The Handbook of the Neuropsychology of Language

Volume 1
Language Processing in the Brain: Basic Science

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The Handbook of the Neuropsychology of Language (2 Volumes)
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Volume 1

Language Processing in the Brain: Basic Science

I dedicate this book with love to the memory of my father, Professor Joseph Alexander Stein, who inspired me with a passion for knowledge, and to the memory of my mother, Yemima Gottesdiener-Stein, who provided me with the support and strength that enabled me to persist in my pursuit of this passion. A significant part of my accomplishments are theirs.

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Contributors

Jubin Abutalebi is a cognitive neurologist and an assistant professor of neuropsychology at the San Raffaele University in Milan. His main research activities focus on the cerebral architecture underlying bilingualism, which he studies by employing functional neuroimaging techniques.

Merav Ahissar works in the Department of Psychology, Center for Neural Computations and ELSC Center for Brain Research, The Hebrew University. Her research focuses on linking between behavioral patterns and neural mechanisms of perceptual and cognitive plasticity. She is interested in the relations between learning difficulties and perceptual and memory mechanisms.

Michael Andric is a graduate student in the Department of Psychology at the University of Chicago. He researches brain function in language processing and motor behaviors such as gesture.

Blair C. Armstrong is a graduate student in the PhD program of the Department of Psychology and the Center for the Neural Basis of Cognition at Carnegie Mellon University in Pittsburgh, Pennsylvania. His research involves using behavioral studies and computational modeling to examine the temporal dynamics of word comprehension and decision processes, and how these adapt in response to feedback.

Errol H. Baker, PhD, located at the VA Boston Healthcare System, is currently the biostatistician to the Research Office and to a VA Research Center of Excellence (Center for Organization, Leadership, and Management Research). He joined the Harold Goodglass Boston University Aphasia Research Center in 1971, and has collaborated with Dr Margaret Naeser since 1977. His research has focused on cognitive processes in patients with aphasia, and led to the development of a computer-based alternative communication system for severely impaired patients (C-ViC).

Juliana V. Baldo is a research neuropsychologist at Veterans Affairs Northern California Medical Center, where she is also the Associate Director of the Center for Aphasia and Related Disorders. Her work focuses on the neural basis of memory

and language. She has worked primarily with brain-injured patients and has used a variety of structural neuroimaging techniques to better characterize brain regions critical for mediating specific cognitive processes. Dr Baldo's work has also addressed how those cognitive processes interact with each other, such as the critical role that language plays in higher reasoning.

Karen Banai, PhD, works at the Department of Communication Sciences and Disorders, University of Haifa. Her research focuses on the interaction between perceptual and cognitive skills in typical and atypical populations and on whether the perception of linguistic and nonlinguistic attributes can be explained by shared mechanisms. She is also interested in perceptual learning and development.

Kathleen Baynes is Professor of Neurology in the Center for Mind and Brain at the University of California, Davis. She studies language processing with a particular focus on understanding language changes after neurological damage. She researches how language is lateralized in the brain by studying healthy young adults, left and right hemisphere focal lesioned patients, and split-brain patients. In recent research, she has been developing intervention programs to support the recovery of naming disorders.

Mark Beeman is an associate professor in the Psychology Department at Northwestern University.

Jeffrey R. Binder is Director of the Language Imaging Laboratory at the Medical College of Wisconsin. His research examines the neural basis of normal language processes and applications of language mapping in neurological patients.

Jesse Bledsoe, MA, is a doctoral candidate in clinical psychology at Michigan State University. Currently, he is a psychology resident at the University of Washington School of Medicine and Seattle Children's Hospital. His master's thesis examined neuropsychological aspects of ADHD and his doctoral dissertation will examine cortical thickness in children with ADHD on and off medication. He has presented this work at several national and international conferences.

Katy Borodkin, PhD, is a research associate in the Department of Psychology, Bar Ilan University. Her research focuses on individual differences in second-language acquisition.

Hiram Brownell received his PhD in psychology from the Johns Hopkins University. His research interests include language, language disorders, and treatment approaches, with a focus on the role of the right hemisphere.

Deborah M. Burke is the W. M. Keck Distinguished Service Professor at Pomona College, Claremont, CA. Her research focuses on cognitive aging, especially aging-related change in language production and the neural substrate.

Cristina Cacciari is full Professor of Psychology at the Department of Biomedical Sciences at the University of Modena. Her research interests concern language comprehension from behavioral and brain-based perspectives.

Christine Chiarello is Professor of Psychology at the University of California, Riverside. She received her PhD from the University of California, Berkeley. Her research explores the unique role of the right hemisphere in language comprehension, specifically processes of meaning access and retrieval, and visual word recognition. More recent interests include individual differences in brain organization for language, and biologically informed models of human variation.

Joanna A. Christodoulou, EdD, conducts research at the intersection of education and cognitive neuroscience, with a focus on reading development and difficulties, and works clinically with struggling students. She has an EdD in human development and psychology from the Harvard Graduate School of Education (HGSE), an EdM in mind, brain, and education from HGSE, and an MA in child development from Tufts University. She is a postdoctoral associate in the Gabrieli Laboratory in the Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology.

Dorothee Chwilla is a cognitive neuroscientist in the field of language at the Donders Institute for Brain, Cognition, and Behavior. She investigates semantic, syntactic, and prosodic processes in language comprehension across contexts (single words, sentences, and discourse). Recent research areas are the processing of semantics in a second language and the interactions of language and attention and of language and emotion.

Henri Cohen is editor of the *Journal of Neurolinguistics* and associate editor of *Brain and Cognition*. He holds appointments in the departments of psychology at Université du Québec, Montreal, and at Université Paris Descartes where he served as Director of Laboratoire de Psychologie et Neurosciences Cognitives (UMR8189 – CNRS). His research interests are wide and include language and speech production in normal and brain-damaged populations, cognition and emotion in movement disorders, the role of complexity in learning and consolidation, among others. He is the organizer or co-organizer of several international conferences, including the 2011 IASCL conference in Montreal. He is fortunate in his collaborations with exciting colleagues in many parts of the world. When he has time, he loves to scuba dive, travel to exotic places, and practice photography.

Max Coltheart is Emeritus Professor of Cognitive Science at Macquarie University in Sydney, having held previous positions elsewhere in Australia and also in Canada and England. He works on normal and impaired processes of reading and spelling (including computational modeling), and also on delusional beliefs.

