



Word order and Broca's region: Evidence for a supra-syntactic perspective

Ina Bornkessel-Schlesewsky^{a,b,*}, Matthias Schlewsky^c, D. Yves von Cramon^{d,e}

^a Department of Germanic Linguistics, University of Marburg, Marburg, Germany

^b Research Group Neurotypology, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

^c Department of English and Linguistics, Johannes Gutenberg-University, Mainz, Germany

^d Department of Cognitive Neurology, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

^e Department of Neurology, Max Planck Institute for Neurological Research, Cologne, Germany

ARTICLE INFO

Article history:

Accepted 12 September 2009

Available online 22 October 2009

Keywords:

Broca's area
Inferior frontal gyrus
Pars opercularis
Word order
Linearization
Referentiality
Definiteness
Prominence

ABSTRACT

It has often been suggested that the role of Broca's region in sentence comprehension can be explained with reference to general cognitive mechanisms (e.g. working memory, cognitive control). However, the (language-related) basis for such proposals is often restricted to findings on English. Here, we argue that an extension of the database to other languages can shed new light on the types of mechanisms that an adequate account of Broca's region should be equipped to deal with. This becomes most readily apparent in the domain of word order variations, which we examined in German verb-final sentences using event-related fMRI. Our results showed that activation in the pars opercularis – a core subregion of Broca's area – was not only modulated by the relative ordering of subject and object, but also by a further factor known to affect word order in a number of languages, namely referentiality. Notably, the finding provides the first demonstration of a word order-related activation difference within subject-initial sentences in this region. Additional parametric analyses using individual behavioral data as predictors further attest to the independence of the pars opercularis activation from: (a) sentence acceptability, and (b) difficulty in performing the experimental (judgment) task. We argue that these and related findings attest to the need for a processing mechanism that can manipulate predicate-independent, interacting and hierarchically structured relational representations during real time comprehension. These properties pose a challenge to existing accounts of pars opercularis function.

© 2009 Elsevier Inc. All rights reserved.

1. Introduction

Of the language-related areas of the human brain, Broca's area (comprising the pars opercularis and triangularis of the left inferior frontal gyrus, IFG) is arguably the most famous. In recent years, the precise role of this region in language comprehension has been subject to a heated debate, the primary focus of which has been its increased activation during the comprehension of sentences in which the object precedes the subject. An example for a “non-canonical” or “permuted” sentence of this type is the (italicized) object-relative clause in ‘Bill caught the burglar *who the detective chased*’.

The involvement of Broca's area in the processing of word order permutations has been demonstrated in a large number of neuro-imaging studies. While increased activation of this region for object-initial sentences was first reported for relative clauses in

English (e.g. Caplan, Alpert, Waters, & Olivieri, 2000; Constable et al., 2004; Just, Carpenter, Keller, Eddy, & Thulborn, 1996; Keller, Carpenter, & Just, 2001; Stromswold, Caplan, Alpert, & Rauch, 1996), it has also been observed for clause-medial word order permutations (“scrambling”) in German (e.g. Bornkessel, Zysset, Friederici, von Cramon, & Schlewsky, 2005; Friederici, Fiebach, Schlewsky, Bornkessel, & von Cramon, 2006; Grewe et al., 2005, 2006, 2007; Röder, Stock, Neville, Bien, & Rösler, 2002) and for object-initial sentences in Hebrew (Ben-Shachar, Palti, & Grodzinsky, 2004) and Japanese (Kinno, Kawamura, Shioda, & Sakai, 2008).

In view of these very consistent results, it is undisputed that Broca's area – and particularly the pars opercularis of the left IFG – plays an important role in the processing of varying word orders. This function (“linearization”) is very important for the comprehension of natural language for at least two reasons: (a) since language unfolds over time, the order in which sentence constituents are encountered in the speech stream imposes crucial constraints on how the comprehension process can proceed; and (b) because an estimated 70% of natural languages exhibit a significant degree of word order freedom (Steele, 1978), the possibility of variations

* Corresponding author. Address: Department of Germanic Linguistics, University of Marburg, Wilhelm-Roepke-Strasse 6A, 35032 Marburg, Germany. Fax: +49 (0) 6421 2824558.

E-mail address: iboke@staff.uni-marburg.de (I. Bornkessel-Schlesewsky).

in this order should be considered the rule rather than the exception. Approaches to the function of Broca's region/the left pars opercularis differ as to whether they attribute its role in the processing of permuted word orders to language-internal (e.g. syntactic movement: Ben-Shachar et al., 2004; Grodzinsky, 2000; Grodzinsky & Friederici, 2006; Grodzinsky & Santi, 2008) or domain-general operations (e.g. working memory: Caplan et al., 2000; Fiebach, Schlesewsky, Lohmann, von Cramon, & Friederici, 2005; Kaan & Swaab, 2002; Müller, Kleinhaus, & Courchesne, 2003; or cognitive control: Thompson-Schill, Bedny, & Goldberg, 2005). From a somewhat more general perspective, it has also been proposed that the language-related function of Broca's region can be subsumed under broader cognitive mechanisms related to "action understanding" (Rizzolatti & Arbib, 1998). Language-specific approaches are often criticised (e.g. Müller & Basho, 2004) because they fail to account for the observation that Broca's region is also activated by non-linguistic tasks, e.g. motor imagery (Binkofski et al., 2000) and the processing of complex relational information (Kroger et al., 2002). One of the main challenges in accounting for the involvement of the pars opercularis in the processing of word order permutations thus lies in determining whether it can be derived from some more general function of this cortical region within higher cognition.

