

## 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).

# ADAPTIVE BEHAVIOR AND LEARNING

SECOND EDITION

J. E. R. STADDON  
*Duke University*



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## Contents

<i>Preface to the second edition</i>	<i>page</i> xiii
<i>Acknowledgments</i>	xvi
1 The evolution, development, and modification of behavior	1
Canalization	3
Explanation	4
Function, causation, and teleonomy	6
Evolution and development	9
Epigenesis and genetic assimilation	13
Lamarck, Darwin, and gemmules	17
Early environment	20
Summary	22
2 Variation and selection: kineses	24
Simple orienting mechanisms	24
Indirect orientation (kineses)	26
Neurophysiology and behavior	35
3 Reflexes	38
Volition and the mind-body problem	40
Sherrington's reflex	41
Individual reflexes	43
Threshold	43
Latency	44
Refractory period	45
Temporal summation	45
Spatial summation	46
Momentum (after discharge)	47
Habituation	47
Rate sensitivity	48
Reflex interaction	52
Reciprocal inhibition (competition)	53

Cooperation	54
Successive induction	55
Averaging	61
Inhibition and reflex strength	62
Summary	66
4 Direct orientation and feedback	67
Taxes	67
Klinotaxis	67
Tropotaxis	70
Light-compass reaction	73
Telotaxis	74
Feedback analysis	75
Dynamic analysis	78
Frequency analysis	80
Three simple feedback responses	85
When is feedback useful?	88
Behavioral integration and the role of variability	90
The nature of explanation	95
The meaning of “black-box” analysis	95
Purpose, teleology, and mechanism	96
Summary	98
Appendix A4.1	99
Linear systems analysis	99
5 Operant behavior	102
Operant behavior and B. F. Skinner	102
Causal and functional analysis of operant behavior	104
Parallel models	108
Operant behavior and learning	112
Information theory	115
Operant and classical conditioning: overview	116
Habituation	116
Sensitization	118
Pseudoconditioning	118
Classical conditioning	119
Operant conditioning	120
Generalization and discrimination	122
The logic of historical systems	124
Finite-state systems	125
Equivalent histories and the experimental method	127
Between-groups experiments: averaging data	128
Within-subject method	131

*Contents*

vii

Memory	132
Summary	133
6 Reward and punishment	135
Reinforcement and the law of effect	137
Experimental methods	142
The Skinner box	144
Response- and time-based schedules of reinforcement	146
Equilibrium states	151
Classical conditioning	154
Contingency and feedback functions	156
Contingency space	161
Temporal and trace conditioning	163
Response contingencies and feedback functions	165
Feedback functions for common schedules	168
Ratio schedules	168
Interval schedules	168
Interlocking schedules	169
Escape, avoidance, and omission schedules	171
Shock postponement	171
Detection of response contingency	172
Summary	174
7 Feeding regulation: a model motivational system	175
Reinforcement and homeostasis	175
Obesity and schedule performance: a static analysis	179
The meaning of brain lesion experiments	181
The effects of hypothalamic lesions on eating	182
A regulatory model	185
Finickiness	191
Response to dilution of diet	191
Weak defense of settling weight	192
Improved defense of low settling weights	194
Poor adaptation to work requirements	194
Effects of taste and body weight on work schedules	197
Other motivational effects	198
Limitations of the linear model	199
Human obesity	200
Derivations	202
Summary	203
8 The optimal allocation of behavior	205
Time constraints and behavioral competition	206

Rate and time measures	206
The allocation of behavior	209
Income and substitution effects	211
Value, reinforcement, and Darwinian fitness	214
Optimal allocation	215
The minimum-distance model	218
Prediction of response functions	223
Bliss point and characteristic space	225
Substitutability and indifference curves	226
Marginal value and substitutability	229
Experimental applications	231
Reinforcement constraints	235
Summary	240
9 Choice: dynamics and decision rules	242
Real time: the cumulative record	244
Choice dynamics and the law of effect	244
Random-ratio choice	247
Identical random ratios	249
Concurrent variable-interval schedules	257
Optimal choice	259
Probability learning	260
Delayed outcomes: “self-control”	263
Temporal discounting	266
Variable outcomes: risk	268
Human choice, risk, and behavioral economics	269
Matching and maximizing	276
Marginal value and momentary maximizing	277
Concurrent VI–VI	278
Momentary maximizing	280
Concurrent VI–VR	285
Summary	286
10 Foraging and behavioral ecology	287
Diet selection and functional response	287
Functional response	288
Diet choice	290
Switching	292
1. Absolute density changes	293
2. Nonrandom spatial distribution	294
3. Changes in profitability with experience	294
4. Changes in effective density with experience	295
Search image	296