Lisa Tabor Connor, PhD, is Assistant Professor of Occupational Therapy, Radiology, and Neurology at Washington University School of Medicine. She received her PhD in experimental psychology from Washington University and completed postdoctoral fellowships at the Georgia Institute of Technology in cognitive aging and Boston University School of Medicine in adult communicative disorders. Her

research focuses on language and cognitive rehabilitation, and reintegration of people with aphasia into the community after stroke.

Seana Coulson is Associate Professor in the Cognitive Science Department at the University of California, San Diego, where she heads the Brain and Cognition Laboratory. She is the author of *Semantic Leaps* (2001).

Tristan S. Davenport is a graduate student in the Cognitive Science Department at the University of California, San Diego. Advised by Seana Coulson, his primary research interest is the neural basis of semantic processing.

Annette M. B. de Groot is Professor of Experimental Psycholinguistics at the University of Amsterdam. She completed a master's degree in general linguistics and a doctorate in psycholinguistics at the University of Nijmegen, the Netherlands. Her present research focuses on bilingualism, with a special interest in bilingual word processing, foreign language vocabulary learning, and simultaneous interpreting.

Pasquale Anthony Della Rosa, PhD, is a post-doc at the Psychology Faculty of the University San Raffaele. His research activities are mainly based on functional neuroimaging studies of cognitive functions.

Rutvik H. Desai is Assistant Professor of Neurology at the Medical College of Wisconsin. His research investigates the neural basis of language and speech processing, with emphasis on the relationship between conceptual processing and sensorimotor systems.

Ton Dijkstra holds a Chair in Psycholinguistics and Multilingualism and is head of the Division of Psycholinguistics in the Donders Centre for Cognition, part of the Donders Institute for Brain, Cognition, and Behavior at Radboud University Nijmegen, the Netherlands.

Nina F. Dronkers is Director of the Center for Aphasia and Related Disorders at the Department of Veterans Affairs Northern California Health Care System and professor of neurology at the University of California, Davis. She specializes in the study of aphasia and other language and communication disorders that can occur with neurological disease. Her research, concerning the localization of language functions in the brain, uses lesion–symptom mapping to assess the relationship between patients' specific behavioral deficits and the areas of the brain that were injured.

Andrew W. Ellis is Professor of Psychology at the University of York, UK. He is interested in the psychology of word recognition and production in both healthy speakers/listeners and people with neuropsychological conditions such as aphasia and dementia. He also has an interest in object and face recognition. His current research combines cognitive, neuropsychological, and neuroimaging approaches, including the use of magnetoencephalography to explore the time course of processing within the brain.

Zohar Eviatar is Associate Professor in the Psychology Department and a member of the Institute for Information Processing and Decision Making, at the University of Haifa, Israel.

Franco Fabbro is full Professor of Developmental Neuropsychiatry at the University of Udine (Italy) and scientific director at the Research Institute E. Medea in San Vito al Tagliamento, Italy. He is author of a number of books and articles in peer-reviewed journals.

Miriam Faust, PhD, is Professor of Psychology in the Department of Psychology and the director of the Brain and Language Laboratory in the Gonda Center for Brain Research at Bar-Ilan University. She studies language processing, focusing mainly on semantic processing by the two cerebral hemispheres, word retrieval, and phonological processing. Two of her recent research projects focus on the neural bases of verbal creativity and on individual differences in foreign language attainment.

Kara D. Federmeier received her PhD in cognitive science from the University of California, San Diego. She is currently an associate professor in the Department of Psychology and the Program in Neuroscience at the University of Illinois and head of the Cognition and Brain Laboratory, located in the Beckman Institute for Advanced Science and Technology.

Patricia Marinaro Fitzpatrick, PhD, CCC-SLP, is a research speech/language pathologist at the Harold Goodglass Aphasia Research Center affiliated with the Department of Neurology at the Boston University School of Medicine and the Boston VA Healthcare System. She received her MSc from the University of Pittsburgh and her PhD from Emerson College. Her research focuses on treatment of aphasia, quality of life issues, and long-term recovery from aphasia.

John D. E. Gabrieli, PhD, is Professor of Health Sciences and Technology and Cognitive Neuroscience at the Massachusetts Institute of Technology (MIT). He has a dual appointment in the Harvard-MIT Division of Health Sciences and Technology and in the Department of Brain and Cognitive Sciences. He is Director of the Imaging Center at the McGovern Institute for Brain Research and co-director of the MIT Clinical Research Center. He has a BA in English from Yale and a PhD in behavioral neuroscience from MIT, and was a postdoctoral fellow in the Psychology Department at Harvard. His area of research is human cognitive neuroscience, in which he studies the brain basis of memory, language, and thought.

Morton Ann Gernsbacher is Vilas Research Professor and Sir Frederic Bartlett Professor at the University of Wisconsin–Madison, USA.

Matthew Goldrick is Associate Professor of Linguistics at Northwestern University, Evanston, Illinois, where he is affiliated with the Northwestern Cognitive Science Program and Northwestern Institute on Complex Systems. He received his under-

graduate and postgraduate degrees in cognitive science from Johns Hopkins University.

Mira Goral, PhD, CCC-SLP, is Associate Professor of Speech-Language-Hearing Sciences at Lehman College, The City University of New York. Her research focuses on multilingualism, aphasia, language attrition, and language and cognition in aging.

Elizabeth R. Graham is currently completing her PhD in applied cognitive psychology at Claremont Graduate University.

William W. Graves is a cognitive neuroscientist in the Language Imaging Laboratory, Department of Neurology, at the Medical College of Wisconsin. He received his PhD in neuroscience from the University of Iowa in 2006. His research into the neural basis of language production and understanding draws on a variety of techniques, including functional magnetic resonance imaging, computational modeling, and, most recently, magnetoencephalography.

Taomei Guo is Associate Research Professor for Cognitive Neuroscience at Beijing Normal University. Her research mainly focuses on the cognitive and neural mechanisms of bilingual language processing and has been supported by the National Science Foundation of China.

Prahlad Gupta graduated from Carnegie Mellon University in Pittsburgh, Pennsylvania, with an MS in computational linguistics and a PhD in cognitive psychology. He is currently a faculty member in the Psychology Department at the University of Iowa, where his research focuses on the relationship between language processing/learning, working memory, implicit memory, explicit memory, and the neural and computational bases of these processes.