Here we will argue that, at least with respect to word order variations, domain-general approaches and highly specific language-internal approaches to pars opercularis function have more in common than is typically acknowledged. In our view, both types of approaches underestimate the complexity of the activation patterns that this region shows in response to fine-grained linguistic differences. Specifically, we will argue that, while the basic finding of increased activation for object-before-subject orders can be derived by all models in a relatively straightforward manner, they are equally challenged by more complex word order patterns. In the following, we first provide a brief summary of previous findings which suggest that the relative ordering of subject and object may not be the key to explaining pars opercularis activation for word order variations before describing an fMRI study which further corroborates this perspective.

1.1. Beyond subjects and objects: interacting information types in word order variations

Despite differing viewpoints on precisely which mechanism should be held responsible for the additional processing costs in object-before-subject orders, virtually all approaches appeal to the inherent dependency between objects and subjects in deriving these costs. For example, it is commonly assumed that comprehending an object-initial sentence involves reconstructing the canonical subject-initial order and that an initial object cannot be interpreted until either the subject or the verb is encountered (see, for example, Kaan & Swaab, 2002).¹ One might therefore assume that it is this type of dependency that engenders the increased activation of the pars opercularis in object-initial orders. If this were indeed the correct functional characterization of word order-related pars opercularis activation, it would provide a candidate mechanism which domain-general models would need to explain. It is, of course, easily derived in a movement-based, language-internal approach, since object-initial orders can be modeled theoretically as involving

an additional movement operation which places the object in front of the subject.²

However, recent results from German indicate that matters are somewhat more complex: under certain circumstances, object-initial orders systematically fail to show increased pars opercularis activation in comparison to their subject-initial counterparts. This is the case, for example, when the object bears a higher-ranking thematic role than the subject, as in (1) (from Bornkessel et al., 2005).

- (1) Gestern wurde erzählt,
yesterday was told,
dass dem Jungen die Lehrer auffallen
that [the boy]_{DAT.OBJ.SG} [the teachers]_{NOM.SUBJ.PL}
be.striking.to_{PL}
'Yesterday, someone said that the boy finds the teachers striking.'

In (1), the verb *auffallen* ('to be striking to') assigns the higher-ranking Experiencer role to the grammatical object, the boy, whereas the grammatical subject, the teachers, bears the lower-ranking role of Theme (or Stimulus) (cf. Grimshaw, 1990; Primus, 1999, for theoretical arguments; and Bornkessel, Schlesewsky, & Friederici, 2003, for empirical evidence). Thus, in sentences such as (1), the object-initial order allows for an independent preference to be upheld, namely that arguments bearing higher-ranking thematic roles should precede arguments bearing lower-ranking thematic roles. This ordering tendency has been assumed to hold for German (Fanselow, 2000; Haider & Rosengren, 2003; Wunderlich, 1997) as well as across a wide range of languages (Tomlin, 1986). It has also been confirmed empirically (see Haupt, Schlesewsky, Roehm, Friederici, & Bornkessel-Schlesewsky, 2008 for the results of a rating study with 1120 native speakers of German). In an fMRI study, Bornkessel et al. (2005) demonstrated that subject-object order interacts with the order of thematic roles in the left pars opercularis: increased activation for object- vs. subject-initial orders was only observed for sentences with action verbs (in which the subject bears the higher-ranking thematic role than the object), but not for sentences with "object-experiencer" verbs of the type in (1).

Further converging evidence that object-initial orders do not engender increased pars opercularis activation when the non-canonical order is motivated by an independent word order rule was provided by Grewe et al. (2005). Here, the independent rule was one of pronoun placement, namely that pronouns should precede non-pronominal arguments in the medial region of the German clause (Bierwisch, 1963; Lenerz, 1977; Müller, 1999). Similarly to Bornkessel et al.'s (2005) results on thematic roles, Grewe et al.'s (2005) findings showed that object-initial orders only engendered increased activation in the left pars opercularis when both subject and object were non-pronominal noun phrases, but not when the initial noun phrase was realized by a pronoun.

On the basis of these findings, Bornkessel et al. (2005) and Grewe et al. (2005) concluded that pars opercularis activation in the domain of word order variations cannot be reduced to a single factor, but rather results from the interaction of multiple information types. They thus put forward the "linearization hypothesis", according to which activation in the left pars opercularis is modulated by a range of non-syntactic "prominence scales", with activation increasing whenever a less prominent argument precedes a more prominent argument. The relevant scales, which are given

¹ The idea that integration of the object is triggered by the subject has been proposed for verb-final languages such as German, in which the base position of the object intervenes between the subject and the verb (see Fiebach, Schlesewsky, & Friederici, 2002). In English, by contrast, the integration of the object can be assumed to be triggered by the verb, irrespective of whether this integration is mediated by a trace or by the direct association between the object and its subcategorizer (Pickering & Barry, 1991). Importantly, however, the processing of the subject is assumed to be a necessary prerequisite for the integration and interpretation of the object in all cases.

² But note that this is only one possible theoretical characterization of object-before-subject orders. By contrast, a number of theories of grammar do not assume movement operations (e.g. Lexical Functional Grammar: Bresnan, 2001; "Simpler Syntax": Culicover & Jackendoff, 2005; Role and Reference Grammar: Van Valin, 2005; Construction Grammar: Goldberg, 2006).

Download English Version:

<https://daneshyari.com/en/article/925666>

Download Persian Version:

<https://daneshyari.com/article/925666>

[Daneshyari.com](https://daneshyari.com)