SPECIAL ISSUE: POSITION PAPER

THE LANGUAGE FACULTY, BROCA'S REGION, AND THE MIRROR SYSTEM

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ABSTRACT

Examples of three types of empirical arguments are given for the modularity of language mechanisms in Broca's region, and against a unified account of the functional role of this region and of the ventral precentral sulcus (vPCS). These are (a) pure syntactic considerations, (b) observations on the comprehension performance of Broca's aphasics, (c) recent fMRI results from receptive tasks at the sentence level.

Key words: syntax, movement rules, sentence processing, aphasia, fMRI, modularity

INTRODUCTION

Some recent fMRI results show activation in the ventral portion of the premotor cortex (vPM) during the application of certain linguistic rules in sentence reception (e.g., Meyer et al., 2000; Ben-Shachar et al., 2004). This region has earned its fame due to the mirror system it appears to house (Galese et al., 1996; Rizzolatti, et al., 2002). The proximity of vPM to Broca's region, the apparent communicative function that both language and the mirror system have, and findings like those just described, naturally lead to the thought that the language faculty and the mirror system are intimately related, perhaps indistinguishably so. Indeed, there have been attempts to place the mirror system and speech under the same umbrella (e.g., Rizzolatti and Arbib, 1998). Seen thus, an attempt to extend this claim to abilities which Universal Grammar characterizes seems a natural next step. This would amount to the claim that the linguistic system is closely related to action schemas (much in line with past proposals; e.g., Lashley, 1951; Kimura, 1976). Before such an extension is attempted, it is important to see what it would be up against – what kinds of (neuro)linguistic evidence a unifying effort would have to grapple with. To underscore the difficulties that a unified account might face, I go over results that provide fairly solid empirical support to an opposite claim: I think that the empirical record suggests that the language faculty (and subsequently whatever neural mechanisms in Broca's region that support it) and the mirror system (and whatever neural networks that underlie it in vPM) are distinct and modularized from one another. From a (neuro)linguistic perspective, it appears that the governing principles, central algorithms and neural mechanisms of Universal Grammar are independent of (although obviously connected to) other parts of cognition, including the mirror system.

Let us then rephrase the initial question: Is it possible to find common underlying principles that govern Broca's area and vPM? Answer: perhaps, but the path toward them seems treacherous. Here are some of the hurdles that a unified account must pass, at a minimum: A. Standard linguistic facts that are used to argue for grammatical modularity. B. Facts from language breakdown patterns at the sentence level, observed in focal brain disease (Broca's aphasia). C. Results from activation patterns in sentence analysis tasks monitored in the healthy brain by neuroimaging technology. As this is a short "position paper", I restrict myself to an example of each type.

A. SYNTAX

At issue are aspects of the language comprehension system (putatively situated in Broca's region), that may or may not be mere instances of more general cognitive mechanisms. It is worthwhile to be reminded of past empirical arguments for a modular view of language, and see how well they fare now – whether current views on cognition and action can accommodate them.

A classical paradigm (dating back to Chomsky, 1957) regards Subject-Auxiliary Inversion (SAI) in English yes/no questions in sentences that contain auxiliary verbs. The facts in (1)-(3) suggest a "structure-dependent" relation between an auxiliary is and the position marked by "__" (with the fronted element **bolded**, and '*' denoting ungrammaticality):

(1) a. John is tall
b. **Is** John __ tall?
(2) a. The man [who is in the room] is tall
b. ***Is** the man [who __ in the room] is tall?
c. **Is** the man [who is in the room] __ tall?
(3) a. John is the man [who is in the room]
b. ***Is** John is the man [who __ in the room]?
c. **Is** John __ the man [who is in the room]?