Michael Ho, PhD, is a postdoctoral fellow at Boston University School of Medicine, working in the Neuroimaging/Aphasia Research Lab of Dr Margaret Naeser, VA Boston Healthcare System and the Harold Goodglass Boston University Aphasia Research Center. He is interested in functional neuroimaging of language, and has studied language recovery after stroke using functional magnetic resonance imaging (fMRI) and language processing using fMRI and magnetoencephalography.

Ken J. Hoyte received his PhD in neuroscience from Brandeis University. His research applies behavioral and imaging paradigms to topics such as speech prosody and understanding why the ability to use language to communicate effectively in social contexts is impaired in children and adolescents who have been diagnosed with autism or an autistic spectrum disorder.

Peter Indefrey holds PhDs in linguistics and medicine. Until 2009 he was head of the research group Dynamics of Multilingual Processing at the Max Planck Institute for Psycholinguistics (together with Marianne Gullberg) and principal investigator at the Donders Centre for Cognitive Neuroimaging (Nijmegen, the Netherlands).

The focus of his research is on the neurocognition of monolingual and bilingual sentence processing and word production. He is Professor for Psycholinguistics and Neurolinguistics at Heinrich Heine University Düsseldorf, Germany.

Clinton L. Johns, PhD, is a postdoctoral scholar at Haskins Laboratories, a research institute for the study of speech, language, and reading. He studies language comprehension in mature readers with a particular focus on the processes that are involved in understanding pronouns and other referring expressions.

Eunike Jonathan is a graduate student in the Department of Psychology at the University of California, Davis. She is the recipient of a National Science Foundation graduate research fellowship. She studies the role of controlled attention in reading by investigating reading processes during episodes of mind wandering.

Elina Kaplan, BS, is a doctoral student in the Neuroscience and Behavior Program at the University of Massachusetts, Amherst. Her area of interest is audiovisual integration in speech processing, and which sensory and cognitive factors predict young and older adults' ability to benefit in comprehension from seeing a speaker talk. She is also interested in visual search and auditory selective attention.

Kristina A. Kellett is a doctoral student in the Cognitive and Cognitive Neuroscience Program at the University of Wisconsin–Madison, USA.

Michael Kiang is Assistant Professor in the Department of Psychiatry and Behavioral Neurosciences at McMaster University in Hamilton, Ontario, Canada.

Saskia Kohnen is a postdoctoral research fellow at Macquarie University in Sydney. She is interested in subtypes of developmental reading and spelling disorders and their remediation.

Sonja A. Kotz is a linguist and cognitive neuroscientist who investigates speech, language, emotion, rhythm, and timing in healthy, clinical (aphasic, neurodegenerative), and bilingual populations using neuroimaging methods such as event-related potentials, magnetoencephalography, functional magnetic resonance imaging, and transcranial magnetic stimulation. She recently received a five-year award from the Max Planck Society's "W 2 Special Programme for the Advancement of Outstanding Female Scientists at the Max Planck Society" that supports her independent research group: Neurocognition of Rhythm in Communication, at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, Germany.

Ioulia Kovelman, PhD, is Assistant Professor at the Department of Psychology, University of Michigan. She has a BA in psychology from Queen's University (Canada) and a PhD from Dartmouth College. She was a postdoctoral associate at the Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology. She is a developmental cognitive neuroscientist interested in bilingual and monolingual language and literacy acquisition.

Judith F. Kroll is Distinguished Professor of Psychology, Linguistics, and Women's Studies and Director of the Center for Language Science (http://www.cls.psu.edu) at Pennsylvania State University. The research that she and her students conduct concerns the acquisition, comprehension, and production of two languages during second-language learning and in proficient bilingual performance.

Marta Kutas is a Distinguished Professor in the Departments of Cognitive Science and Neuroscience and Director of the Center for Research in Language at the University of California, San Diego.

Michal Lavidor is Associate Professor in the Department of Psychology in Bar Ilan University, Israel, and a Reader at the Department of Psychology, University of Hull, UK. While studying for her PhD at Bar Ilan University, she specialized in visual word recognition, in particular hemispheric differences in processing written words. She moved to the University of York as a Marie Curie Research Fellow and developed further her research interests to investigate brain structures involved in ortho-graphic processing of words and letters. She now has her own transcranial magnetic stimulation laboratory with the aim of investigating the neural pathways of word processing, prosody, and gestures comprehension.

Chia-lin Lee received an MA in linguistics from the National Taiwan Normal University and a PhD in psychology from the University of Illinois. She is currently a post doctoral research fellow at the Moss Rehabilitation Research Institute.

Christiana M. Leonard is Professor Emeritus of Neuroscience at the University of Florida, where she has been since 1976. She was educated at Radcliffe College and Massachusetts Institute of Technology. In her early career, she investigated the neural substrate of taste, olfaction, and birdsong in rodents and canaries. She now uses magnetic resonance imaging to study the cognitive correlates of individual variation in brain structure in children and adults.

Laurence B. Leonard is Rachel E. Stark Distinguished Professor at Purdue University. His research is concerned with the proper characterization of the lin-guistic and cognitive difficulties experienced by children with specific language impairment. Along with his work with English-speaking children, Leonard and his collaborators have studied children with specific language impairment acquiring such languages as Italian, Hebrew, Swedish, Cantonese, Spanish, Hungarian, and Finnish.

Debra L. Long, PhD, is Professor of Psychology at the University of California, Davis, and International Research Professor at the University of Central Lancashire in England. She studies language comprehension in healthy, young adults and in patients with focal lesions in the brain. She focuses primarily on understanding how variation in language-specific processes (e.g., word recognition, syntactic analysis) and general cognitive abilities (e.g., working-memory capacity, reasoning) give rise to individual differences in language comprehension.

Nira Mashal received her PhD in brain science (The Leslie and Susan Gonda Multidisciplinary Brain Research Center) at Bar-Ilan University and currently she is a senior lecturer at the School of Education at Bar-Ilan University. She studies the cognitive and the brain mechanisms of nonliteral language processing in healthy individuals and in special populations including schizophrenia, attention deficit hyperactive disorder, and learning disability.

Andrea Marini is Assistant Professor in Cognitive Psychology at the University of Udine, Italy. He is responsible for research projects about the neuropsychology of language in the research institutes E. Medea in San Vito al Tagliamento and Santa Lucia in Rome. He is author of a number of books and articles in peer-reviewed journals.

