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The Role of Prominence Information in the Real-Time Comprehension of Transitive Constructions: A Cross-Linguistic Approach

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Abstract

Approaches to language processing have traditionally been formulated with reference to general cognitive concepts (e.g. working memory limitations) or have based their representational assumptions on concepts from generative linguistic theory (e.g. structure determines interpretation). Thus, many well-established generalisations about language that have emerged from cross-linguistic/typological research have not as yet had a major influence in shaping ideas about online processing. Here, we examine the viability of using typologically motivated concepts to account for phenomena in online language comprehension. In particular, we focus on the comprehension of simple transitive sentences (i.e. sentences involving two arguments/event participants) and cross-linguistic similarities and differences in how they are processed. We argue that incremental argument interpretation in these structures is best explained with reference to a range of cross-linguistically motivated, hierarchically ordered information types termed 'prominence scales' (e.g. animacy, definiteness/specificity, case marking and linear order). We show that the assumption of prominence-based argument processing can capture a wide range of recent neurocognitive findings, as well as deriving well-known behavioural results.

The Role of Prominence Information in the Comprehension of Transitive Sentences

Language is exceptional in its capacity for conveying information. Thus, it not only allows us to refer to existing states of affairs, but also lets us describe internal experiences and scenarios that may never take place. In many cases, the situations communicated in this manner will involve several participants and, consequently, some type of activity that is 'transferred' or 'carried over' between them (Hopper and Thompson 1980). The simplest instantiation of such a transfer, a transitive event, involves an information flow between two participants, one of which is more strongly responsible for the state of affairs (more 'agent-like', A), while the other (the more 'patient-like', P) participant is more strongly affected by what takes place (DeLancey 1981; Comrie 1989).

Within linguistic typology (i.e. the subdiscipline of linguistics that seeks to classify similarities and differences between the languages of the world), a number of scholars have attempted to identify how transitive events are naturally or prototypically expressed in human languages. An oft-cited observation in this regard was made by Comrie (1989, p. 128), who noted that 'the most natural transitive construction is one where the A is high in animacy and definiteness, and the P is lower in animacy and definiteness.' According to this definition, a sentence such as *The boy ate an apple* is an example of a natural transitive construction, as the A-argument (*the boy*) is animate and definite and the P-argument (*an apple*) is inanimate – or at least less animate than *the boy* – and indefinite. Of course, events that do not adhere to natural transitivity (e.g. *The cricket ball hit Bill*) can also be expressed, though they occur less frequently in natural discourse (e.g. Jäger 2007) and, in some languages, require additional morphological marking or the choice of a special construction (e.g. passive).

In this article, we discuss how transitive events are comprehended in real time and which neurocognitive mechanisms underlie this comprehension process. Specifically, we focus on two basic questions:

(a) Role identification: How does the human language comprehension system identify who is who in the information transfer situation (i.e. how does it identify which is the A and which is the P participant)?
(b) Role prototypicality: To what degree is online comprehension affected by the role prototypicality of the arguments, that is, does a less prototypical A and/or P participant render a transitive construction more difficult to process?

We will argue that both role identification (Question a) and role prototypicality (Question b) are crucially influenced by the information types that have been identified as cross-linguistic contributors to 'natural transitivity', that is, animacy, definiteness and a small number of additional features (see below for details). All of these features have in common that they serve to render the participants of the event more or less 'prominent' along some semantic dimension. We will present evidence that, within the comprehension process, prominence features (which would traditionally be classified as semantic or pragmatic) are functionally equivalent to information types such as word order and morphological case marking (which are traditionally viewed as syntactic). These observations provide the basis for a fundamentally new perspective on the interface between syntax and semantics during language comprehension.

This article is organised as follows. We begin by reviewing the traditional treatment of role identification and role prototypicality within the sentence comprehension literature, which is essentially based on the subdivision between syntactic and non-syntactic information types. In the second section of the article, we then discuss some recent empirical findings that have been used to question the classical picture and rather argue for the use of heuristics during sentence processing. Subsequently, we introduce a third possible perspective on role identification and role prototypicality (the 'interface view'), which is based on cross-linguistic considerations and makes crucial reference to prominence features as grammatical information. Initial empirical evidence for this view is reviewed in Sections 4 and 5 of the article. In Section 6, we introduce the latest version of a neurocognitive model of language comprehension that incorporates the interface view, before concluding the article with an outlook on further research.

Prominence in Language Processing: The Traditional View

Traditionally, research within the domain of sentence comprehension has assumed that role identification (our main Question a) is the responsibility of the syntax. As different sentential meanings/thematic role assignments correlate with different syntactic structures, it is the choice of syntactic structure that determines how a sentence is interpreted. In the words of Miller (1962, p. 752): 'the proper functioning of our syntactic skill is an essential ingredient in the process of understanding a sentence.' In contrast, non-syntactic information types such as animacy are thought to be crucially involved in the evaluation of role prototypicality (our main Question b). Thus, they essentially serve to determine how well the event participants fit into the roles assigned to them by the syntax. From this perspective, the distinction between role identification and role prototypicality can essentially be subsumed under the broader dissociation between syntax and semantics (or, more generally, between syntactic and non-syntactic information).

Whereas the idea of sentence interpretation being syntactically determined is shared by the major classes of comprehension models, these models differ markedly with respect to how they conceptualise the interplay between the aspects of processing that we have termed role identification and role prototypicality. Modular (or 'two-stage') approaches (e.g. Frazier 1978; Frazier and Rayner 1982; Frazier and Clifton 1996) assume an initial stage of analysis that only draws upon syntactic category information and a small set of structural preference principles. Non-syntactic information types, such as animacy, plausibility and frequency of occurrence only influence processing choices in a post-initial stage. From this perspective, (syntactically determined) role identification precedes the (extra-syntactically determined) assessment of role prototypicality. Interactive models, in contrast, assume that all available information types are jointly taken into account from the very first stages of processing (e.g. MacDonald et al. 1994; Trueswell and Tanenhaus 1994). In this type of architecture, the potential role prototypicality of an argument may serve to guide the choice of syntactic structure, hence influencing role identification.

This crucial distinction between the two classes of models can be illustrated on the basis of the sentences in (1) (from Ferreira and Clifton 1986).

(1) Example stimuli from Ferreira and Clifton (1986)
  a. The witness examined by the lawyer turned out to be unreliable.
  b. The evidence examined by the lawyer turned out to be unreliable.

Like the classic garden-path sentence *The horse raced past the barn fell* (Bever 1970), the sentences in (1) involve a syntactic ambiguity between a main-clause (MC) and a relative-clause (RC) reading: the verb *examined* could either be the finite verb of the main clause (as in *The witness examined the evidence*) or the verb of a reduced relative clause (as in 1). The main clause reading is clearly preferred, thus leading to increased processing difficulty when the sentence is disambiguated towards a relative clause analysis (e.g. Rayner et al. 1983). Whereas modular models predict that the initial (mis-)analysis of the sentence (role identification) should be independent of animacy (role prototypicality) and thereby also apply in (1b), interactive models predict that animacy should modulate the preference in the ambiguous region (examined), because of the incompatibility between the initial argument (evidence) and the A role that would be assigned to that argument under a main clause reading. Which of these two scenarios is supported by the data has proved surprisingly controversial (for an overview, see Clifton et al. 2003, and the references cited therein). Crucially for present purposes, however, all existing findings are compatible with the idea that an inanimate first NP reduces the overall difficulty of sentence interpretation in the context of a reduced relative clause. Thus, complex sentence structures become easier to process when the argument roles identified by the syntactic analysis are filled prototypically, that is, when there is a convergence between syntactic and non-syntactic representations.

