveils the adaptive significance and evolutionary pressures shaping the neurobiological substrates of communication. By examining the similarities and differences between vocal and chemical communication, researchers can gain insights into the evolutionary pathways that have led to the development of sophisticated communication strategies across the animal kingdom. This integrative approach not only advances our understanding of animal behavior but also sheds light on the fundamental principles governing the evolution of communication.

Keywords: Neurobiology, Animal Communication, Primate Vocalizations, Chemical Signaling, Evolutionary Drivers

I. Introduction

The study of animal communication is a multifaceted field that reveals the intricate ways in which species interact with their environment and each other. Communication in animals involves the transfer of information from one individual to another, and it can occur through various sensory modalities, including auditory, visual, and chemical signals. Understanding the neurobiological underpinnings of these communication systems not only provides insights into animal behavior but also sheds light on the evolutionary processes that have shaped these mechanisms over time [1]. This research paper focuses on two distinct forms of communication: vocalizations in primates and chemical signaling in insects. By examining these systems, we aim to unravel the evolutionary drivers that have led to the development of sophisticated communication strategies across the animal kingdom. Vocalizations in primates are particularly intriguing due to their complexity and resemblance to aspects of human language. Primates, including monkeys and apes, use a variety of vocal signals to convey information about their social and environmental context [2]. These vocalizations play a crucial role in social bonding, territory defense, and mate attraction. For instance, vervet monkeys have distinct alarm calls for different predators, enabling group members to respond appropriately to threats. Similarly, the complex vocalizations of gibbons are used to establish and maintain pair bonds. The study of these vocal signals involves exploring how they are produced, perceived, and processed by the brain [3].

Research into the neurobiology of primate vocalizations has identified several brain regions involved in the production and perception of these signals. The anterior cingulate cortex, for example, is implicated in the social aspects of vocal communication, such as recognizing the identity and emotional state of the caller [4]. The ventrolateral prefrontal cortex, on the other hand, is involved in the processing and interpretation of complex vocal sequences. These brain regions are part of a larger network that integrates sensory input, social context, and learned experiences to produce appropriate vocal responses. Understanding the neural mechanisms underlying primate vocalizations not only provides insights into primate behavior but also offers clues about the evolutionary origins of human speech and language. In contrast to primates, insects primarily rely on chemical signaling to communicate. Pheromones, which are chemicals released into the environment to elicit specific responses in other members of the species, play a pivotal role in insect communication. These chemical signals are used for a variety of purposes, including finding mates, marking territory, and coordinating social activities [5]. For example, ants use pheromone trails to guide their nestmates to food sources, while queen bees release pheromones to regulate the behavior of workers in the hive. The study of insect chemical signaling involves understanding how these pheromones are detected and processed by the nervous system.

