INTRODUCTION

In this short note, I consider and reject two arguments that Broca’s area is involved in syntactic processing because of its relation to sensory-motor processing. I conclude that the alternative – that Broca’s area supports syntactic processing because of its intrinsic neural properties – is an attractive possibility.

ARGUMENT 1
FROM HISTOLOGY, NEUROANATOMIC PROXIMITY, CONNECTIVITY AND LESION EFFECTS

Broca’s area is adjacent to the dorsolateral prefrontal cortex (DLPFC) and, like the DLPFC, its cytoarchitectonic features are those of association, not motor, cortex. The DLPFC is involved in high-level motor planning, especially planning action sequences, inhibition of actions, and switching between actions. Broca’s area is also adjacent and connected to the part of the motor cortex that projects to the bucco-oral musculature. Its position, histology and connectivity suggest that Broca’s area does the same thing for language as more rostral portions of the DLPFC do for motor planning (Luria, 1980). This includes planning syntactic structure. Evidence that this is the case comes from the fact that lesions in Broca’s area are commonly associated with grammatically simplified speech missing function words and morphemes (‘agrammatism’) (Menn and Obler, 1990; Vanier and Caplan, 1990).

ARGUMENT 2
FROM LESION EFFECTS AND EVOLUTION

The effects of lesions suggest Broca’s area is involved in syntax in speech production (see above). Patients with lesions in Broca’s area who have agrammatic speech production also often have disturbances of the ability to use syntactic information to determine the meaning of sentences (Caramazza and Zurif, 1976). This suggests that Broca’s area is involved in the perception of syntactic structure. The combination of these two findings suggests that Broca’s area is involved in syntactic operations that occur in both speech production and perception (Zurif, 1982). This happens because Broca’s area has evolved from cortex that contains mirror neurons that are involved in both production and perception of transitive actions (Rizzolatti and Arbib, 1998).

Both these arguments come to the conclusion that Broca’s area is involved in syntax because of its relation to sensori-motor functions. These arguments have powerful intellectual appeal, as they unite disparate neural functions in an evolutionary context. But are they sustainable?

COUNTERARGUMENTS TO ARGUMENT 1

One counterargument to the view that Broca’s area derives its role in syntactic processing from its functional relation to the DLPFC is that syntactic sequences differ from those in other domains. Therefore, if language perception and production utilize operations common to other stimuli, these operations apply to a special set of representations in speech. Two phenomena argue that this is not how skills develop. This first is that transfer of skills across domains is limited. If all that were required to acquire a skill was to learn the representations that were targeted by perceptual processes, one would expect a much greater homogeneity of skill levels across domains within individuals than is seen. The second is that skills are permeated by domain-specific regularities.
Skilled typists, for instance, are slowed by scrambling letters in words. These two phenomena suggest that skills are tied to the representations that are perceived and planned. If this is the case, the syntactic perceptual and planning operations in Broca’s area are specializations.

Saying that Broca’s area supports specializations of perceptual and planning skills whose actual operations are tied to particular representations is not the same as saying that Broca’s area applies the same perceptual and planning skills that other parts of the DLPFC support to special representations. The former acknowledges that Broca’s area differs functionally from other parts of the DLPFC and requires additional steps to get from the functions of the DLPFC to those of Broca’s area. Two such steps are possible.

The first is an evolutionary argument to the effect that Broca’s area and DLPFC evolved from the same substrate and hence share functional abilities (this claim differs from the evolutionary argument made by Arbib, 2005, which is discussed below). The second is an ontogenetic argument that Broca’s area became specialized for these operations during development (I read Luria, 1961, as making this second claim because of his emphasis on skill development in childhood). The problem these positions face is in relating the functions of Broca’s area to those of the DLPFC is that they still both accept that the functions of the DLPFC and Broca’s area differ. Actual operations common to their functions are thus “pushed upstairs” to higher-level control processes. What higher-level control processes that apply to planning syntactic structures and motor actions are has never been worked out. Characterizing them by saying that they “plan sequences,” “switch” from one operation to another, are involved in “the detection, extraction, and/or representation of patterns in arbitrary dynamic, i.e., temporally extended perceptual events,” and other positions I am aware of, are statements of a research program, not actual models.

