The Boundaries of Babel

The Brain and the Enigma of Impossible Languages

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Prologue

In 1811, Monsieur Leborgne arrived at the Bicêtre Hospital in Paris. He was a twenty-one-year-old man who exhibited an unusual linguistic problem: Whenever he was asked a question, he would always answer by saying one syllable twice, *tan tan*, in conjunction with quite varied intonation and expressive gestures. For this reason the patient was nicknamed Tan-Tan, or sometimes simply Tan. He spent the remainder of his life hospitalized. Through the years his condition deteriorated, until, eventually, the limbs on his right side were paralyzed. On April 12, 1861, he was transferred to the surgery ward to be treated for gangrene. It was then that Pierre Paul Broca, a doctor who worked at the hospital, met him.

A little more than one week earlier, on April 4, Broca had participated in a meeting of the Anthropological Society, which he himself had founded two years earlier. During this meeting, another doctor, Ernest Auburtin, presented some interesting studies about the possibility of pinpointing the location of language in the human brain. Auburtin was attempting to support the hypothesis that the brain did not work as a homogenous mass, at least when it came to higher functions such as language. At that time, this hypothesis was supported by a minority of the Society's members that included Auburtin's father-in-law, Jean-Baptiste Bouillaud, who had been a student of the founder of phrenology, Franz Joseph Gall. Phrenology was the study of the psychological characteristics of an individual based on the external shape of the cranium. Phrenology never yielded acceptable scientific results, but it had left a strong impression on Bouillaud, who became convinced that the ability to speak was located in a specific area of the brain, the frontal lobes. Although Aubertin did not bring any conclusive evidence in favor of the hypothesis that specific areas of the brain are dedicated to specific functions, his efforts helped to keep this hypothesis alive.

It did not take long for Broca to realize that the case he had stumbled upon constituted strong evidence to decide the scientific controversy. Although exactly how much Tan-Tan understood could not be determined with absolute certainty, he clearly was able to understand almost everything. He could count and understand time. And, despite the fact that the right side of his body was paralyzed, neither his tongue nor his facial muscles had been affected by the paralysis. In other words, Tan-Tan did not lack the cognitive or motor skills necessary for talking. Nevertheless, the only utterance that came out his mouth was just "tan tan." His problem must have been, therefore, a language-specific impairment. Also, the anamnesis for the first few years of Tan-Tan's disease showed, crucially, that lack of language was his *only* evident deficit at that time; the paralysis of his limbs occurred later.

Tan-Tan died on April 17, 1861, and Broca did an autopsy of his brain. After careful examination, he reached the conclusion that a lesion in Tan-Tan's left frontal lobe must have been the cause of his loss of language. Broca had discovered the first anatomic evidence for localization of a specific brain function. Shortly thereafter, Broca gave a talk at the Anthropological Society that would change our conception of how the brain works: "Loss of Speech, Chronic Softening, Partial Destruction of the Left Frontal Lobe of the Brain" (Broca 1861). Not all of Broca's colleagues accepted his conclusions, and some, such as the famous neurologist Pierre Flourens, continued to argue that the brain's high functions could not be localized in any specific area of the brain. But by that time the road to studying the biological basis of language had already been taken.

A little less than a century later, in 1957, at the Massachusetts Institute of Technology in Cambridge, Massachusetts, a young professor by the name of Noam Chomsky had just published a short monograph based on his ponderous doctoral thesis (Chomsky 1957), which as yet had no publisher; in the end it took nearly twenty years for his entire thesis to be published (see Chomsky 1975b). Chomsky found himself in a particularly favorable cultural environment: his father, a famous Hebrew scholar, had introduced him to linguistics before turning him over to another famous linguist, a Russian, Dr. Zelig Harris, at the University of Pennsylvania, which Chomsky entered at the age of sixteen. In those years (partly spent at Harvard as a Harvard junior fellow), in addition to pursuing his linguistics studies, Chomsky was exposed to logic, mathematics, and theories of computation, which brought him in touch with the thinking

of Alan Turing, a British mathematician who, among other things, was responsible for a rigorous definition of what an algorithm is.

Furthermore, in the fifties interesting communication theories were being developed at nearby MIT, where Chomsky started teaching in 1955. In particular, Claude E. Shannon's information theory was circulating, according to which the grammars of human languages could be interpreted using statistics. At that time Chomsky was also working at MIT in the Research Laboratory of Electronics (RLE), where an effort was under way to try to build machines for automated translation. The results of the research at RLE were making people hope for a quick method for automated translation (especially from Russian—it was the Cold War), automated archiving of printed material on the basis of content, and automated writing of abstracts for archived papers. These ambitious goals, which at that time were assumed to be reachable, also triggered crucial research projects focused on understanding how human thinking works: "There was an ubiquitous and overwhelming feeling around the Laboratory that with the new insights of cybernetics and the newly developed techniques of information theory the final breakthrough towards a full understanding of the complexities of communication 'in the animal and the machine' had been achieved" (Bar Hillel 1970, 294).

