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## Introduction

Linguistics is a domain in which language is studied. The notion of language is a common sense notion. In general, a common sense name is not sufficient to characterize a field of research, as there may be many different fields studying more or less the object referred to by the same common-sense name. For example, one can study the oceans from the point of view of a marine biologist, a climate oceanographer, a plate tectonics physicist, a zoologist, a botanist, or a chemist. To get a more precise idea of the field of linguistics, it is necessary to define the type of questions that one is asking about the object of study. Most of what modern linguistics studies falls under the heading of the study of the “language faculty” that human beings possess as part of their human biology. The capacity for language shared by all normal members of our species includes, among other things, the ability to physically manifest thoughts, to linguistically express diverse and original ideas, in diverse and original ways. This faculty also underlies the ability to understand others, to have coherent conversations, and to deduce other people’s intentions from their utterances. These properties of language point to a field where the object of study is some mental property of individuals. So linguistics is a part of individual psychology, viewed in contemporary research as part of the study of the human brain.

Investigating this complex and often mysterious faculty appears a daunting task. One way to start is to try to formulate sensible questions about the output of our linguistic capacity – the sounds, the words, the sentences – so as to provide a framework within which incremental knowledge about this faculty can be gained.

### 1.1 Where to Start

We can start by looking at a simple case of basic linguistic behavior in an individual. When I hear language, my ears are sensing small, rapid variations in air pressure. This vibration, sound, is transformed into nerve impulses that travel to my brain, where the signal is somehow decoded and transformed into an idea, a thought. This is speech perception, or recognition. A similar process occurs in users of sign language: a visual signal is somehow decomposed and converted into an idea. Inversely, when I speak, an idea in my mind is physically manifested through speech or visual signs: this is speech production. These simple observations raise many questions. What exactly goes on when we produce or recognize speech? How does perception or production unfold in real time and how is this coded in brain tissue?

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To understand language processing in the brain, we aim to understand how it rapidly changes state in ways that we can interpret as analytical steps in decoding the linguistic signal. How does the brain do this, exactly? In engineering jargon, we are faced with a problem of “reverse engineering,” a common problem for industrial spies. We have a machine – a body, particularly a brain – capable of accomplishing a certain task and we try to understand how it works and how it could be built. We have similar questions in vision, acoustic processing, and other domains of cognitive science. Note that our question is not simply how a particular ability could be produced or imitated in principle. Rather, we aim to identify how it is really produced in the human language user.

This “reverse engineering” problem is very difficult to approach directly. First, to find the physical mechanisms responsible for some ability, we need to have a good understanding of the basic properties of that ability. For example, studies show that certain areas of the brain (Broca’s and Wernicke’s areas, etc.) are active when we perform certain kinds of linguistic tasks, but to decipher what exactly they are doing, what computations are being performed, we need to know a lot about what these tasks involve. To obtain this kind of understanding, we must initially approach the problems of production and perception abstractly.

We start with the hypothesis that, stored in our mind somehow, we possess some information about certain basic things, some atoms of information that we can deploy in given contexts. As a starting point, we could assume that these atoms are “words” or something similar, such as *table* and *book*, and *eat* and *curious*, and *the* and *before*, and further that these elements have phonetic properties, or instructions on how to physically realize the atoms through speech, as well as meanings, a pairing of the elements to bits of thoughts.

So when it comes to expressing a thought to someone else, a simple story is that I search in my mind for the words corresponding to what I want to talk about and string them together in a particular way to express the thought. Of course, this string of words has to be physically manifested, as in speech or signing, which means that a signal has to be sent to the motor centers that coordinate physical gestures of the mouth or the hand, as the case may be.

Similarly, successful perception of a sentence might be achieved by an electrical signal sent to my brain by the hearing system, which is then segmented by my brain into words, each corresponding to a bit of thought. As my brain receives the particular sequential arrangement of these words, it can also calculate what the combination of the words in the sentence means as a whole.

We can schematize these processes with the following flow chart:

sounds ↔ ordered sets of words ↔ meanings

If we go from left to right, we have a crude model of spoken language perception, from right to left a crude model of spoken language production. If we replaced “sounds” with “signs,” we would have crude models of sign language perception and production.

