Contents

List of Contributors Acknowledgement

xxi xxvii

SECTION A

INTRODUCTION

1. The Neurobiology of Language

STEVEN L. SMALL AND GREGORY HICKOK

1.1 History	3
1.2 Lesion Analysis	3
1.3 From Neuropsychology to Cognitive	
Neuroscience	4
1.4 The Neurobiology of Language	5
1.5 Some Common Fallacies	5
1.6 Humans in Particular	6
1.7 Cognition and the Neurobiology of Language	7
1.8 Brain Disease, Treatment, and the Neurobiology	
of Language	7
1.9 Summary	8
References	8

SECTION B

NEUROBIOLOGICAL FOUNDATIONS

2. A Molecular Genetic Perspective on Speech and Language

SIMON E. FISHER

2.1	Introduction	13
2.2	The Discovery of FOXP2	14
2.3	FOXP2 Mutations in Speech and Language	
	Disorders	15
2.4	Functions of FOXP2: The View from the	
	Bench	16
2.5	Insights from Animal Models	17
2.6	FOXP2 in Human Evolution	20
2.7	Conclusions	20
	References	21

3. The Ventrolateral Frontal Region

MICHAEL PETRIDES

	3.1	Cytoarchitectonic Areas of the Ventrolateral	
		Prefrontal Cortex	27
	3.2	Parietal and Temporal Cortico-Cortical	
		Connection Patterns of the Language	
		Production Areas in the Ventrolateral	
		Frontal Region	28
	3.3	Functional Implications	30
	3.4	Non-Ventrolateral Prefrontal Areas	
		and Their Possible Role in Language	31
		Acknowledgments	32
		References	32
4.	On	the Neuroanatomy and Functional Role	
	of t	he Inferior Parietal Lobule and	
	Int	raparietal Sulcus	

FERDINAND CHRISTOPH BINKOFSKI, JULIANE KLANN AND SVENJA CASPERS

4.1 Gross Anatomy of the IPL and IPS	35
4.2 Modern Parcellation of the IPL and IPS	35
4.3 Connectivity of the IPL and IPS	38
4.4 Anatomical Differences Between Humans	
and Monkeys	39
4.5 Functions and Functional Connectivity	
of the IPL and IPS	39
4.6 Summary	43
References	43

5. Human Auditory Cortex

BRIAN BARTON AND ALYSSA A. BREWER

5.1	Introduction	49
5.2	Cortical Field Maps	49
5.3	Tonotopy: The First Dimension of AFMs	50
5.4	Cortical Organization of the Monkey	
	Auditory System	50
5.5	Cortical Organization of the Human	
	Auditory System	51
5.6	Periodotopy: The Second Dimension of AFMs	52
5.7	Similarities to AFM Organization in the	
	Human Visual System	53
5.8	"Clover Leaf" Clusters Across Senses	55

vi	ii		CONT	ents
	5.9 Conclusion References		55 56	
6.	Motor Cortex and Monkeys and Hu	d Mirror System in mans		
GIA	ACOMO RIZZOLATTI AN	D STEFANO ROZZI		10.
	6.3 The Human M	and Communication	59 59 65 67 68 69 69	JESS
7.	Cerebellar Contr Language	ibutions to Speech and		
HE	ERMANN ACKERMANN A	ND BETTINA BRENDEL		11.
	7.1 Introduction	nd Microscopic Anatomy	73	HUC
	of the Human	- · ·	73	
	and Compositi	on of the Cerebellum port of Motor Control in	76	
	Humans: Uppe	er Limb Movements of the Cerebellum to Speech	76	
	Motor Control	_	77	
	Functions 7.7 Conclusion References		80 82 82	

8. The Anatomy of the Basal Ganglia

KATE E. WATKINS AND NED JENKINSON

8.1 Introduction	85
8.2 Historical Background	85
8.3 Overview of Basal Ganglia Anatomy	86
8.4 The Role of the Basal Ganglia in Speech	
Motor Control	90
8.5 The Role of the Basal Ganglia in Language	91
8.6 Segregated Functional Loops for Speech and	
Language	92
8.7 Summary	92
References	92

9. The Thalamus and Language

DANIEL A. LLANO

9.1	Overview of Thalamic Organization	95
9.2	Defining the Role of the Thalamus in Language	96
9.3	A Thalamic "Locus" for Language?	103
9.4	Imaging of the Thalamus in Language Tasks	105
9.5	Thalamic Circuitry and Physiology	107

9.6 Models of Thalamus and Language9.7 Summary and Conclusions Acknowledgments References	109 110 112 112
10. The Insular Cortex	
JESSICA D. RICHARDSON AND JULIUS FRIDRIKSSON	
10.1 Gross Anatomy	115
10.2 Cytoarchitecture	115
10.3 Vasculature	117
10.4 Connectivity	118
10.5 Insular Cortex and Behavior	120
10.6 Association with Speech–Language	
Behavior	122
References	125

11. White Matter Pathways in the Human

HUGUES DUFFAU

11.1 Introduction	129
11.2 Projection Pathways	130
11.3 Long-Distance Association Pathways	131
11.4 Implication of a Hodotopical View of	
Brain Organization in Humans: Rethinking	
the Connectivity of Language and Its	
Relationships with Cognition	133
11.5 The Limiting Role of Axonal Connectivity	
in Brain Plasticity	134
11.6 Conclusion	135
References	135

SECTION C

BEHAVIORAL FOUNDATIONS

12. Phonology

WILLIAM J. IDSARDI AND PHILIP J. MONAHAN

12.1 Introduction 12.2 Speech Sounds and the MAP Loop	141 141
12.3 Features or the Internal Composition of	
Sounds	145
12.4 Local Sound Combinations and Chunking	147
12.5 Nonlocal Sound Combinations	148
12.6 Summary	149
References	149