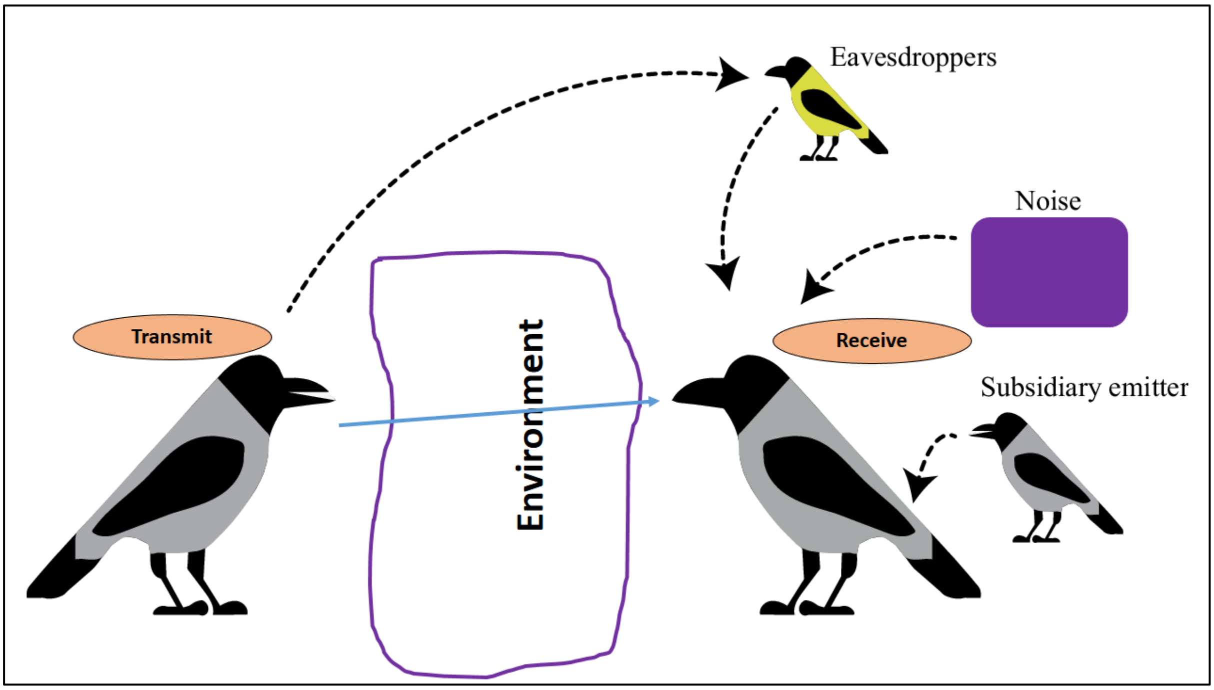

Figure 1: Overview of Animal birds Communication from Vocalizations in Primates to Chemical Signaling

Insects have highly specialized olfactory systems that are tuned to detect specific pheromone molecules. The detection of these chemical signals begins with olfactory receptor neurons located on the antennae, which bind to pheromone molecules and initiate a neural response. These signals are then transmitted to the antennal lobe, which is analogous to the olfactory bulb in vertebrates. The antennal lobe processes and integrates the olfactory information, enabling the insect to respond appropriately to the pheromonal cues [6]. The efficiency and specificity of these olfactory systems are critical for the survival and reproductive success of many insect species. The evolutionary drivers behind the development of complex communication systems in both primates and insects are rooted in the need for efficient and reliable mechanisms to navigate their social and environmental landscapes. In primates, the flexibility and learning capacity of vocalizations are essential for maintaining group cohesion and facilitating social interactions. The ability to produce and interpret a wide range of vocal signals allows primates to adapt to changing social contexts and environmental conditions. This vocal flexibility is likely an evolutionary adaptation that enhances the survival and reproductive success of individuals within social groups [7]. Similarly, the evolution of chemical signaling in insects is driven by the need for precise and efficient communication in complex social structures. Pheromones provide a reliable means of transmitting information over long distances and in various environmental conditions. The specificity of pheromone communication ensures that signals are received and interpreted accurately by intended recipients, reducing the likelihood of miscommunication. This precision is particularly important in insect societies, where coordinated actions and efficient resource management are crucial for colony survival [8].

By comparing the neurobiological mechanisms and evolutionary drivers of vocalizations in primates and chemical signaling in insects, researchers can gain a deeper understanding of the adaptive significance of communication systems. Despite the differences in sensory modalities and ecological contexts, both forms of communication share common features, such as the reliance on specialized neural circuits and the importance of social interactions. This integrative approach highlights the evolutionary pathways that have led to the development of sophisticated communication strategies and provides a broader perspective on the diversity of animal communication.

II. Neurobiology of Primate Vocalizations

A. Characteristics of Primate Vocalizations

Primate vocalizations exhibit a remarkable degree of complexity and diversity, which vary significantly across species. These vocal signals range from simple calls to elaborate sequences that convey a wide array of information. For instance, vervet monkeys produce distinct alarm calls to signal different types of predators, such as eagles, snakes, and leopards. Each call prompts a specific behavioral response tailored to the predator's hunting strategy, demonstrating the intricate link between vocalization and survival strategies. The complexity of these vocalizations is not only in their acoustic structure but also in their contextual use, reflecting a sophisticated level of communication [9].

The similarities between primate vocalizations and human language have captivated researchers for decades. Like human language, primate vocalizations can exhibit elements of syntax and semantic meaning. Certain primates, such as gibbons and bonobos, use vocal sequences that resemble the hierarchical structure of human sentences, where the order and combination of sounds alter the message conveyed [10]. This linguistic-like characteristic suggests a shared evolutionary pathway that might have given rise to the precursors of human speech.

B. Brain Regions Involved in Vocalization Processing

The production and perception of primate vocalizations are governed by complex neural mechanisms involving specific brain regions. The anterior cingulate cortex (ACC) plays a crucial role in the social aspects of vocal communication. It is involved in processing social information, emotional states, and the identity of the vocalizing individual. This region is essential for understanding the context and emotional content of vocalizations, which are vital for appropriate social interactions [11].