Understanding how this could work, even at an abstract level, is not easy. For example, it is imaginable that the rules governing how sounds are composed into ordered sets of words in a particular situation depend on what the hearer is looking at when perceiving the sounds. This would mean that we have to worry the visual system and how it relates to the linguistic system. This is why we decide to concern ourselves with an even more abstract problem, and will not investigate how the flow chart above really works, how it unfolds in real time. Instead, we will ask: What **necessary linguistic** properties does the language processing task have? By **linguistic**, we mean that we are going to abstract away from the influence of visual clues or background knowledge about the world, and (initially at least) focus on grammatical properties (akin to those found in traditional grammar books). By **necessary**, we mean that we will concentrate on properties that hold across all normal uses of the language, properties that linguistic computations must respect in order to yield the linguistic phenomena we observe.

Here is a sample of more precise questions about necessary linguistic properties:

- Do all orders of words yield meaningful expressions (in the way that all orders of decimal digits represent numbers)? If not, why not?
- Do meaningful word sequences have any structure beyond their linear, temporal ordering? If so, what kind of structure, and why would this structure exist?
- How are the meanings of a sentence determined by (or restricted by) the meanings of its component parts?

The discovery that speech can be symbolically transcribed, can be written down, is certainly among the most momentous human discoveries ever. It allowed the transmission of information across distances and across generations in ways that were never before possible.

In the famous 1632 *Dialogue Concerning the Two Chief World Systems* written by Galileo Galilei one of the characters, Sir Giovanni Francesco Sagredo, “a man of noble extraction and trenchant wit,” so marvels about this invention: “But surpassing all stupendous inventions, what sublimity of mind was his who dreamed of finding means to communicate his deepest thoughts to any other person, though distant by mighty intervals of place and time! Of talking with those who are in India; of speaking to those who are not yet born and will not be born for a thousand or ten thousand years; and with what facility, by the different arrangements of twenty characters upon a page!”

What is less obvious is that this invention is also a theoretical discovery about human psychology: the structure of language, the nature of this system, allows thoughts to be transmitted in this way. One fundamental aspect of this discovery can be stated as follows: the speech signal – even though it is a continuous physical phenomenon – namely a continuous variation of air pressure for normal speech, or continuous motion for sign language – can be represented with a finite (sometimes small) number of discrete units. A particularly striking example of this property is illustrated by alphabetic writing systems, as the quote in the box opposite emphasizes: with a small number of symbols – letters – they can very effectively

(partially) code speech. Informally speaking, it is clear that this segmentation of the speech signal occurs at various levels of “graininess.” Alphabetic writing systems segment the speech signal in very small units of writing, while Chinese characters or Egyptian hieroglyphic writing systems segment it in somewhat larger units. That this segmentation can occur at various degrees of “magnification” can be illustrated with the following string:

these books burned

Evidence confirms that English speakers segment and analyze this expression at some levels roughly like these, where the number in the leftmost column indicates the number of units in its line (and the first line is written in phonetic alphabet and is meant to represent the sequence of sounds found in this string):

12	ð	i:	z	b	ʊ	k	s	b	ə	r	n	d
6	Demonstrative		Plural	Noun		Plural		Verb		Past		
3	Demonstrative+Plural			Noun+Plural			Verb+Past					
2	Subject						Predicate					
1	Sentence											

Linguists have extensively documented the relevance of such segmentations for our understanding of language structure. Hypothesizing that these modes of segmentation, these different “levels of

magnification,” correspond to real psychological properties of the speech signal, we will need to at least answer the following questions about each level as part of understanding how our flow chart above really works:

- What is the inventory of the smallest pieces, the atomic elements, that are assembled at each level?
- What are the rules or principles that govern how these units can be assembled?

Traditionally, linguists have postulated the following divisions: Phonology studies the atoms and combinations of sounds; Morphology considers the atoms and how words are built; and Syntax considers how words are put together to form phrases. Of course, this preliminary division into such subdomains may not be correct. It could be that the atoms of syntax are not words but morphemes, and that the rules of combination for morphemes are the same as the rules of combination for words. If this were the case, there would really be no distinction between morphology and syntax. Or morphology might be part of phonology. (These kinds of proposals have been seriously explored.) But we will start with this traditional picture of the components, modifying it as necessary. In fact, where syntax books start with words, this book will start with morphology, i.e. the structure of words.