Paula I. Martin, BS, is a graduate student in the Behavioral Neuroscience PhD program at Boston University School of Medicine. Since 1999, she has worked in the Neuroimaging/Aphasia Research laboratory of Dr Margaret Naeser at the VA Boston Healthcare System, and the Harold Goodglass Boston University Aphasia Research Center. Her projects include functional neuroimaging of speech output in aphasia patients and transcranial magnetic stimulation to improve naming in aphasia. Her interests include language processing, language recovery after stroke, and language and aging.

Heather J. Mirous is a graduate student in the Cognitive Psychology Program at Northwestern University, under the direction of Mark Beeman.

Maya Misra is a cognitive neuroscientist who received her PhD from Tufts University. Her research uses event-related potentials and functional magnetic resonance imaging to investigate the cognitive and neural mechanisms underlying language processing, with specific emphasis on lexical processing in bilinguals and on the development of component skills in reading.

Margaret A. Naeser, PhD, located at the VA Boston Healthcare System, is Research Professor of Neurology, Boston University School of Medicine. She joined the Harold Goodglass Boston University Aphasia Research Center in 1977. Her earlier aphasia research focused on lesion localization on structural CT scan or magnetic resonance imaging scan, and potential for recovery in aphasia. Her current aphasia research investigates transcranial magnetic stimulation to improve naming and speech, in chronic aphasia patients. She also conducts research on transcranial, red, and near-infrared light-emitting diode (LED) therapy to improve cognitive function in chronic, mild traumatic brain injury.

Loraine K. Obler, PhD, is Distinguished Professor of Speech-Language-Hearing Sciences at the CUNY Graduate Center, and affiliated with the Linguistics Program there, and the Language in the Aging Brain Laboratory at Boston University School of Medicine and the Boston VA Healthcare System. Her books include *Language and the Brain*, with K. Gjerlow, *The Bilingual Brain: Neuropsychological and Neurolinguistics Aspects of Bilingualism*, with M. L. Albert, *Agrammatic Aphasia: A*

Cross-Language Narrative Sourcebook, edited with L. Menn, and *The Exceptional Brain: Neuropsychology of Talents and Special Abilities,* edited with D. Fein.

Costanza Papagno, MD, PhD, neurologist, is full Professor of Physiological Psychology at the Department of Psychology at the University of Milano-Bicocca. Her research interests concern language and memory processes in brain-damaged patients.

Alvaro Pascual-Leone, MD, PhD, is Professor of Neurology at Harvard Medical School, Director of the Berenson-Allen Center for Noninvasive Brain Stimulation, and the program director of the Harvard-Thorndike Clinical Research Center at Beth Israel Deaconess Medical Center, Boston, MA. Dr Pascual-Leone is internationally recognized as one of the pioneers in the field of transcranial magnetic stimulation (TMS). His work has been fundamental in establishing TMS as a valuable tool in cognitive neurology, increasing knowledge about its mechanisms of action, critically improving the technology and its integration with several brain imaging methodologies, and helping to create the field of therapeutic noninvasive brain stimulation. His primary interest is to understand neural plasticity at the system's level. This includes learning enough about the mechanisms of plasticity in order to manipulate them, suppressing some changes and enhancing others, to gain a clinical benefit and behavioral advantage for a given individual.

Seija Pekkala, PhD, is a University Lecturer in Logopedics and a speech and language pathologist working at the Institute of Behavioral Sciences of the University of Helsinki, Finland. Her research interests focus on language and communication in normal aging and dementia.

Orna Peleg, PhD, is a lecturer at the program of Cognitive Studies of Language Use at Tel-Aviv University. Her research focuses on the processes and mechanisms underlying real-time language comprehension, specifically focusing on how readers access the meaning of written words.

Daniela Perani, MD (Vita-Salute San Raffaele University, Milan Italy; Nuclear Medicine Department and Division of Neuroscience, San Raffaele Scientific Institute, Milan, Italy), is a neurologist and neuropsychologist with long-standing experience in neuroimaging research. Her research activities concern language and bilingualism, dyslexia, dementia, and other neurological and psychiatric diseases.

Tepring Piquado received her PhD in Neuroscience from Brandeis University. She currently is a postdoctoral fellow in the Department of Cognitive Sciences, University of California, Irvine. Her research interests include auditory perception and language processing.

David C. Plaut is Professor in the Department of Psychology and the Center for the Neural Basis of Cognition at Carnegie Mellon University in Pittsburgh, Pennsylvania. His research involves using computational modeling, complemented

by empirical studies, to investigate the nature of normal and disordered cognitive processing in the domains of reading, language, and semantics.

Alexander Michael Rapp, MD, is a senior psychiatrist and researcher at the Department of Psychiatry at the University of Tuebingen, Germany. His research interests include the functional neuroanatomy of nonliteral language in healthy subjects and patients with psychiatric diseases.

Kathrin Rothermich is a linguist and educational scientist who is currently a PhD candidate in cognitive neuroscience in the independent research group Neurocognition of Rhythm in Communication at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, Germany. Her research focuses on semantics, syntax, and the interface of semantics and prosody utilizing event-related potentials, magnetoencephalography, and functional magnetic resonance imaging.

Maren Schmidt-Kassow received training in linguistics, phonetics, psychology, and cognitive neuroscience. She obtained a PhD in cognitive science from the University of Potsdam in Germany, and is currently working as a postdoctoral fellow at the Institute of Medical Psychology in Frankfurt, Germany. She is investigating the interface of prosody and syntax in second-language acquisition as well as the role of rhythmic patterns in poetry with event-related potentials and functional magnetic resonance imaging.

Richard G. Schwartz, PhD, is Presidential Professor in the PhD Program in Speech-Language-Hearing Sciences, The Graduate Center, City University of New York. He has served as an editor of the *Journal of Speech, Language, and Hearing Research*. He has published widely on children's language development and disorders, most recently focusing on language processing for production and comprehension.

Mark S. Seidenberg is Hilldale and Donald O. Hebb Professor of Psychology and Cognitive Neuroscience at the University of Wisconsin-Madison. He studies normal and disordered reading and language, with an emphasis on the role of statistical learning mechanisms in acquisition and skilled performance.

