



Research Methods in Psycholinguistics and the Neurobiology of Language

A Practical Guide

Edited by Annette M. B. de Groot and Peter Hagoort

WILEY Blackwell

"This important collection of chapters by leading researchers - ranging over methods from preferential looking to cutting-edge imaging to molecular genetics - will be an essential resource for researchers and students of language processing. The book provides an impressive overview and useful hands-on tips regarding the wide range of techniques used to investigate many aspects of language."

David Poeppel, Max Planck Institute and New York University, USA

"The astounding proliferation of new research methodology during recent decades has deeply affected theoretical progress in psycholinguistics. This volume provides the first comprehensive guide to these methods, behavioral, neurobiological and computational. The editors, Annette de Groot and Peter Hagoort, not only managed to attract superb specialists for each and every chapter, they also convinced them to organize their chapters in similar ways, such providing a transparent, unified perspective. It makes for a most user-friendly guide, indispensable for any researcher in this interdisciplinary field."

Willem Levelt, Max Planck Institute for Psycholinguistics, USA

Bringing together contributions from a distinguished group of researchers and practitioners, editors Annette M. B. de Groot and Peter Hagoort explore the methods and technologies used by researchers of language acquisition, language processing, and communication, including: traditional observational and behavioral methods; computational modelling; corpus linguistics; and virtual reality. The book also examines neurobiological methods, including functional and structural neuroimaging, and molecular genetics.

Ideal for students engaged in the field, *Research Methods in Psycholinguistics and the Neurobiology of Language* examines the relative strengths and weaknesses of various methods in relation to competing approaches. It describes the apparatus involved, the nature of the stimuli and data used, and the data collection and analysis techniques for each method. Featuring numerous example studies, along with many full-color illustrations, this indispensable text will help readers gain a clear picture of the practices and tools described.

Annette M. B. de Groot, PhD, is Professor of Psycholinguistics and former Chair of the Department of Psychology at the University of Amsterdam, The Netherlands. Currently her research focuses on individual bilingualism and multilingualism.

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Research Methods in Psycholinguistics
and the Neurobiology of Language

Guides to Research Methods in Language and Linguistics

Series Editor: Li Wei, Centre for Applied Linguistics, University College London

The science of language encompasses a truly interdisciplinary field of research, with a wide range of focuses, approaches, and objectives. While linguistics has its own traditional approaches, a variety of other intellectual disciplines have contributed methodological perspectives that enrich the field as a whole. As a result, linguistics now draws on state-of-the-art work from such fields as psychology, computer science, biology, neuroscience and cognitive science, sociology, music, philosophy, and anthropology.

The interdisciplinary nature of the field presents both challenges and opportunities to students who must understand a variety of evolving research skills and methods. The *Guides to Research Methods in Language and Linguistics* addresses these skills in a systematic way for advanced students and beginning researchers in language science. The books in this series focus especially on the relationships between theory, methods, and data—the understanding of which is fundamental to the successful completion of research projects and the advancement of knowledge.

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Edited by Annette M. B. de Groot and Peter Hagoort

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Peter Hagoort is Academy Professor of the Royal Netherlands Academy of Arts and Sciences, and Professor of Cognitive Neuroscience at Radboud University. He is a Director of the Max Planck Institute for Psycholinguistics and of the Donders Institute for Brain, Cognition, and Behaviour. His research focuses on the neurobiological infrastructure for language with the help of advanced neuroimaging methods such as fMRI, MEG, and TMS.

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Preface

In many aspects the human language system is a unique support system for communication and thinking. Ways to investigate this complex cognitive capacity were traditionally restricted to observational and behavioral methods in healthy people and neuropsychological patients with a language disorder. In recent decades this picture has changed dramatically. Partly due to technological developments and partly as a result of developments in other fields of research, methods to study language and communication have seen a vast increase in number and level of sophistication. Due to the technological progress in computing power, we are now able to build way more advanced computational models of language processing than ever before. Thanks to developments in neuroimaging and genetic sequencing, we are able to study the neural basis and the genetic underpinnings of the language-ready brain in an unprecedented manner. These developments, however, come at a price. To be able to appreciate research findings or actively participate in this research field, one has to be acutely aware of the ins and outs of the research methods that are currently available. Until now a volume that summarizes and discusses all available methods in this field of research was missing. *Research Methods in Psycholinguistics and the Neurobiology of Language* intends to fill this gap. It provides a comprehensive overview of all relevant methods currently used in research on human language and communication. Some of them have their roots in psycholinguistics, others were introduced from other fields of science such as the biological sciences. Some require highly specialized technical knowledge and skills, whereas others take little time and effort to learn. For some methods a modest, inexpensive laboratory infrastructure suffices, whereas others depend on equipment that takes millions to acquire and interdisciplinary groups of specialists to operate. Some are offline methods that only measure the outcome of mental processing, whereas others continuously monitor mental processes as they unfold in real time, producing information-rich and dense datasets. Presenting this diverse collection of methods, we anticipate that this book will be a useful guide for doctoral students, postdocs, and active researchers in our field who would want to inform themselves about the basics, the advantages and disadvantages of available research methods, and to get for each one of them pointers to additional method-related information and best practice examples.