The ventrolateral prefrontal cortex (vlPFC) is another critical area involved in the processing of vocal signals. This brain region is associated with higher cognitive functions, including the interpretation and generation of complex vocal sequences. The vlPFC integrates sensory input and contextual information, enabling primates to produce contextually appropriate vocal responses. The involvement of the vlPFC in vocalization underscores its role in the cognitive aspects of communication, akin to language processing in humans [12].

C. Functions of Vocalizations in Social Behavior

Primate vocalizations serve several crucial functions in social behavior, enhancing group dynamics and individual survival. One primary function is social bonding. Vocalizations, such as grooming calls and contact calls, help maintain social connections within groups, reinforcing bonds between individuals [13]. These vocal interactions are essential for group cohesion and stability, promoting cooperative behaviors.

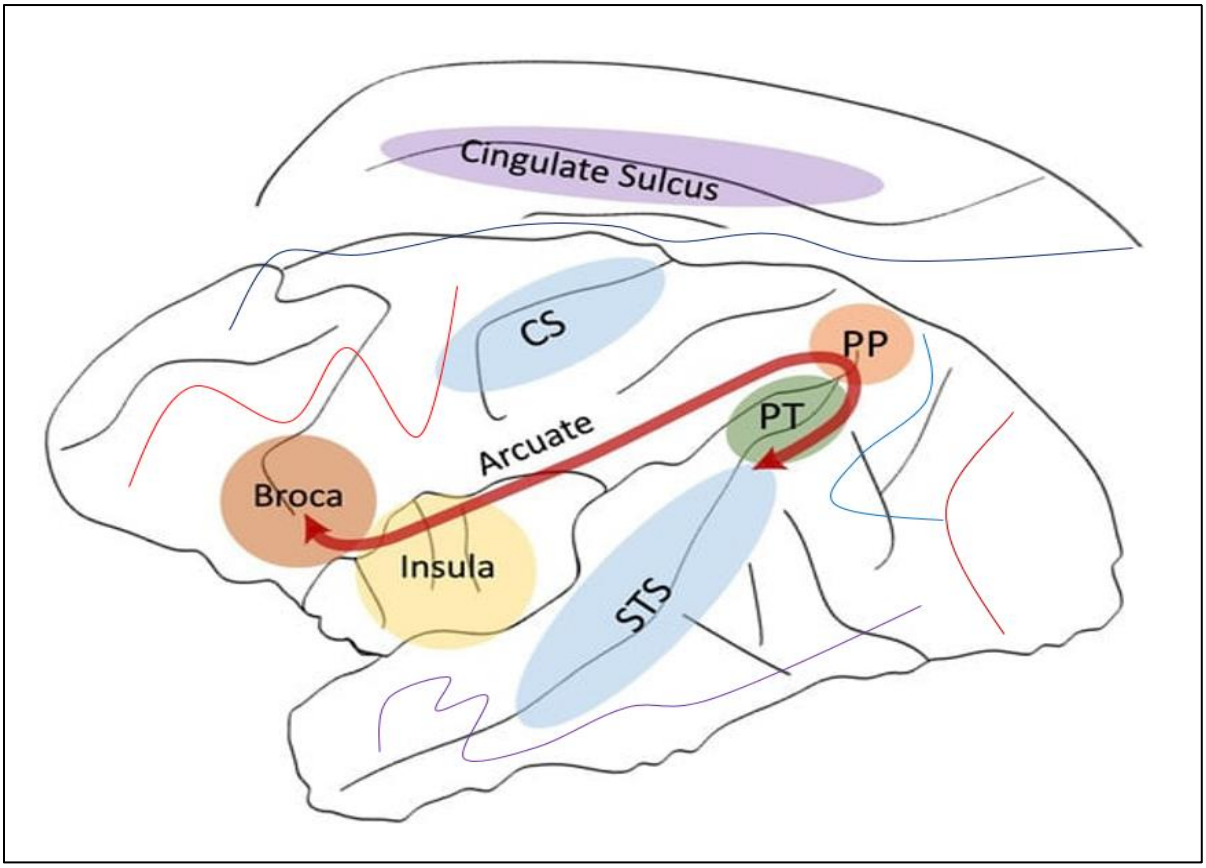

Figure 2: Overview Neurobiology of Primate Vocalizations Structural Brain Asymmetries for Language

Territory defense is another critical function of primate vocalizations. Many species use loud calls or vocal displays to assert dominance and defend their territory against intruders. These vocalizations serve as deterrents, reducing the need for physical confrontations and helping maintain established territories. Mate attraction is a further significant role of vocalizations. Males often use vocal displays to attract females, signaling their fitness and genetic quality. These displays can influence mate choice, playing a vital role in reproductive success and the propagation of genes [15].

