# **Contents**



# C H A P T E R O N E

Introduction 1

WHAT IS COGNITIVE PSYCHOLOGY? 1

PARADIGMS IN PSYCHOLOGY 2

STRUCTURALISM 2

BEHAVIORISM 2

COGNITIVE PSYCHOLOGY 3

# COGNITIVISM VERSUS BEHAVIORISM 6 INFORMATION PROCESSING VERSUS BEHAVIORISM 7 NEURAL NETWORKS AND INFORMATION

# PROCESSING 8 NEURAL NETWORKS AND THE MIND 11

BASIC PRINCIPLES 11
PROFESSORS AND STOCKBROKERS 14

PRACTICAL APPLICATIONS 16
SUMMARY AND CONCLUSIONS 18

## C H A P T E R T W O

# Pattern Recognition 19

## THE PROBLEM OF RECOGNITION 19

Anatomy and Physiology of the Visual System 20 Vision as Transduction 23

# TEMPLATE MATCHING 24 FEATURE ANALYSIS 25

What Is a Distinctive Feature? 25

Pandemonium and Hierarchical Feature Analysis 26

Implications of the Pandemonium Model 28

Substituting Logic Gates or Neurons for Demons 28

# WHAT THE FROG'S EYE TELLS THE FROG'S BRAIN 29

FEATURE DETECTION IN THE FROG'S RETINA 30
ORGANIZATION OF THE TECTUM 31
SOMATOTOPIC MAPPING 31

### IMPLICATIONS 32

# LATERAL INHIBITION AND FEATURE DETECTION 32

Edge Detection 32

Edge Detection in a Lateral Inhibitory Network 32 Edge Detectors in the Eye of the Horseshoe Crab 34 Mach Bands and Edge Enhancement 35

MOTION DETECTION 36

Lateral Inhibition and Motion Detection 36

Illusions of Motion 37

Motion-Detecting Neurons in Humans 38

# HIERARCHICAL FEATURE DETECTION IN THE CAT'S BRAIN 39

STRUCTURE OF THE CAT'S VISUAL SYSTEM 39

PANDEMONIUM IN THE CAT'S BRAIN 39

Hubel and Wiesel's Experiment 39

Simple Cells 40

Complex Cells 42

Hypercomplex Cells 42

CONCLUSIONS ABOUT CATS 43

ARE THERE COMPLEX OBJECT DETECTORS? 43
SUMMARY AND CONCLUSIONS 44

# C H A P T E R T H R E E

Mental Modules and Mental Contents 45

INTRODUCTION 45

MENTAL DIVISION OF LABOR 46

THE ARCHITECTURE OF MENTAL MODULES 46

# Basic Design 46 Lateral Inhibition 47 What Happens on Each Layer of a Module 48

### SENSORY ANALYSIS 50

General Principles 50
Segregation of Visual Sensations 50

### PERCEPTUAL ANALYSIS 51

VISUAL ANALYZERS 52
Printed-Word Analyzer 52
Visual-Object Analyzer 53
Facial Analyzer 53

AUDITORY ANALYZERS 53

#### CONCEPTUAL ANALYSIS 55

Levels of Processing 55
Characteristics of Conceptual Analyzers 55
Semantic Analyzer 55
Syntactic Analyzer 56
Episodic Analyzer 57
The Action System 58

# OVERVIEW OF HUMAN COGNITION 59

MENTAL CHRONOMETRY 60

Depth of Processing 60 Speed/Accuracy Trade-off Studies 61

# PERCEPTS, IMAGES, IDEAS, AND HALLUCINATIONS 63

BOTTOM-UP VERSUS TOP-DOWN ACTIVATION 63
THE CONTENTS OF CONSCIOUSNESS 64
MENTAL IMAGERY 64
HALLUCINATIONS AND DREAMS 67

### SUMMARY AND CONCLUSIONS 67

## C H A P T E R F O U R

# The Structure and Dynamics of Neural Networks 69

# COGNITIVE UNITS AS LOGIC GATES AND AS HYPOTHESES 69

### INTERACTIONS OF NODES AND LAYERS 70

ACTIVATION FUNCTIONS 70

MASKING FIELDS 71

OUTPUT FUNCTIONS 73

AMPLIFICATION OF ACTIVATION 73

RESONANCE AND UNCONSCIOUS INFERENCE 75

DIPOLES AND OPPONENT-PROCESS NODES 78

### ACTIVATION EFFECTS 81

Operating Characteristics of Cognitive Units 81
All-or-Nothing Versus Graded Activation 82