A similar conclusion was reached by Traxler et al. (2002, 2005) on the basis of a series of experiments that examined the effects of animacy on the processing of object relative clauses (e.g. *The director that the movie pleased . . .* vs. *The movie that the director watched . . .*). It is well-established in the psycholinguistic literature that object relative clauses are more difficult to process (e.g. in terms of reading times, error rates) than subject relatives (e.g. King and Just 1991), with the increased processing costs typically attributed to increased working memory load (e.g. Gibson 1998), increased interference/competition between the two NPs in the relative clause (e.g. Vosse and Kempen 2000; Gordon et al. 2001; Lewis and Vasishth 2005), or to an increase in the number/distance of filler-gap relations (e.g. Frazier 1987; Grodzinsky 2000). However, in contrast to the predictions of all of these approaches, Traxler et al. (2002; 2005) observed in a series of eye-tracking studies that the increased processing difficulty for object relative clauses is attenuated – and in some cases almost completely neutralised – when the head noun is inanimate and the relative clause subject is animate. They interpreted their findings as evidence that role prototypicality (prototypicality of subject- and objecthood in their approach) determines the ease or difficulty with which the processing system can abandon its original preference to equate the relative clause subject with the subject of the main clause. On the basis of very similar findings from Dutch, Mak et al. (2002, 2006) came to the even stronger conclusion that animacy actually serves to guide readers' initial analysis of a relative clause.[1]

In summary, findings such as those by Traxler et al. (2002; 2005) and Mak et al. (2002; 2006) attest to the importance of prominence features such as animacy during sentence processing. They also suggest that such information types play a crucial role in the comprehension of complex constructions such as object relative clauses, the difficulty of which was classically attributed to syntactic or working memory-based factors. Nevertheless, findings such as these do not challenge the traditional division of labour between syntax and semantics: they remain compatible with the notion that the syntax determines role identification, whereas role prototypicality is crucially influenced by non-syntactic information. What remains controversial is the temporal relationship between these two aspects of sentence-level interpretation.

Prominence Features as a Short-Cut to Interpretation?

The status quo of role identification as a syntactic and role prototypicality as a non-syntactic issue has been increasingly challenged in recent years. Specifically, a number of approaches have posited that sentence interpretation may not always be determined by the syntax (e.g. Bever 1970; Townsend and Bever 2001; Ferreira 2003; Kolk et al. 2003; Kim and Osterhout 2005; van Herten et al. 2005, 2006; Ferreira and Patson 2007). The idea is that the processing system does not always (or immediately) establish a complete and accurate representation of the linguistic input with which it is confronted, but that it may rather employ a number of heuristics that serve as quick and efficient shortcuts to interpretation. One famous example of a heuristic is Bever's noun-verb-noun strategy (Bever 1970), according to which the comprehension system (at least in English) prefers an order of Agent-Action-Patient. Sentences deviating from this order (e.g. passives, object relative clauses or object clefts) are therefore prone to being misunderstood (Ferreira 2003).

Crucially for present purposes, several researchers have assumed that animacy information may also be used in a heuristic manner during sentence comprehension, that is, thematic roles may be assigned purely on the basis of an argument's animacy status and independently of the syntax (see, for example, Ferreira 2003, for a discussion of an animacy-based interpretation heuristic). This argument has perhaps been made most forcefully on the basis of a number of recent findings using event-related brain potentials (ERPs). For example, Kim and Osterhout (2005) observed that implausible sentences such as *The hearty meals were devouring* . . . do not engender the electrophysiological response traditionally associated with semantically anomalous sentences (the so-called 'N400'). Rather, they give rise to an ERP signature that is also engendered by syntactic violations (a so-called 'P600').[2] Similar results have been obtained in several other ERP studies (e.g. Kolk et al. 2003; Kuperberg et al. 2003; Hoeks et al. 2004; van Herten et al. 2005, 2006). These 'semantic P600' effects have been interpreted as evidence for a plausibility-based heuristic, which outputs the most plausible combination of verbs and noun phrases. This heuristic is either thought to apply before syntactic analysis (Kim and Osterhout 2005) or in parallel with it (Kolk et al. 2003; van Herten et al. 2005, 2006). Under the first interpretation, the P600 in sentences such as *The hearty meals were devouring* . . . is interpreted as a syntactic violation (because, under the plausible interpretation, the correct form of the participle would be *devoured*), whereas it is viewed as the result of a conflict between the outputs of the plausibility heuristic and the syntactic analysis in the second.

The idea of interpretation heuristics thus calls into question the classic assumption that role identification is primarily determined by the syntax. Rather, it may also be driven by non-syntactic information types, including prominence features such as animacy. While the effects of animacy are most often subsumed under a more general plausibility heuristic (Kolk et al. 2003; Kim and Osterhout 2005; van Herten et al. 2005, 2006), a specific animacy-based assignment of thematic roles has also been proposed (Kuperberg et al. 2003, 2007; Hoeks et al. 2004). Nevertheless, these heuristic processing strategies are mostly not viewed as fully fledged sentence comprehension mechanisms, but rather as surrogate strategies that are applied in lieu of a full syntactic analysis. For this reason, Ferreira and colleagues have subsumed them under the broader cover-term of 'good enough' representations during language processing (see Ferreira and Patson 2007, for a recent review). Hence, while the heuristically based approach differs from the traditional assumptions discussed in the previous section in that it allows non-syntactic information types to determine role identification, it nevertheless maintains a subdivision between syntactic analysis and other types of interpretation processes. Only the former is viewed as providing a complete and accurate analysis of the linguistic input.

Is Prominence Information Indeed Different? Some Cross-linguistic Considerations

In the last two subsections, we introduced two distinct perspectives on the function of prominence information during language comprehension.

The first of these (the 'traditional view') assumes that prominence features such as animacy determine role prototypicality, but not role identification. The second (the 'heuristic view') posits that prominence information may influence role identification (via role prototypicality), but in a qualitatively different manner to syntactic information. In the following, we will provide evidence for a third perspective, namely, for the view that prominence information is an integral part of the form to meaning mapping during language comprehension and that, in this respect, it is functionally equivalent to information types that are typically considered syntactic (e.g. case marking, word order). According to this 'interface view', prominence information influences both role prototypicality and role identification, though not as part of a heuristic.

In this section, we motivate the interface view on the basis of cross-linguistic evidence. Specifically, we will show that, in some languages, features such as animacy may be the primary determinants of role identification, that is, they play a similar role to that of 'syntactic' information types in other languages (e.g. word order in a language like English or case marking in languages like German or Japanese). In the following subsections, we shall then demonstrate how these observations generalise to the domain of language comprehension.

