

Martin Stevens: Sensory Ecology, Behaviour, and Evolution

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Sensory ecology is a relatively new field of study that focuses on the ways in which animals obtain and use information about their surroundings. Approaches based on questions of sensory perception have been increasingly integrated into primatological research, particularly in the areas of foraging and communication. In his seminal volume “Sensory Ecology,” Dusenbery (1992) focused primarily on the acquisition of information, the physical properties of signals in different sensory modalities, and the ways in which these relate to different types of behavior, especially those related to spatial navigation and migration. In *Sensory Ecology, Behaviour, and Evolution*, Martin Stevens sets out to integrate this sensory approach with evolutionary theory and behavioral ecology by refocusing on the evolutionary processes and adaptive significance of perception and its links to behavior. The book itself is relatively slim. Given the potential breadth of topics and wealth of examples from the literature, such a broad subject cannot be covered exhaustively in a single volume. Instead, *Sensory Ecology, Behaviour, and Evolution* serves as a general introduction to the topic.

The book is divided into five parts: 1) Introduction, 2) Sensory Processing, 3) Communication, 4) Diversification and Divergence, and 5) Conclusions, with the bulk of the content concentrated in the middle 3 parts. Each part consists of one to four chapters that provide an overview of the theoretical issues associated with, and the empirical investigation of, different topics. Stevens has elected to structure the book not around sensory modalities (as in Dusenbery 1992), but by concepts such as sensory integration, sensory exploitation, and sensory drive. By doing so, he emphasizes how different sensory modalities can be influenced by the same evolutionary processes (albeit sometimes in different ways) and encourages readers always to consider the total sensory experience of the animal and the way in which this is influenced by and influences evolutionary adaptation.

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Part 1, composed of a single chapter (Chapter 1: “Sensory Ecology, Information, and Decision-Making”), introduces the topic of sensory ecology as well as key concepts relevant to this field of study. Stevens highlights the interdisciplinary nature of sensory ecology as a topic of study, and the importance of considering how stimuli are perceived from the perspective of relevant species, which is sometimes very different to human perception. The chapter also introduces various approaches to investigating behavior, and the different levels at which we might seek to explain how behavior develops. Also covered in this introductory chapter is the concept of “information” in animal behavior, which continues to be subject to debate. Stevens reasonably characterizes information as being something that is acquired by animals from environmental stimuli, including signals and cues from other organisms, and that results in a reduction in uncertainty about the state of the world.

Part 2 of the book consists of three chapters and is focused on sensory processing. In Chapter 2 (“Sensing the World”), Stevens overviews the key properties and characteristics of chemical, electric, visual, magnetic, mechanical, and auditory signals, and the ways in which these are produced and detected by animals. This chapter introduces the basic physics behind signal production and propagation as well as the types of information that can be extracted from signals, and provides foundational information for interpreting the discussion of signals in all modalities discussed throughout the book. Chapter 3 (“Encoding Information”) focuses on the ways in which sensory systems detect and encode information, focusing primarily on vision, hearing (including echolocation), and olfaction. Here, the emphasis is on the neural and perceptual systems that are involved in signaling, and the links between these systems and behavioral responses. The physical and neurological properties of signal production and reception are covered in less detail compared to some volumes on animal communication (e.g. Bradbury and Vehrencamp 2011), though given the concise style of the present book and its emphasis on evolutionary ecology, this seems appropriate. Chapters 2 and 3 cover these topics in sufficient detail to allow naïve readers to understand the remaining sections of the book. Finally, in Chapter 4 (“Sensory Systems: Trade-Offs, Costs, and Sensory Integration”), Stevens discusses the costs of sensory systems and the resulting evolutionary constraints, optimization versus generalization of sensory systems, trade-offs involved in placing emphasis on different components of signals, and the advantages of multisensory communication. Different sensory systems are assessed from evolutionary and economic perspectives, with the emphasis on how and why sensory systems can be tuned to environmental inputs and integrated to provide maximum benefit.

Part 3 of the book concentrates on communication, and is composed of four chapters. Chapter 5 (“Signalling and Communication”) provides an overview of animal communication and its relevant terms and concepts, including signals versus cues, strategy and efficacy costs of signals, honest signaling, and informational concepts in communication, and ends with a discussion of the role of cognition in communication. The reader is provided with a good deal of requisite terminology, which is necessary for understanding future chapters, with Stevens’s discussion of signal efficacy and strategy being particularly useful. It is always a difficult balance between presenting one’s own opinion while being even-handed in reviewing controversial topics, particularly in an area in which concepts and terminology are as disputed as they are in animal communication. Stevens generally does a good job in presenting different sides of debates

