

Introduction to Neurolinguistics

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John Benjamins Publishing Company

Amsterdam / Philadelphia



The paper used in this publication meets the minimum requirements of American National Standard for Information Sciences — Permanence of Paper for Printed Library Materials, ANSI Z39.48-1984.

Cover design: Françoise Berserik

Library of Congress Cataloging-in-Publication Data

Ahlsén, Elisabeth

Introduction to Neurolinguistics / by Elisabeth Ahlsén

p. cm.

Includes bibliographical references and index.

1. Neurolinguistics. I. Title.

QP399.A39 2006

612.8'2336--dc22

2006042986

ISBN 978 90 272 3233 5 (Hb; alk. paper)

ISBN 978 90 272 3234 2 (Pb; alk. paper)

ISBN 978 90 272 9344 2 (Eb)

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John Benjamins Publishing Company • P.O. Box 36224 • 1020 ME Amsterdam • The Netherlands
John Benjamins North America • P.O. Box 27519 • Philadelphia PA 19118-0519 • USA

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Preface

It is not uncommon to search for a particular type of book, only to discover that you will have to write it yourself. The idea of this book emanates from a conversation with a representative of John Benjamins at an International Cognitive Linguistics Conference some years ago, concerning the difficulty of finding an up-to-date book of reasonable size, price and coverage for introductory courses in neurolinguistics. By then, I had been teaching such courses for students of linguistics and communication disorders for a long time. Both of us were well aware of this problem, and when it was suggested that I should write such a book, I agreed. We were also in agreement concerning the relative lack of communication between neurolinguistics and cognitive linguistics, pragmatics and communication studies at the time and the need for these areas to be better integrated into basic neurolinguistics. This discussion and further reflections on the “state of the art” led to the fairly broad selection of topics that are covered in this book and to the relative weighting given to the different chapters. One important concern has been to place the different theories, methods and studies discussed in a historical perspective, showing how different frameworks have developed, sometimes in parallel, sometimes in sequence, and left their traces on the ways we think about language and the brain and how we apply this thinking in our research and therapy. The book grew gradually out of many years’ work, as preliminary versions were used in introductory courses, and chapters were revised and added.

This book is a basic introduction to neurolinguistics, intended for anybody who wants to acquire a grounding in the field. It was written for students of linguistics and communication disorders, but students of psychology, neuroscience and other disciplines will also find it valuable. It can be used as coursebook for introductory courses or as a source of information on specific topics in neurolinguistics. The only prerequisite for using it is a basic knowledge of linguistics, including linguistic terminology. Students who have no linguistic background at all should first read an introductory linguistics text. As for students who have no background in neuroanatomy and neurophysiology, some basic information about the brain is provided in Chapter 14.

The book is divided into four parts. The first is an introduction to what neurolinguistics is, what the important questions are, and how the main neurolinguistic frameworks have developed over time. This section provides an important background for understanding why the representatives of specific present-day approaches presented later in the book reason in the way they do. The second part constitutes the linguistic core of the book, in which different components or aspects of neurolinguistics

(phonology, morphology, syntax, lexical semantics, and semantics and pragmatics in communication) are described. The third part contains chapters on selected topics that are of central interest to many neurolinguists and other scientists seeking to understand how language and the brain interact. The four topics are reading and writing, bilingualism, the evolution of language, and multimodality in communication, all viewed from the perspective of describing and explaining disorders of language and communication. The fourth part contains an introduction to the brain, which can read before the rest of the book or used as a reference, and two additional resource chapters on matters that are often referred to in neurolinguistics: neuroimaging (and other methods for investigating brain activity and brain damage) and modeling, especially with artificial neural networks. These chapters are not the core of the book, but should be regarded as resources to be consulted for more information.

Each chapter has a short table of contents at the beginning and a summary at the end. It also suggests further readings from the reference list that will help students learn more about the topics covered in that particular chapter. Each chapter (except the resource chapters) also has a set of assignments at the end. These assignments are not simple factual questions, but are designed to make students apply, think, reason about and discuss the contents of the chapter and what they imply. They are mainly intended for homework, group work and discussion in seminars, for example.

As mentioned above, the book's aim is to provide an up-to-date linguistic perspective, focusing especially on semantics and pragmatics, evolutionary perspectives, neural network modeling and multimodality, areas that may have been neglected by earlier introductory works. It presents theories from the 19th century, when many of our most basic ideas about language and the brain were formed (the Wernicke-Lichtheim model, Jackson's evolutionary perspective, etc., as well as more holistic views), classical frameworks that have had and still have a considerable influence on clinical practice (the neoclassical "Bostonian" and Lurian approaches), and frameworks that are in their development phase today (pragmatics and communication, multimodality, communication technology, cognitive neuropsychology and neurolinguistics), as well as some brief information on emerging topics and frameworks that are likely to influence neurolinguistics in the near future (mirror neuron findings, embodiment and alignment in communication).