13. Morphology

ALEC MARANTZ

13.1 Introduction	153
13.2 Why Morphology?	154
13.3 What Makes Morphology, Morphology	156

	13.4	Types of Morphemes, Types of Morphologies,	
		Types of Morphological Theories	157
	135	The View from Above	160
		Words and Rules: The Modern	100
	15.0	Consensus on Decomposition	161
		-	163
		Acknowledgments References	163
		Kelefences	105
11	S	and the Comitive Neurossian eq	
14.	-	ax and the Cognitive Neuroscience	
	of S	yntactic Structure Building	
JON 3	SPROU	SE AND NORBERT HORNSTEIN	
	1 4 1	T 1	165
		Introduction	165
		A Brief History of Syntactic Theory	166
	14.3	Two Concrete Examples of Syntactic	
		Structure-Building Computations	168
	14.4	Additional Properties of Syntactic Theories	
		That One Would Expect from a Theory of	
		Cognitive Computations	170
	14.5	The Collaboration Necessary to Engage	
		in This Program	171
	14 6	Challenges to This Research Program	172
		Conclusion	173
	17.7	References	173
		Kelelelices	175
15	Snor	ech Perception as a Perceptuo-Motor	
15.	-		
	Skill	l	
CAR	ol a. f	FOWLER	
	1 7 1	T . 1	175
		Introduction	175
		Research Findings	177
	15.3	Conclusion	181
		References	182
16.	Spee	ech Perception	185
AND	REW I	LOTTO AND LORI L. HOLT	
1110	ICE 11 J.	LOTTO MAD LON L. HOLT	
	16.1	Introduction	185
	16.2	Effects of Auditory Distinctiveness	
	10.2	on the Form of Speech	186
	163	Effects of Auditory Interaction on the	100
	10.5	Form of Speech	187
	161	-	107
	10.4	Effects of Learnability on the Form	100
	1.6 5	of Speech	189
	16.5	Moving Forward	191
		References	192
17.	Und	erstanding Speech in the Context of	
	Vari	ability	
SHAT	NON	HEALD, SERENA KLOS AND HOWARD NUSBAUM	
		,,,,,	
	17.1	Speech and Speakers	195
		The Lack of Invariance Problem	197

	17.3	Adaptive Processing and Perceptual	
		Learning	198
		Empirical Evidence for Active Processing	222
		in Talker Normalization	200
		Toward an Active Theory of Contextual Normalization	201
		Neurobiological Theories of Speech	201
		Perception	202
		Subcortical Structures and Adaptive	
]	Processing	204
		Conclusion	205
		Acknowledgments	206
		References	206
18	Succe	essful Speaking: Cognitive	
10.		nanisms of Adaptation in	
		uage Production	
GAR	0	L AND CASSANDRA L. JACOBS	
0/11	I O. DEL	L AIND CASSAINDIALE. JACODS	
	18.1	Language Production	209
	18.2	Long-Term Speaker Tuning: Implicit	
		Learning	211
		Short-Term Speaker Tuning	214
		Conclusion	218
		Acknowledgments References	218 218
	1	References	210
19.	Speed	ch Motor Control from a Modern	
	-	rol Theory Perspective	
JOHI		IDE AND SRIKANTAN S. NAGARAJAN	
		Introduction	221
	19.2	The Role of the CNS in Processing	221
	19.3	Sensory Feedback During Speaking The CNS as a Feedforward Source	221
	19.3	of Speech Motor Commands	222
	19.4	Current Models of the Role of the	LLL
	17.7	CNS in Speech Motor Control	224
	19.5	The Concept of Dynamical State	224
	19.6	A Model of Speech Motor Control	•
		Based on State Feedback	225
	19.7	SFC Models Motor Actions as an	
		Optimal Control Process	226
	19.8	Speaking Behaves Like an Optimal	
		Control Process	227
	19.9	SFC Explains the Task-Specific Role of	222
	10.10	the CNS in Speech Feedback Processing	230
		Is SFC Neurally Plausible?	230
	19.11	SFC Accounts for Efference Copy Phenomena	721
	10 17	Neural Substrate of the SFC Model	231 232
		Conclusion	232
	17.17	References	234

ix

20. Spoken Word Recognition: Historical Roots, Current Theoretical Issues, and Some New Directions

DAVID B. PISONI AND CONOR T. MCLENNAN

20.1 Introduction	239
20.2 Historical Roots and Precursors	
to SWR	239
20.3 Principle Theoretical Issues in SWR	240
20.4 SWR and the Mental Lexicon	246
20.5 Some New Directions and Future	
Challenges	248
20.6 Summary and Conclusions	249
Acknowledgments	249
References	249

21. Visual Word Recognition

KATHLEEN RASTLE

21.1 The Architecture of Visual Word	
Recognition	255
21.2 Orthographic Representation	256
21.3 Processing Dynamics and Mechanisms of	
Selection	258
21.4 Visual Word Recognition and the	
Reading System	260
21.5 Conclusion	262
Acknowledgment	262
References	262

22. Sentence Processing

FERNANDA FERREIRA AND DERYA ÇOKAL

22.1	Sources of Information for Sentence	
	Processing	265
22.2	Theoretical Controversies	268
22.3	Classes of Models of Sentence Processing	270
22.4	Conclusion	272
	References	272