Margaret Semrud-Clikeman, PhD, is Professor of Pediatrics and Division Head of Behavioral Neuroscience at the University of Minnesota Medical School in Minneapolis. She is the author of numerous articles, chapters, and books. Her research areas are in neuroimaging of developmental disorders as well as the neuropsychology of attention deficit hyperactivity disorder and autistic spectrum disorders.

Valerie L. Shafer, PhD, is Professor in the PhD Program in Speech-Language-Hearing Sciences, The Graduate Center, City University of New York. She has published widely on neurophysiological indices of speech and language processing in child language development and disorders and on cross-linguistic and bilingual speech perception.

John J. Sidtis is Director of the Brain and Behavior Laboratory in the Geriatrics Division of the Nathan Kline Institute and a research professor in the Department of Psychiatry at the New York University School of Medicine. He was an original member of the first Cognitive Neuroscience Program at Cornell University Medical School and Rockefeller University. He has used functional imaging in his research for 30 years and has been a licensed neuropsychologist over that same period. He is currently studying the effects of deep brain stimulation on speech and brain function in Parkinson's disease.

Steven Small, PhD, MD, is Stanley van den Noort Professor and Chair of Neurology at the University of California, Irvine, and Professor Emeritus of Neurology and Psychology at the University of Chicago. He is editor-in-chief of the international journal *Brain and Language*, and founder of the Society for the Neurobiology of Language. His work focuses on the human brain organization for language, both in the healthy state and in the face of neurological injury, particularly stroke. The basic work emphasizes distributed neural processing of language comprehension, with focus on network models of context- and task-dependent disambiguation processes. The stroke work brings the distributed network approach to the study of both natural recovery and the systems neurobiology of treatment interventions. Most of this work involves functional magnetic resonance imaging, but this is often coupled with computer modeling, and sometimes also coupled with electrophysiological and electromagnetic approaches.

Avron Spiro III, PhD, is a Research Career Scientist at VA Boston Healthcare System, and Research Professor of Epidemiology at Boston University School of Public Health. He is co-editor of *Handbook of Health Psychology and Aging* (with Carolyn Aldwin and Crystal Park), and has written widely on cognition, health, personality, and aging. He has been affiliated with the Aphasia Research Center and the Language in the Aging Brain laboratory at Boston University for nearly 15 years.

John Stein is Emeritus Professor of Neuroscience and Fellow in Medicine at Magdalen College, University of Oxford. His research focuses on the specialized system of "magnocellular" nerve cells that mediate temporal processing, and their role in movement disorders and dyslexia. He doesn't cook fish and his younger brother, British TV fish chef, Rick Stein, doesn't do neuroscience!

Jennifer L. Stevenson is Assistant Professor in the Psychology Department at Ursinus College, USA.

Kim Sweeney is a doctoral candidate in the Department of Cognitive Science at the University of California, San Diego.

Marco Tettamanti, PhD (Nuclear Medicine Department and Division of Neuroscience, San Raffaele Scientific Institute, Milan, Italy), studied neurobiology in Basel and then took a doctoral training in neurosciences at the University of Zurich. His main interests focus on neuroimaging research on the neural bases of language acquisition and aphasia.

Ethan Treglia, MS, CCC-SLP, is a speech-language pathologist working in the Neuroimaging/Aphasia Research laboratory of Dr Margaret Naeser, VA Boston Healthcare System, and the Harold Goodglass Boston University Aphasia Research Center. He screens potential participants, and provides evaluations and treatments to patients with aphasia. His interests include novel treatments for aphasia, language processing, and language recovery after stroke.

Cosimo Urgesi is Assistant Professor in Cognitive Neuroscience at the University of Udine, Italy. He is responsible for research projects concerning the neurocognitive substrates of body representation in the Research Institute E. Medea in San Vito al Tagliamento, Italy. He is author of a number of articles in peer-reviewed journals.

Walter J. B. Van Heuven is a lecturer in the School of Psychology at the University of Nottingham, UK. His research interests include bilingual word processing, language processing in the bilingual brain, orthographic processing, and computational modeling.

Diana Van Lancker Sidtis, PhD, CCC-SLP, is Professor of Communicative Sciences and Disorders at New York University and a research scientist in the Geriatrics Division at the Nathan Kline Institute for Psychiatric Research in New York. Licensed and certified as a speech pathologist, she teaches and performs speech science and neurolinguistic research.

Christine E. Watson is a postdoctoral research fellow in the Department of Neurology and the Center for Cognitive Neuroscience at the University of Pennsylvania in Philadelphia. She uses behavioral studies of normal and brain-damaged individuals, in conjunction with computational modeling, to elucidate the relationship between action and event comprehension and verb knowledge, as well as the neural bases of solving verbal and nonverbal analogies.

Christine Weber-Fox is Professor in the Department of Speech, Language, and Hearing Sciences at Purdue University. She studies the development of neural functions for language processing in children with typical speech and language abilities and in children with communication disorders, such as specific language impairment and stuttering.

Stephen R. Welbourne graduated from the University of Oxford in 1989 with a physics degree. For the next 12 years he worked in the IT industry. In 2000 he made a major career change and started training in psychology. He did his PhD with Professor Matthew Lambon Ralph at Manchester University, where he now works as a lecturer in cognitive neuroscience.

Suzanne E. Welcome received her PhD from the University of California, Riverside, exploring relationships between brain anatomy and reading ability. She is currently working on functional magnetic resonance imaging studies of reading ability and disability in children and adults as a postdoctoral fellow at the University of Western Ontario.

Stephen M. Wilson is Assistant Professor in the Department of Speech, Language and Hearing Sciences at the University of Arizona. His research combines structural and functional neuroimaging techniques with linguistic analysis to study the neural basis of language processing, and how it breaks down in patients with different kinds of aphasia.

Arthur Wingfield received his DPhil in experimental psychology from the University of Oxford. His research interests include cognitive aging with special focus on hearing acuity, language comprehension, and memory.

Preface

The capacity for language is generally acknowledged as one of the characteristics of what it is to be human. Onkelos, a second-century CE translator of the Old Testament into Aramaic, the then common language of the Middle East, makes this point vividly. In Genesis chapter 2, verse 7, the Bible concisely describes the creation of man in the following manner: "The LORD GOD formed man of the dust of the ground, and breathed into his nostrils the breath of life and man became a living soul." Back translating from Onkelos' Aramaic to modern English, the expression "man became a living soul" becomes "and it became in Adam a discoursing spirit." Thus, according to Onkelos, language, the innate desire and ability to discourse with others, breathed into Adam by the LORD GOD, constitutes the essence of the human spirit – what many today would prefer to term the human mind.