As a basis for the relevant cross-linguistic observations with regard to prominence information, let us return to the notion of natural transitivity that was introduced in the introduction. The concept of natural transitivity in fact forms part of a broader discussion within the typological literature, which is centred around the idea that certain noun phrase types are more likely to play certain roles in a transitive event (i.e. more likely to be in A or P function) than others. This observation is encoded within the so-called 'nominal hierarchy' (also known as the 'referential hierarchy' or 'animacy hierarchy'), which was first proposed by Silverstein (1976) and is shown in Figure 1A.

The nominal hierarchy was introduced to explain 'splits' in case marking patterns, primarily with reference to Australian languages. In particular, Silverstein (1976) assumed that the likelihood for accusative case marking (which applies to P arguments) is highest for noun phrases at the left end of the hierarchy, whereas the likelihood for ergative case marking (which applies to A arguments) is highest for noun phrases at the right end of the hierarchy. (See Figure 1B for a schematic introduction to these different case marking patterns.) This proposal captures the intuition that noun phrases closer to the top of the hierarchy are good agents (i.e. prototypical A arguments), whereas those closer to the bottom of the hierarchy are good patients (i.e. prototypical P arguments), with 'non-typical' functions more likely to be indexed by overt morphological marking.[3] For example, many languages case-mark atypical (i.e. definite/specific or animate) P arguments, whereas typical (i.e. indefinite/unspecific or inanimate) P arguments remain unmarked. This phenomenon, which is illustrated by

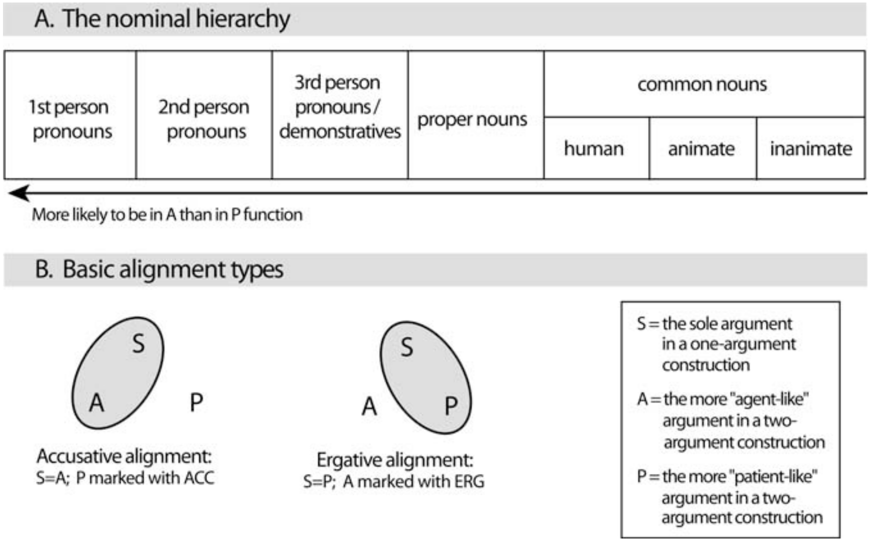

Fig. 1. (A) The nominal hierarchy (Silverstein 1976) in the version given by Dixon (1994, p. 85). (B) A schematic illustration of accusative and ergative alignment systems. In accusative systems, the sole argument of an intransitive event (S; for example, *John* in *John slept*) and the more 'agent-like' (A) argument of a two-argument event (e.g. *John* in *John hit Bill*) are marked in the same way. The more 'patient-like' (P) argument of a two-argument event (*Bill* in the previous example) is marked differently and bears accusative case. In ergative systems, in contrast, S and P arguments are marked similarly, while A arguments are distinguished (bear ergative case). Languages with a case marking 'split' show accusative alignment under certain circumstances and ergative alignment under others. For a comprehensive introduction to the properties of ergative languages and languages with split case-marking systems, see Dixon (1994).

the Turkish examples in (2), is known as 'differential object marking' (Bossong 1985).

(2) Differential object-marking in Turkish (from Erguvanlı 1984, p. 21)
   a. Murat kitabı ok-uyor
      Murat book-ACC read-PROG
      'Murat is reading the book.'
   b. Murat kitap ok-uyor
      Murat book read-PROG
      'Murat is reading a book.' (i.e. Murat is 'book-reading', object is non-referential)

In addition to such examples of additional morphological marking triggered by atypical role assignments (which are quite common across the languages of the world, see Aissen 2003), instances of prominence-driven role identification are also attested. For example, several languages in Papua New Guinea show an animacy-driven mapping between arguments and argument roles, as illustrated in (3) for Awtuw.

(3) Animacy-based argument interpretation in Awtuw (Feldman 1986; cited from de Swart 2007, p. 90)

a.	Tey	tale	yaw	d-æl-i.
	3.F.SG	woman	pig	FAC-bite-PAST
	'The woman bit the pig.' (Not: 'The pig bit the woman.')			
b.	Tey	tale-re	yaw	d-æl-i.
	3.F.SG	woman-OBJ	pig	FAC-bite-PAST
	'The pig bit the woman.' (Not: 'The woman bit the pig.')			

As (3a) shows, sentences in Awtuw require an interpretation that corresponds to the nominal hierarchy in Figure 1, that is, the argument that is higher in animacy must be interpreted as the A-argument (independently of argument order). For the opposite meaning to be expressed, additional morphological marking is required (3b). Hence, in a language like Awtuw, role identification is primarily determined by animacy.[4] Similar observations hold for other languages and other types of prominence features. In Lummi (Straits Salish, British Columbia), for example, the A argument of a transitive active sentence cannot be outranked in person by the P argument (Jelinek and Demers 1983). Thus, a sentence such as **The man knows me/you* cannot be expressed and a passive must be used instead (i.e. *I am/you are known by the man*). In this case, role identification is governed by the person hierarchy (1st/2nd person > 3rd person).

If our research goal lies in the formulation of a universal architecture for language, languages such as Awtuw and Lummi seriously challenge the traditional division of labour between syntax (as governing role identification) and semantics (as responsible for role prototypicality). Rather, we must consider the possibility that there exists an interface between form and meaning that incoporates a variety of different information types (e.g. an argument's position in the sentence, its case marking, animacy, person). Languages differ not with respect to the information types that make up this interface, but rather with respect to the relative weighting that they assign to the interface features. Whereas a feature such as animacy is weighted very highly in Awtuw, thereby determining role identification, it is much less important in English. In theoretical linguistics, this type of perspective has been advocated within Functional Optimality Theory (e.g. Aissen 1999; Bresnan and Aissen 2002). In this context, Bresnan et al. (2001) argued that constraints that are 'hard' (i.e. determine grammaticality) in one language may be 'soft' in another, thereby impacting upon a particular structure's frequency of occurrence. On the basis of a corpus count of spoken English, they showed that passivisation is more likely to occur in English under precisely the same circumstances that render it obligatory in Lummi (i.e. when expressing an event in which a third person acts upon a first or second person). Thus, even though the person hierarchy is not an absolute determinant of A and P identification in

English, it is still reflected in the likelihood of a particular argument being chosen as bearing a particular role. Similar frequency-based arguments have been made for animacy and definiteness (Jäger 2007).