Over the years, many people have contributed in various ways to the approach, contents and form of this book. I have been greatly influenced by the books that focused my interest on neurolinguistics in the 1980s: the *Studies in neurolinguistics* series published by Whitaker and Whitaker, Ruth Lesser's book on linguistics and aphasia, and the work of my supervisor in logopedics, Bibi Fex, who directed my clinical interest towards aphasia and brain damage. I am also indebted to the teachers and fellow students at the 1982 Linguistic Institute on Neuro- and Psycholinguistics at the University of Maryland, the members of Lise Menn and Loraine Obler's Cross Language Aphasia Study project and my colleagues in the Nordic Linguistic Network.

An important influence on my particular perspective on linguistics and neurolinguistics is the work of colleagues at the Department of Linguistics and the SSKKII Center for Cognitive Science, Göteborg University, especially my former supervisor Jens Allwood, whose theories on communication as cooperation and action made me look at neurolinguistics with a critical eye and relate it more to theories from semantics, pragmatics, communication and cognitive linguistics. Special thanks are also due to the research group on neurolinguistics and communication disorders, my Ph.D. students, and the numerous students of linguistics and logopedics who have been subjected to earlier versions of the book and who have given me valuable feedback.

I would probably neither have started nor finished this project without the support and encouragement I received from Benjamins, especially Kees Vaes, and the text would not have been in its present shape without the meticulous copy-editing work of Zofia Laubitz and of Shirley Nicholson for earlier versions.

This book has mainly been a project I worked on in my “spare time,” but I have received some valuable support for related research projects financed by the Swedish Council for Working Life and Social Science Research, the Swedish Research Council and the Vårdal Foundation. During my time as a research fellow in the Embodied Communication group at the ZiF Interdisciplinary Center for Research, University of Bielefeld, in 2005 and 2006, I was given the possibility of finishing the manuscript at last.

I would like to express my thanks to everyone mentioned above and many others, not least the patients and research subjects who have given me new insight into the intriguing relationship between language and the brain.

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Part I

Introduction to neurolinguistics

Chapter 1

What is neurolinguistics?

In this chapter:

- *What is included in neurolinguistics?*
- *Different views of the relation between brain and language*
- *The central questions of neurolinguistics*
- *Outline of the book*

What is neurolinguistics?

Neurolinguistics studies the relation of language and communication to different aspects of brain function, in other words it tries to explore how the brain understands and produces language and communication. This involves attempting to combine neurological/neurophysiological theory (how the brain is structured and how it functions) with linguistic theory (how language is structured and how it functions). Apart from neurology and linguistics, psychology is another central source discipline for neurolinguistics. Neurolinguistics has a very close relationship to psycholinguistics, but focuses more on studies of the brain. Studies of language and communication after brain damage are perhaps the most common type of neurolinguistic studies. However, experiments, model construction, computer simulations, and neuroimaging studies are also very frequently used methods today.

In order to identify relevant models and frameworks of neurolinguistics, let us first try to delimit this research field. The main questions of interest for neurolinguistics (see the section with this title below) were first addressed very far back in history. There was a period of intensified focus in the late 19th century; since then, they have become central to researchers in many disciplines. “Neurolinguistics” became the established term for the field in the 1960s, under the influence of the Chomskyan boost to linguistics and the development of psycholinguistics as a defined field. The subject matter of neurolinguistics is described in the introduction to the series of volumes

known as *Studies in Neurolinguistics*, edited by Whitaker and Whitaker in the 1970s, as follows: even though the field of neurolinguistics is frankly interdisciplinary, there is a common theme of the relationships between language and the brain (Whitaker & Whitaker, 1976, p. xi).

A similar description, although more focused on functional aspects, can be found in the introductory description of *Brain and Language*, one of the most influential journals in this field:

human language or communication (speech, hearing, reading, writing, or nonverbal modalities) related to any aspect of the brain or brain function (*Brain and Language*: “Description”)

The common problem in relating aspects of language or communication to brain function in this dynamic formulation, is posed by Luria in *Basic problems in neurolinguistics*: what are the real processes of formation of verbal communication and its comprehension, and what are the components of these processes and the conditions under which they take place (Luria, 1976, p. 3).

The interdisciplinary character of the field

The **many disciplines** dealing with neurolinguistics provide inspiration and energy to the field. They introduce many different kinds of data, theories, and models for research.