While conceiving this book we wondered how the great diversity of methods used in the study of language—its acquisition, use, neural and genetic basis, and disorders—could be covered within the limited space available. The solution was to not

focus on the specific type of research methods called *tasks*, of which an innumerable variety exists, but on a broader notion of what research methods are. A task is what participants in an experiment are asked to do, for instance, to name the objects on a set of pictures shown to them. The participants' behavioral and/or brain responses are registered and constitute the database from which the researcher subsequently extracts information. A research method in the more general sense that we had in mind for this volume is a much broader construct, one that covers a complex of procedures to study the question of interest (e.g., designing a study, constructing stimulus materials, and collecting and analysing the data), and that also includes the technical apparatus, tools, and instruments that support these procedures. Although many methods in this broad sense include data gathering by having participants perform some task, other methods do without this altogether because the data already exist (corpus linguistics; Chapter 12) or because the method produces artificially generated data (computational modeling; Chapter 11). There are also methods that elicit data from participants without the latter explicitly being asked to perform some task (e.g., the habituation techniques and visual preference techniques presented in Chapters 1 and 2, respectively). Other methods can be combined with a multitude of different tasks (e.g., word priming and interference paradigms, Chapter 6; structural priming, Chapter 7; the electrophysiological and hemodynamic neuroimaging methods presented in Chapters 13 and 14, respectively). All this shows that tasks and methods are not the same things.

A feature that characterizes many methods in the broad sense of the word is that they are domain-nonspecific. Those developed within psycholinguistics can typically be used in various of its sub-fields: They are suitable to address questions concerning more than one, or all three, of psycholinguistics' main areas of study (language acquisition, comprehension, and production) and/or to answer questions about multiple linguistic domains (e.g., phonology, morphology, syntax, and semantics). The neurobiological methods included in this volume are even more multipurpose, not being restricted to studying language but domain-general *pur sang*, also applicable in studying other areas of cognition and other aspects of human (and animal) behavior.

While the majority of the 17 contributions to this book present domain-nonspecific methods, a couple of them deal with domain-specific methods: Chapter 3 presents three approved methods for assessing vocabulary in children (language sampling, parent report, and direct assessment); Chapter 4 discusses the ins and outs of the presumably most ecologically valid behavioral research method for examining the reading process: the tracking of eye-movements; Chapter 8 exclusively deals with conversation analysis. But even these domain-specific methods allow variability in how they are used and are thus able to inform multiple aspects of language processing. For instance, having the participants read complete paragraphs is what qualifies eye-movement tracking as an ecologically valid method to study reading, but the stimulus does not *need* to be a whole paragraph. Sentences, even single words, may also serve as stimuli and, when they do, inform accounts of syntactic parsing, semantic analysis, and word recognition. Similarly, though the primary goal of conversation analysis is to study human social interactions and how people perform actions through talking, the database on which the analyses are done, often a corpus of naturally occurring conversations, contains information on all aspects of the conversational partners' language use and, thus, on phonology, vocabulary, and more.