On the basis of observations such as these, we would like to put forward the 'interface hypothesis of incremental argument interpretation', which is stated in (4). Note that, here and in the following, we use 'prominence' as a cover term for (traditionally 'semantic') features such as animacy/definiteness/person as well as (traditionally 'syntactic') features such as case marking and linear order. This is in line with the assumption that all of these information types play a functionally equivalent role for the form-to-meaning mapping during language comprehension.

(4) *The interface hypothesis* of incremental argument interpretation

Incremental argument interpretation (i.e. role identification and assessment of role prototypicality) is accomplished by the syntax–semantics interface, that is, with reference to a cross-linguistically defined set of prominence scales and their language-specific weighting. The relevant prominence scales are:

a. morphological case marking (nominative > accusative / ergative > nominative)
b. argument order (argument 1 > argument 2)
c. animacy (+animate > −animate)
d. definiteness/specificity (+definite/specific > −definite/specific)
e. person (1st/2nd person > 3rd person)

In the following, we review some initial evidence for the interface hypothesis that has emerged from recent neurocognitive studies of sentence comprehension. We first draw upon data from a number of cross-linguistic ERP studies in order to demonstrate that features such as animacy have a qualitatively similar impact upon the assessment of role prototypicality in languages of different types (i.e. across languages with very different relative weightings of animacy information). In a second step, we discuss findings from functional magnetic resonance imaging (fMRI), which provide converging support for the proposed functional equivalence of ('semantic') features such as animacy and ('syntactic') information such as case marking. Note that, with respect to both issues, our arguments are based entirely upon studies using grammatical and plausible sentences. Furthermore, as all critical sentences are unambiguous with respect to grammatical functions, none of the findings discussed are due to the reanalysis of a local ambiguity.

The Neural Correlates of Role Prototypicality

The aim of this section is to show that the neural response to role prototypicality mismatches is qualitatively similar across languages of different types and from different language families. Even more importantly, existing findings suggest that the reaction to prototypicality mismatches involving a particular prominence feature is independent of the weighting of that feature in the language under consideration. We will demonstrate this on the basis of ERP findings on the processing of inanimate A arguments across languages.

In order to examine whether the electrophysiological response to role prototypicality mismatches is qualitatively similar or different across languages with a different weighting of the prominence feature under consideration, we must first have some idea of how to determine feature weightings in a given language. To this end, we can draw upon the comprehensive results on offline argument interpretation in different languages that were gathered in the context of the competition model (e.g. Bates et al. 1982; MacWhinney and Bates 1989). This model envisaged sentence comprehension as a direct form-to-function mapping based on a variety of interacting information types ('cues'; for example, word order, animacy, agreement and stress). The relative importance of a particular cue is language specific and determined via the notion of 'cue validity': a cue that is highly valid in a particular language exerts the strongest influence on interpretation. Cue validity is determined by the combination of 'cue applicability' (which is high when a cue is always available) and 'cue reliability' (which is high when a cue is always unambiguous and never misleading). The interpretation of a sentence (e.g. with respect to the question of which argument is identified as the actor of the event being described) is thought to result from a competition between different cues. As all cues interact directly and only differ in their language-specific weighting, the competition model was the first proponent of an 'interface'-type sentence processing architecture in the sense introduced above.

Experimental studies conducted within the framework of the competition model provide evidence for the relative influence of factors such as word order, agreement, animacy and definiteness in different languages. Animacy, in particular, was shown to be a cross-linguistically applicable cue for the (offline) interpretation of sentential arguments. Furthermore, the degree to which animacy determined argument interpretation varied from language to language: the effects of this feature were relatively weak in English, somewhat stronger in Italian, and relatively strong in German and Mandarin Chinese (MacWhinney et al. 1984; Li et al. 1993). Overall, these studies showed that animacy may determine which argument is interpreted as A and which as P, even in languages in which animacy is not grammaticalised as the primary determinant of role identification (e.g. German and Chinese). However, these experiments were neither suited to revealing the influence of animacy during online sentence interpretation nor to determining whether it may have qualitatively different effects depending on its relative importance in a particular language.

Both of these issues (online processing and possible qualitative differences) can be addressed by examining the effects of animacy on role prototypicality processing using neuroscientific methods. Event-related potentials are particularly well-suited to the question at hand, because they provide a direct measure of the electrical activity of the brain and can therefore reveal neural correlates of language comprehension as a sentence unfolds. They are also multidimensional, thereby revealing possible qualitative differences between effects of interest. For an introduction to the ERP methodology in the context of language processing, see Kutas et al. (2006).

The first electrophysiological investigation of role prototypicality effects was conducted by Weckerly and Kutas (1999) using sentence stimuli such as (5).

(5) Example stimuli from Weckerly and Kutas (1999)
  a. The novelist that the movie inspired praised the director for staying true to the complicated ending.
  b. The movie that the novelist praised inspired the director to stay true to the complicated ending.

Among several other effects, Weckerly and Kutas (1999) observed a central negativity between approximately 200 and 500 ms (N400) for an inanimate (vs. animate) head noun and for an inanimate (vs. animate) A-argument within the relative clause. This finding provided a first indication that the N400, an ERP component that is traditionally associated with lexical–semantic integration (see Kutas and Federmeier 2000), may also be sensitive to role prototypicality mismatches during online comprehension. From this perspective, the initial inanimate NP leads to a mismatch with the preference for the first argument to bear the highest-ranking role in English. The finding of a similar conflict for the second argument, which is unambiguously identified as an A-argument by its structural position, supports this perspective. However, an interpretation along these lines is subject to the caveat that the N400 might also be due to the lexical difference between animate and inanimate nouns.

Several further findings attest to the cross-linguistic stability of the N400 as a correlate of role prototypicality mismatches and to the fact that this effect is not grounded in lexical differences or the infrequency of inanimate subjects. Consider the following German examples (from Frisch and Schlesewsky 2001; Roehm et al. 2004):

(6) Example stimuli from Frisch and Schlesewsky (2001)
Paul fragt sich, . . .
Paul asks himself, . . .

a. . . . welchen Angler	der Jäger	gelobt	hat.
. . . [which angler]:ACC	[the hunter]:NOM	praised	has.
'. . . which angler the hunter praised.'			
b. . . . welchen Angler	der Zweig	gestreift	hat.
. . . [which angler]:ACC	[the twig]:NOM	brushed	has.
'. . . which angler the twig brushed.'			