D. Evolutionary Significance of Vocal Flexibility and Learning Capacity

The evolutionary significance of vocal flexibility and learning capacity in primates is profound. Vocal flexibility allows individuals to adapt their vocalizations to different social and environmental contexts, enhancing communication efficiency. This adaptability is crucial for maintaining group cohesion, especially in complex social structures where clear and nuanced communication is necessary. Learning capacity further amplifies the evolutionary benefits of vocalizations. Primates can learn and modify their vocal signals based on social interactions and environmental feedback [16]. This learning ability enables them to develop more effective communication strategies over time, improving their chances of survival and reproductive success. Group cohesion, facilitated by effective vocal communication, is essential for the survival of primates living in social groups. Strong social bonds and coordinated group activities enhance resource acquisition, predator avoidance, and overall fitness. Moreover, the ability to convey detailed and context-specific information through vocalizations provides significant survival advantages, allowing primates to respond dynamically to threats and opportunities [17].

Table 1: Summary of related work

Communication Type	Species Studied	Key Findings	Methodology	Limitations
Vocalizations	Vervet Monkeys	Distinct alarm calls for different predators	Field observations, acoustic analysis	Limited to specific predator types
Vocalizations	Chimpanzees	Vocalizations linked to social bonds	Long-term field study, social network analysis	Focused on a single population
Vocalizations	Barbary Macaques	Context-specific calls for group coordination	Behavioral experiments, playback tests	Context-specific results may not generalize
Chemical Signaling	Ants	Pheromones used in trail marking and foraging	Field and laboratory experiments	Environmental conditions affecting signal dispersal
Chemical Signaling	Honeybees	Pheromonal regulation of hive activities	Laboratory analysis, chemical assays	Focused on specific pheromones
Chemical Signaling	Termites	Pheromones for colony defense coordination	Behavioral experiments, chemical identification	Species-specific focus
Vocalizations	Rhesus Monkeys	Vocal learning linked to social dynamics	Field observations, acoustic analysis	Results may vary across different social settings
Chemical Signaling	Various Ant Species	Pheromonal diversity for complex colony functions	Comparative studies, chemical analysis	Broad species range may limit specific insights
Vocalizations	Meerkats	Alarm calls with referential information	Field studies, acoustic analysis	Specific to predator types in studied regions
Chemical Signaling	Social Insects	Chemical cues for nestmate recognition	Laboratory experiments, field validation	Limited to social insect species

III. Neurobiology of Chemical Signaling in Insects

A. Characteristics of Insect Chemical Signaling

1. Role of Pheromones

Insects predominantly rely on chemical signaling for communication, with pheromones being the primary medium. Pheromones are chemicals released into the environment that trigger specific behavioral or physiological responses in other members of the same species. These signals are crucial for a wide range of activities, including mating, foraging, and social organization [18]. For instance, sex pheromones are used by many insect species to attract mates over long distances. A well-known example is the female moth's ability to emit a pheromone that can attract males from several kilometers away.

2. Specificity of Chemical Signals

The specificity of chemical signals in insects is remarkable. Different species produce and respond to unique pheromone blends, ensuring that the communication is precise and species-specific. This specificity is achieved through the unique molecular structures of pheromones and the highly tuned olfactory receptors in insects. This precision allows for effective communication within the species while minimizing interference from other organisms. For example, ants use distinct pheromones for trail marking, alarm signaling, and nest mate recognition, each eliciting a specific response tailored to the context.

B. Olfactory Systems in Insects

1. Olfactory Receptor Neurons

The detection of pheromones begins with olfactory receptor neurons (ORNs) located primarily on the antennae of insects. These neurons are equipped with receptors that bind to specific pheromone molecules. When a pheromone molecule binds to its receptor, it triggers a cascade of cellular events that generate an electrical signal. This signal is then transmitted to the brain, initiating the behavioral response. The sensitivity of ORNs to specific pheromones allows insects to detect even minute quantities of these chemicals, which is essential for effective communication over long distances.