Stopped Images 83 Categorical Perception 83

EASE OF ACTIVATION 84

Threshold Effects 84

Sensitization Effects 85

Adaptation Effects 85

## CONNECTIONS AMONG COGNITIVE UNITS 8

VERTICAL EXCITATION 87

Misreading 87
The Word-Superiority Effect 88
The Sentence-Superiority Effect 89
The Object-Superiority Effect 89
LATERAL INHIBITION 90

Metacontrast 90 Tilt Illusions 91

# ADAPTIVE RESONANCE VERSUS SERIAL SEARCHES 91 SUMMARY AND CONCLUSIONS 93

## C H A P T E R F I V E

# Attention 95

THE STREAM OF CONSCIOUSNESS AND THE WAVE OF ATTENTION 95

ATTENTION, ANALYZERS, AND COGNITIVE UNITS 96
VOLUNTARY SELECTIVE ATTENTION 97

SHADOWING 97
EARLY-SELECTION MODELS OF ATTENTION 99
Broadbent's Model 99
Problems with Broadbent's Model 100

LATE-SELECTION MODELS OF ATTENTION 101

Norman's Model 101

Problems with Late-Selection Models 102

TREISMAN'S ATTENUATION MODEL 103

THE CAPACITY OF ATTENTION 103

EVAPORATION OF THE BOTTLENECK 103
RESOURCE MODELS 104
WHAT OPERATIONS REQUIRE ATTENTION? 104
Perception is Effortless and Preattentive 104
Divided Attention 106
Automaticity 107

**INVOLUNTARY SELECTIVE ATTENTION 108** 

What Attracts Attention? 108
The Orienting Reflex 108
Habituation 109
The Arousal System 109
Sokolov's Theory of Attention 110
Cortical Modeling 110
The Match/Mismatch Rule 111
Explanation of Voluntary Attention 111

### THE MECHANISMS OF SELECTIVE ATTENTION 112

Lateral Inhibition and the Seizure of Attention 112
The Arousal System and Attention 113
Gated Dipoles and Attentional Resetting 114

SUMMARY AND CONCLUSIONS 116

## C H A P T E R S I X

# Primary Memory 119

ASPECTS OF AWARENESS 119

Dissecting Consciousness 119

Sensory Memory Versus Short-Term Memory 120

SENSORY MEMORY 120

ICONIC MEMORY 120
ECHOIC MEMORY 121
Duration of Echoic Memory 122
The Stimulus-Suffix Effect 122

SHORT-TERM MEMORY 124
Information-Processing Approach 124
Neural-Network Approach 125

THE CAPACITY OF SHORT-TERM MEMORY 125
The Span of Immediate Apprehension 125
Stimulus Qualities and Capacity 126

THE FORM OF CONSCIOUSNESS 127
Short-Term Memory Capacity and Arousal 127
The Yerkes-Dodson Law 129

Short-Term Memory and Normalization 130

SERIAL-POSITION EFFECTS 132

Shape of the Serial-Position Curve 132 The Primacy Effect 133 The Recency Effect 133

Time-Order Errors 133

ACTIVATION EFFECTS 135

The von Restorff Effect 135
Inhibition and Disinhibition Effects 136

REHEARSAL 139

Loss from Short-Term Memory 140

Prevention of Rehearsal 140 Interference 141 Retroactive Inhibition 141 Proactive Inhibition 142 Release from Proactive Inhibition 142

RETRIEVAL 143

Sternberg's Experiment 143 Types of Memory Search 144 Evidence for Direct Access of Short-Term Memory 144

SUMMARY AND CONCLUSIONS 145

# C H A P T E R S E V E N

Learning and Forgetting 147

LEARNING 147

To Be Conditioned Is to Develop a Theory 148

Basic Principles of Learning 149

Synchronization of CS and UCS 150

Overshadowing 151

Blocking and the Turkey/Love Fiasco 152

Secondary Reinforcers 153

Attention and Reinforcement 154

Latent Learning and Attention 155

Repetition and Learning 155

GENERALIZATION AND DISCRIMINATION 156
PEAK SHIFT AND BEHAVIORAL CONTRAST 156

## FORGETTING 158

EXTINCTION 158

EXTINCTION, REINFORCEMENT, AND HUMAN MEMORY 159

INTERFERENCE VERSUS DECAY 160

INTERFERENCE THEORIES 161

The Basic Data 161

Response Competition 162

Unlearning 163

Response Inhibition 164

Conclusions about Interference 165
Decay Theory Revisited 165

THE HEBB RULE 166

A NEURAL NETWORK LEARNS ABOUT MEN, WOMEN, AND DOUGHNUTS 166

SUMMARY AND CONCLUSIONS 169

# C H A P T E R E I G H T

Long-Term Memory 171

# DISSECTING LONG-TERM MEMORY 171

# SEMANTIC MEMORY 172

The Semantic Analyzer 172
Network Models of Semantic Memory 173
Stored Versus Inferred Knowledge 173
Spreading Activation 174
Finding Falsehood 175