while using available evidence to support his own conclusions. Chapter 6 (“Multimodal Signals and Communication”) focuses on multimodal communication, a current hot topic. Here, Stevens goes into more detail on the benefits of communicating in multiple modalities, and distinguishes between multimodal signaling and both multicomponent signaling and signaling to multiple receivers. In Chapter 7 (“Trade-Offs and Costs in Signalling”), Stevens concentrates on the costs of communication, focusing on physiological costs, eavesdropping by predators and parasites, the ways in which animals can ameliorate these costs, and how this can influence signal form. The final chapter in Part 3, Chapter 8 (“Deception, Mimicry, and Sensory Exploitation”) assesses the ways in which characteristics of sensory systems can be manipulated. The chapter includes discussion of the origin and function of sensory exploitation (broadly defined by Stevens to include all instances of exploitation of biases or traits of sensory systems, including sensory biases, sensory traps, and perceptual exploitation), how sensory exploitation relates to traditional sexual selection theory, and the use of deception and mimicry in antipredator defenses, foraging, and prey capture.

Part 4 consists of three chapters, and focuses on the factors influencing divergence and the generation of diversity, linking issues of signal form and evolution to population and species level processes. In Chapter 9 (“Arms Races, Coevolution, and Diversification”), Stevens discusses evolutionary arms races, coevolution, and the interplay between defensive coloration in prey and predator counter-adaptations. Stevens provides an excellent overview of visual stimuli, where most research has been conducted, and also discusses examples from other modalities where available. Chapter 10 (“Adapting to the Environment”) covers the ways in which the environment influences signal form and efficacy, including signal plasticity, tuning of sensory systems to habitats, and the impact of environmental noise. Particular emphasis is placed on how differences in the environment influence signal transmission and thus the optimal form of a signal when fulfilling its function. Finally, Chapter 11 (“Divergence, Sensory Drive, and Speciation”) focuses on the ways in which signaling and sensory systems influence divergence and speciation. Various mechanisms that can lead to divergence are discussed, including trait development (elaboration or innovation), sensory drive, and reproductive or ecological character displacement. Stevens’s coverage of the topics in Part 4 is particularly useful in driving home a central theme of the book: that species’ morphological and behavioral phenotypes are often best understood when studied from the converging perspectives of sensory ecology, behavioral ecology, and evolutionary theory.

In Part 5 Stevens concludes the book with a single chapter (Chapter 12: “Concluding Remarks”), in which he emphasizes the importance of considering the perspective of the receiver when studying sensory ecology, and on areas of the discipline that could particularly benefit from increased research focus, including those related to communication, molecular genetics, evolutionary processes, and animal cognition. The chapter ends with a call for increased collaboration and discussion within the field of sensory ecology, and a suggestion that the discipline might benefit from a dedicated journal and its own international conference.

Numerous examples are given through the book to illustrate the topics and principles of focus. These do seem to be somewhat biased toward auditory and visual stimuli, though this in large part of course reflects bias in the literature. Stevens makes efforts throughout to include examples from varied modalities, including electric and magnetic

inputs. Similarly, there is good taxonomic coverage, with examples being drawn from across a variety of different animal groups. Overall, examples given throughout the text are well chosen, and serve to reinforce the topics discussed in each chapter, and Stevens strikes a good balance between discussing classic examples while presenting new research. The book is also visually attractive in this regard, with numerous color images and figures throughout, which serve to reinforce the examples given in the text.

Stevens frequently emphasizes the importance of considering the sensory system of the receiver when studying sensory ecology. This cannot be understated. All too many studies have been conducted based on human perception, without sufficient regard to the perceptual systems of the species of interest. The use of models of animal sensory systems to simulate the perspectives of receivers is one approach to tackle such issues, but ultimately, observational or experimental evidence of receiver responses to stimuli is the gold standard for assessing receiver perception and determining responses to inputs.

Throughout *Sensory Ecology, Behaviour, and Evolution* readers get the feeling that sensory ecology is an exciting field in which there is a good foundation of research, as well as many exciting new avenues to develop and findings to come. This is undoubtedly due to both the excellent overview of the field provided by the book, as well as to the author's clear enthusiasm for the topic. Stevens highlights many areas in which progress awaits, and in each chapter there is a "Future Directions" section that explicitly outlines topics of future research that are likely to be particularly fruitful. This combination of enthusiasm for current research and consideration of future directions in the field is likely to inspire new generations of sensory ecologists.

Overall, the book is an excellent contribution to an emerging field. We highly recommended it for advanced undergraduates and graduate students interested in animal behavior. Researchers looking for an introduction to a new area, or for highlights of key results and interesting topics, will also find the book at an appropriate level, and at the end of each chapter Stevens points to relevant literature for readers interested in a greater depth of information. As sensory ecology continues to expand and develop as a discipline, it is important for the field to have clear literature sources by which fruitful topics and areas of research are guided. *Sensory Ecology, Behaviour, and Evolution* is likely to be the go-to general reference on sensory ecology for years to come.

References

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