In addition, both these ideas are hard to defend because other cortical regions, far from the DLPFC, appear to carry out the same syntactic operations as Broca’s area. In a significant number of agrammatic patients, the lesions are outside Broca’s area (Vanier and Caplan, 1990). In other cases, lesions outside Broca’s area produce so-called “paragrammatism,” which is often contrasted with the “agrammatic” speech of patients with lesions in Broca’s area. However, it is not at all clear that paragrammatism and agrammatism result from different deficits in syntactic planning, as opposed to different compensations to the same deficits. They co-occur in patients more often than not (De Bleser, 1987). Many differences between the two types of syntactic abnormalities may reflect features of motor speech production, such as rate and articulatory control, more than differences in the ability to construct syntactic structures. If the same syntactic planning disorder arises after lesions in many areas, the argument relating Broca’s area and the DLPFC must be that Broca’s area carries out syntactic operations because its functions are derived from an evolutionary precursor of the DLPFC or are an ontogenetic specialization of those of the DLPFC, and other brain regions do so for entirely different reasons. Although it may be true, this is not a very convincing argument1.

COUNTERARGUMENT TO ARGUMENT 2

Argument 2 rests on the assumption that there are syntactic operations that are common to both speech production and perception. However, though many experts have associated “syntagmatic” aspects of language with Broca’s area (for an important historical precedent, see Jakobson, 1941, 1956), actual syntactic operations common to speech and comprehension have never been described. Models of speech production and those of speech perception – both those that are rule-based and those that are lexically-based (see Garrett, 1980, rule-based production models; Frazier and Clifton, 1996, rule-based parsing models; Levelt, 1989, and Bock and Levelt, 1994, lexically-based production models; MacDonald et al., 1994, lexically -based parsing models) – incorporate different operations in production and perception. The only models I know of that postulate exactly the same syntactic operations in production and perception are ones that think of perception as “analysis by synthesis” – models that claim that, in perception, syntactic structures are internally generated by the production system and matched to the input (Halle and Stevens, 1964; Garrett, 2002). These models have never actually been worked out; they remain ideas. In fact, in the area of aphasiology, researchers abandoned their initial attempts to specify an “overarching” deficit in syntactic operations that affected both perception and production after lesions in Broca’s area (Zurif, 1982) and have suggested that different disturbances affect syntax in the two modalities (Grodzinsky, 2000). If there is no operation that is common to both the planning and perception of syntax, the argument that Broca’s area plays the role it does in these functions because it evolved from brain areas that contain mirror neurons must

1 Though not strictly relevant to the present argument, which deals with planning speech production, I note, in relation to extensions of the first argument to perception, made at the conference that led to this issue, that lesions in multiple perisylvian cortical regions also produce disturbances in syntactic comprehension, with no particular distinguishing features associated with Broca’s area lesions (Berndt et al., 1996; Caplan et al., 1996, 2002). Functional neuroimaging studies also show activation of many cortical structures in association with syntactic processing (Stromswold et al., 1996; Ben-Shachar et al., 2003; Chen et al., 2006, this issue; Just et al., 1996).
be wrong. Evolution from mirror neuron containing areas could be relevant to Broca’s area being involved in the same operations in perception and production, but these do not seem to exist.

There is another way to view the mirror neuron concept that does not run into this problem. Arbib (2005) has argued that mirror neurons are critical to syntax because the fact that they respond when both the individual and an external agent undertake an action is the basis for perceiving transitive actions as being composed of an agent, an action and a recipient, which is the basic semantic relationship expressed by syntax. If Broca’s area evolved from a brain area that allowed for this decomposition, it could play a critical role in representing syntactic relations.

This argument also has a hidden premise. It requires that many features of syntax be cultural developments, which strikes me as unlikely. Cultural development is highly varied across cultures with respect to its degree of elaboration, whereas, as far as I know, there are no structurally simple languages. In addition, cultural developments are learned consciously with formal instruction, are often confined to certain individuals (especially when they are complex), and are partly changeable by conscious individual or social decision; syntax has none of these features. The more abstract and domain-specific one thinks syntax is, the greater the force of these observations and the harder it is to conceive of syntax as a cultural development. What is missing in Arbib’s argument (2005) is a demonstration of how we get from simple sequences that express transitive relations to the full range of syntactic structures and the semantics they convey in all languages. Chomsky (1995) answers this challenge by postulating innate abstract representational schema in which parameters are set by exposure to individual languages. As he recognizes, it is unlikely that current proposals within this framework are correct, but they address this basic question, on which Arbib’s work (2005) is silent.

CONCLUDING COMMENTS

Efforts to derive the syntactic functions of Broca’s area from its similarity and proximity to the DLPFC or the evolutionary history of the area are unconvincing. The alternative is that this area supports such functions because of its intrinsic neural features, as other cortical areas do if the evidence cited above is correct. Some aspects of language are different from other cognitive domains, and the neural basis of the operations associated with these features of language may be sui generis.

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REFERENCES