Chomsky immediately realized that this conception of language was not acceptable and that human minds could not be assessed as machines. Language cannot be represented as just a sequence of symbols regulated by statistical rules. Linguistics is a science like all other empirical sciences: experiments are necessary to obtain results. Theory cannot be derived from data alone. Like a falling rock, which does not have the law of gravity written on it, a speaking person, when he utters a sentence, does not also utter the rule of grammar that governs it. With a series of indestructible arguments—drawing on the rigorous methods he learned from his studies of abstract formal systems (involving, for example, recursive nested dependencies)—Chomsky showed not only that the structure of grammar is more complex than the statistically based model, but that complexity itself immediately raised a fundamental problem concerning language acquisition in children: "The fact that all normal children acquire essentially comparable grammar of great complexity with remarkable rapidity suggests that human beings are somehow specially designed to do this, with data-handling or 'hypothesis-formulating' ability of unknown character and complexity" (Chomsky 1959, 57).

The jump had occurred: linguistics could no longer ignore the problem of language acquisition; linguistics in fact had to consider the specific

biologically determined ''design'' that allows human beings to develop this capacity. The path had opened for the study of the formal properties that characterize all and only human grammars, the so-called ''Universal Grammar.''

In January of 1962, a child was born in England and his parents named him Christopher. Six weeks after his birth, he was diagnosed with brain damage that would have major consequences for the rest of his life. He learned to speak and walk late, but from the age of three on he had a burning passion for books. Unlike most children, he did not favor illustrated books or fairy tales. He liked reading dictionaries, phone books, and books illustrating the flags and currencies of the world. His parents were left astonished when they realized, that, around the age of three, Christopher was already able to read the advertisements printed in local newspapers. Even more strange, he could read them, irrespective of their position: upside down, right side up, or sideways. A next remarkable step in Christopher's development occurred when he first encountered technical papers written in foreign languages. From that moment on, learning foreign languages became his absolute passion. Any occasion was good for learning a new language, which among other things, made him locally famous. Christopher's talent was exceptional—for instance, it was enough for him to hear his brother-in-law speak Polish for him to learn it. What had happened to Christopher that could explain his behavior? Clinically, his pathology was never diagnosed with certainty, although a careful analysis of the patient showed some typical characteristics of autism, such as insensitivity to irony. The results of the most common intelligence tests showed that Christopher was well below average.

   Neil Smith and Ianthi-Maria Tsimpli teach linguistics at University College, London, and the University of Newcastle-on-Tyne, respectively. The meeting between the two linguists and Christopher would produce unique results with implications for the study of the relationship between mind and language. First of all, Christopher's mental development was unique. It was already known, of course, that there are some people who develop exceptional mnemonic skills—such as memorizing entire calendars or big phone books, and others who are able to perfectly perform virtuoso pieces on a musical instrument or render extremely complex drawings. People with these exceptional skills are often unable to live a normal life or simply take care of themselves. They are often autistic, and even more often, demonstrate impaired linguistic skills. This is why

Christopher's "talent" was already exceptional by itself: it was exactly his linguistic capacity that had developed in an extraordinary way. Other cases of people with great linguistic skills accompanied by cognitive deficits were known by that time, such as the cases described by Giuseppe Cossu and John Marshall (1986); these people, however, spoke only one language. Christopher was the first recorded case in which a dissociation between language and other cognitive skills coincided with the knowledge of many languages and the ability to learn new ones.

The meeting between two linguists and Christopher yielded a crucial experiment. By that time, in addition to his first language, English, Christopher knew, with varying degrees of competence, Danish, Dutch, Finnish, French, German, Modern Greek, Hindi, Italian, Norwegian, Polish, Portuguese, Russian, Spanish, Swedish, Turkish, and Welsh. It would not have added much to what we already knew about Christopher to try to test him while he was learning another new language. For this reason, Smith and Tsimpli came up with a radically different experiment. The idea that inspired them is found in Chomsky (1991, 40), quoted in Smith-Tsimpli (1995, 137): "Knowing something about [universal grammar], we can easily design 'languages' that will be unattainable by the language faculty," where Universal Grammar means, as already mentioned, the set of properties that characterize all and only human languages. With this, Smith and Tsimpli knew how to proceed: they invented a vocabulary and a grammar, called this language Epun, and included "impossible" rules—that is, rules that violate the properties of Universal Grammar. The result left no doubt: no matter how hard he tried, Christopher could not learn the impossible rules—unlike control subjects who were able to use their general intelligence to learn them. The mechanisms of general intelligence that the control subjects used, in fact, had nothing to do with spontaneous language learning. On the other hand, Christopher, who could only count on his language faculty, was not able to correct himself, thus providing unequivocal psychological evidence for the distinction between possible rules and impossible rules based on mere linguistic generalizations.

In the century between Tan-Tan and Christopher, our knowledge of the structures of language advanced enormously, perhaps more than ever before in the history of linguistics. Moreover, thanks to techniques that combine radiology and computer science, we are now able to explore the functional architecture of the brains of healthy human subjects in vivo.