The editors of *Studies in Neurolinguistics* in the 1970s described the series as “heterogeneous both in theoretical perspective and in topical coverage” and they claimed that the discipline at the time was “not working under a uniform paradigm and there [were] not a few, narrowly defined areas of research” (Whitaker & Whitaker, 1979, p. xi). They also refer to substantial disagreements among the researchers in the field. They do, however, also mention the positive side of heterogeneity: the richness and diversity of ideas and the fact that “attempts at synthesis must take account of many different kinds of data” (Whitaker & Whitaker, 1977, p. xi). To these points, we should add that not only data, but also theories, paradigms, models, and frameworks from different disciplines need to be taken into account, that synthesis seems necessary in this diverse field, and that, at the same time, diversity necessarily increases with further specialization.

Which disciplines have to be taken into account in neurolinguistics? *Brain and Language* states that its interdisciplinary focus includes the fields of linguistics, neuroanatomy, neurology, neurophysiology, philosophy, psychology, psychiatry, speech pathology, and computer science. These disciplines may be the ones most involved in neurolinguistics, but several other disciplines are also highly relevant, having contributed to theories, methods, and findings in neurolinguistics. They include

neurobiology, anthropology, chemistry, cognitive science, and artificial intelligence. Thus, the humanities, and medical, natural, and social sciences, as well as technology are all represented.

Different views on the relation between brain and language

A number of different views about the relationship between brain and language have existed and still do. Some of those that have had a considerable influence are mentioned below.

Localism tries to find locations or centers in the brain for different language functions. **Associationism** situates language functions in the connections between different areas of the brain, making it possible to associate, for example, perceptions of different senses with words and/or “concepts.” **Dynamic localization of function** assumes that functional systems of localized subfunctions perform language functions. Such systems are dynamic, and thus they can be reorganized during language development or after brain damage. **Holistic** theories consider many language functions to be handled by widespread areas of the brain working together. **Evolution-based** theories stress the relationship between how the brain and language evolved over time in different species, how they develop in children, and how adults perform language functions.

The central questions of neurolinguistics

Some of the **central questions** for neurolinguistics are:

- What happens to language and communication after brain damage of different types?
- How did the ability to communicate and the ability to use language develop as the species evolved? How can we relate this development to the evolution of the brain?
- How do children learn to communicate and use language? How can we relate their acquisition of language to the development of their brains?
- How can we measure and visualize processes in the brain that are involved in language and communication?
- How can we make good models of language and communication processes that will help us to explain the linguistic phenomena that we study?
- How can we make computer simulations of language processing, language development, and language loss?
- How can we design experiments that will allow us to test our models and hypotheses about language processing?

The first of the questions above occupies a special place in neurolinguistics. **Aphasia** is defined as “language loss due to brain damage.” The cause can, for example, be an infarction (blockage of blood vessels in the brain), a hemorrhage (bursting of a blood vessel), or a head trauma. The effect of the lesion is that the comprehension and/or production of language is changed. By studying these changes, we can study how functional systems related to language work and which brain structures are involved in them. People have always studied the loss of different abilities in order to map the functions of the brain. When it comes to higher cognitive abilities, such as language, this poses many problems, but the data acquired from studies of aphasia have roughly the same degree of reliability as the data obtained with other neurolinguistic methods. **Aphasiology** or **linguistic aphasiology** is the dominant branch of neurolinguistics. Aphasia is an acquired language disorder, often defined as a focal lesion (i.e., a lesion of one or more specific areas). Acquired disorders are also caused by **progressive neurological diseases**, such as **dementias**. Language and memory are closely connected and interdependent, especially in complex higher cognitive functions.

Not only acquired language disorders, but also **developmental language disorders**, that is, disorders that are found in children who have not experienced any specific lesion event, are of interest to neurolinguistics. Neurolinguistic approaches to developmental language disorders, such as **SLI** (specific language disorder), and **developmental reading and writing problems**, including **dyslexia**, typically compare these conditions to similar acquired disorders, bearing in mind the special conditions of language acquisition and the plasticity (ability to be molded) of young brains. Neurolinguists also study the language development of children with nonspecific developmental disorders affecting language.

The development of language and speech and prerequisites **for language and speech in the evolution of the species** also need to be considered by neurolinguists. The changes in the structures and function of the brain are compared to different species’ ways of living. Animal communication systems are studied under natural conditions, especially those of primates, and experiments are carried out with primates that are being taught human communication systems.