This two-volume book consists of 46 chapters that present the most current state-of-the-art understanding of how the above innate capacity for language and discourse is embodied in the brain. These chapters were authored by scientists from a variety of disciplines concerned with the theoretical and clinical implications of the brain–language relationship. Specifically, these chapters are concerned with the bidirectional nature of these implications and this relationship. Accordingly, they explicate what the brain can teach us about language as well as how advances in our understanding of language require that we expand our comprehension of the brain. In addition, the chapters of Volume 1 describe basic research into the brain–language relationship and attempt to show how theories describing this relationship can contribute to our ability to cope with problems associated with the use of language. The chapters of Volume 2 describe how various clinical phenomena can motivate the theoretical work described in Volume 1. The book thus relates to some of the modern hot debates concerning brain–language relationship, including nature versus nurture, basic versus applied clinical research, and the interactions between genetics, early experiences, and later events such as multilingualism and brain injury.

The two volumes could have been divided into parts and chapters in many different ways. Thus, the way they are organized and presented here is just one of several plausible options. Volume 1 includes 25 chapters divided into five parts. Part I focuses on the differences between the two brain hemispheres in language processing. This issue has raised much interest since the discoveries of language areas in the human brain in the mid-nineteenth century. Part I opens with a chapter by Chiarello, Welcome, and Leonard on individual differences in brain organization for language. The chapter documents the range of variation in brain anatomy and behavior within a large, normally functioning group of young adults. The authors consider variation in brain structure, in behavior, and in the relation between structure and behavior.

The second chapter, by Cohen, deals with a major theoretical issue related to hemispheric involvement in language processing, i.e., whether hemispheric involvement is absolute or relative. The chapter presents a new technique to examine the above issue and to properly assess the relative contribution of each hemisphere to the presentation of speech sounds. In the third chapter, by Lavidor, the author reviews transcranial magnetic stimulation (TMS) and language studies. This chapter highlights the evolution of TMS-language studies and shows how the initial concept of "virtual lesion" (or, in other words, TMS-induced inhibition) has evolved to encompass hemispheric connectivity and facilitation.

Peleg and Eviatar present in Chapter 4 a model which is a general account of how the integration between phonological, orthographic, and semantic representations occurs in the two cerebral hemispheres. They propose the three representations are related to each other differently in each hemisphere. Chapter 5, by Long, Johns, Jonathan, and Baynes, describes a method, called item priming in recognition, for examining the nature of discourse representation and the use of this method to understand how discourse concepts are stored and organized in the two cerebral hemispheres.

The central theme of parts II and III of Volume 1 is language comprehension and language production. Part II approaches this issue from a computational perspective whereas the Part III offers an empirical perspective. Chapter 6, by Watson, Armstrong, and Plaut, illustrates how connectionist modeling has furthered our understanding of normal and impaired processing in semantic memory, knowledge of grammatical class, and word reading and how the connectionist approach has provided for theoretical advancement that would not have occurred using the double-dissociation rubric of traditional cognitive neuropsychology.

Chapter 7, by Goldrick, focuses on three core principles of connectionist theories of speech production, and the impact of each of these principles on psycholinguistic theories of speech production is reviewed. The author examines how learning-based modification of spreading activation may (or may not) lead to novel theories of cognitive processes. In the last chapter of Part II, Gupta reviews evidence for the proposal that the processing and learning of words can usefully be understood as lying at the intersection of a variety of memory mechanisms. He offers a framework

that integrates functional and computational considerations in word processing and word learning.

Part III, on empirical studies of the neural correlates of language production and comprehension, opens with Chapter 9, by Graves, Binder, Seidenberg, and Desai. They present behavioral and hemodynamic neuroimaging studies on three variables thought to influence the degree of semantic processing in reading aloud: imageability, spelling–sound consistency, and word frequency. They attempt to clarify the different contributions of neural systems supporting semantic processing in reading aloud.

In Chapter 10, Lee and Federmeier review behavioral and eye-tracking studies on lexical frequency, word class, linguistic concreteness, and lexical semantic ambiguity and relate the findings to event-related potential (ERP) studies. Taken together, these studies suggest that word recognition is a flexible and dynamic process that is sensitive to features within the lexical item itself as well as to information in the surrounding linguistic context. In Chapter 11, Indefrey reviews research that used hemodynamic techniques for studying syntactic processing. Based on meta-analysis of the relevant studies he concludes that there is good and largely consistent evidence for Broca's area and the left posterior temporal lobe as neural substrates of syntactic processing in sentence comprehension and production. It is suggested that Broca's area may be involved in the bidirectional mapping of thematic and syntactic structures.

Chapter 12, by Tettamanti and Perani, presents evidence from a wide host of empirical studies showing that the same anatomical brain structures, and notably the pars opercularis of Broca's area, play a crucial role in the processing and in the acquisition of hierarchical syntactic dependencies in adult subjects. The authors suggest that this computational capacity may be at the core of what makes us a linguistic species. The central topic of Chapter 13, by Chwilla, is how the mind/brain creates meaning. The author presents recent ERP results revealing that familiar meanings, and, crucially, novel meanings too, are immediately accessed/integrated into the ongoing context and argues that the electrophysiological findings support embodied views of language and challenge abstract symbol theories of meaning.

Mashal, Andric, and Small discuss in Chapter 14 motor regions of the cerebral cortex and their participation in a number of functions related to human language, i.e., producing and perceiving speech and language and representing the meaning of words and sentences. The authors elaborate on motor system involvement in articulate speech, continue to characterize its involvement in manual gesture, and, lastly, discuss its more general role in interpreting a message's content. In the final chapter of this part, Chapter 15, Kellett, Stevenson, and Gernsbacher examine the role of the cerebellum in language processing by reviewing brain imaging studies of healthy adults performing phonological, lexical, semantic, syntactic, and discourse-level processes. Their review includes experiments that employed a high-level baseline that controls for motor processes and reports cerebellar lobular regions across studies to identify similar areas of activations for language tasks.