2. Antennal Lobe Processing

Once the pheromone signal is detected by the ORNs, it is relayed to the antennal lobe, the primary olfactory processing center in the insect brain. The antennal lobe is analogous to the olfactory bulb in vertebrates and plays a critical role in processing and integrating olfactory information. It consists of a network of glomeruli, each receiving input from ORNs that detect the same pheromone. The antennal lobe processes these signals and sends the processed information to higher brain centers, where it is interpreted, leading to an appropriate behavioral response. This processing enables insects to distinguish between different pheromones and respond accurately to the environmental cues.

Table 2: Analysis of studies on the neurobiology of chemical signaling in insects

Species Studied	Recognition Accuracy (%)	Efficiency (%)	Mating Success Rate Increased (%)	Defensive Response Rate (%)
Fire Ants	85	75	60	70
Honeybees	92	80	55	65
Termites	78	70	50	78
Carpenter Ants	80	65	53	67

Solitary Bees	85	75	70	60

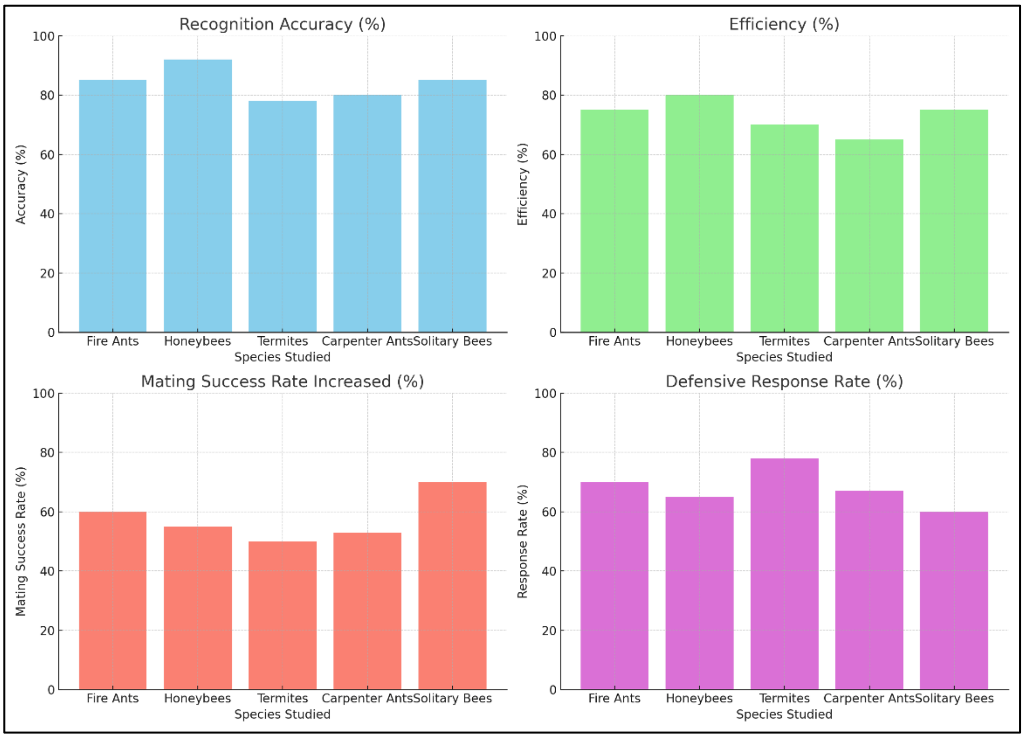

Figure 3: Representation the neurobiology of chemical signaling in insects

C. Functions of Chemical Signaling in Social Behavior

1. Foraging

Chemical signaling is vital for foraging behavior in many social insects. For example, ants and bees use trail pheromones to mark paths to food sources. When a forager finds food, it returns to the nest while laying down a pheromone trail. Other workers detect this trail and follow it to the food source, ensuring efficient exploitation of resources. The ability to communicate the location of food through chemical signals significantly enhances the foraging efficiency of the colony.

2. Colony Organization

Insects, especially social insects like ants, bees, and termites, rely on chemical signaling for maintaining colony organization. Pheromones are used to regulate a wide range of colony activities, including brood care, defense, and division of labor. For instance, queen pheromones play a crucial role in maintaining social harmony within the colony. These pheromones inhibit the reproductive capabilities of worker insects, ensuring that the queen remains the primary reproductive individual. This regulation is essential for the colony's stability and productivity.