A yes/no question here is formed by extracting an auxiliary verb, and putting it in the front (1). Yet, how does SAI determine which auxiliary is fronted when there is more than one auxiliary? From (2) and (3) we see that extraction and fronting must somehow be constrained, otherwise, certain applications would result in ungrammatical strings [e.g., (2b), (3b)]. Can a constraint on SAI be formulated over linear sequences of words (i.e., one that makes reference only to terms like *first, second, last in the string*, etc.)? Looking at (2), a linearly based account seems to work. It would say that in English, only the fronting of the first (or perhaps the penultimate) auxiliary in a sequence is illicit. Since in (2b) the first auxiliary is fronted, a violation of this rule follows, hence ungrammaticality. Curiously, (3) shows that this account is inadequate, because the situation may be reversed: in (3b), it is the fronting of the second (or maybe last) auxiliary that leads to ungrammaticality. Our attempt failed. To reconcile the contradiction, we must find a property common to both illicit representations (2b)-(3b), so that the fronting of the auxiliary they contain can be blocked by a single statement. Observe that in both ungrammatical cases the fronting is from an embedded clause (marked by brackets). What seems to block auxiliary extraction in these cases is not the linear ordering of auxiliaries, but the fact that it is done from an embedded sentence. SAI thus allows auxiliary extraction only from a main clause, as Chomsky (1957) proposes. A rule that blocks auxiliary extraction, or fronting, from an embedded clause, covers (1)-(3) and many related facts, and is said to be part of speakers' knowledge of English. However, a ban of this type presupposes hierarchical, as opposed to linear, relations to exist in sentences.

A reader may argue that this type of facts demonstrates nothing beyond the need for hierarchical relations in linguistic analysis. Hierarchy, she would note, is characteristic of many biological systems, and thus a demonstration that it exists does not show that a particular system (in this case language) is special[1]. Yet if she agrees on the existence of a hierarchy here, we are more than half way done. First, it is now agreed that the facts in (1)-(3) are relevant, which opens the way to more; second, such agreement immediately excludes a class of rather popular frequency-driven accounts of linguistic ability (which use concepts like 'frequent structure', 'adaptation', 'habituation', 'transition probability' to explain syntactic regularity), because such accounts are incapable of handling (1)-(3). Indeed, Chomsky (1957) originally introduced these facts in an argument against a probabilistic, Markov-source based, approach to syntactic analysis.

Still, there is arguably some road ahead; namely, it remains to be shown that the particular hierarchy we see here has a special, linguistic, character. For that, one must reflect on the nature of rule SAI. To convince the skeptical reader, what is needed is evidence that the formulation of SAI makes crucial reference to grammatical notions. What is given below is precisely this kind of evidence. I will now show a set of related grammaticality contrasts with respect to yes/no question formation, indicating that SAI must appeal to grammatical types.

The extraction operation that SAI constrains is complex (simple as its yes/no question output might appear). Importantly, even in a main clause, SAI cannot take just any word and move it to any location. It can only front a verb. Furthermore, it cannot front just any verb to form a yes/no question (4b), although a yes/no question can always be formed (4c); nor can SAI freely extract just any auxiliary verb, if there is more than one [(5b) *vs.* (5c)]; and it cannot front more than one either (5d). SAI, then, is a not only a ban on extraction of an auxiliary verb from an embedded clause; it also constrains the fronting of auxiliaries in main clauses:

(4) a. George saw John
b. ***Saw** George __ John?
c. Did George see John?
(5) a. George will be asked to leave
b. **Will** George __ be asked to leave?
c. ***Be** George **will** __ asked to leave?
d. ***Will be** George __ __ asked to leave?

Even this handful of snippets (chosen for brevity, as this short essay isn't meant to be an introductory syntax course) leads to a reasonably clear conclusion: Sentences are not only organized hierarchically, but also, the rules that compose them from words must make reference to grammatical notions. And these do not seem easily derivable from other vocabulary, let alone the one used to describe the motor system. And, as many have pointed out (most succinctly Osherson, 1981), a unifying approach to cognitive modules must require that the relevant facts from the respective cognitive domains follow from the same theory. Here, a unified linguistic/motor theory would require that what appear to be specialized grammatical systems [usually invoked to account for facts like (1)-(5)] can be put under the same umbrella with systems that govern motor behavior. Yet (1)-(5) seem to be governed by a *linguistic* rule. Is it possible to construct an account that unifies these facts with facts that pertain to the mirror system? Perhaps, yet it would seem to be an exceedingly difficult task.