Part IV of Volume 1 focuses on the representation of higher-level language processes in the brain, emphasizing figurative language and linguistic creativity. This part opens with Chapter 16 by Mirous and Beeman, describing some of the cognitive processes and neural substrates that underlie a few categories of creative language use, highlighting similarities and a few differences. The chapter discusses how each hemisphere contributes to processing jokes, drawing inferences, and creatively solving problems and outlines a theoretical mechanism for these hemispheric differences. Van Lancker Sidtis presents in Chapter 17 a historical and critical survey of phraseology, the study of formulaic language, in the context of analytic, experimental, and biological approaches, culminating in current views of formulaic language as an integral component of speech performance and language competence. The author concludes that the empirical evidence supports a dual-process model of language, whereby novel expressions and formulaic expressions differ essentially in how they are learned or acquired, stored, and processed.

Chapter 18, by Cacciari and Papagno, reviews literature concerning the neural architecture underlying idiom comprehension in language-unimpaired and language-impaired participants. The review includes neuropsychological, brain imaging (fMRI), and TMS data and the authors draw some conclusions about possible answers to the basic question that motivated this chapter, i.e., hemispheric involvement in idiom comprehension. Coulson and Davenport focus in Chapter 19 on two well-defined examples of creative language that utilize frames and mappings: jokes and metaphors. The authors review cognitive neuroscience research used to test and develop models of the comprehension of these phenomena and evidence for the importance of the right hemisphere in each. They conclude with some speculations about the potential relevance of such research to general issues relevant to meaning in language.

In Chapter 20, Rapp postulates that nonliteral expressions constitute a challenge for comprehension as they go beyond the literal meaning of the words and require the ability to process more than the literal meaning of an utterance in order to grasp the speaker's intention in a given context. This chapter reviews the current functional brain imaging evidence on the comprehension of metaphors, idioms, proverbs, and ironic expressions. In the concluding chapter of this part, Chapter 21, Faust presents research on the processing of novel metaphoric expressions and discusses the relation to linguistic creativity. The chapter presents converging evidence from studies using behavioral, brain imaging (fMRI, magnetoencephalography), electrophysiological (ERP), and TMS techniques suggesting that the right hemisphere plays a major role in processing novel metaphoric word combinations.

In our increasingly globalizing modern society, learning and mastering foreign languages has become a basic requirement. Consequently, in Part V of Volume 1, the linguistic processes discussed in the previous parts are reassessed from the perspective of the multilingual brain. Part V begins with Chapter 22, by Dijkstra and van Heuven, describing a number of assumptions shared or discussed by researchers in bilingual word recognition, and assesses to what extent the findings

of neuroimaging and electrophysiological studies with bilinguals agree with these. The authors conclude that, overall, the neuroscientific data support many of the architecture and processing assumptions shared by behavioral models. In Chapter 23, de Groot discusses aspects of the acquisition of vocabulary in two very different populations of learners, monolingual and bilingual infant first-language (L1) learners and late second-language (L2) learners. The chapter highlights the fact that L1 vocabulary learning involves the learning of both word form and word meaning, whereas in L2 vocabulary learning the targeted L2 meanings are already largely in place in the form of lexical concepts in the learners' L1.

Chapter 24, by Kroll, Guo, and Misra, considers a set of research questions on bilingualism comparing behavioral and electrophysiological research. The chapter reviews the empirical evidence from behavioral and ERP studies demonstrating the presence of cross-language activity. The implications of these results for claims about the neural basis for a bilingual advantage in executive function tasks that require the resolution of competition are discussed. The closing chapter of this part, Chapter 25 by Abutalebi and Della Rosa, reviews and analyzes functional neuroimaging research showing how the brain acquires, processes, and controls an L2. The authors conclude that the reviewed works support a dynamic view concerning language acquisition. "Dynamic" because there may be proficiency-related changes in the brain, i.e., once an L2 learner has gained sufficient proficiency, she will engage exactly the same brain areas as she would for her native language.

Volume 2 of the book focuses on neuropsychological research and on the connections between basic science and clinical research. The research described in this volume shows how clinical work drives research in basic neuroscience. Thus, for example, existing brain–language theories may have to be re-examined and adjusted to account for new clinical findings. This process may generate new hypotheses and stimulate basic neuroscientific research on brain–language relations.

Volume 2 includes 21 chapters divided into three parts. Part I emphasizes methods and paradigms used in neuropsychological research and opens with Chapter 26, by Kutas, Kiang, and Sweeney, on event-related brain potentials and neuropsychology. This chapter describes how the use of this technique has impacted our understanding of normal cognitive processes, including language, and thus has great potential for investigating their disruption by disease states. The authors claim that ERP components are one of the few available tools for demarcating and dissecting the human language architecture in all human brains – young or old, intact or compromised, compliant, defiant, or simply incapable.

Chapter 27, by Sidtis, invites serious reflection on the assumptions, methods, and meaning of functional imaging studies. The author argues that the long and often insightful history of clinical observations of brains that cannot speak, brains that speak nonsense, or brains that speak poorly should not be ignored in the age of functional imaging and that listening to these accounts may lead to a better understanding of what functional imaging is trying to tell us. Baldo, Wilson, and Dronkers present in Chapter 28 a new lesion analysis technique, called voxel-based lesion–symptom mapping (VLSM), that has been applied to a number of questions regard-

ing the brain basis of language. This approach has produced a number of unique findings and has shown that many regions of the left hemisphere outside Broca's and Wernicke's classical language areas play a critical role in linguistic functions.

Chapter 29, by Brownell, Hoyte, Piquado, and Wingfield, uses the investigation of naming deficits to illustrate some current methodological issues and options associated with patient-based research. The authors discuss a study of naming in several mildly impaired aphasic patients, explore the distinction between group studies and case studies, and bring to bear a variety of analytic techniques that are straightforward, already in the literature, and accessible. Chapter 30, by Pekkala, shows how the use and analysis of performance on verbal fluency tasks can not only reveal the cognitive processes underlying the tasks but also lead to a successful differentiation between normal and impaired word retrieval. Pekkala suggests that verbal fluency tasks can be used as a reliable method when assessing word retrieval skills of individuals with different cultural and language backgrounds.