For a neurolinguist, an essential source of knowledge is the possibility of **measuring brain activity** during language tasks in normal and damaged brains. Static pictures of the brain, where lesion sites can be seen, such as the **CT scan** (computer tomography scan), which constructs a three-dimensional picture of a lesion from X-rays of many planes of the brain, or the **MRI** (magnetic resonance image) are standard information in hospitals today. The measurement of dynamic activity in the brain during language tasks by methods such as **EEG** (electroencephalography), **PET** (positron emission tomography), **fMRI** (functional magnetic resonance imaging), and **MEG** (magnetic encephalography) is an important tool for research.

Psycholinguistics, often in combination with information about brain activity in different areas of the brain, provides the basis for neurolinguistic **modeling** of processes for language comprehension, linguistic memory, language production, language acquisition, and language loss. Such models can be the basis of **computer simulations** using serial (i.e., basically “box-and-arrow”) models, models with parallel processes running at the same time, interconnections between processes, and feedback loops between levels of process models. Computer simulations involving so-called “artificial neural networks” (ANN) or connectionist networks are also used. The models are also the basis of **off-line** and **on-line** (i.e., with real-time measurement of processes) **experiments** on language functions.

Outline of the book

This introductory section will be followed by a historical overview, tracing the different theoretical standpoints of neurolinguistics to their roots and following the development of neurolinguistics. The models and frameworks that form the basis of today’s neurolinguistic research and practice will then be presented in more detail.

In the second part of the book, we will examine different aspects of neurolinguistics, (i.e., phonetics/phonology, morphology/syntax, lexicon/semantics, and pragmatics). The interaction between the different aspects will also be stressed.

The third part covers certain specific themes and phenomena from a neurolinguistic perspective. These phenomena are reading and writing processes, multilingualism, evolutionary and developmental perspectives on brain and language, and multimodality.

The book also contains a fourth part with three resource chapters. The first chapter of part 4 briefly presents some methods for investigating the brain (neuroimaging techniques) and the second chapter introduces computer simulation using artificial neural network (ANN) models. The chapter on ANN is included, since ANN modeling is increasingly popular in neurolinguistics. It is, however, a bit more technical than the other chapters. A final resource chapter provides a short introduction to neuroanatomy and neurophysiology; this chapter can be read at the outset of the course or consulted during the reading of the other chapters.

Summary

This introductory chapter delimits the scope of neurolinguistics by defining it as the study of the relation between brain and language. It mentions some of the definitions given and central questions raised by leading researchers in the area, such as the focus on language processing, involving predictive and explanatory psycholinguistic models, experimental studies, computer simulations, and the measurement of brain activity during language tasks. The central position of studies of language pathology after brain damage — aphasia and related disorders — and the related questions of language development in the species and the human individual are also emphasized. The main contributing disciplines — linguistics, medical neurosciences, psychology, and speech-language pathology — are identified. The chapter also briefly outlines the contents of the book.

Further reading

More extensive overviews of different areas in neurolinguistics can be found in David Caplan's introductory book from 1987 and in the *Handbook of Neurolinguistics*, which contains short chapters on a number of topics in neurolinguistics.

Caplan, D. (1987). *Neurolinguistics and linguistic aphasiology. An introduction*. Cambridge: Cambridge University Press.

Stemmer, B., & Whitaker, H. (Eds.) (1998). *Handbook of neurolinguistics*. New York: Academic Press.

Assignments

1. Try to think of three important questions about language and brain that you would like to find an answer to. Think about the different contributing disciplines and what type of relevant investigations, methods, and potential findings they might come up with to help answer the question.
2. Imagine a study you would like to carry out on one of these questions. Try to develop an outline of the actual design using methods that the different disciplines might contribute.
3. Try to describe what you think happens when you (silently) read (a) a word, (b) a text. Which different functions are needed and in what order?
4. Now, try to describe what happens when a child reads his or her first words. How does this differ from when you read a word?

Keep your answers to these questions handy and return to them when you have read the main parts of the book.

Chapter 2

The development of theories about brain and language

In this chapter:

- *Different views of the brain–language relationship*
- *Ideas about brain and language before the 19th century*
- *The foundations of neurolinguistic theories in the late 19th century*
- *Further developments in the 20th century*

Different views of the brain–language relationship

As we saw in Chapter 1, a number of different views of the relationship between the brain and language have existed and still exist. We will first very briefly describe some that have had a relatively great influence. We will return to them later in the chapter and see how they first arose, how they developed, and what their influence is today.

Figure 2.1 below presents an approximation of different views of the language–brain relationship along the continuum from localism to holism.

