

# LEARNING AND MEMORY

### AN INTEGRATED APPROACH

**Second Edition** 



Carnegie Mellon University



JOHN WILEY & SONS, INC.

## **PERSPECTIVES ON LEARNING AND MEMORY**

Learning and Adaptation 1 Behaviorist and Cognitive Approaches 3 Definitions of Learning and Memory 4 History of Research on Learning and Memory 6 Hermann Ebbinghaus (1850–1909) 7 Ivan Petrovich Pavlov (1849–1936) 9 Edward L. Thorndike (1874–1949) 12 Clark L. Hull (1884-1952) 16 Edward C. Tolman (1886–1959) 17 B. F. Skinner (1904–1990) 20 The General Problem Solver (Newell & Simon, 1961) 24 A Model of Memory (Atkinson & Shiffrin, 1968) 27 Neural Basis of Learning and Memory -30 The Nervous System 30 The Neuron 33 Neural Explanations and Information-Processing Explanations 35 Outline of the Book 37

### Further Readings 38

### CLASSICAL CONDITIONING

Overview 39

The Phenomena of Classical Conditioning: Eye Blink in Humans 39

Sensitization and Habituation 41 Conditioning and Awareness 42 What This Chapter Covers 43 39

Neural Basis of Classical Conditioning 44
Simple Learning in Aplysia (Sea Slug) 45
Classical Conditioning of the Eye Blink in the Rabbit 47
S–S or S–R Associations? 49
Response-Prevention Paradigm 50
US Devaluation Paradigm 51
Sensory Preconditioning Paradigm 51
Second-Order Conditioning Paradigm 52
Conclusions 53
What Is the Conditioned Stimulus? 53
What Is the Conditioned Response? 54
Association: The Role of Contingency 58
Rescorla's Experiment 58
Conditioned Inhibition 60
Associative Bias 61
Conclusions about the Nature of the Association 62
Conditioning to Stimulus Combinations 63
Blocking 63
Configural Cues 64
Conclusions 65
The Rescorla–Wagner Theory 65
Application to Compound Stimuli 66
Application to Blocking and Conditioned Inhibition 68
Problems with the Rescorla–Wagner Theory 70
Neural Realization: The Delta Rule 72
Final Reflections on Classical Conditioning 75
Further Readings 77

## **3** INSTRUMENTAL CONDITIONING

78

Overview 78

Classical and Instrumental Conditioning Compared 79 What This Chapter Covers 80

### What Is Associated? 80

Associations Between Responses and Neural Outcomes 81 Secondary Reinforcement 82

### What Is the Conditioned Stimulus? 83

Generalization84Discrimination86Spence's Theory of Discrimination Learning88Relational Responding: Transposition89Dimensional or Attentional Learning90Configural Cues and Learning of Categories93

What Is the Conditioned Response? 94
Maze Learning 95
Response Shaping and Instinctive Drift 97
Autoshaping 98
Association: Contiguity or Contingency? 99
Superstitious Learning 101
Partial Reinforcement 102
Learned Helplessness 103
Associative Bias 104
Instrumental Conditioning and Causal Inference 106
Application of the Rescorla-Wagner Theory 107
Interpretations 108
The Hippocampus and Conditioning 109
The Nature of Hippocampal Learning 112
Long-Term Potentiation (LTP) 114
Long-Term Potentiation and Hippocampal Learning 115
Final Reflections on Conditioning 116
Further Readings 117

## **4** REINFORCEMENT AND LEARNING

Some Basic Concepts and Principles 118 Rational Behavior 119 Effects of Reinforcement on Learning 121 Reward and Punishment 123 Aversive Control of Behavior 125 Punishment 125 Negative Reinforcement 129 The Nature of Reinforcement 130 Drive-Reduction Theory 130 Premack's Theory of Reinforcement 132 Neural Basis for Reinforcement 134 Equilibrium Theory and Bliss Points 134 Studies of Choice Behavior 137 Schedules of Reinforcement 137 Variable-Interval Schedules and the Matching Law 139 Momentary Maximizing 140 Probability Matching 142 Optimal Foraging Theory 143 Effects of Delay of Reinforcement 145 Mechanisms of Choice 148 Human Decision Making 148 Final Reflections 150 **Further Readings** 151

5 **TRANSIENT MEMORIES** Conditioning Research Versus Memory Research 152 Animal Research Versus Human Research 153 Sensory Memory 155 Visual Sensory Memory 155 Auditory Sensory Memory 157 Conclusions about Sensory Memory 159 The Rise and Fall of the Theory of Short-Term Memory 160 Effects of Rehearsal 160 Coding Differences 162 The Retention Function 164 Conclusions about Short-Term Memory 166 Rehearsal Systems 166 The Phonological Loop 167 The Visuo-spatial Sketch Pad 169 Working Memory and the Central Executive 171 The Sternberg Paradigm 172 Rehearsal Processes in Lower Organisms 175 The Neural Basis of Working Memory 178 Neural Imaging of Working Memory in Human 180 Final Reflections 183 Further Readings 184

