ADAPTIVE BEHAVIOR AND LEARNING

Every day at about 4:30, Jazz, a Hungarian Vizsla dog, leaps up on the sofa and looks out for his owner who always comes home at 5:00. He doesn't need an internal clock because he has an acute sense of smell that allows him to measure how long his master has been absent. Explaining complex behavior in simple ways, this book is a fascinating exploration of the evolution, development, and processes of learning in animals. Now in its second edition, there is increased emphasis on development, evolution, and dynamics; new accounts of taxic orientation, reflex induction, habituation, and operant learning in organisms; more discussion of spatial learning and the processes underlying it; expanded chapters on choice, and completely new chapters on molar laws, classical conditioning theories, and comparative cognition. J. E. R. Staddon provides a definitive summary of contemporary theoretical understanding suitable for graduates and advanced undergraduates.

J. E. R. STADDON is James B. Duke Professor of Psychology and Professor of Biology and Neurobiology, Emeritus at Duke University. He has written and lectured on public-policy issues such as education, evolution, traffic control, and the effects of sociobiological aspects of the financial system, and is the author of over 200 research papers and five books, including *The New Behaviorism* (2014), *Unlucky Strike* (2013), *The Malign Hand of the Markets* (2012), and *Adaptive Dynamics: The Theoretical Analysis of Behavior* (2001).

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J. E. R. STADDON
Duke University

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Preface to the second edition

The first edition of *Adaptive Behavior and Learning* was published at a time when research on animal learning was at its apogee. By 1983 the divisions of the field and its basic principles had already been established. Advances have been made since then in mapping neurophysiological underpinnings and in the elaboration and refinement of theoretical models. Many new experimental papers have been published. But relatively little has been added by way of fundamental principles or new behavioral techniques. Even without revision, therefore, *AB&L* had acquired relatively little of a Rip van Winkle aspect even after thirty years. This impression was confirmed as I continued to receive requests for the book even though it had long been out of print. Cambridge University Press issued a digitally printed edition of the original book in 2009. Hints that the book still had signs of life led me over the years to revise and modify it, leading to the creation of an internet edition in 2003, revised again in 2010.

In 2013, I approached Cambridge with the idea that they might be willing to convert my 2010 PDF file into a Kindle format, so the book could reach a larger audience. They declined, but after some discussion made a counter offer of a new paper edition. I happily agreed. But this new development forced me to reconsider the whole project.

I decided to do a complete revision. The original book had an odd format: relatively elementary chapters, each followed by a more advanced appendix. Citations were named in the text, in the standard style. I have modified both these features in this edition. The research literature on animal learning has grown vast. To cite every author in the text would be otiose – and distracting, encouraging the reader to focus on the names rather than the ideas. So citations are now largely confined to footnotes. The internet, which did not exist at the time of the first edition, now provides ready access to scholarly sources. It makes unnecessary a totally comprehensive reference list. As for the mathematical appendices, only Chapter 4 retains an appendix. Otherwise, I have incorporated that material, plus several new topics, into the chapters, some of which are slightly more mathematical than before.

The field of neuroscience now dwarfs purely behavioral studies. I have little to say about this vast efflorescence. Unfortunately, too much neuroscience is based on outdated or simplistic learning models – or happily reinvents the theoretical wheel. There is a recurring tendency to think that if an experience can be shown to "change the brain" it is somehow

more significant than if it merely changes behavior,[1] as if there are changes in behavior *unaccompanied* by changes in the brain – behavior caused by the soul, perhaps, or astral forces? A coherent reminder of what we really do know at the behavioral level may be helpful.

The book is behavioristic in tone. But unlike radical behaviorism it recognizes that internal states, in the computational sense, are essential to any theoretical account of historical processes. "Behavior" alone is not enough for a full account (it will be a task for historians to figure out why this barren notion once dominated the field). An animal is a historical system. What it does or can do *now* depends on what it did and what happened to it in the past. "We step and do not step into the same rivers" in the mystical words of Heraclitus. The animal we study today is not the same as the animal we studied yesterday. Operant conditioning adapted to this essential irreversibility by restricting itself to reversible phenomena, the apparently stable performances on schedules of reinforcement. But of course the animal may behave in the same way on repeated exposure to a given procedure, but it isn't in the same *state*. Its potential is changed by each new experience. If we are interested in individual organisms, the *only* way to understand them is through theory – theory that conjectures about the organism's state and how it is changed by experience. Ignoring, indeed denying, the need for theory of this type was a huge mistake in the early history of operant conditioning. This book does not perpetuate it.