23. Gesture's Role in Learning and Processing Language

ÖZLEM ECE DEMIR AND SUSAN GOLDIN-MEADOW

23.1 Gesture Not Only Reflects Thought, It
Can Play a Role in Changing Thought
23.2 Role of Gesture in Language Learning
23.3 Role of Gesture in Language Processing
23.4 Implications for the Neurobiology of
Language

L L	07
Language	
References	

SECTION D LARGE-SCALE MODELS

24. Pathways and Streams in the Auditory Cortex	
JOSEF P. RAUSCHECKER AND SOPHIE K. SCOTT	
24.1 Human Speech Perception	287
24.2 Where Is "Wernicke's Area"?	287
24.3 Dual Processing Streams and Hierarchical	
Organization in the Auditory Cortex of the	
Monkey	288
24.4 Dual Processing Streams in the Auditory	
Cortex of Humans	290
24.5 Conclusions: A Common Computational	
Function for the Postero-Dorsal Stream?	293
Acknowledgments	294
References	294
25 Noural Basis of Spaceh Demonstrian	

25. Neural Basis of Speech Perception

GREGORY HICKOK AND DAVID POEPPEL

25.1 Introduction	299
25.2 The Dual Route Model of Speech	
Processing	299
25.3 Clinical Correlates of the Dual Stream	
Model	307
25.4 Summary	307
References	308

26. Brain Language Mechanisms Built on Action and Perception

FRIEDEMANN PULVERMÜLLER AND LUCIANO FADIGA

26.1	Introduction	311
26.2	Phonemes	312
26.3	Signs	314
26.4	Meaning	314
26.5	Combinations and Constructions	317
26.6	Speech Acts and Social-Communicative	
	Interaction	318
26.7	Outlook: Key Issues in Brain Language	
	Research	319
	Acknowledgments	321
	References	321

27. The Dual Loop Model in Language

275

276

279

281 281 CORNELIUS WEILLER, TOBIAS BORMANN, DOROTHEE KUEMMERER, MARIACHRISTINA MUSSO AND MICHEL RIJNTJES

27.1 Patients	327
27.2 Neurospsycholo	gy 328

27.3 Functions of the Dual Loop Model	329
27.4 Anatomy, Hubs, Divisions	329
27.5 Development	333
References	334

28.	MUC (Memory, Unification, Control):
	A Model on the Neurobiology of Language
	Beyond Single Word Processing

PETER HAGOORT

28.1 Introduction	339
28.2 Memory, Unification, and Control	339
28.3 The Network Topology of the Language	
Cortex	340
28.4 The Empirical Evidence for the	
MUC Model	342
28.5 A General Account of the Role of	
LIFC in Language Processing	343
28.6 The Dynamic Interplay Between Memory	
and Unification	344
28.7 Attentional Control	345
28.8 Beyond the Classical Model	345
Acknowledgments	346
References	346

29. The Neuroanatomical Pathway Model of Language: Syntactic and Semantic Networks

ANGELA D. FRIEDERICI

29.1 Introduction	349
29.2 From Dorsal and Ventral Streams to	
Fiber Tracts	349
29.3 The Neuroanatomical Pathway Model	
of Language	350
29.4 Conclusion	354
Acknowledgments	354
References	354

30. The Argument Dependency Model

INA BORNKESSEL-SCHLESEWSKY AND MATTHIAS SCHLESEWSKY

30.1	Introduction	357
30.2	A Brief History of the Development	
	of eADM	357
30.3	Design Principles	358
30.4	The Model Architecture	360
30.5	Evidence for the Model	364
30.6	Consequences for Electrophysiology	366
30.7	Outlook	366
	Acknowledgments	367
	References	367

SECTION E

DEVELOPMENT, LEARNING, AND PLASTICITY

31. Language Development

FREDERIC DICK, SALONI KRISHNAN, ROBERT LEECH AND SUZANNE CURTIN

31.1	Precursors to Language	373	
31.2	0 0	376	
		570	
31.3			
	Trajectories, and the Vocabulary "Burst"	377	
31.4	Early Language and Its Relationship to		
	Nonlinguistic Abilities	378	
31.5	Relationship Between Early Development		
	and Later Language Abilities	379	
31.6	The Relationship Between Vocabulary		
	and Grammar	379	
31.7	The Nature of Children's Early Grammar	381	
31.8	Language Development in Older Children	381	
31.9	Neural Measures of Language Development	382	
31.10	Conclusion	384	
	Acknowledgments	384	
	References	384	
32. The Neurobiology of Gesture and Its			
Development			
-			
ANTHONY STEVEN DICK AND IRIS BROCE			

32.1 Exploring Gesture and Its Develo	opment
at the Behavioral Level	389
32.2 Gesture and Its Development in	the
Context of a Broader Neurobiolo	ogy of
Language	390
32.3 The Neurobiology of Gesture:	
Electrophysiology	390
32.4 The Neurobiology of Gesture: Fu	nctional
Imaging	391
32.5 The Neurobiology of Gesture De	velopment 395
32.6 Conclusion	395
References	395

33. Development of the Brain's Functional Network Architecture

DEANNA J. GREENE, CHRISTINA N. LESSOV-SCHLAGGAR AND BRADLEY L. SCHLAGGAR

33.1 What Is a Network and How Can	
We Study Brain Networks?	399
33.2 Organization of the Brain's Functional	
Network Architecture	401
33.3 Is There a Language Network?	401
33.4 Development of Brain Networks	403

404

405 405 405

33.5 Implications of Development of Brain
Networks to Language-Related Brain
Regions
33.6 Future Directions
Acknowledgment
References