Localism

Localism claims that different “higher functions” are localized in different centers of the brain, mainly the cortex. Either these centers can be seen as “sisters,” being equally important, or one center, such as the prefrontal area (in front of the frontal lobes), may be seen as superordinate to the others. In this view, aphasia is seen as the result of a lesion in a language center. Well-known localists include Gall and Broca.

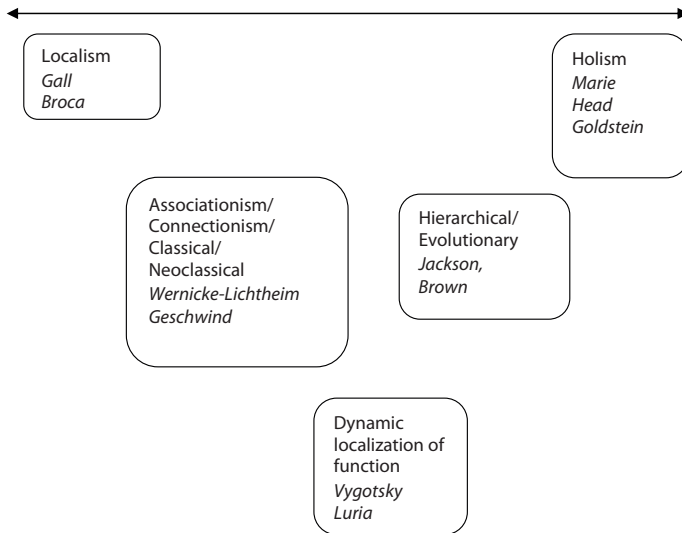


Figure 2.1. The localist–holist continuum, with a simplified placement of different views

Associationism (or connectionism)

Associationism assumes that higher functions are dependent on the connections between different centers in the cortex. Linguistic ability is seen as the relationship between images and words. Aphasia results from broken connections between the centers that are needed for linguistic function. Representatives of this view are Wernicke, Lichtheim, and Geschwind. This view is also sometimes called the classical (Wernicke-Lichtheim) or neoclassical (Geschwind) view.

Dynamic localization of function

With this type of theory, different subfunctions are seen as localized in different parts of the brain. These subfunctions must be combined in order to achieve more complex functions, which can be “put together” in a number of different ways. The relationship between a localized lesion and the functions that are disturbed becomes more complex in this case. This is the view of Luria, for example.

Hierarchical or evolution-based view

Evolution-based theories emphasize the layered structure of the brain from inner/lower and more primitive structures to the later developed and superimposed cortical layer and the role of all of these layers in language and communication. Jackson is an early representative of this view, Brown a contemporary one.

Holism

Holism is the opinion that the brain works as a whole, at least to accomplish higher functions. The cortex is said to handle, for example, “higher cognitive functions,” “symbolic thinking,” “intelligence,” or “abstraction,” and aphasia is a sign of a general cognitive loss, not a specific language loss. This view has also been called “cognitivism” and some representatives are Marie, Head, and Goldstein. Hierarchical views are also sometimes deemed to be holistic and Jackson is regarded as the founder of the “cognitive school.”

Other terms: Unitarism and equipotentiality

Other terms that are used for *one unitary* function of the brain are “unitarism,” the view that the soul is one and cannot be divided, and “equipotentiality,” which means that all parts of the cortex have the same functional potential and that the size of a brain lesion determines the extent of the aphasia (the mass effect).

Ideas about Brain and Language before the 19th Century

Ancient Egypt, Greece, and Rome

The first reference to the brain as the center of language is found in the *Edwin Smith papyrus* from about 3500 BC. Here we find observations that damage to the head can result in symptoms in other parts of the body and that this must depend on the function of the brain. Language loss is said to be caused by an external god or death sending its spirit or breath into the brain, so that the patient becomes “silent in sadness.” This condition was cured by trepanation, or drilling a hole in the skull to let the god’s spirit out. The earlier view that the soul resided in the heart continued to exist.

In writings from Greek antiquity, language disorders are discussed, for example, by Hippocrates (400 BC), who described a man who lost his memory for letters; he also observed that language disorders coincided with hemiparesis (paralysis of one side of the body) in the side of the body opposite to that of the brain lesion. According to Hippocrates, the brain was the organ of the intellect (*mnemonikon*) and the heart was the organ of the senses. Around the same time, Democritus compared the brain to a guard or sentinel with two functions: the internal function of guarding the intelligence and the external function of guarding the senses. Herophilus localized intelligence in the ventricles (cavities) of the brain at about 300 BC. This view remained dominant for a long time and was still found as late as the end of the 18th century.

Plato (4th century BC) wanted to localize the different abilities of the soul in different parts of the brain, which he saw as the center of all senses. It was with Plato that