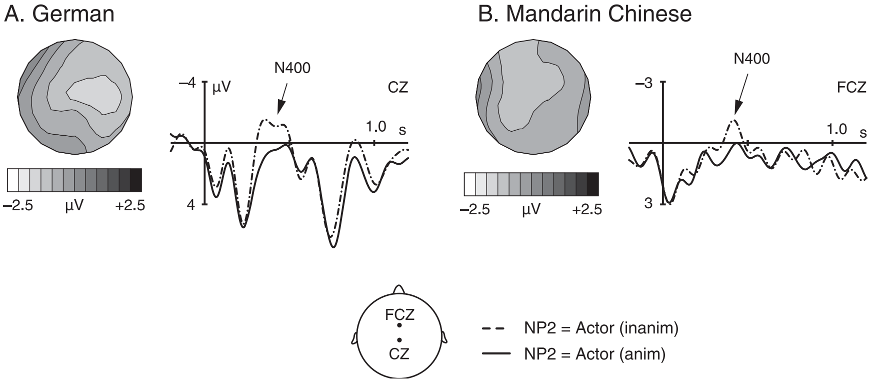

Fig. 2. Grand average event-related brain potentials at the position of inanimate (dash-dotted line) vs. animate (solid line) A arguments following a P argument in German (A) and Mandarin Chinese (B). The data are taken from Roehm et al. (2004) and Philipp et al. (2008), respectively. In each case, the onset of the critical argument is signalled by the vertical bar and negative voltage is plotted upwards. The topographical maps depict the scalp distribution of the N400 effect at its maximum (inanimate NP – animate NP). Note that the study on German employed visual stimulus presentation, while the stimuli in the experiment on Mandarin Chinese were presented auditorily.

In a reanalysis of Frisch and Schlesewsky's (2001) data (in which sentences such as (5) served as control stimuli for another manipulation), Roehm et al. (2004) found an N400 for inanimate vs. animate nominative arguments following an initial accusative [e.g. *der Zweig*, 'the twig', in (6b) vs. *der Jäger*, 'the hunter', in (6a); see Figure 2A]. In contrast, in an experiment using the identical sentence stimuli, no comparable effect was observed for initial inanimate nominatives (Ott 2004; see Schlesewsky and Bornkessel 2004). Similar findings have been reported for Tamil, a Dravidian language spoken in southern India, in a study that employed a within-experiment control of animacy at the position of the first and second arguments (Muralikrishnan et al. 2008). These observations indicate that the N400 in (6b) is neither due to a lexical difference between animate and inanimate nouns nor to a principled mismatch between inanimacy and nominative case marking or to the infrequency of inanimate nominative arguments. Rather, it suggests that the role prototypicality mismatch effect results when the language comprehension system is confronted with an A argument after it has already processed a P argument. This might be due to the fact that, at the position of an initial nominative in German, the processing system cannot unambiguously identify this argument as an A. Rather, it could also be the only argument in an intransitive construction (abbreviated as 'S' in the A/P-terminology; see Figure 1), or even the P argument in a transitive construction.[5] Hence, a nominative NP is only clearly recognisable as an A argument after an accusative-marked NP has already been processed. Perhaps effects of role prototypicality therefore only show up at this point.

The interpretation of the N400 effects for atypical role assignments can be fine-tuned even further on the basis of recent results from Mandarin Chinese. Chinese is fundamentally different from all of the languages discussed so far (English, German and Tamil) in that role identification is governed neither by word order (as in English) nor by morphological case marking (as in German and Tamil). One might therefore expect effects of animacy to be particularly strong in a language of this type. The effects of animacy on argument interpretation in Chinese were examined in an ERP study (Philipp et al. 2008) using sentences such as (7).

(7) Example stimuli from Philipp et al. (2008)

a.	王子	被	挑战者	刺死	了。
	wáng zǐ	bèi	tiǎo zhànzhě	cì sǐ	le
	Prince	bèi	contender	stab	PERF
	'The prince was stabbed by the contender.'				
b.	王子	被	绳子	勒死	了。
	wáng zǐ	bèi	shéng zi	lēi sǐ	le
	Prince	bèi	cord	strangle	PERF
	'The prince was strangled by the cord.'				

The examples in (7) illustrate the so-called bèi-construction in Mandarin Chinese, which is often described as a passive-like construction.[6] Crucially for present purposes, the coverb bèi unambiguously identifies the first argument as the lower-ranking argument in a transitive relation, thus leading to an analogous comprehension situation to that in the German examples in (6). Just as in German, the processing of an unambiguous inanimate A argument following a P argument gave rise to an N400 effect in Mandarin Chinese (Philipp et al. 2008; see Figure 2B). This finding is particularly informative for the interpretation of the 'role prototypicality N400' for several reasons. First, using further experimental conditions (e.g. 小刀被挑战者拿走了。'The knife was taken away by the contender.'), Phillip and colleagues also contrasted animate and inanimate NPs in the sentence-initial position and found no difference in terms of ERPs. This observation therefore again shows that the effect in question does not result from simple animacy differences at the single argument level. (Note that the choice of lexical items was balanced across lexical sets such that, over all trials, the same groups of animate and inanimate nouns were contrasted at NP1 and NP2 positions.) Second, Philipp et al. also examined constructions with an A-before-P order such as (8).

(8) Example stimuli from Philipp et al. (2008)

a.	王子	把	挑战者	刺死	了。
	wáng zǐ	bǎ	tiǎo zhànzhě	cì sǐ	le
	Prince	bǎ	contender	stab	PERF
	'The prince stabbed the contender.'				

b.	小刀	把	挑战者	刺死	了。
	xiǎo dāo	bǎ	tiǎo zhànzhě	cì sǐ	le
	Knife	bǎ	contender	stab	PERF

'The knife stabbed the contender.'

Like bèi, the coverb bǎ makes clear that the event being described is transitive. However, in contrast to bèi, it calls for an interpretation of the first NP as the A and the second NP as the P argument. Interestingly, Philipp et al. (2008) did not observe animacy-based N400 effects in these constructions, neither at the position of bǎ (at which point it becomes clear that the first argument is an A rather than an S) nor at the position of the second argument (at which point the relation between A and P becomes clear). These results thus suggest that the N400 for atypical A arguments only occurs when the A is encountered after a P. This interpretation was corroborated by an additional experiment (Philipp et al. 2008, Experiment 2), in which the order of the arguments was reversed by the use of relative clause constructions (e.g. 把挑战者刺死了的小刀褪色了。lit: bǎ contender stab-PERF de knife bleach-PERF, '*The knife that stabbed the contender was bleached*.'). At the position of the head noun (e.g. *knife*), an N400 was observed for inanimate vs. animate head nouns (i.e. for inanimate A arguments encountered after a P argument) in exactly the same bǎ-constructions that did not engender such an effect when the A argument preceded the P argument.

When taken together, the results discussed in the preceding paragraphs provide evidence for the following four claims:

(i) *Atypical role assignments are reflected in N400 effects*. In terms of ERPs, atypical role assignments are reflected in modulations of N400 components.

(ii) *Verb-independence*. As these effects are observable prior to the verb, they attest to the verb-independence of role prototypicality assessment, that is, to an abstract, verb-independent notion of A and P roles.

(iii) *Relationality*. Role prototypicality processing does not simply involve the matching of an argument's features to a particular role prototype (e.g. A). If this were the case, we should observe N400 effects whenever an atypical A argument is processed. However, inanimate A arguments only engender an N400 when they follow a P argument. This suggests that the precise nature of the relation between the A and the P argument is somehow involved in giving rise to this effect (see below for a more precise interpretation). In addition, the asymmetry of the effect (i.e. the 'A-after-P' requirement) indicates that it cannot be reduced to the degree of lexical fit (or semantic association) between the arguments.