These two questions – what are the atoms of language, and how are they combined – characterize very well what this book is about. We view language as a system of symbols (e.g. sounds, which are paired up with meanings), and a combinatory system, where symbols combine to yield more complex objects, themselves associated with meanings. Here we concentrate on how aspects of this particular symbolic combinatory system are put together: this is a technical manual that almost exclusively worries about how to investigate and characterize the combinatory structure of morphological and syntactic units.

Even though the scope of this book is relatively narrow, the research perspective on language it embodies is part of a much broader research program that tries to characterize cognitive functions. The questions we address here are limited to the structure of the syntactic and morphological combinatory systems but, as will become clear, a substantial amount is known about these systems that suggests that non-trivial principles regulate how it works. This in turn raises all sorts of questions which we will not address but that are central research questions: how is this system put to use when we speak or understand? How much computational power is needed to master such a system? Is language fundamentally shaped by our communicative intentions? Where do the fundamental principles of language structure come from? Are they innate? Are they learned? Are they completely specific to language, or only partially so, or not at all? Are they specific to humans? Or only partially so? How did they appear in our species? Suddenly? Progressively? By themselves?



The approach to the study of language described above took off in the mid 20th century and is now a dynamic field incorporating an increasing panoply of methods or tools, from the methods used by traditional grammarians and language fieldworkers, to laboratory methods originating in experimental psychology, to neuro-imagery, to mathematical methods imported from pure and applied mathematics, to statistical tools and the tools of modern genetics. Noam Chomsky, pictured here on the left, presently (2013) Institute Professor at the Massachusetts Institute of Technology is the most influential pioneer of this research perspective and agenda and the research methods that carry it out.

In conjunction with other mental or physical properties? All these questions are (on their way to) being investigated in the rapidly developing field of cognitive science.

It is important to emphasize that apart from framing questions about language in a useful way, the new, systematic methods of investigation have met with great success. It is fair to say that in the past 50 years, our knowledge of linguistic structures has increased at a pace unparalleled in the history of linguistics. Because this approach to language is relatively young, progress is rapid and our progressively increasing understanding means that new, better hypotheses emerge all the time, sometimes revealing inadequacies of previous assumptions.

## 1.2 What this Book is and is Not, and How to Use It

First, a book like this one, which tries to provide a snapshot of our current state of understanding, is to a certain extent bound to be or to become incorrect as research progresses. It is thus important to remember that although the results described herein are sound and reasonable, most important are the methods used to reach them.

As was stated, this book is a technical manual focusing on syntactic and morphological structures. It is not meant to be exhaustive. Nor is it meant to be a systematic introduction to the relevant literature. Because the field progresses rapidly, notions once thought to be useful or important no longer play a prominent role. In general we do not discuss them. Other notions are not included because they are too advanced for such an introductory book. Rather we aim to provide a reasoned introduction to the central tools and concepts that seem necessary and well justified by the research of the past 50 years.

Although this book uses quite a bit of formal notation, it does not, by design, present a formalized theory of syntax, except in the last chapter. In that chapter, a complete formalization is introduced. This formalization of a part of our linguistic system has allowed researchers to precisely investigate important issues, like the expressive power of our model of the combinatory system. It has also allowed us to prove results showing that this model is in principle well behaved with respect to a number of important measures, like parsability and learnability.

The main text of this book is definitely anglocentric, focusing on English. This is in part due to the fact this book grew out of class notes written for English-speaking students in syntax classes at the University of California at Los Angeles. But the focus on English is motivated by the field: supporting the conclusions reached requires sophisticated argumentation and thus requires looking in depth at an individual language. English is the best and most deeply studied language by a wide margin, so it is not unreasonable to think that there is a greater chance that deep, perhaps universal, properties of language have been discovered, and that some of the results have wide, perhaps universal, validity. This anglocentricity is also somewhat illusory, as a very substantial amount of how English is analyzed today is, and will continue to be, informed by in-depth work done on other languages, most notably by work in the 1960's on the Romance languages, the other Germanic languages, and Japanese, and by more recent work on an ever expanding variety of languages spanning all language families and broad regions of the planet. Theoretical research is crucially informed by cross-linguistic research, and it is our firm belief – buttressed by the life-long personal experience of working on a wide variety of human languages – as well as the very large number of studies that bear on a wide variety of languages, that the methods and tools introduced here are reliable, productive, and necessary for the study of any natural human language.