Chapter 31 by Ellis opens Part II, on language loss, and deals with the acquisition, retention, and loss of vocabulary in aphasia, dementia, and other neuropsychological conditions. The author concludes that age of acquisition is clearly a powerful determinant of processing speed and retention or loss of knowledge, although it is by no means the only determinant. In Chapter 32, Welbourne traces the evolving relationship between cognitive neuropsychology and computational models of language focusing on language processing and its breakdown in aphasia. The author discusses the use of computational neuropsychological techniques and shows how they can significantly enhance our understanding of the underlying brain disorders and the mechanisms that allow recovery. Chapter 33, by Naeser, Martin, Ho, Treglia, Kaplan, Baker, and Pascual-Leone, reviews functional brain imaging studies related to recovery of language in aphasia, and presents the rationale for the use of repetitive TMS (rTMS) in treating aphasia patients. The authors describe their current rTMS treatment protocol used with aphasia patients and a diffusion tensor imaging (DTI) study that examined possible white matter connections between specific brain areas. Finally, they address the potential role of mirror neurons in relationship to improved naming post-TMS with nonfluent aphasia patients.

The main aim of Chapter 34, by Fitzpatrick, Obler, Spiro, and Connor, was to address the question of long-term recovery in aphasia using confrontation naming and word-finding measures. Their results indicate that single-word naming continues to show significant improvement at least as long as 15 years post-onset. This finding supports the observations of Geschwind and other clinicians that it is possible for patients to continue to recover long after 1 year. Chapter 35, by Goral, focuses on multilingualism. The author reviews two types of neurolinguistic studies, namely, neuroimaging of multilinguals and multilingual aphasia in order to answer questions about the representation and processing of multiple languages in the brain. In the last part of the chapter current data concerning cognitive abilities and multilingualism are briefly presented. Marini, Urgesi, and Fabbro conclude in Chapter 36 that bilingual patients with different etiologies and ages may present differential patterns of impairment and/or recovery of their languages. This applies

to adult aphasia, childhood aphasia, specific language impairment, neuropsychiatric disorders, and neurodegenerative disorders. The authors thus assume that the cerebral representation of different languages must be implemented in different cerebral circuits.

In Chapter 37, Kotz, Rothermich, and Schmidt-Kassow discuss the temporal and neural correlates of language subprocesses by providing ERP and fMRI evidence from healthy and brain-damaged populations. The chapter ends with an overview of the possible interfaces between language subprocesses, including syntax, prosody, and semantics, in sentence processing. Their review suggests that investigations of dependencies between language subprocesses are necessary to understand the dynamics of sentence comprehension. In the last chapter of the part on language loss, Chapter 38, Burke and Graham discuss the neural basis for aging effects on language. The authors review evidence for the behavioral dissociation in aging effects on semantic and phonological retrieval processes and then consider research that might link this dissociation to an asymmetry in how the brain ages. They note that language provides a promising approach for examining the neurobiological substrates that are associated with functional cognitive decline and cognitive preservation, as occurs in phonological and semantic processing, respectively.

The final part of the book focuses on developmental language disorders. The goal of the first chapter in this part, Chapter 39, by Semrud-Clikeman and Bledsoe, was to provide insight into developmental language disorders as well as into the underlying brain function in language development. The authors emphasize intervention and conclude that fruitful research that continues to tease apart the similarities and differences in these diagnoses will be helpful not only for understanding the disorders but also for developing appropriate remediation programs. In Chapter 40, Leonard and Weber-Fox describe processing deficits in linguistic, cognitive, and sensory domains in specific language impairment (SLI). They point to weaknesses in the detection, perception, storage, and integration of information and conclude that one of the next steps toward understanding SLI will come from attempts to relate the particular weaknesses in processing that are seen in SLI to the specific language symptoms that individuals with this disorder exhibit. The neurobiology of SLI is discussed in Chapter 41 by Schwartz and Shafer. The authors review MRI, fMRI, and ERP studies and emphasize the use of these methods to provide early identification of children at risk for SLI, as well as their use to measure changes following intervention. They argue that the great challenges remaining in the study of the neurobiology of SLI include the continuing establishment of relations between neurological findings and behavior, determining the specific cognitive and linguistic implications of anatomical and functional differences between children with SLI and their typically developing peers.

Chapters 42–45 focus on developmental reading disabilities. In Chapter 42, Kovelman, Christodoulou, and Gabrieli postulate that there are multiple pathways to dyslexia and that individuals with dyslexia vary with regard to their strengths and weaknesses. They review neuroimaging research showing that children undergo functional and anatomical reorganization as a result of reading experience, but that

there are important differences between typical and dyslexic readers. These differences may be related to the learning and perceptual differences in the processing patterns of individuals with dyslexia. Chapter, 43 by Coltheart and Kohnen, describes the features of eight subtypes of acquired dyslexia and considers how each might be interpreted as arising via specific selective impairments of a general information-processing model of visual word recognition and reading aloud. The authors argue that developmental dyslexia is very similar to acquired dyslexia in that seven of the eight acquired dyslexias they describe can also be seen in developmental form.

In Chapter 44, Banai and Ahissar present evidence that normal anchoring mechanisms, i.e., the implicit formation of internal representations, which allow most individuals to benefit from the statistics that characterize each episode or context, are malfunctioning in dyslexia and that this malfunction can account for dyslexics' difficulties in discriminating both simple tones and speech elements. The authors list evidence for interrelations across cognitive domains that are typically studied in isolation and present anchoring as a putative mechanism that could account for these interrelations and provide evidence for its failure in dyslexia. In Chapter 45, Stein argues that all the manifestations of developmental dyslexia could be explained by a single underlying cause, namely impaired development of a discrete system of nerve cells throughout the brain, magnocellular neurones, that are specialized for timing functions. The final chapter of the volume and book, Chapter 46 by Borodkin and Faust, is similar to the first chapter of this part in that it relates to developmental language impairments including both SLI and dyslexia. However it adds a third, subclinical group of persons who have marked difficulties in learning foreign languages. The chapter reviews research on word retrieval difficulties in developmental language disorders, focusing on the application of the tip-of-the-tongue experimental paradigm for studying impaired phonological processes in these populations.

I would like to conclude the preface by making the point that the 46 chapters of the two volumes were not intended to cover all relevant issues related to brain–language research in a systematic manner. Instead we aimed to provide a comprehensive overview of current trends and recent advances in neuroscientific and neuropsychological research, emphasizing state-of-the-art methodologies and paradigms and their application to the central questions in brain–language relationship. I hope this goal was achieved.

Miriam Faust

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