34. Bilingual Development and Age of Acquisition

ARTURO E. HERNANDEZ

34.1	Introduction	407
34.2	Age of Acquisition	407
34.3	AoA in a Single Language	408
34.4	The Relationship Between AoA and	
	Sensitive Periods	409
34.5	AoA and Second Language Learning	409
34.6	Phonology in a Second Language	410
34.7	AoA and the Bilingual Brain	411
34.8	Grammatical Processing and AoA	412
34.9	Isolating AoA	413
34.10	AoA Effects During Grammatical	
	Processing	413
34.11	Comparing First and Second Languages	415
34.12	AoA and Development	415
	References	416

35. Bilingualism: Switching

ALBERT COSTA, FRANCESCA M. BRANZI AND CESAR ÁVILA

35.1	Introduction	419
35.2	Language Switching: Instantiating the	
	Paradigm	419
35.3	Evidence from Electrophysiology	421
35.4	The Neural Correlates of Language	
	Control: A Frontal, Parietal, and	
	Subcortical Network	424
35.5	Conclusion	428
	References	428

36. Neurobiology of Sign Languages

DAVID P. CORINA AND SHANE BLAU

36.1	Introduction	431
36.2	Sign Language Aphasia	431
36.3	Right Hemisphere Damage	435
36.4	Neuroimaging	437
36.5	Sign Language and the Mirror Neuron	
	System	439
36.6	Conclusion	440
	Acknowledgments	441
	References	441

SECTION F

PERCEPTUAL ANALYSIS OF THE SPEECH SIGNAL

37. Phoneme Perception

JEFFREY R. BINDER

JEITRET R. DINDER	
 37.1 Neuropsychological Studies 37.2 Functional Imaging Studies 37.3 Direct Electrophysiological Recordings 37.4 The Role of Articulatory Representations in Phoneme Perception 37.5 Hemispheric Specialization in Phoneme Perception References 	450 450 454 455 457 458
38. A Neurophysiological Perspective on Speech Processing in "The Neurobiology of Language"LUC H. ARNAL, DAVID POEPPEL AND ANNE-LISE GIRAUD	
 38.1 Overview 38.2 Cortical Processing of Continuous Sounds Streams 38.3 Broadening the Scope: Functional Models References 	463 466 472 475
39. Direct Cortical Neurophysiology of Speech PerceptionMATTHEW K. LEONARD AND EDWARD F. CHANG	
 39.1 Introduction 39.2 Invasive Neural Recording Methods 39.3 Intracranial Contributions to the Neurobiology of Language 39.4 The Future of Invasive Methods in Language Research References 	479 479 482 487 487
40. Factors That Increase Processing Demands When Listening to Speech INGRID S. JOHNSRUDE AND JENNIFER M. RODD	
40.1 Types of Processing Demand40.2 Summary References	493 499 499
41. Neural Mechanisms of Attention to Speech Lee M. MILLER	
41.1 Overview and History 41.2 Neural Networks for Attentional Control	503 504

	41.3 Levels of Attentional Selection	505
	41.4 Speech Representations that Attention	
	Selects	507
	41.5 Neural Mechanisms and Top-Down/	
	Bottom-Up Interactions	508
	41.6 Interactions Between Attention,	
	Perception, and Prediction	509
	41.7 Future Directions	510
	Acknowledgments	511
	References	511
	Audiovisual Speech Integration: Neural Substrates and Behavior IAEL S. BEAUCHAMP	
	42.1 Neuroarchitecture of Audiovisual Speech	
	Integration	515
	42.2 Behavioral Approaches for Studying	
	Audiovisual Speech Integration	518
	42.3 Intersubject Variability	519
	42.4 Neural Substrates of the McGurk Effect	521
	Acknowledgments	524
	References	524
43.	Neurobiology of Statistical Information	

Processing in the Auditory Domain

URI HASSON AND PASCALE TREMBLAY

43.1	Introduction	527
43.2	Brain Systems Involved in Statistical	
	Information Processing	529
43.3	Connectional Anatomy of the Statistical	
	Network	533
43.4	Related Work and Further Afield	534
43.5	Conclusion and Future Work	535
	References	535

SECTION G WORD PROCESSING

44. The Neurobiology of Lexical Access

MATTHEW H. DAVIS

44.1	Introduction	541
44.2	Three Challenges for Lexical Access in	
	Speech	541
44.3	Mapping Lexical Computations onto	
	Neurobiology	542
44.4	Functional Segregation and Convergence	
	in Lexical Processing	549
44.5	Conclusion	550
	Acknowledgment	551
	References	551

45. A Common Neural Progression to Meaning in About a Third of a Second kara d. federmeier, marta kutas and danielle s. dickson	
45.1 Part 1: The Timecourse of Semantic Access	
Out of Context	558
45.2 Part 2: Context and the Timecourse	
of Semantic Access	562
45.3 Conclusions	565
Acknowledgments	565
References	565
46. Left Ventrolateral Prefrontal Cortex in Processing of Words and Sentences NAZBANOU NOZARI AND SHARON L. THOMPSON-SCHILL	
46.1 Introduction	569
46.2 VLPFC in Single-Word Processing	570
46.3 VLPFC in Sentence Processing	574
46.4 Summary	576
46.5 Concluding Remarks and Future Avenues	579
Acknowledgments	580
References	580

SECTION H SENTENCE PROCESSING

47. The Role of the Anterior Temporal Lobe in Sentence Processing

CORIANNE ROGALSKY

47.1	What About Broca's Area?	587
47.2	Where Is the ATL?	588
47.3	Domain-General Semantics	588
47.4	The ATL Responds to Sentence Structure	589
47.5	Syntax	590
47.6	Combinatorial Semantics	591
47.7	Prosody	591
47.8	The ATL Is Part of a Large Language	
	Network	592
47.9	Summary	592
	Acknowledgments	592
	References	592

