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The FOXP2 gene, human cognition and language

Philip Lieberman *

Department of Cognitive and Linguistic Sciences, Box 1978, Brown University, Providence, RI 02912, USA

Abstract. The creative "reiterative" powers of human language and thought appear to have evolved from brain mechanisms initially adapted for motor control. Humans can form a potentially infinite number of spoken words from a finite number of speech gestures by freely reiterating, i.e., reordering and recombining them. By the same means, we can form a potentially infinite number of sentences from finite number of syntactic "rules". Traditional theories that localize language to Broca's and Wernicke's areas of the cortex are incorrect; contrary to the traditional theory, permanent loss of language occurs only with subcortical damage. Neurodegenerative diseases such as Parkinson's, oxygen deprivation and other conditions that yield basal ganglia dysfunction cause speech, language and cognitive deficits similar in nature to Broca's syndrome. Neural circuits linking different regions of the cortex and the subcortical basal ganglia regulate speech production and syntax. The basal ganglia constitute a reiterative "sequencing engine" that works in concert with different regions of the cortex as we walk, speak and form or comprehend a sentence. They also provide the basis for cognitive flexibility, allowing humans to change the direction of a thought process or change plans as circumstances dictate. The FOXP2 regulatory gene, which governs the embryonic development of these subcortical structures, provides an insight on human evolution. Genetic studies indicate that FOXP2 reached its present form about 100,000 years ago when modern human beings first appear in the fossil record.

Resumen. Las energías "reiterativas" creativas del lenguaje y el pensamiento humanos parecen haberse desarrollado de los mecanismos cerebrales inicialmente adaptados para el control motor. Los seres humanos pueden formar un número potencialmente infinito de palabras habladas a partir de un número finito de gestos del discurso mediante la libre reiteración, es decir, reordenándolos y recombinándolos. Por los mismos medios podemos formar un número potencialmente infinito de oraciones de un número finito de "reglas sintácticas". Las teorías tradicionales que localizan el lenguaje en las áreas de Broca y de Wernicke de la corteza son incorrectas; en contra de la teoría tradicional, la pérdida permanente del lenguaje ocurre solamente por daño subcortical. Enfermedades neurodegenerativas, como el Parkinson, la privación del oxígeno, y otras condiciones que provocan

* Tel.: +1 401 863 1857; fax: +1 401 863 2255.
E-mail address: Philip_Lieberman@brown.edu.

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disfunción de los ganglios basales causan déficits en discurso, lengua y déficit cognoscitivo similares en su naturaleza al síndrome de Broca. Los circuitos nerviosos que ligan diversas regiones de la corteza con los ganglios basales subcorticales regulan la producción del discurso y la sintaxis. Los ganglios basales constituyen una "máquina de secuenciar" reiterativa que trabaja en concierto con diversas regiones de la corteza mientras caminamos, hablamos, y formamos o comprendemos una oración. También proporcionan la base para la flexibilidad cognoscitiva, permitiendo que los seres humanos cambien la dirección de un proceso del pensamiento o que cambien de planes si las circunstancias lo dictan. El gen regulador FOXP2, que gobierna el desarrollo embrionario de estas estructuras subcorticales, proporciona un avance en la evolución humana. Los estudios genéticos indican que FOXP2 alcanzó su forma actual hace aproximadamente 100,000 años, cuando los seres humanos modernos aparecieron por primera vez en el registro fósil.

Keywords: Evolution; Cognition; Language; Motor control; Neural circuit; Speech deficit

1. Introduction

It is clear that human beings have cognitive and linguistic abilities that transcend those of closely related species such as chimpanzees. Although apes raised in contact with human beings can communicate about 150 words using manual gestures and can understand spoken sentences that have simple syntax, they cannot talk. Apes cannot command complex syntax, nor can they acquire the tens of thousands of words that children effortlessly learn by age 10 years or so. Although it is becoming apparent that apes possess more advanced cognitive abilities than early observations revealed, they again do not function at a human level. I shall focus on a set of the characteristics that mark human beings, our ability to talk, form a potentially infinite number of sentences and flexibly adapt our thoughts and behavior to changing circumstances. These apparently unrelated human faculties paradoxically appear to derive from subcortical structures of the human brain that can be traced back to the ancestors of present-day frogs—the basal ganglia.

Traditional theories on how the human brain confers these abilities have focused on the neocortex. Broca's and Wernicke's areas, which were identified in the 19th century, are thought to be the "seats" of language. Cognitive abilities distinct from language are generally thought to be regulated by other parts of the cortex. Motor control is thought to have little to do with either the syntax of language or higher cognitive processes. The neural bases of motor control also involve subcortical brain structures such as the basal ganglia that are "primitive" in an evolutionary sense. The designation "primitive" here merely notes that these neural structures brain occur in species as far removed from human beings as frogs and reptiles. Many theories on how the brain works also contend that emotion is controlled by these primitive brain mechanisms.

In short, the brain bases of human language and thought are thought to be exclusively cortical and distinct from motor control. Moreover, different aspects of behavior are thought to be regulated by "modules", functionally distinct parts of the brain. Many current studies further subdivided these modules, parts of the cortical language areas control syntax, other parts control speech and so on. These theories ultimately derive from early 19th century phrenology, which proposed that various aspects of human behavior were