individual, the opponent action might require a form of cognitive control. For instance, an individual might only reassess the situation, and consider different options, when she detects a mismatch between response bias and reward availability. Previous research has already suggested that the anterior cingulate cortex plays an important role in evaluating potential conflicts [14] and effort-related decisions [15]. Might the opponent action in centromedian nucleus in some way depend on input from anterior cingulate cortex?

Now that we have with a firm idea of what the neural signal for opponent action looks like, the obvious next question is how this activity depends on, or interacts with, other neural structures. The data cry out for a systems approach, examining the neurophysiological and neuropharmacological properties of the different projections. This can be done by simultaneous recording in multiple areas, combined with local electrical stimulation and/or administering of chemical agents. Much remains to be learned about how this system operates, but perhaps the most exciting message from the study of Minamimoto *et al.* is that we now already know at least one mechanism of goal-oriented control of action that is altogether different from the traditional story of dopamine, reward, and voluntary behavior. Researchers in the field will have to broaden their scope in order to understand fully how we manage to get so many difficult and unattractive tasks done.

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Understanding the architecture of language: the possible role of neurology

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Culicover and Jackendoff have recently described an approach to language representation where semantic structure works, alongside syntax, as a generative system with its own structure and principles of composition. Well-known neurological observations support this view. They show that in the presence of a syntactic impairment, comprehension can take place but only if the sentence's *semantic* structure is rich enough. This would suggest the existence of syntax-independent semantic combinatorial mechanisms, as Culicover and Jackendoff's model proposes.

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Sentence comprehension is one manifestation of linguistic composition. It results, in part, from lexicalized meaning coming together through at least one combinatorial system: (morpho-)syntax. Some of the information guiding (morpho-)syntactic composition, such as syntactic category, is also lexicalized. Nevertheless, syntactic categories are correlated with, but not definable by, meaning classes. Capitalizing on this insight, which is fundamental to most approaches to language representation, Culicover and Jackendoff [1] propose that these two kinds of information – syntax and semantics – are not only differentiated at the lexical level but are also deployed and manipulated via 'parallel tracks', as it were, at the phrasal and sentential levels. This view, consistent with some (but not all) current models of language representation, has two important consequences: (i) that *both* syntax and semantics have independent combinatorial properties; and (ii) that semantic structure need not mirror syntactic composition; that is, that semantics can have *generative* properties of its own. Important for present purposes, the proposal of syntax-independent semantic composition suggests that it should be observable during its implementation; that is, during language comprehension and production. Here, it is argued that a solid body of evidence from studies of sentence comprehension already suggests that this parallel track system indeed carries over beyond the lexical level. This is revealed in well-known comprehension/production asymmetries reported in lesion-based studies. This body of literature illustrates in a clean and direct manner the ways in which abstract models of representation and cognitive neuroscience in general can serve as mutually constraining forces.

Semantics in the architecture of the language system

The insight that the language system contains independent syntactic and semantic components, each with its own units and combinatorial principles, is well-represented in the field [2–5]. Culicover and Jackendoff's model [1] is one of the strongest instantiations of this idea because it endows semantics with full *generative* power (and makes syntax proportionately narrower). The proposed model argues for the possibility that the meaning associated with a particular syntactic structure need not be a simple composition of the meanings of the words in a fashion dictated by syntax. Instead, it confers combinatorial autonomy not only to phonology and (morpho)syntax, but also to semantics, endowing them all with generative capacity. In this manner, semantics has a more substantial role than merely interpreting syntactic output, as more traditional architectures suggest [6]. In allowing generative semantics, this approach makes the claim that semantic composition is part of the language system: that semantico-conceptual information interacts with syntax in a linguistically relevant manner through the system of correspondence that constitutes the syntax–semantics interface.

From a processing perspective, this parallel-track approach to sentence construction would define sentence interpretation as the establishment of a real-time correspondence between these three different combinatorial systems. This approach therefore allows for the possibility that the combinatorial principles of semantics will be observable during comprehension. The independence of these systems would not be particularly 'visible' during *production* because, by its very nature, production requires that syntactic structures such as word order and agreement must be created by the speaker to utter a sentence, thereby 'masking' the workings of combinatorial semantics as a syntax-independent process. However, combinatorial semantics would certainly be visible during *comprehension*, because during that process, syntactic mechanisms (e.g. word-order, agreement morphology) are already provided in the input (i.e. they do not have to be recalled but only recognized), making the process less demanding on the syntactic generative capacity. As it turns out, the hypothesis that semantic composition can be seen to operate independently of syntactic composition during comprehension (but not production) is consistent with long-standing neurological observations. It is to this evidence that we now turn.