From a practical standpoint, we intend this book to be readable on its own, by anyone, even those without any prior knowledge of linguistics. Since this is a technical manual, it should be read slowly, making sure to the greatest extent possible that nothing is left unclear. To this end, it is essential to do exercises. This cannot be overemphasized. The exercises are meant to let the reader check that the content relevant for them has been mastered. Additionally, the exercises may sometimes

introduce results not discussed in the body of the chapters, or discuss alternatives to hypotheses previously adopted.

Wherever possible and accessible, we try to show how the conclusions reached connect with other modes of investigation of cognitive capacities, such as the (neuro-)psychology of learning and processing and computational approaches.

Scattered in the chapters are three types of box. They have different functions, indicated by their titles. Boxes marked “Practice” indicate points at which particular practice should be done. Shaded boxes should be read and paid particular attention to: they highlight important information. Material in double-ruled boxes is not critical to the reading of the chapter. These boxes introduce, discuss, or anticipate more advanced material. Read with this material, the book is a pretty advanced introduction to current theorizing and results.

While the emphasis in this book is on methods of investigation, the current results are important too. In general we summarize both at the end of each chapter in a section entitled “What to remember.”

### 1.3 Further Reading

Reading original literature in syntactic theory can be difficult. The original literature by now spans more than 60 years. As mentioned in the Introduction, this field is very young, progress has been and continues to be rapid. In this time span, many discoveries have been made, sometimes making earlier work obsolete, new notations are constantly introduced to encode new understanding, making earlier notations opaque. At the moving frontiers of knowledge, several hypotheses, incompatible with each other, were and are simultaneously entertained. All this contributes to making reading the original literature difficult. It is important to replace the literature in its time: what exactly was the particular theoretical understanding then? What was known and what was not? What did the overall model look like? What were the particular questions linguists were worrying about, and what technical vocabulary or notation was used to talk about the phenomena discussed? As part of language, the meaning of words sometimes shifts, and technical vocabulary or notation evolves.

We recommend to the reader to first carefully work through the (relevant parts of this) textbook, and read only general background or foundational literature. Only once a good understanding has been gained of the properties that any linguistic theory will have to account for, should a start be made with the original literature.

**General resources** There are many textbooks and handbooks that can be used to complement the current textbook. We list a selection of general syntax textbooks, some of which are helpful to prepare reading the literature of what was broadly understood at the time they were published: Van Riemsdijk and Williams (1986), McCawley (1998), Haegeman (1994), Ouhalla (1994), Culicover (1997), Roberts (1997), Carnie (2002), Adger (2003), Radford (2004), Hornstein, Nunes, and Grohmann (2005).

In this general context, the site <http://tgraf.bol.ucla.edu/timeline.html> is a useful resource: Thomas Graf attempts to provide an annotated timeline of how new analytical or theoretical ideas were introduced in generative linguistics. In addition, the reader may also want to check out the Blackwell Series “Classic Readings in Syntax,” currently in development, as well as the very useful Blackwell Companion to Syntax: (Everaert and Riemsdijk, 2006).

For a current assessment of the general results of the generative enterprise, written for a broad general public, the collection of articles about core ideas and results in syntax in the *Lingua* volume edited by Luigi Rizzi (2013) is particularly noteworthy.

For descriptive grammars, or grammars informed by work in the type of syntactic framework broadly construed we have described, we mention the following selection of works, often the

result of collaborations of many linguists, comprising multiple volumes or thousands of pages, and by no means exhaustive: (Hualde and De Urbina, 2003) for Basque, (Haeseryn and Haeseryn, 1997) for Dutch. (Huddleston and Pullum, 2002) on English, (Renzi, 1988–1995) for Italian, and (Demonte Barreto and Bosque, 1999) for Spanish.

There are other, valuable introductory books at various levels and with different objectives. The following are general, fairly systematic introductions to the research program we pursue: Anderson and Lightfoot (2002), Baker (2001), Chomsky (1975), Jackendoff (1995), Lightfoot (1982), Pinker (1994). It is also a good idea to look around the Internet, in particular for Noam Chomsky’s writings.

Finally, we highly recommend the site <http://ling.auf.net/lingbuzz> maintained by Michal Starke. It is a searchable, openly accessible repository of scholarly papers, discussions, and other documents for linguistics. Current research in its various subfields – most relevantly syntax and semantics – is continually being uploaded by researchers.