48. Neural Systems Underlying the Processing of Complex Sentences

LARS MEYER AND ANGELA D. FRIEDERICI

48.1	Introduction	597
48.2	Why Are Word-Order Deviations	
	Difficult to Process?	597
48.3	Why Are Embedded Sentences	
	Difficult to Process?	598

	48.4	Which Brain Regions Are Involved	
	48.5	in Processing Complex Sentences? What Do Word-Order Deviations and	599
		Embedding Have in Common?	603
	48.6	Summary	604
		References	604
49.		Timecourse of Sentence Processing	
	in tł	ne Brain	
		ÆSSEL-SCHLESEWSKY, ADRIAN STAUB AND SCHLESEWSKY	
	49.1	Preliminaries: Challenges to a	
		Neurobiological Perspective on the	
		Timecourse of Sentence Processing	607
		Neurobiological Considerations	608
	49.3	Differing Perspectives on the Timecourse	(20)
	40.4	of Sentence Processing in the Brain	609
		Behavioral Insights	615
	49.5	Open Questions/Perspectives for Future Research	617
		References	618
		References	010
50.	Con	position of Complex Meaning:	
300		rdisciplinary Perspectives on the	
		Anterior Temporal Lobe	
LIINL		KÄNEN	
LIII (I	11 ILI		
	50.1	"Semantics" in the Brain Sciences Versus	
		Linguistics	622
		The Sentence Versus List Paradigm	623
	50.3	An Empirical Question: Do Concepts	(2)
	50.4	Matter for Composition?	624
	50.4	Methodological Starting Points for the	
		Cognitive Neuroscience of Semantic Composition	624
	50.5	The LATL as a Combinatory Region:	024
	50.5	Evidence from MEG	625
	50.6	Delving Deeper: What Types of	025
	50.0	Representations Does the LATL Combine?	626
	50.7	Closing Remarks	628
		Acknowledgments	629
		References	629
51.		king Memory and Sentence	
	Con	nprehension	
DAV	ID CAP	LAN	
	51.1	Early Studies of STM/WM and Its	
		Relation to Comprehension	633
	51.2	Changes in Models of STM/WM	634
		Retrieval Mechanisms in Parsing	635
	51.4	Capacity Limits in STM/WM and	
		Sentence Comprehension	638

51.5	An Alternative Framework for Viewing	
	the Memory System for Parsing and	
	Interpretation	638
51.6	A Comment on the Neural Basis of	
	Procedural (LT-WM) Memory Mechanisms	
	Underlying Sentence Comprehension	641
	Acknowledgments	641
	References	641
	Further Reading	645

52. Grounding Sentence Processing in the Sensory-Motor System

MARTA GHIO AND MARCO TETTAMANTI

52.1	Introduction	647
52.2	Grounding of Action-Related Sentence	
	Processing in the Sensory-Motor System	648
52.3	Flexible Modulations of Sensory-Motor	
	Grounding by Grammatical and Syntactic	
	Aspects	650
52.4	Figurative Language as an Abstract	
	Sentential-Semantic Context for	
	Action-Related Verbs	651
52.5	Emotion-Related Language: Abstract	
	but Partially Grounded in the	
	Sensory-Motor System	653
52.6	Abstract Sentence Processing Is	
	Grounded in Experiential	
	Neurocognitive Systems	654
52.7	Concluding Remarks	655
	References	655

SECTION I

DISCOURSE PROCESSING AND PRAGMATICS

53. Discourse Comprehension

JEFFREY M. ZACKS AND EVELYN C. FERSTL

53.1 Cohesion	662
53.2 Coherence	664
53.3 Situation Model Construction	665
53.4 Shifting and Mapping	668
53.5 Conclusion	669
References	671

54. At the Core of Pragmatics

BRUNO G. BARA, IVAN ENRICI AND MAURO ADENZATO

54.1 Communicative Intention: The Core	
Feature of Pragmatic Phenomena	675

xiv

54.2 Neural Substrates of Communicative Intention:	
The Intention Processing Network	676
54.3 Communication Is More than Language	679
54.4 Communicative Exchange	681
54.5 Steps Toward an Ecology of	
Communication	683
Acknowledgments	684
References	684

SECTION J

SPEAKING

55. Neurobiology of Speech Production: Perspective from Neuropsychology and Neurolinguistics

SHEILA E. BLUMSTEIN AND SHARI R. BAUM

55.1	Introduction	689
55.2	Historical Perspective: Speech Production	
	Deficits in Aphasia	689
55.3	Phonological Processes in Speech Production	690
55.4	Phonetic Processes in Production	692
55.5	Summary	696
	Acknowledgments	697
	References	697

56. Word Production from the Perspective of Speech Errors in Aphasia

MYRNA F. SCHWARTZ AND GARY S. DELL

56.1	Speech Errors in Aphasia: The Neurological	
	Tradition	701
56.2	Two Stages of Lexical Access in Production	703
56.3	Model-Inspired Lesion Analysis of Semantic	
	Errors	705
56.4	Summation Dual-Route Model of	
	Repetition	707
56.5	Implications for Neurocognitive Models of	
	Language	710
56.6	Conclusion	711
	Acknowledgments	712
	References	712

57. Motor-Timing and Sequencing in Speech Production

SONJA A. KOTZ AND MICHAEL SCHWARTZE

57.1	Formal and Temporal Prediction:	
	Fundamentals in Speech Processing	717
57.2	A Synchronized Speech Processing Mode	718
57.3	Timing Speech: Subcortico-Cortical	
	Interactions	720
57.4	Conclusion	722
	References	723