On the other hand, the book is not "cognitive" in the conventional sense. I don't believe that "Pavlovian and operant protocols" are best treated formalistically as "multivariate, nonstationary time – series problems" or that learning is – or is not – "associative" or "modular." I doubt that advance prescriptions about what theory *must* be are very helpful: "computational processing of information-bearing sensory signals constructs a symbolic representation of selected aspects of the animal's experience, which is stored in memory and subsequently retrieved for use in the decision processes that determine the behavior we observe." Well, you can certainly look at *any* learning process in that way. But is it an accurate description of what is going on in the laboratory rat? Maybe – or maybe not. I also doubt whether ideas derived from introspection can provide profitable targets for animal research. On the other hand, I agree with cognitive theorists who accept that learning is an adaptive specialization rather than a single general-purpose process.

The original edition was designed neither as a textbook nor as a comprehensive review of what was even then a substantial literature. It had too many equations and too many theoretical speculations to be a successful text – and was too focused on operant (as opposed to classical) conditioning to present a balanced picture of the whole field of animal learning. Nevertheless, I believe it presented a unique mix of topics that are closely related in fact, even though they don't usually find themselves discussed in the same context: philosophy of behavior, systems analysis, orientation mechanisms in simple organisms and their relation to operant behavior, feeding regulation, optimality analysis and behavioral

[1] "Studies in neuroplasticity – the brain's adaptability – have proved that repeated experiences actually change the physical structure of the brain." *TIME*, September 23, 2014. The behavior changes but the brain doesn't? Now that *would* be amazing!

economics, behavioral ecology, animal cognition, memory, choice behavior, and operant conditioning. This edition has more to say about classical conditioning, which conditions not just salivation or the nictitating membrane but an animal's whole repertoire. In the Darwinian duo of selection and variation that governs all adaptive behavior, classical conditioning modulates variation, operant conditioning is about selection.

The book is not punctilious about terminology. I'm happy to call some behavior "instinctive" or "learned" and use "reward" and "reinforcement" more or less interchangeably. But in every case I've tried to be clear about what is meant. It is appropriate to be strict about terminology when a field is mature. After Newton, Joule, and James Clerk Maxwell, there is no excuse for not defining heat and energy in a precise way. But psychology has not reached that level of theoretical understanding. In its absence, to obsess about terminology is mere pedantry.

As for theory, my bias is for simplicity. Computation and statistical and neural modeling now allow simulation of almost any data set to any degree of precision. But simulation is not understanding. Science is about understanding, which means explaining much with little. The famous Rescorla–Wagner conditioning theory, for example, doesn't explain everything and ignores much that is critical to conditioning. But it remains influential after more than 40 years because it does a great deal with a very simple formula. I have tried to follow the same principle, to present the simplest analysis/model for a phenomenon, even if it doesn't account for everything.

The organization of the book is improved. It now comprises 21 chapters rather the original 14. A number of topics have been rewritten or given more extensive coverage in this edition. There is more on reflex dynamics, an expanded discussion of classical conditioning, a separate chapter on conditioning models, a new chapter on the molar matching law and its progeny, much more on the dynamics of choice, expanded discussion of timing and memory and popular operant procedures. There is a new chapter on comparative cognition.

The book assumes no prior knowledge of psychology. But familiarity with graphs and the algebra of simple functions – the kind of sophistication acquired after a course or two of college math, chemistry, physics, or engineering – will make things much easier. There is a little elementary differential/difference calculus in the text, but it can be skipped over and the arguments should be clear without it.

This book is about adaptive behavior and learning in animals, not about learning in people. Animals are worth studying because they are intrinsically interesting, relatively easy to experiment on, complicated enough to be a challenge – and not as smart as we are. Perhaps we can actually begin to understand them scientifically in a reasonable time. I firmly believe that if we want to build a scientific understanding of the evolution and meaning of intelligence, in people as well as animals and machines, we must begin with animals – and in study that is directed at the problems they pose, without one eye always on what ails humanity. I am certain that the eventual payoff will indeed be an understanding of people as well as beasts. But solving human behavioral problems is likely to take some time, and it may be impeded by trying to run before we can walk.

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For the internet edition, I am grateful first of all to several generous reviewers of the first edition (especially Sara Shettleworth for a kind review in *Nature*) and to Gerry Edelman who brought the book to the attention of neuroscientists through extensive citation in his pioneering *Neural Darwinism* (1987). I thank Tony Nevin who encouraged me to revisit the ideas developed in the new Chapter 13 and read an early version; Doug Elliffe was also kind enough to comment on Chapter 13. I am grateful to my assistant Teresa Scott who rendered a crude OCR version of the original text into an approximation of its final format and made sense of often incoherent instructions on making the final files presentable.

I am grateful to Duke University for an environment hospitable to scholarship, to the John Simon Guggenheim Memorial Foundation for a fellowship that allowed me to finish

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Finally, I thank my students who, as a *festschrift* reminded me, have provided me with so much enthusiasm, energy, and intellectual stimulation over many years. I dedicate this edition to them.