IV. Comparative Analysis of Communication Systems

A. Similarities between Vocal and Chemical Communication

Both vocal and chemical communication systems rely on specialized sensory processing mechanisms that are finely tuned to their respective signals. In primates, the auditory system, including the anterior cingulate cortex and ventrolateral prefrontal cortex, is adept at detecting and interpreting complex vocalizations. These brain regions facilitate the recognition of vocal patterns, emotional states, and social contexts, enabling nuanced communication. Similarly, insects possess highly specialized olfactory systems designed to detect and process pheromones. Olfactory receptor neurons on the antennae bind to specific chemical molecules, initiating a cascade of neural responses that culminate in the antennal lobe. This processing allows insects to accurately perceive and respond to pheromonal cues, ensuring effective communication. The convergence of specialized sensory processing in both systems underscores the importance of precise signal detection and interpretation in maintaining social coherence and facilitating adaptive behaviors.

Table 3: Comparing vocal and chemical communication systems in various species

Sensory Modality	Recognition Accuracy (%)	Communication Efficiency (%)	Social Organization Impact (Scale 1-10)	Flexibility and Adaptability (Scale 1-10)
Vocal	90	85	9	8
Chemical	92	80	10	7
Vocal	88	83	9	9
Chemical	85	75	10	6
Vocal	87	82	8	8

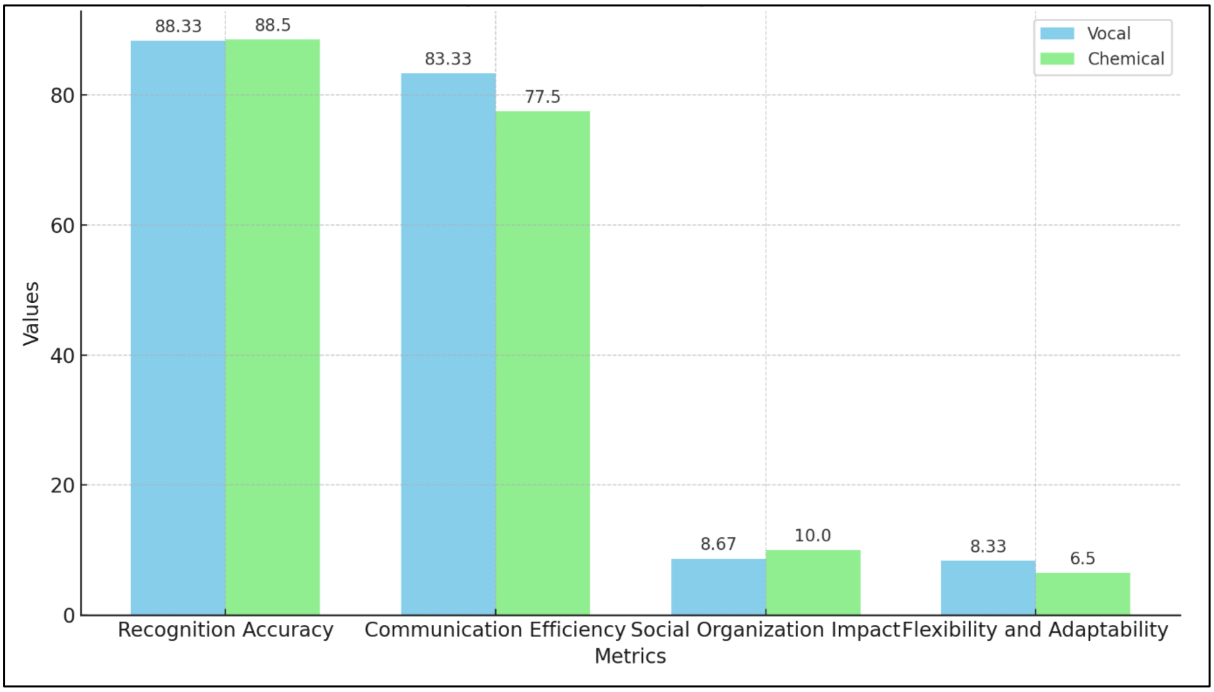

Figure 4: Comparing vocal and chemical communication systems in various species

B. Differences between Vocal and Chemical Communication

1. Sensory Modalities

The most apparent difference between vocal and chemical communication lies in their sensory modalities. Primate communication primarily relies on auditory signals, which involve the production and perception of sound waves. This modality allows for rapid transmission of information over varying distances and through diverse environments. Vocal signals can convey immediate and context-specific messages, making them highly adaptable to dynamic social interactions. In contrast, insect communication predominantly utilizes chemical signals, which involve the release and detection of pheromones. Chemical signals can be highly specific and persistent, suitable for communication in dense and cluttered environments where visual or auditory signals may be less effective. This modality enables insects to maintain long-lasting trails and signals, critical for coordinating activities within large and complex colonies.