58. Neural Models of Motor Speech Control

FRANK H	I. GUENTI	her and	GREGORY	HICKOK

58.1 Introduction	725
58.2 The Planning of Speech Movements	726
58.3 Brain Regions Involved in Speech	
Articulation	727
58.4 Neurocomputational Models of Speech	
Production	727
58.5 The DIVA Model	728
58.6 The GODIVA Model of Speech Sound	
Sequencing	733
58.7 The HSFC Model	733
58.8 Future Directions	736
Acknowledgments	737
References	737

59. Neurobiology of Speech Production: A Motor Control Perspective

PASCALE TREMBLAY, ISABELLE DESCHAMPS AND VINCENT L. GRACCO

59.1 Introduction	741
59.2 Neurobiology of Speech Motor Control	741
59.3 Speech Movement Execution	744
59.4 Feedback Processing and Sensory-Motor	
Integration	745
59.5 Conclusion	746
Acknowledgments	746
References	747

60. Sentence and Narrative Speech Production: Investigations with PET and fMRI

RICHARD J.S. WISE AND FATEMEH GERANMAYEH

60.1	Introduction	751
60.2	What Have We Learned from	
	Meta-Analyses of Language Studies	754
60.3	Narrative Speech Production	756
60.4	Functional MRI Studies of Sentence	
	Production	758
60.5	Conclusion	760
	References	761

SECTION K

CONCEPTUAL SEMANTIC KNOWLEDGE

- 61. The Hub-and-Spoke Hypothesis of Semantic Memory
- KARALYN PATTERSON AND MATTHEW A. LAMBON RALPH
 - 61.1 Introduction

766
767
769
105
770
772
773
773
777
777 777
777 780
777
777 780 780
777 780

SECTION L

WRITTEN LANGUAGE

63. Acquired Dyslexia

H. BRANCH COSLETT AND PETER TURKELTAUB

63.1 Introduction	791
63.2 Peripheral Dyslexias	792
63.3 Central Dyslexias	795
63.4 Computational Models of Reading	798
63.5 Assessment of Reading	800
References	800

64. Imaging Brain Networks for Language: Methodology and Examples from the Neurobiology of Reading

ANJALI RAJA BEHARELLE AND STEVEN L. SMALL

64.1 Introduction	805
64.2 Functional Connectivity Analyses: A Set of Exploratory Techniques	806
64.3 Effective Connectivity Analyses: A Set of Confirmatory Techniques	808
64.4 Techniques Spanning Both Functional and Effective Domains	811

64.5 Conclusions References	813 813
References	015
65. Developmental Dyslexia	
GUINEVERE F. EDEN, OLUMIDE A. OLULADE, TANYA M. EVANS, ANTHONY J. KRAFNICK AND DIANA R. ALKIRE	
65.1 Introduction	815
65.2 Functional Anatomy of Reading	816
65.3 Neuroanatomical Bases of Dyslexia	816
65.4 Neurofunctional Bases of Dyslexia	817
65.5 Genetic and Physiological Mechanisms in	
Dyslexia	819
65.6 Neurobiology of Reading Interventions	820
65.7 Cause Versus Consequence?	821
65.8 Important Variables in Studies of Dyslexia	821
65.9 Conclusion	822
Acknowledgments	822
References	822

SECTION M

ANIMAL MODELS FOR LANGUAGE

66. Rodent Models of Speech Sound Processing

CRYSTAL T. ENGINEER, TRACY M. CENTANNI AND MICHAEL P. KILGARD

66.1 Rodent Models Are Important for Studying	
Neural Correlates of Speech Perception	829
66.2 Speech Sound Discrimination by Rodents	829
66.3 Speech Sound Neural Coding	831
66.4 Speech Sound Processing Problems	833
References	836

SECTION N

MEMORY FOR LANGUAGE

67. Introduction to Memory

SHAUNA M. STARK AND CRAIG E.L. STARK

	·1
67.2 Medial Temporal Lobe Memory System 84	
67.3 Episodic Memory 84	3
67.4 Semantic Memory 84	4
67.5 Procedural Memory 84	-5
67.6 Memory Consolidation and Sleep 84	6
67.7 Neurogenesis 84	7
67.8 Aging and Memory 84	7
67.9 Language Learning and the Medial	
Temporal Lobe 84	8
References 84	9

xvi

68. Neural Basis of Phonological Short-Term Memory

JULIE A. FIEZ

68.1	Theoretical Perspectives on Phonological	
5	Short-Term Memory	855
68.2 1	Neural Perspectives on Short-Term	
I	Phonological Memory	857
68.3 5	Summary	860
H	References	860

69. Working Memory and Language

BRADLEY R. BUCHSBAUM

69.1	Introduction	863
69.2	The Emergence of the Concept	
	of Short-Term Memory	863
69.3	Neurological Evidence for a Separation	
	of Short-Term and Long-Term Memory	864
69.4	The Emergence of the Concept of	
	Working Memory	865
69.5	The Phonological Loop	866
69.6	Neural Basis of Verbal Working Memory	867
69.7	Neurological Studies of Language and	
	Verbal Short-Term Memory	868
69.8	Functional Neuroimaging Investigations	
	of Verbal Working Memory	869
69.9	Event-Related fMRI Studies of Verbal	
	and Auditory Working Memory	870
69.10	Reconciling Neuropsychological and	
	Functional Neuroimaging Data	872
69.11	Summary and Conclusion	872
	References	873