(iv) *Cross-linguistic generalisation*. The N400 effects for role prototypicality mismatches are qualitatively similar across a range of typologically different languages from different language families. Moreover, previous behavioural results show that the languages discussed here differ considerably with respect to the relative weighting of animacy as a cue to role identification (MacWhinney et al. 1984; Li et al. 1993). This observation suggests that the neural response to role prototypicality mismatches is, at least to some degree, independent of the weighting of a particular prominence feature within the language under consideration. (For a summary of the status of animacy in the languages discussed in this section, see Table 1).

In summary, the cross-linguistically stable finding of N400 effects for role prototypicality mismatches in grammatical and plausible sentences provides converging support for the interface view: it shows that the brain's reaction to a particular dimension of prominence is independent of that dimension's language-specific weighting/degree of grammaticalisation. This observation speaks against the assumption of functionally separable roles for syntactic and non-syntactic features during sentence processing. It also calls into question whether prominence features such as animacy exert a 'heuristic' influence on role identification that is qualitatively distinguishable from a full, algorithmic syntactic analysis.

Prominence Features and the Syntax-Semantics Interface: Additional Neurocognitive Evidence

Having shown qualitatively similar responses to prominence mismatches across different languages, we now turn to further neurocognitive findings that attest to a qualitatively similar treatment of features such as animacy (traditionally classified as semantic) and case marking (traditionally classified

Table 1. The language-specific impact of animacy in the languages discussed in the present article (English, German, Tamil and Mandarin Chinese). For the notion of cue strength (cue validity) within the competition model, please see the explanation in the main text. Morphosyntactic relevance refers to whether the language in question has any grammatical rule that makes reference to animacy; this is only the case in Tamil, which only case-marks animate (or specific) direct objects (see (2) for an example of differential object marking).

Language	Cue strength within the competition model	Morphosyntactic relevance	Can determine role identification	ERP correlate of role prototypicality mismatch
English	Low	No	No	N400
German	Relatively high	No	Yes	N400
Tamil	–	Yes	No	N400
Chinese	Relatively high	No	Yes	N400

as syntactic). To this end, we first focus on a particularly clear example of such a correspondence, namely, on the neuroanatomical correlates of word order variations in German. We then go on to discuss a possible neural locus for prominence-based assignments of argument roles (A/P). All of the findings discussed in this section stem from experiments using fMRI, a method that can reveal stimulus- or task-related changes in the activation of neural regions based on relative blood oxygenation. In contrast to electroencephelographic/ERP data, fMRI offers a very high spatial resolution, thereby allowing for the precise localisation of brain functions. However, its temporal resolution is relatively poor due to the delay of the haemodynamic response. For an introduction to fMRI as applied to sentence and discourse processing, see Bornkessel-Schlesewsky and Friederici (2007).

From the earliest neuroimaging studies on language processing onwards, it has been recognised that sentences with an object-before-subject order engender increased activation in Broca's region in the left inferior frontal gyrus (IFG) (Just et al. 1996; Stromswold et al. 1996 and many subsequent findings, see Caplan 2007, for a review). While this finding was first demonstrated for complex constructions (relative clauses) in English, it has also been observed in simple declarative sentences in languages with a more flexible word order (e.g. German, Röder et al. 2002 and Hebrew, Ben-Shachar et al. 2004). For example, Röder et al. (2002) observed that German sentences with an object-before-subject order (e.g. 9a) engender increased activation in the pars opercularis of the left IFG in comparison to subject-initial sentences (9b). The location of the pars opercularis is shown in Figure 3.

(9) Example stimuli from Röder et al. (2002)

a.	Jetzt	wird	dem	Forscher	den Mond	der Astronaut	beschreiben.
	now	will	[the	scientist]: DAT	[the moon]: ACC	[the astronaut]: NOM	describe

'Now the astronaut will describe the moon to the scientist.'

b.	Jetzt	wird	der	Astronaut	dem Forscher	den Mond	beschreiben.
	now	will	[the	astronaut]: NOM	[the scientist]: DAT	[the moon]: ACC	describe

'Now the astronaut will describe the moon to the scientist.'

Whereas Röder et al. (2002) employed a binary contrast, subsequent research revealed that the activation of the pars opercularis can be modulated parameterically as a function of the number of deviations from the basic word order NOM > DAT > ACC (Friederici et al. 2006).

At a first glance, findings such as these appear to lend themselves to a syntactic explanation. For example, one might attribute the increased activation of the pars opercularis to the requirement for additional movement

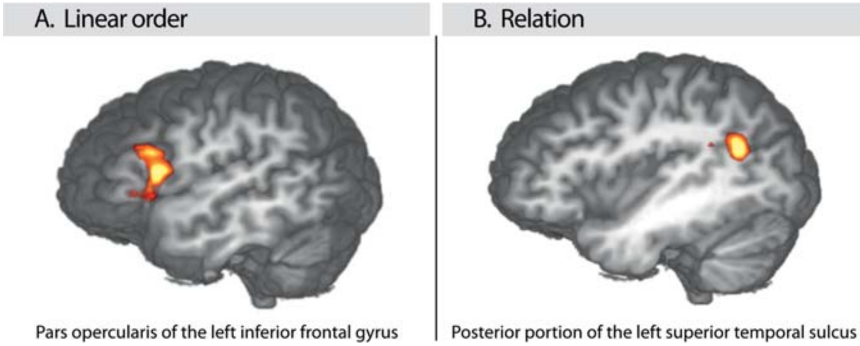

Fig. 3. Brain regions involved in the processing of prominence information. The left panel shows activation in the pars opercularis of the left inferior frontal gyrus, that is, a subportion of 'Broca's region' in the inferior posterior part of the left frontal lobe. The pars opercularis shows increased activation whenever there is a mismatch between argument prominence and linear order. The right panel shows activation in the left posterior superior temporal sulcus, that is, a subportion of 'Wernicke's area' in the posterior part of the left temporal lobe. Activation in this region is observable when the A argument does not outrank the P argument in terms of all available dimensions of prominence (irrespective of the linear order of the arguments). The data are from Grewe et al. (2007).

operations, which derive the permuted word order from the basic word order (e.g. Grodzinsky and Friederici 2006). Alternatively, the activation might reflect the increased load on working memory that is required to support these syntactic operations (e.g. Fiebach et al. 2005). In contrast to these assumptions, however, a series of neuroimaging studies on German has shown that word order-related activation differences within the pars opercularis are not due to the presence of an object-initial order in and of itself, but rather to the application of several prominence scales and their mapping onto linear argument order. Notably, object-initial orders no longer elicit an activation increase within the pars opercularis when the object is rendered more prominent than the subject on some dimension other than grammatical function/case marking, for example, when the object is a pronoun and the subject is a definite noun phrase (Grewe et al. 2005) or when the grammatical object is the A argument and the subject the P argument (Bornkessel et al. 2005; see example (11) below, for an illustration of sentences of this type). These observations are difficult to reconcile with the assumptions of purely syntactic accounts.

Perhaps even more strikingly, it has been demonstrated that subject-initial orders can engender increased activation within the pars opercularis in comparison to their object-initial counterparts under certain circumstances. This is the case, for example, when an inanimate nominative subject precedes an animate dative object, thereby violating the preferred linearisation animate-before-inanimate (Grewe et al. 2006). The application of different prominence hierarchies in these sentences is summarised in Table 2, which also provides sentence examples.