An independent semantic system: the empirical record

It is a well-known observation in the neurological literature that constructions such as object relatives, for which patients with Broca's aphasia normally exhibit comprehension at chance level, can be made less taxing on the Broca's system if the lexical and discourse content of the sentences is rich enough. This non-syntactic knowledge sometimes compensates for and sometimes competes with the interpretation that would be suggested from combinatorial syntactic mechanisms alone, and has traditionally been taken to be part of general heuristics: non-linguistic patterns that result from induction over experience [7]. However, a closer look at descriptive generalizations of the Broca's comprehension deficit shows that the kind of knowledge that conforms to these heuristic processes involves fundamental *linguistic* knowledge, which is present in most models of language representation, including those that take syntax to be the only combinatorial system in language. This 'heuristic' knowledge ranges from semantic roles, animacy, and argument structure [8,9], to co-reference [10] – knowledge that in current theories of language has been independently invoked to explain prototypical linguistic phenomena such as word-order variations and syntax-dependent anaphora interpretation. Furthermore, the systematicity in the behavior of these semantic mechanisms in impaired and normal comprehension suggests that the comprehension process is making use of linguistic subsystems that, together with syntax, contribute to the full interpretation of spoken language. Finally, given the fact that this knowledge has been independently shown to be active during the unfolding of comprehension, it would appear to be part of the mandatory knowledge that must be deployed for even initial interpretation to take place.

Importantly, these generalizations do not account for Broca's *production* deficit, also taken to be syntactically based [11,12], which suggests that in comprehension there is a clearer possibility of compensating for the impaired syntactic parsing process, and that the means of doing so are themselves 'linguistic' but not of a syntactic nature.

Accounting for the record

Culicover and Jackendoff's model provides a possible explanation for the visibility of semantics during Broca's comprehension because, according to this model, syntax is but one of the combinatorial systems that must be triggered to achieve interpretation. In the case of comprehension, the processing system is allowed to consider the product of combinatorial semantics *alongside* the product of syntactic composition (i.e. semantic processing is incremental). This possibility is most clearly observed in Broca's comprehension precisely because in this system syntactic composition is impaired.

In Broca's production, semantics is less visible because in this case syntax guides the process by which semantic information is encoded within a sentence through word order and inflectional processes. So, as the neurological evidence shows, the system can make less use of available semantic information.

The possibility of an independent generative semantic system is also independently supported by reports that indicate that the posterior superior temporal region, associated with Wernicke's aphasia, and *not* the left anterior frontal cortex, associated with Broca's aphasia, is engaged during lexico-semantic processing both at the lexical [13,14] and sentence levels [15,16]. (In fMRI studies, this association sometimes also involves BA 47, an area not crucially associated with *syntactic* processing). This converges with the analysis presented here. It points to a cortical substrate for semantic combinatorial processes, one which predictably remains intact in the Broca's system.

Concluding remarks

Altogether, three points have been argued here: (1) a large body of neurological evidence suggests that semantics behaves as an independent combinatorial system in the brain; (2) one current linguistic model shows how this system is actually part of the architecture of grammar; and (3) syntax and semantic processes are not equally visible in comprehension and production. This highlights the inevitable connection between the language capacity and the manner in which it is accessed.

As we seek to build connections between brain-based linguistic observations and abstract models of representation, several long-term research questions suggest themselves: In what way can cognitive neuroscience in general inform research that seeks to isolate purely syntactic processes from semantic ones? How do world knowledge and semantics connect? What are their cortical 'markers'? What other neurological and processing criteria could be used for determining this? To be sure, these questions have long been at the center of cognitive neuroscience of language research; the present arguments constitute a motivation to pursue them through less traditional, theoretical architectures and look at what neurology and cognitive neuroscience can contribute.

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Language, thought and color: recent developments

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The classic issue of color naming and color cognition has been re-examined in a recent series of articles. Here, we review these developments, and suggest that they move the field beyond a familiar rhetoric of 'nature versus nurture', or 'universals versus relativity', to new concepts and new questions.

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