SECTION O LANGUAGE BREAKDOWN

70. Language Development in Autism

MORTON ANN GERNSBACHER, EMILY M. MORSON AND ELIZABETH J. GRACE

- 70.1 Delay in Autistic Language Development
- 70.2 Heterogeneity and Variability in Autistic Language Development 880 881
- 70.3 Trajectories of Language Development
- 70.4 Language Delay Versus Language Deviance References
- 71. Symptoms and Neurobiological Models of Language in Schizophrenia

ARNE NAGELS AND TILO KIRCHER

71.1 Introduction

71.2	Phenomenology, Assessment, and	
	Course of Formal Thought and	
	Language Disorder	888
71.3	Structural Brain Changes and FTD	889
	Neural Correlates of FTD (Symptom	
	Catching)	889
71.5	Semantics	890
71.6	Pragmatics	891
	Auditory Sensory, Phonological, and	
	Prosodic Processing	892
71.8	Syntax	893
	Neurotransmitter Dysfunction	893
	Genetic Influence on Speech and	
	Language Dysfunctions in Schizophrenia	894
71.11	Lateralization Asymmetry in Schizophrenia	894
	Conclusions and Future Perspectives	894
	References	895

72. Specific Language Impairment

JULIA L. EVANS AND TIMOTHY T. BROWN

72.2 72.3 72.4 72.5	Introduction Neuropsychological Profile Structural Imaging of SLI Functional Imaging of SLI Conclusion	899 899 900 902 906
	Towards a Neurobiology of SLI References	907 908

73. Vascular Aphasia Syndromes

DONNA C. TIPPETT AND ARGYE E. HILLIS

Introduction	913
Classic Aphasia Categorization: Vascular	
Syndromes	913
Vascular Syndromes and Contemporary	
Paradigms	917
Cognitive Processes Underlying Aphasia	917
Potential Usefulness of Vascular	
Syndromes	918
Conclusion	920
Acknowledgments	920
References	920
	Vascular Syndromes and Contemporary Paradigms Cognitive Processes Underlying Aphasia Potential Usefulness of Vascular Syndromes Conclusion Acknowledgments

74. Psycholinguistic Approaches to the Study of Syndromes and Symptoms of Aphasia

SHEILA E. BLUMSTEIN

879

883

884

887

74.1 Introduction	923
74.2 The Aphasia Syndromes	923
74.3 Some Caveats and Challenges	924
74.4 Language Deficits Underlying Aphasia	
Syndromes	925

74.5 Lexical Impairments	927
74.6 Syntactic Impairments	929
74.7 Conclusion	930
Acknowledgments	930
References	930

75. Introduction to Primary Progressive Aphasia

MARIA LUISA GORNO-TEMPINI AND PETER PRESSMAN

75.1 Introduction and History of Primary	
Progressive Aphasia	935
75.2 The Nonfluent/Agrammatic Variant	937
75.3 The Semantic Variant	941
75.4 The Logopenic Variant (lvPPA)	944
75.5 Future Directions in PPA	947
References	948

76. The Declarative/Procedural Model: A Neurobiological Model of Language Learning, Knowledge, and Use

MICHAEL T. ULLMAN

xviii

76.1 The Memory Systems	954
76.2 Predictions for Language	958
76.3 Evidence	961
76.4 Summary and Conclusion	965
Acknowledgments	965
References	965

77. Perinatal Focal Brain Injury: Scope and

Limits of Plasticity for Language Functions susan C. Levine, Anjali raja beharelle, özlem ece demir and steven L. small

77.1 Perinatal Focal Brain Injury: Language	
Development and Neural Plasticity	969
77.2 Four Central Questions	970
77.3 How Do Focal Perinatal Lesions Affect	
Language Development?	970
77.4 How Do Biological Characteristics	
of Early Focal Lesions Relate to	
Language Functioning?	972
77.5 What Is the Role of Language Input	
on the Language Development of	
Children with Perinatal Lesions?	976
77.6 What Is the Mechanism of Language	
Plasticity After Early Lesions?	977
77.7 Summary and Future Directions	979
References	979

78. Motor Speech Impairments

WOLFRAM ZIEGLER AND ANJA STAIGER

78.1 Introduction

78.2 Motor Impairments Within a Neurological Framework

78.3 Motor Impairments for Spoken Language	
Production	988
78.4 Sensory-Motor Aspects of Speech Sound	
Production Impairment	990
78.5 Conclusion	993
Acknowledgment	993
References	993

79. The Neurobiology of Developmental Stuttering

KATE E. WATKINS, JENNIFER CHESTERS AND EMILY L. CONNALLY

79.1	Introduction	995
79.2	Developmental Stuttering	995
	Enhancing Fluency in People Who Stutter	996
	Genetic Studies of Developmental Stuttering	997
	The Neural Basis of Developmental	
	Stuttering	998
79.6	Conclusion	1002
	References	1002

SECTION P

LANGUAGE TREATMENT

80. Neuroplasticity Associated with Treated Aphasia Recovery

JULIUS FRIDRIKSSON AND KIMBERLY SMITH

80.1 Neuroplasticity	1007
80.2 Acute and Chronic Considerations	1008
80.3 Structural Brain Changes and Aphasia	
Recovery	1009
80.4 Functional Brain Changes and Aphasia	
Recovery	1009
References	1011