The findings by Grewe et al. (2006) provide strong converging evidence that features such as animacy play a functionally similar role to information such as case marking in the processing of argument order permutations in German. Both types of features modulate activation of the same neural substrate (the pars opercularis of the left IFG) and, in doing so, appear to interact directly with one another. In addition, a comparison of the Grewe et al. (2006) data with the findings from a further experiment, which examined the effects of animacy in nominative-accusative structures (Grewe et al. 2007), revealed that animacy only modulates word order-related activation in the pars opercularis in sentences with dative – rather than accusative – objects. This suggests that it is not the inanimacy of the initial argument per se that engenders the activation increase, but rather the relational assessment of both arguments in comparison to one another (see the section on modelling below for a discussion of why the effects of animacy should be confined to constructions with dative case marking). The pars opercularis thus appears to function as an interface between argument prominence computation (which, as we have argued, is central to the interpretation of transitive sentences) and sequential order (which is an inherent feature of linguistic utterances). Furthermore, as we have argued recently, this notion of a relational word order processing mechanism that serves to assess the prominence status of the first argument in relation to (possible) upcoming arguments can also account for cross-linguistic electrophysiological findings on the processing of word order permutations (Wolff et al. 2008).

In addition to the pars opercularis of the left IFG, which plays a crucial role in prominence-based argument linearisation, we have identified a second cortical region that appears to be involved in the processing of prominence information during sentence comprehension, namely, the posterior portion of the left superior temporal sulcus (pSTS). The location of this region is depicted in Figure 3. Increased activation in the pSTS arises whenever the A-argument does not outrank the P-argument in terms of some dimension of prominence. This has been demonstrated for both animacy (Grewe et al. 2006, 2007) and definiteness/specificity (Bornkessel-Schlesewsky, I., M. Schlesewsky, and D. Y. von Cramon, submitted for publication). For example, sentences like (10a), in which both the A and the P arguments are animate and definite, engender increased activation in this region in comparison to sentences like (10b), in which the A-argument is animate and the P-argument is inanimate. Note that this activation difference is unlikely to be due to a difference of animacy at the word level (i.e. to the processing of two animate arguments as opposed to one animate and one inanimate argument) as this is known to engender activation differences in other neural regions (for a detailed discussion, see Grewe et al. 2006).

Table 2. Example sentences from Grewe et al. (2006) and their classification in terms of relevant prominence scales. The case scale refers to the preference for nominative arguments to precede non-nominative arguments (which, in German, corresponds to the preference for a subject-first order). The thematic hierarchy refers to the preference for higher-ranking argument roles to precede lower-ranking argument roles (i.e. for A-arguments to precede P-arguments). The animacy scale refers to the preference for animate arguments to precede inanimate arguments. The fulfilment of a particular prominence scale is marked with a '+' whereas its violation is marked with a '–'. 'N/A' (not applicable) indicates that the animacy scale is not applicable in sentences with two animate arguments. Grewe et al. (2006) found that, while conditions A and B did not differ from one another in terms of pars opercularis activation, condition D engendered increased activation in comparison to condition C in this region. This pattern can be explained with reference to the application of the different prominence scales: conditions A, B and C violate one scale each, thereby not engendering activation differences (cf. Bornkessel et al., 2005), whereas condition D violates two. Thus, the increased activation for condition D can be attributed to the additional violation of the animacy scale. (Note that these findings cannot be explained via differences in sentence acceptability or frequency of occurrence. See Kempen and Harbusch 2005 for a corpus count involving these types of sentences.)

Common sentence lead-in:
Dann wurde . . .
Then was . . .

Condition	Example			Case	Thematic hierarchy	Animacy
A. DAT-AN NOM-AN	dem Arzt [the doctor]:DAT 'The policeman was introduced to the doctor.'	der Polizist [the policeman]:NOM	vorgestellt introduced	–	+	N/A
B. NOM-AN DAT-AN	der Polizist [the policeman]:NOM 'The policeman was introduced to the doctor.'	dem Arzt [the doctor]:DAT	vorgestellt introduced	+	–	N/A
C. DAT-AN NOM-IN	dem Arzt [the doctor]:DAT 'The coat was stolen from the doctor.'	der Mantel [the coat]:NOM	gestohlen stolen	–	+	+
D. NOM-IN DAT-AN	der Mantel [the coat]:NOM 'The coat was stolen from the doctor.'	dem Arzt [the doctor]:DAT	gestohlen stolen	+	–	–

(10) Example stimuli from Grewe et al. (2007)

a. Wahrscheinlich hat der Mann den Direktor gepflegt.
Probably has [the man]:NOM [the director]:ACC cared.for
'The man probably took care of the director.'

b. Wahrscheinlich hat der Mann den Garten gepflegt.
Probably has [the man]:NOM [the garden]:ACC cared.for
'The man probably took care of the garden.'

These findings provide a first indication that the pSTS may be crucially involved in the assessment of role prototypicality during language comprehension. Interestingly, an interpretation along these lines is highly compatible with the observation that this region (or its right-hemispheric homologue) is also involved in the inference of agency (Frith and Frith 1999) and the processing of goal-directed action (Saxe 2006) in non-linguistic tasks. The pSTS thus appears to provide an interface between the comprehension of (linguistically expressed) transitive events and more general cognitive mechanisms for the processing of goal-directed actions involving human participants.

The importance of the left pSTS for the processing of A and P roles is supported by further findings. In an fMRI study, Bornkessel et al. (2005) examined German verb-final sentences that were either unambiguously case-marked or locally case ambiguous, subject- or object-initial and included either a dative active verb (calling for a nominative A argument and a dative P argument) or an object-experiencer verb (calling for a dative A argument and a nominative P argument). Examples of the case-marked sentences are given in (11).

(11) Gestern wurde erzählt, . . .
yesterday was told . . .
'Yesterday, someone said . . .'

a. . . . dass der Junge den Lehrern hilft/auffällt
. . . that [the boy]:NOM [the teachers]:DAT helps/is.striking.to
'. . . that the boy helps the teachers.' / '. . . that the teachers find the boy striking.'

b. . . . dass dem Jungen die Lehrer helfen/auffallen
. . . that [the boy]:DAT [the teachers]:NOM helps/are.striking.to
'. . . that the teachers help the boy.' / '. . . that the boy finds the teachers striking.'