We no longer need to wait for disease or damage to provide us with research material, nor do we need to limit ourselves to doing autopsies to explore how the brain works.

The journey that this book will take you on starts here. We will return to Broca, once we are armed with contemporary knowledge of linguistics. Then we will see how *the distinction between possible and impossible rules has not only psychological relevance, but also specific neuropsychological relevance.* We will do so by looking at the fundamental aspects of two neuroimaging experiments that I designed with the essential collaboration of different teams of researchers. The first experiment provided evidence of the autonomous nature of syntax with respect to the brain's activities by isolating a dedicated neuronal net. The second experiment showed us how such a net is able to recognize only the possible rules while it ignores the impossible rules. Both experiments made use of invented languages: in these two experiments, the discovery of what is real was guided by the unreal.

The winner of the Nobel Prize for Medicine or Physiology in 1969, Salvador E. Luria, used to say that in the end, every discipline is characterized by the ten or so fundamental experiments that are at its foundation. I cannot say for sure that the experiments described here will be counted among the top ten experiments in the discipline that has been called biolinguistics, but I hope that they will at least contribute to a better understanding of what such an experiment will need to be.

Preface

This is not a neuroscience or linguistics textbook. Many good textbooks on those subjects are available.[1] This book is the history of an encounter of two cultures: linguistics and the neurosciences (or, more precisely, the cognitive neurosciences).[2] It is also the attempt to expose a "hidden" revolution in contemporary science: *the discovery that the number of possible grammars is not infinite and that their number is biologically limited.* I say "hidden" because, despite the fact that concepts as difficult and revolutionary as natural selection and black holes have made their way into the public discourse, little has been said about this radical change in the way we look at language, a change that is no less surprising than the discovery of black holes. It requires a rethinking not just of the fundamentals of linguistics and the neurosciences but also of our view of the human mind.

Together we will move forward in search of the boundaries of Babel,[3] the neurobiological constraints on the apparent chaotic variation of

1. For a general introduction to linguistics, see Akmajian et al. (1995); Haegeman (1997); Roberts (1997); Chierchia and McConnell-Ginet (2000); Fromkin (2001); Carnie (2006); Fromkin, Rodman, and Hyams (2007). For an overview of neuropsychology see Denes and Pizzamiglio (1999) and Kandel, Schwartz, and Jessel (2000); for a general introduction to linguistic issues and interactions with other sciences see Chomsky (1988, 2004); Jackendoff (1993); and Pinker (1994). For a critical and detailed survey of the notion of possible language across different theoretical perspectives see Newmeyer (2005).

2. I use the label "cognitive neurosciences" and not "cognitive neuroscience," because I'm referring more to the heterogeneous group of methodologies than to a specific field. This is in accordance with Marconi's (2001) distinctions between "cognitive science" and "cognitive sciences."

3. Babel is the original name of the city of Babylon cited in the Bible and in the Koran. It has different etymologies: it can either be derived from Akkadian Bab-Ilu (the gate of God) as a translation from Sumerian Ka-dingir; the connection

human languages. I will try to give the essential elements so that readers who are not experts in linguistics or the neurosciences can grasp this revolution. In order to do this, I will give a short summary of some of the fundamental results from linguistics research in the last fifty years. I will also describe two recent neuroimaging experiments that I was fortunate enough to take part in. Finally, I will present a line of language research where the impact of our biological structure is crucial.

The book is organized into three chapters. In each part I present only the essentials—a collection of samples—for linguistics and the neurosciences. In chapter 1, "Hidden Texture," I start with a methodological discussion, and then I introduce some fundamental aspects of human languages. In the second part, "Language in the Brain," these fundamental aspects of language will be used to understand two brain experiments. The presentation of the experiments is preceded by a brief sketch of the two fundamental neuroimaging techniques they make use of: positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). This section is crucial for understanding the limits and potentials of these new neuroimaging techniques. We will see how, if a sound theoretical framework is lacking, techniques and machines cannot provide interesting data.

Chapter 3, "The Form of Grammar," is speculative: I discuss some general consequences of a peculiarity of human languages at the intersection of biology and linguistics that is emerging as one of the dominant themes of contemporary research: the connection between the linear nature of the linguistic code and grammatical rules. The book's structure allows readers with expertise in linguistics to skip the first chapter and go directly to the second chapter. Readers who are mostly interested in linguistics issues can jump from the first chapter to the third chapter without going into the issues of neurobiology covered in the second chapter.

It is, of course, up to the reader to decide whether this journey between grammar and brain in search of "boundaries of Babel" is convincing. My minimum goal is to convey the same amazement and curiosity that I felt when I first considered the following simple question: Why aren't all the grammars that we can conceive realized?

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with the history of the fall of the tower in chapter 11 of the Genesis and the spread of different languages after the original substantial unity has yielded to a false etymology tracing it back to the Hebrew verb *balal* (confound). By coincidence, it is often pronounced in English as the word *babble*, also referring to linguistic action, like irrelevant chatter or murmuring.