[1] I am grateful to Michael Arbib for his incisive comments on this issue.

TABLE I

Construction	Performance level
(6) a. The man pushed the woman	***Above Chance***
b. **The woman** was pushed __ by the man	***Chance***
(7) a. The cat that chased the dog was very big	***Above Chance***
b. **The cat** that the dog chased __ was very big	***Chance***

TABLE II

Construction	Performance level
(8) **The woman** was pushed __ by the man	***Chance***
(9) a. **Der Vater** wird vom Sohn __ geküßt	***Above Chance***
b. **De jongen** wordt door het meisje __ gekust	***Above Chance***
(10) a. The cat that [chased the dog] was very big	***Above Chance***
b. **The dog** that [the cat chased __] was very big	***Chance***
(11) a. [__ zhuei gou] de **mau** hen da	***Chance***
Chased dog that cat very big	
The cat that chased the dog was very big	
b. [Mau zhuei] de gou hen xiao	***Above Chance***
Cat chased that dog very small	
The cat that chased the dog was very big	

B. Aphasia

Cross-linguistic breakdown patterns observed in Broca's aphasia provide a complex picture of the syntactic function that Broca's area supports. Like before, this function seems to be intimately connected to syntactic variables, which in turn do not easily lend themselves to an analysis in terms of more general cognitive mechanisms. Let me describe some recent results, and then try to examine their theoretical significance.

It is well known that focal insult to Broca's area and its vicinity leads to deficiency in comprehension performance of sentences that involve syntactic movement (*a k a* grammatical transformations). This is illustrated in (6)-(7), where the a examples do not contain movement, and the b examples do (the moved element **bolded**, the position it moved from marked '__'). In binary forced choice interpretive tasks, with error rate is the dependent measure, Broca's aphasics exhibit the patterns illustrated in Table I.

This picture has led to the claim that Broca's region houses mechanisms responsible for transformational analysis (e.g., Grodzinsky, 1984, 1986). Subsequent growth in amount of relevant data pointed to a certain degree of individual variation. Yet, quantitative analysis of a large data set from Broca's aphasics has indicated that the syntactic movement effect persists. Focal insult to Broca's area and its vicinity thus consistently impairs transformational analysis (Drai and Grodzinsky, 2006). Corresponding failures in real-time processing have also been documented (Zurif, 1995, 2003).

This function of Broca's area already suggests a highly specific linguistic role. Yet, there are two intriguing exceptions to the pattern I just described, that underscore this point even more poignantly: While English passive sentences are comprehended at chance (8), German and Dutch passives with the same meaning, which are also derived by movement (9), nonetheless give way to near-normal comprehension performance by Broca's aphasics (e.g., Kolk and van Grunsven, 1985; Friederici and Graetz, 1987; Burchert and de Bleser, 2004). Similarly, English relative clauses yield the performance patterns in (10), but their Chinese counterparts (11) reveal exactly the opposite pattern (see Table II) (Su, 2000; Law, 2000).

These facts seem varied, but they are highly structured linguistically. Variation seems to be linked to contrasts between the languages in question in specific syntactic properties. That is, performance contrasts between English and Dutch/German on the one hand, and English and Chinese on the other hand, is predicted from reasonably well understood cross-linguistic grammatical variation (Grodzinsky, 2000, 2006). Details aside, a unified theory of the functional role of the language and the motor cortices must deal with these intriguingly complex patterns (for which a linguistic explanation seems feasible). That is, a unified theory of action must at the very least allow for such deficits to exist. It is difficult to imagine how such an intricate pattern of performance can be accounted for by general cognitive (as opposed to specifically linguistic) terms.