*Contents*

ix

Receiver operating characteristic (ROC) analysis	297
Ecological implications	302
Nutrient constraints and sampling	305
Natural feedback functions	307
Summary	309
Appendix A10.1	310
The effect of prey density on prey risk	310
Appendix A10.2	311
Switching and functional response	311
Appendix A10.3	312
Foraging in a repleting food source	312
11 Stimulus control and cognition	313
Discriminative and eliciting stimuli	314
Stimulus equivalence and data structure	316
Analog versus digital coding	318
Psychophysics and similarity	319
Measuring stimulus control	320
Stimulus generalization	323
Generalization gradients	323
Compounding of elements	325
Stimulus control and reinforcement: variation and attention	326
Attention	328
Attention to different dimensions	329
Similarity	334
Maps	337
Multidimensional scaling	340
Spatial representation as a data structure	341
Summary	343
12 Stimulus control and performance	345
Inhibitory and excitatory control	345
Feature effects	346
Behavioral contrast and discrimination performance	348
Schedule-induced behavior	351
Intertemporal effects	353
Inhibitory generalization gradients	356
Conjoint stimulus control and peak shift	359
Historical Note: Spence's Theory of Transposition	366
Transitive Inference	367
Dynamic effects in multiple schedules	369
Stimulus effects	374
Summary	375



x	<i>Contents</i>	
13	Molar laws	377
	Matching and optimality	377
	Matching and minimum distance	378
	Contrast and matching	379
	1. Simple VI (single-response case)	380
	2. Concurrent VI–VI (two-response case)	380
	3. Multiple VI–VI	381
	Boyle and the molar law	384
	Historical review	384
	Resistance to change	387
	A continuous model	390
	Multiple VI–VI	391
	Multiple VI–VI–VT	391
	CMP Model: Conclusion	393
	Problems	393
	Summary	397
14	Time and memory, I	398
	Temporal control	398
	The reinforcement omission effect	400
	Excitatory and inhibitory temporal control	403
	Conditions for temporal control	405
	Timing and fixed-ratio schedules	408
	Characteristics of the time marker	409
	Overshadowing	415
	Conclusion: the discrimination of recency	415
	Time estimation	416
	Proaction and retroaction	418
	Summary	419
15	Time and memory, II	421
	Discrimination reversal and learning set	423
	Reversal learning in human infants	426
	The serial position effect (SPE)	428
	Learning set	428
	Learning dynamics	429
	Memory and spatial learning	430
	The radial-arm maze	431
	Radial-maze performance	431
	A two-part code	433
	Spatial code	433
	Temporal code	433

*Contents*

xi

Response rule	434
Spatial effects	435
Temporal effects	437
Other spatial situations	438
The route finder	441
Summary	443
16 Template learning	445
Imprinting	446
Song learning	451
Summary	455
17 Learning, I	457
Bees	458
Learning as program assembly	459
Reinforcement and learning	460
Latent learning	461
Inference	463
Partial reinforcement	465
Bayes' rule	466
Taste-aversion learning	467
Delay-of-reward gradient	471
The order of learning	472
What is learned?	473
Surprise	473
Methodology	477
Expectation and classification	478
Learning and classification	479
Recognition and expectation	483
Summary	484
18 Models of classical conditioning	486
Inference and classical conditioning	486
Contingency space	487
Blocking	488
Conditioning to novel tastes	488
Latent inhibition	488
Preexposure to the US	488
Models for conditioning	490
New learning model	496
Conclusion: trial-level models	499
Temporal variables	500

xii	<i>Contents</i>	
19	Learning, II	501
	Classical conditioning and the origins of operant behavior	503
	The “superstition” experiment	506
	Behavioral variation: the origins of operant behavior	511
	Inference, action, and operant conditioning	512
	Misbehavior	514
	Behavioral variation and sampling	515
	The guidance of action	516
	Initial state	516
	Selection rules	519
	Response–reinforcer contiguity	519
	Shaping	523
	Feedback function	525
	Schedule-induced behavior	526
	Conclusion: operant learning	529
	Summary	529
20	Learning, III: procedures	532
	Conditioned reinforcement	532
	Concurrent chained schedules	536
	On the virtues of optimality analysis	539
	Quasi-reinforcement	539
	Second-order schedules	541
	Conditioned emotional response	542
	Anxiety?	543
	Avoidance and escape	544
	Limits to variation: response-produced shock and “learned helplessness”	548
	Learned helplessness (LH)	550
	Sampling versus exploitation	551
	Extinction	554
	Summary	561
21	Comparative cognition	563
	Insight	564
	Fast mapping	567
	Metacognition	569
	The logic of metacognition	572
	Summary	577
	<i>Index</i>	579

## 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,<sup>1</sup> 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

<sup>1</sup> “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.

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xvii

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