Contradictions 175
Responding to Ridiculous Assertions 176
Salient Counterexamples 176

Strength of Excitatory Connections in Semantic Memory 177

LATERAL INHIBITION IN SEMANTIC MEMORY 178

Production of Category Instances 178

Part-List Cues 179

Mach Bands in Memory: Inhibition by Category Priming 179

FORGETTING SEMANTIC INFORMATION 180

# EPISODIC MEMORY 181

RECONSTRUCTION VERSUS VERIDICAL MEMORIES 181
STRUCTURE OF THE EPISODIC ANALYZER 183
EVENT UNITS 183
EPISODE, STORY, AND PLOT UNITS 184
WHAT IS REMEMBERED 185
MY MEMORIES OF THE THIRD REICH 185
ASSIMILATION TO SCHEMAS 186
EYEWITNESS TESTIMONY 187

Demonstration that Memory Involves Assimilation to Schemas 188

Stories, Memory, and Affect 188
Memory For Sequential Order 189
Encoding Specificity 191

PROCEDURAL KNOWLEDGE AND ACTION 192
THE STRUCTURE OF ACTION 193

THE ACTION SYSTEM 194

Propositional Nature of Action 194
Executive Ignorance 194
Sensorimotor Memories 194
Structure of the Action System 195
Connections to Other Analyzers 197

AVALANCHE CIRCUITS 198

### SUMMARY AND CONCLUSIONS 199

### CHAPTERNINE

# Language 201

# THE POWER OF LANGUAGE 201 THE GLORY OF LANGUAGE, WITH A NOTE ON ITS ORIGIN 202

LANGUAGE VERSUS COMMUNICATION 203
WHAT IS LANGUAGE? 203

GRAMMAR 205

Overview 205
Survival in the Prison House of Language 206

# LANGUAGE COMPREHENSION 207

Phonology 207

Components of Speech 207
Distinctive Features 208
The Silence of Sounds and the Sounds of Silence 210

SEMANTICS 211

Meaning and Context 211 Meaning is Metaphorical 211 SYNTAX 213

Surface Structure 213
Deep Structure 213
Case Grammar 214
Assimilation to Propositions 215

PARALLEL PARSING 216

### LANGUAGE DISORDERS 218

Broca's Aphasia 218 Wernicke's Aphasia 218 What Aphasia Tells Us 219

LANGUAGE ACQUISITION 220
Is Language Ability Innate? 220
First Words 221
First Syntax 222

SUMMARY AND CONCLUSIONS 223

# CHAPTERTEN

Thinking 225

WHAT IS THINKING? 225

DEDUCTIVE REASONING 226

How Logicians Think 226 Conditional Logic 226 Representation of the Problem 227

PROBLEM SOLVING 228

DEFINITION 228

REPRESENTING THE PROBLEM 228

#### DIFFERENCE REDUCTION 229

### CREATIVE PROBLEM SOLVING 230

Definition 230
Creativity and Analogy 230
Analogies and Concepts 230
Stages of the Creative Process 231
Incubation, Effortless Inspiration, and Primary
Memory 231

#### INDUCTIVE REASONING 233

Induction and Scientific Reasoning 233
Hypothesis Testing and Confirmation Bias 234

### CHOICE AND DECISION MAKING 235

STRATEGIES OF CHOICE 236
Additive Strategy 236
Short-Cut Strategies 237

Choosing Something Similar 237
Expected Value and Expected Utility 239

Expected Utility 240
The Psychophysics of Money and Happiness 240
The Future Is Not Worth Much 241
The Value of Gains and Losses 242
Framing and Choice 243

SUBJECTIVE PROBABILITY 244

Availability 245

Representativeness 246

SUMMARY AND CONCLUSIONS 247

REFERENCES 249
AUTHOR INDEX 271
SUBJECT INDEX 277