In addition to guaranteeing a broad coverage of relevant research methods by predominantly selecting domain-general methods, the volume's coverage was increased yet further by inviting authors to present several related methods within a single chapter, directing the readers to these methods' similarities and differences. For instance, the authors of Chapter 2 contrast multiple conceptually related variants of the visual-preference technique to study language development in very young children, at an age at which they do not yet produce language or their verbal productions are still incomprehensible. The differences between the various implementations of the general method are often subtle and could easily escape readers if not presented in opposition. Similarly, the authors of Chapter 14 discuss two non-invasive functional neuroimaging methods, fMRI and fNIRS, that both make use of the fact that neural activity leads to changes in the local cerebral blood flow in the brain and that can both reveal which parts of the brain are activated while participants perform a particular task. Contrasting the pros and cons of these two related techniques within a single chapter will help readers to make a well-informed choice between the two during the planning of their own research project. Likewise, after detailing the specifics of the EEG/ERP methodology, in which electrical brain activity can be measured with a temporal resolution in the order of milliseconds, the authors of Chapter 13 contrast it with MEG, which provides a record of the magnetic activity of the brain. Chapter 15 differentiates multiple non-invasive techniques for structural neuroimaging based on MRI, which reveals the neuroanatomy of language with good spatial resolution. Among the presented methods is *tractography*, a novel technique for visualizing white matter pathways in the living human brain. Chapter 16 also presents various structural neuroimaging methods, but whereas in Chapter 15 the major focus is on the healthy brain, in this contribution the emphasis is on the lesioned brain. Yet another example of a chapter that presents several related methods is Chapter 17, where inter-individual variability in language skills is linked to genetic variation. The specific method used depends on whether the studied trait is suspected to be *monogenetic* (due to a single genetic variant) or *multifactorial* (resulting from the combined effects of multiple genes). Finally, the chapters dealing with the Visual World Paradigm (Chapter 5) and priming (Chapters 6 and 7) actually concern families of related methods (e.g., masked priming and cross-modal priming).

The inevitable consequence of choosing domain-nonspecific methods as themes for the separate chapters was that ways of organizing them that appeared obvious at first sight turned out to be neither feasible nor appropriate on second thoughts: The chapters could not be organized according to the main areas of language study, input and output modalities, or the various structural subsystems that languages consist of. After all, most of the presented methods are not specifically tied to any such subdivision of study. A presentation according to the type of measures used, behavioral or neurobiological, would be more appropriate and feasible but is complicated by the fact that studies using neurobiological methods generally encompass behavioral measures as well, and the opposite also occurs. This is shown in many of the chapters, for instance in Chapter 16, where the authors illustrate the "two-pronged" nature of most lesion studies, which combine structural neuroimaging data and a diversity of behavioral data that index patients' linguistic performance. Another example concerns Chapter 7 on structural priming. Though in its early days this method only involved behavioral measures, it increasingly uses brain measures such as ERPs and the BOLD response that indexes brain activation in fMRI. Still, for most language

researchers it makes sense to qualify methods as behavioral or neurobiological (and computational as a third category), so this is how we ordered the chapters, from primarily behavioral (Chapters 1-10) and computational methods (Chapters 11 and 12) to neurobiological methods (Chapters 13-17). But because the partitions between these classes of methods are not clear-cut and a continued growth in interdisciplinary research will likely result in their further integration, we have decided against explicitly labeling these three subsections in the table of contents.

In the preceding paragraphs almost all chapters have been introduced, however briefly. The exceptions were Chapter 9, on virtual reality, and Chapter 10, which presents ways for studying language outside the laboratory. These chapters were saved for now, where we mention two limitations of many traditional methods for studying language processing: Their ecological validity and external validity are often low; that is, their findings cannot easily be generalized to real-world settings and to other populations and situations. The main reason why much traditional research lacks ecological validity is that in order to obtain reliable data and make sense of them, strict control over the experimental variables is required. Such control can generally only be secured by using laboratory tasks that are impoverished substitutes of the real phenomena under study, the latter being stripped of many of their essentials, including the context in which they take place. The authors of Chapter 9 show how with virtual-reality techniques it is possible to realize ecological validity in the laboratory while at the same time controlling numerous experimental variables. The authors of Chapter 10 describe ways to enhance ecological validity and external validity by, for example, taking the experiment out of the laboratory into institutionalized public spaces such as museums, by crowdsourcing data on the internet, or by conducting cross-cultural fieldwork. But unlike in research that makes use of virtual reality, in such studies maintaining experimental control is a real challenge.

A final feature that characterizes this volume is that many of its chapters contain the same or very similar sections, this resulting from our instructions to the authors. They were asked to explain the underlying assumptions and rationale of “their” method, to describe the required apparatus, the nature of the stimuli and data, the way the data are collected and analysed, and what the method’s strengths and weaknesses are in comparison to related methods. We also asked them to illustrate the method with an exemplary study so that the actual research practices and tools could be more vividly pictured, and to provide a glossary for easy accessibility of the method’s central concepts and features.

We are confident that the broad collection of research methods presented in this volume is varied enough for all beginning researchers interested in human language processing to find a topic to their liking and get going, and for researchers already active in language studies to become familiar with techniques they have not yet practiced themselves.

Annette M. B. de Groot and Peter Hagoort