## **6** ACQUISITION OF MEMORIES

Stages of Memory 185 Practice and Trace Strength 186 The Power Law of Learning 187 Repetition and Conditioning 191 Long-Term Potentiation and the Environment 192 Significance of a Power Function 195 Elaborateness of Processing 197 The Generation Effect 198 Differences Between Elaboration and Strength 200 Incidental Versus Intentional Learning 201 Implications for Education 202 The Structure of Memory 203 The Brain and Memory 203 <sup>4</sup> An Abstract Representation of Permanent Memory 205 Priming 206 Chunking 207 Representation of Knowledge 210 Memory for Visual Information 211

Effects of Imagery 214 Meaningful Memory for Sentences 215 Differential Decay of Sensory and Semantic Information 216 Kintsch's Propositional Theory of Text Memory 218 The Bransford and Franks Study 219

### Memory Representation in Other Species 221

Sequential Memory of Pigeons 221 Representational Structures in Primates 222

Final Reflections 223 Further Readings 225

### **RETENTION OF MEMORIES**

226

### Overview 226

### The Retention Function 227

Decay: The Power Law of Forgetting 228

Degree of Learning and Forgetting 231

Environmental and Neural Bases for the Power Law of Forgetting 232

#### Spacing Effects 234

Spacing Effects on the Retention Function 237 Spacing Effects in the Environment 238

#### Interference 239

Item-Based Interference 241

A Theory of Associative Interference 243

Relationship to the Rescorla–Wagner Theory 245

Recognition Memory and Multiple Cues 246

Item Strength and Interference 248

Interference with Preexperimental Memories 249

Context-based Interference 252

Is All Forgetting a Matter of Interference? 254

### Retention of Emotionally Charged Material 256

Freud's Repression Hypothesis 256 Arousal and Retention 257 The False Memory Syndrome 259 Eyewitness Memory and Flashbulb Memories 260 Final Reflections 262 Further Readings 264

### **RETRIEVAL OF MEMORIES**

265

Overview 265 The Relationship Between Various Explicit Measures of Memory 266 Recognition Versus Recall of Word Lists 268

Retrieval Strategies and Free Recall 270 Mnemonic Strategies for Recall 271 Evaluation of the Generate-Recognize Theory 273 Measuring Recognition Memory: The High-Threshold Model 276 Signal Detectability Theory 276 Conclusions about Recognition Versus Recall 279 Interactions Between Study and Test 279 Context Dependency of Memory 279 State-Dependent Memory 280 Mood-Dependency and Mood-Congruence Effects 282 Encoding-Specificity Principle and Transfer-Appropriate Processing 284 Reconstructive and Inferential Memory 285 Inferential Intrusions in Recall 287 Conclusions About Study–Test Interactions 289 Explicit Versus Implicit Memories 290 Feeling of Knowing 290 Familiarity 291 Retrieval Facilitation 294 Interactions with Study Conditions 295 Amnesia in Humans 298 Selective Amnesia 301

Final Reflections302Further Readings303

## *9 skill acquisition*

Overview 304 Power Law Learning 307 Stages of Skill Acquisition 310 The Cognitive Stage 311 Difference Reduction 312 Operator Subgoaling 314 The Associative Stage 319 The Conversion of Problem Solving into Retrieval 320 Production Rules 322 The Knowledge-Intensive Nature of Skill 324 The Autonomous Stage 325 The Motor Program 326 Noncognitive Control 328 Generality of Motor Programs 329 Learning of Motor Programs 330 Tuning of Motor Program: Schema Theory 331 The Role of Feedback 334 Final Reflections 336 Further Readings 337

### xvi

## **10** INDUCTIVE LEARNING

Overview 338 Concept Acquisition 340 Concept-Identification Studies 341 Hypothesis Testing 343 Natural Concepts 346 A Schema Theory: Gluck and Bower 349 An Exemplar Theory: Medin and Schaffer 350 A Pluralistic View of Concept Acquistion 352 Causal Inference 354 Statistical Cues 355 Cues of Spatial and Temporal Contiguity 357 Kinematic Cues 361 Understanding Complex Systems 362 Conclusions about Causal Inference 364 Language Acquisition - 364 Character of Language Acquisition 366 Theories of Past-Tense Acquisition 368 A Critical Period for Language Acquisition 370 Innate Language-Learning Abilities 371 Animal Language Learning 372 Final Reflections 375 Further Readings 376

## **11** APPLICATIONS TO EDUCATION

The Goals of Education 377 Reading 379 Mathematics 380 Psychology and Education 383 The Behaviorist Program 383 Mastery Learning 386 The Cognitive Approach 387 **Reading Instruction** 387 Nature of the Adult Skill 388 Phonetic Decoding Skills 391 Comprehension Skills 393 Conclusions about Reading Instruction 396 Mathematics Instruction 397 Basic Arithmetic Facts 399 Multicolumn Subtraction 400 Algebraic Word Problems 401

р

Geometric Proof Skills 405 Intelligent Tutoring Systems 407 The Role of Mathematics in Life 411 *Final Reflections* 413 *Further Readings* 414

GLOSSARY 415

---1

**BIBLIOGRAPHY 426** 

PHOTO CREDITS 467

AUTHOR INDEX 469

SUBJECT INDEX 481