81. Melodic Intonation Therapy

GOTTFRIED SCHLAUG

985

985

81.1	The Impact of Nonfluent Aphasia	1015
81.2	The Basis and Components of	
	Intonation-Based Speech Therapy	
	for Patients with Nonfluent Aphasia	1016
81.3	Experiences with the Application of MIT	1017
81.4	Examining Aspects of Rhythm and	
	Melody in Cross-Sectional Studies	1018
81.5	Neural Correlates of MIT: Neuroimaging	
	Findings	1018
81.6	Possible Mechanisms Explaining the	
	Effects of an Intonation-Based Speech	
	Therapy	1020
81.7	Conclusion	1021
	Acknowledgment	1021
	References	1021

		CONT	TENTS		
82.	Constraint-Induced Aphasia Therapy: A Neuroscience-Centered Translational Method			85.5	Conc Ackr Refei
FRIE	DEMANN PULVERMÜLLER, BETTINA MOHR AND EDWARD TA	AUB	86	Cell	-Base
	82.1 Aphasia Therapy: Relevance and Classic		00.		asia
	Paradigms	1025	НΔΙ	. X. NGU	
	82.2 Neuroscience and Language Evidence	1025	11/11	. A. NO	JILIN
	82.3 CIAT: Methods and Efficacy	1028		86.1	Intro
	82.4 Variants and Extensions of Original CIAT			86.2	Stem
	Methods	1031		86.3	Hum
	82.5 Summary and Outlook	1032			Adul
	References	1032		86.5	Hum
0.2				06.6	Deriv
83.	Noninvasive Brain Stimulation in Aphasia			86.6	Hum
	Therapy: Lessons from TMS and tDCS			067	and l
H. BF	RANCH COSLETT				Mese
	83.1 Introduction	1035		00.0	of St
	83.2 TMS as Treatment for Aphasia	1035			Refer
	83.3 tDCS as Therapy for Aphasia	1033			itterer
	83.4 tDCS as a Treatment for Aphasia	1043			
	83.5 General Discussion	1049			
	References	1050		PI	ROS
84.	Imitation-Based Aphasia Therapy				
	1 1/		87	Proc	essin

E. SUSAN DUNCAN AND STEVEN L. SMALL

	84.1	Introduction: Repetition and Imitation	
		in Aphasia	1055
	84.2	Neurobiological Approaches to Language	
		and Aphasia	1055
	84.3	Mirror Neuron System	1055
	84.4	Mirror Neuron System and Language	1057
	84.5	Dual Streams for Speech	1059
	84.6	Aphasia Therapy: Speech Imitation as	
		Therapeutic Tool	1060
	84.7	Mirror Neuron System and Rehabilitation	1061
	84.8	Aphasia Therapy: Speech Imitation as	
		Therapeutic Theory	1061
	84.9	Aphasia Therapy: Nonspeech Motor	
		Observation and Imitation	1062
	84.10	Conclusion	1063
		References	1063
85.	Pharr	nacotherapy for Aphasia	
DAN	iel A. Li	ANO AND STEVEN L. SMALL	
	85.1 I	Introduction	1067
	85.2 1	Major Challenges	1067

05.2	Major Chanenges	1007
85.3	Mechanisms of Recovery and	
	Pharmacotherapy	1068
85.4	Human Studies: Pharmacotherapy for	
	Aphasia	1072

S			XIX
	85.5	Conclusion Acknowledgments References	1078 1078 1078
5.	Cell Aph	-Based Therapies for the Treatment of asia	
٩L	X. NGU	JYEN AND STEVEN C. CRAMER	
	86.1	Introduction	1085
	86.2	Stem Cell Therapies: Introduction	1085
		Human Neural Stem Cells	1086
	86.4	Adult/Fetal hNSCs	1086
	86.5	Human Embryonic Stem Cells and Neural	
		Derivatives	1086
	86.6	Human-Induced Pluripotent Stem Cells	
		and Neural Derivatives	1087
	86.7	Mesenchymal Stem Cells	1088
	86.8	Issues Related to Clinical Application	
		of Stem Cell Therapies	1088
		References	1089

SECTION Q SODY, TONE, AND MUSIC

87. Processing Tone Languages

JACKSON T. GANDOUR AND ANANTHANARAYAN KRISHNAN

87.1 Introduct	tion	1095
87.2 Tone Lar	nguages of East and Southeast Asia	1095
87.3 Lexical V	ersus Sublexical Units	1096
87.4 Tonal Ve	rsus Segmental Units	1100
87.5 Tonal Fe	atures	1101
87.6 Tonal Pre	ocessing at the Level of the	
Auditory	Brainstem	1101
87.7 Categorie	cal Perception of Tone	1102
87.8 Tone Ver	sus Other Suprasegmental Units	1103
87.9 Conclusi	on	1104
Acknowl	edgment	1104
Referenc	es	1104

88. The Neurocognition of Prosody

SILKE PAULMANN

88.1 Introduction	1109
88.2 Brain Mapping of Prosody	1109
88.3 The Neural Basis of Linguistic Prosody	
Processing	1110
88.4 The Neural Basis of Emotional Prosody	
Processing	1114
88.5 Summary	1117
Acknowledgments	1117
References	1118

89. Environmental Sounds		89.4 Section 7
FREDERIC DICK, SALONI KRISHNAN, ROBERT LEECH AND AYŞE PINAR SAYGIN		Environn 89.5 Conclusio
89.1 What Are Environmental Sounds?	1121	Acknowl Reference

69.2 reiceptual, Cognitive, and Neural	
Processing of Environmental Sounds	1123
89.3 Section One: Perceptual and Cognitive	
Factors in Processing Environmental	
Sounds	1123

xx

89.4	Section Two: Neural Factors in Processing	
	Environmental Sounds	1128
89.5	Conclusion	1134
	Acknowledgments	1135
	References	1135
Index		1139