C. fMRI in Health

Recent results from fMRI experiments complement the picture regarding the role of Broca's region in sentence analysis. These experiments feature a host of receptive tasks with sentence stimuli, and evince a BOLD response pattern that is unique to syntactic movement operations. In series of minimal pairs of sentences,

TABLE III

(12) ± **Movement (other 'complexity' held constant)**	
a. I told John that the nurse slept in the living room	(– Movement)
b. *I helped **the nurse** that John saw __ in the living room*	(+ *Movement*)
(13) ± **Topicalization**	
a. Danny gave the book to the professor from Oxford	(– Movement)
b. ***To the professor from Oxford** Danny gave the book __*	(+ *Movement*)
(14) ± **Wh-movement**	
a. The waiter asked if the tourist ordered avocado salad in the morning	(–Movement)
b. *The waiter asked **which salad** the tourist ordered __ in the morning*	(+*Movement*)

TABLE IV

(15) ± **Reflexivization**	
a. The girl supposes the **older man** scratched **himself**	(+ reflexive)
b. The girl supposes the cunning man scratched Christopher	(– reflexive)
(16) ± **Dative shift**	
a. Danny gave to the professor from Oxford the red book	(– Dative Shift)
b. Danny gave **the red book** to the professor from Oxford __	(+ Dative Shift)

one involving syntactic movement, the other not, *ceteris paribus*, activation is observed in left Broca's region, and in Wernicke's region bilaterally (Ben-Shachar et al., 2003, 2004) (Table III).

While the results above were obtained in Hebrew, similar effects have been observed in English (see Caplan, 2001), and in a variety of experiments in German (mostly from scrambling, Fiebach et al., 2004; Friederici et al., 2003, Röder et al., 2001). Curiously, the contrasts in (13) and (14) activated the vPCS. Such activations have been ascribed to general, as opposed to linguistic, effort (Meyer et al., 2000). Their co-occurrence with the rest of the activation pattern [and absence in (12)] is mysterious, perhaps accidental.

One possibility – that could perhaps be recast in more general, non-linguistic terms – is that Broca's regions has some kind of generic working memory entrusted with the task of linking intra-sentential dependencies of any kind, as long as these require the linking of non-adjacent elements. This possibility opened way for tests of the specificity of the movement effect through sentences containing reflexives and their antecedents [(15); Grodzinsky and Santi, 2004], and sentence in which one of two objects crosses the other [(16); Ben-Shachar et al., 2004]. In both instances, there was no effect in Broca's region (Table IV).

An outline of a linguistic account of the functional role of Broca's region, one that is based on all these results, is in sight. We know, that is, how to consider the possibility that all the facts above fall under a single linguistic account, even though they come from different languages, and are adduced by varied methodologies. All these are relatively clear signs that specific linguistic rules have an identifiable brain locus. This conclusion naturally isn't problem free: there seem to be some findings to suggest that non-linguistic, potentially motor, functions are represented in the same region as well.

If all this is correct, then Broca's region, and perhaps vPM, are multi-functional. Does it mean that we must collapse linguistic theory and the theory about motor functioning into one? The answer, it seems, depends on the relative weight one puts on each type of empirical argument. Anatomists would think that the anatomical proximity (and sometimes even overlap at the gross anatomical level) of brain parts supporting motor and linguistic ability should lead to the conclusion that we are dealing with a unified function; linguists, on the other hand, would tend to put more weight on the way the different functions are described, and on the subtle relationship among the different theoretical vocabularies.

It should be evident that no definitive answer can be given at this stage. It is just important to remember that everyone – anatomists, physiologists, linguists, and neurologists – is in the same boat: We are all trying to improve our understanding of cognitive functions, and of the way they are computed in neural tissue. And, while the realization that a cerebral region is multi-functional does not improve much our understanding of how multi-functionality is computationally feasible, attempts to approach this complex reality from the opposite direction are just as bad: Just stating that because two functions reside in the same general region does not really advance our understanding of how their apparent distinctness can vanish or how the two theories can be reduced to one.

In any event, the facts I described do not seem to follow from principles that govern other structured behavior (i.e., action schemas, motor principles, or principles that underlie imitation behavior and are thought to reside in and around the motor cortex). At the very least, then, I would like to put these facts on the table, in an attempt to find ways to bridge the gap between (seemingly narrow) linguistically oriented approaches, and more general neurocognitive approaches to language and the motor system.

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