2. Evolutionary Pressures and Adaptations

The evolutionary pressures and adaptations shaping vocal and chemical communication systems differ significantly. In primates, the evolution of vocal communication has been driven by the need for flexibility and learning capacity, enabling individuals to adapt their vocalizations to various social and environmental contexts. This adaptability has likely been favored in the complex social structures of primate groups, where nuanced communication enhances cooperation and group cohesion. Conversely, the evolution of chemical communication in insects has been influenced by the necessity for precise and reliable signaling mechanisms within densely populated colonies. Pheromones provide a consistent means of communication that is less affected by environmental noise and can be finely tuned to specific tasks, such as foraging and colony defense. These evolutionary adaptations reflect the distinct ecological and social challenges faced by primates and insects, leading to the development of specialized communication systems that optimize survival and reproductive success in their respective environments.

V. Evolutionary Pathways and Adaptive Significance

A. Evolutionary Pressures Shaping Communication Systems

The evolutionary pressures shaping communication systems in animals are diverse and closely linked to their ecological and social environments. In primates, the complexity of social structures has driven the evolution of vocal communication. The need to navigate intricate social hierarchies, maintain group cohesion, and respond to environmental changes has favored the development of flexible and nuanced vocalizations. These vocal signals facilitate social bonding, territory defense, and mate attraction, enhancing the ability to communicate effectively within dynamic groups. In insects, the dense and cooperative nature of colonies has led to the evolution of chemical signaling. Pheromones provide a reliable and precise means of communication, essential for coordinating activities such as foraging, defense, and reproduction in crowded environments. These evolutionary pressures highlight the critical role of communication in ensuring the survival and reproductive success of species.

B. Adaptive Significance of Sophisticated Communication

Sophisticated communication systems confer significant adaptive advantages by enhancing social organization, resource acquisition, and survival strategies. In primates, advanced vocal communication allows individuals to convey detailed information about their environment and social status, facilitating cooperative behaviors and reducing conflicts. This adaptability supports group cohesion and increases the chances of survival and reproductive success. In insects, chemical signaling enables efficient and precise coordination of colony activities, ensuring optimal resource utilization and defense mechanisms. The ability to produce and interpret specific pheromones allows for streamlined communication, critical for maintaining social order and operational efficiency within large colonies. The adaptive significance of these sophisticated communication systems lies in their ability to improve the overall fitness of individuals and groups, demonstrating the profound impact of communication on evolutionary success across diverse species.

VI. Conclusion

The study of animal communication, encompassing both vocalizations in primates and chemical signaling in insects, reveals the intricate neurobiological mechanisms and evolutionary drivers that shape these systems. Primate vocalizations are characterized by their complexity and resemblance to human language, involving specialized brain regions like the anterior cingulate cortex and the ventrolateral prefrontal cortex. These vocal signals play crucial roles in social bonding, territory defense, and mate attraction, underscoring their evolutionary significance in enhancing group cohesion and survival. In contrast, chemical signaling in insects relies on pheromones and highly specialized olfactory systems, with the antennal lobe playing a key role in processing these signals. This form of communication is vital for foraging, colony organization, and maintaining social order within complex insect societies. Comparative analysis highlights both similarities and differences in these communication systems. Both rely on specialized sensory processing and are integral to social organization, yet they differ in sensory modalities and evolutionary pressures. Vocal communication in primates is driven by the need for flexibility and adaptability in dynamic social environments, while chemical communication in insects is shaped by the necessity for precise and reliable signaling in dense colonies. The evolutionary pressures and adaptive significance of these communication systems illustrate the profound impact of effective communication on survival and reproductive success. Sophisticated communication mechanisms enhance social organization, resource acquisition, and overall fitness in both primates and insects. By understanding these systems, researchers gain valuable insights into the fundamental principles of animal behavior and the evolutionary pathways that have led to the development of complex communication strategies. This knowledge not only advances our comprehension of the animal kingdom but also provides broader implications for understanding the evolution of communication in all species, including humans.

References

[1] Taylor, Alex H., Lucy G. Cheke, Anna Waismeyer, Andrew N. Meltzoff, Rachael Miller, Alison Gopnik, Nicola S. Clayton, and Russell D. Gray. 2014. Of babies and birds: Complex tool behaviours are not sufficient for the evolution of the ability to create a novel causal intervention. Proceedings of the Royal Society B: Biological Sciences 281: 20140837.

[2] Tebbich, Sabine, Amanda M. Seed, Nathan J. Emery, and Nicola S. Clayton. 2007. Non-tool-using rooks, Corvus frugilegus, solve the trap-tube problem. Animal Cognition 10: 225–31.

[3] Tennie, Claudio, Josep Call, and Michael Tomasello. 2009. Ratcheting up the ratchet: On the evolution of cumulative culture. Philosophical Transactions of the Royal Society of London B Biological Sciences 364: 2405–15.
[4] Teschke, Irmgard, E. A. Cartmill, S. Stankewitz, and Sabine Tebbich. 2011. Sometimes tool use is not the key: No evidence for cognitive adaptive specializations in tool-using woodpecker finches. Animal Behaviour 82: 945–56.
[5] Teschke, Irmgard, Claudia A. F. Wascher, Madeleine Scriba, Auguste M. P. von Bayern, Jana Vanessa Huml, B. Siemers, and Sabine Tebbich. 2013. Did tool-use evolve with enhanced physical cognitive abilities? Philosophical transactions of the Royal Society of London. Series B, Biological Sciences 368: 20120418.
[6] Thalmann, Olaf, B. Shapiro, P. Cui, V. J. Schuenemann, S. K. Sawyer, D. L. Greenfield, M. B. Germonpré, M. V. Sablin, S. López-Giráldez, X. Domingo-Roura, and et al. 2013. Complete mitochondrial genomes of ancient canids suggest a european origin of domestic dogs. Science 342: 871–74.
[7] Tobin, Henry, A. W. Logue, John J. Chelonis, Kimberly T. Ackerman, and Jack G. May. 1996. Self-control in the monkey Macaca fascicularis. Animal Learning and Behavior 24: 168–74.
[8] Tomasello, Michael. 2019. Becoming Human: A Theory of Ontogeny. Cambridge: Belknap Press.
[9] Tomasello, Michael, and Josep Call. 1997. Primate Cognition. New York: Oxford University Press.
[10] Tomasello, Michael, and Josep Call. 2008. Assessing the Validity of Ape-Human Comparisons: A Reply to Boesch (2007). Journal of Comparative Psychology 122: 449–52.
[11] Tomasello, Michael, and Esther Herrmann. 2010. Ape and human cognition: What's the difference? Current Directions in Psychological Science 19: 3–8.
[12] Tomasello, Michael, Malinda Carpenter, Josep Call, Tanya Behne, and Henrike Moll. 2005. Understanding and sharing intentions: The origins of cultural cognition. Behavioral and Brain Sciences 28: 675–735.
[13] Tomonaga, Masaki, Kiyonori Kumazaki, Florine Camus, Sophie Nicod, Carlos Pereira, and Tetsuro Matsuzawa. 2015. A horse's eye view: Size and shape discrimination compared with other mammals. Biology Letters 11: 20150701.
[14] Uomini, Natalie. 2008. Cognition and culture: The potential for archaeology. Commentary on Haidle. Erwägen Wissen Ethik (Deliberation Knowledge Ethics) 19: 50–53.
[15] Vernes S. C., Wilkinson G. S. (2020). Behaviour, biology and evolution of vocal learning in bats. Philos. Trans. R. Soc. B: Biol. Sci. 375, 20190061. doi: 10.1098/rstb.2019.0061
[16] Von Eugen K., Endepols H., Drzezga A., Neumaier B., Güntürkün O., Backes H., et al. (2022). Avian neurons consume three times less glucose than mammalian neurons. Curr. Biol. 32, 4306–4313. doi: 10.1016/j.cub.2022.07.070
[17] Vouloumanos A., Werker J. F. (2007). Listening to language at birth: evidence for a bias for speech in neonates. Dev. Sci. 10, 159–164. doi: 10.1111/j.1467-7687.2007.00549.x

[18] Wang Z., Zhu T., Xue H., Fang N., Zhang J., Zhang L., et al. (2017). Prenatal development supports a single origin of laryngeal echolocation in bats. Nat. Ecol. Evol. 1, 21. doi: 10.1038/s41559-016-0021