In the left pSTS, Bornkessel et al. (2005) observed a three-way interaction between case marking, word order and verb type: for case-marked sentences, this region showed increased activation when there was a mismatch between verb type and word order such that the P-argument preceded the A-argument. In other words, sentences with active verbs (e.g. *helfen*, 'to help') showed increased activation for dative-initial (11b) vs. nominative-initial (11a) sentences, whereas objext-experiencer verbs (e.g. *auffallen*, 'to be striking to') showed increased activation for nominative-initial (11a) vs. dative-initial sentences (11b). Assuming, as suggested by the interface hypothesis (4), that the language comprehension system uses information such as case marking and word order to assign A and P roles to the arguments of a sentence, the pSTS activation in this study can be viewed as a result of the mismatch between these verb-independent cues to A/P assignments and the A/P assignments called for by the verb. The information that one argument bears nominative whereas the other bears dative case indicates that, as there were no animacy differences between the arguments, either argument can be A or P. If word order is drawn upon to arbitrate, it should lead to a higher likelihood for an A-analysis of the first argument, that is, for the nominative in nominative-initial sentences and for the dative in dative-initial sentences. When this assumption is disconfirmed by the clause-final verb, increased activation arises in the pSTS. This observation suggests that the pSTS is not only involved in the assessment of role prototypicality, but also in the online processing of role identification. Furthermore, just like the pars opercularis of the left IFG, this region is sensitive to (semantic) features such as animacy and definiteness/specificity (Grewe et al. 2007; Bornkessel-Schlesewsky, Schlesewsky and van Cramon, submitted for publication) as well as to (syntactic) information types such as case marking and word order. This finding provides further converging support for the interface hypothesis.

In summary, functional imaging results have revealed that the processing of prominence information in sentence comprehension draws upon a left-lateralised fronto-temporal neural network comprising the pars opercularis of the IFG and the posterior superior temporal sulcus. This assumption is further supported by data from English, which has shown that animacy information serves to modulate (or even neutralise) the activation of Broca's region in the processing of object relative clauses, in addition to influencing activation in left posterior superior temporal regions (Chen et al. 2006). Existing findings thus suggest that the pars opercularis is particularly involved in mapping prominence information onto linear order, with a general preference for more prominent arguments to precede less prominent arguments. The pSTS, in contrast, engages in the relational construction of an argument hierarchy, with a preference for natural transitivity (i.e. for the A-argument to outrank the P-argument on all available dimensions of prominence).

Modelling the Influence of Prominence Information in Language Comprehension

Having reviewed the available evidence for the application of prominence information during online sentence comprehension, we will now sketch out a model of how this information is applied in the comprehension process. As a point of departure, let us consider why prominence scales might be useful for real time language processing. From our perspective, the primary functional motivation for the online application of these information types is that they allow for the establishment of an interpretive relation between the arguments independently of the verb. Given that verb-final word orders are very frequent in the languages of the world (i.e. subject-object-verb is the most frequent basic word order; Dryer 2005), this is an essential prerequisite for efficient communication: it serves to guarantee that interpretation is not delayed until the verb.

ROLE IDENTIFICATION AND ROLE PROTOTYPICALITY ASSESSMENT: VERB-INDEPENDENT AND VERB-BASED CONSIDERATIONS

The question of how incremental interpretation proceeds in verb-final structures provided a crucial point of departure for the model to be introduced in this section, the extended Argument Dependency Model (eADM; Bornkessel 2002; Schlesewsky and Bornkessel 2004; Bornkessel and Schlesewsky 2006a; Bornkessel-Schlesewsky and Schlesewsky 2008a). The latest version of the model architecture is shown in Figure 4. The eADM assumes that incremental argument interpretation involves the assignment of the generalised semantic roles 'actor' and 'undergoer'.[7] These roles, which correspond to the Agent- and Patient-prototypes, respectively, subsume individual thematic roles such as agent/effector/causer/experiencer (actor) and patient/theme/stimulus (undergoer) (Van Valin 2005). Following Primus (1999), actors are prototypically sentient, cause the event described and are also (consciously) in control of it. The difference between a controlling and a non-controlling actor is illustrated in (12): the adverb *absichtlich* (deliberately) can only be inserted when the actor bears nominative case (12a), but not when it is marked with dative (12b).

(12)	a.	Ich	habe	die Vase	(absichtlich)	zerbrochen.
		1SG.NOM	have	[the vase]:ACC	(deliberately)	broken
		'I (deliberately) broke the vase.'				
	b.	Mir	ist	die Vase	(*absichtlich)	zerbrochen.
		1SG.DAT	is	[the vase]:NOM	(deliberately)	broken
		'~ The vase (*deliberately) broke on me.'				

In contrast to actors, undergoers have no defining prototypical features of their own. Rather, they are the opposing counterparts of actor arguments, that is, they are the target of sentience, causally affected by an event and controlled. Hence, undergoers are best characterised in terms of their dependence on an actor. Another way of describing this crucial difference between actors and undergoers is in terms of the notion of independent

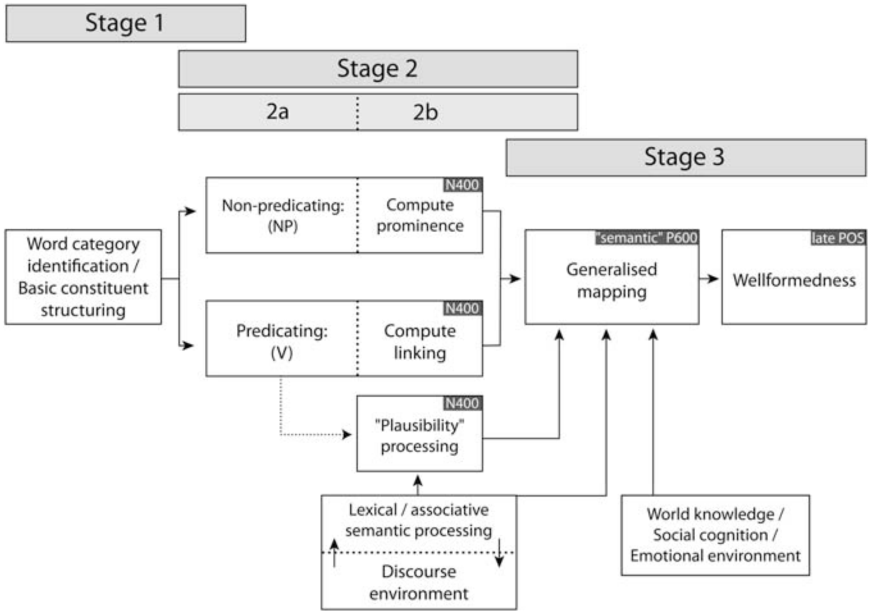

Fig. 4. The architecture of the latest version of the extended Argument Dependency Model (eADM; Bornkessel-Schlesewsky and Schlesewsky 2008a).

existence: whereas actors exist independently of the event being described, undergoers need not. These ideas, which are based on Primus (1999), are summarised in Figure 5A, which also outlines the relationship between actor/undergoer properties and prominence features such as animacy. In brief, animacy is closely related to actorhood, because it is entailed by both (conscious) control/volition and by sentience. Definiteness/ specificity, in contrast, is related to the actor property of independent existence, which goes hand in hand with specific reference (see Primus 1999).

The eADM posits that, during online language comprehension, actor and undergoer roles are assigned to arguments on the basis of prominence information. This is accomplished by the COMPUTE PROMINENCE step in stage 2 of processing (see Figure 4). Note that prominence information in this sense encompasses all of the information types listed in (4) and shown in Figure 5: features such as animacy and definiteness/specificity, but also morphological case marking and linear order. In accordance with the interface hypothesis, these different information types are considered functionally equivalent and collectively serve the dual purpose of role identification (which argument is the actor and which is the undergoer?) and role prototypicality assessment (how prototypical are the actor and undergoer arguments?).

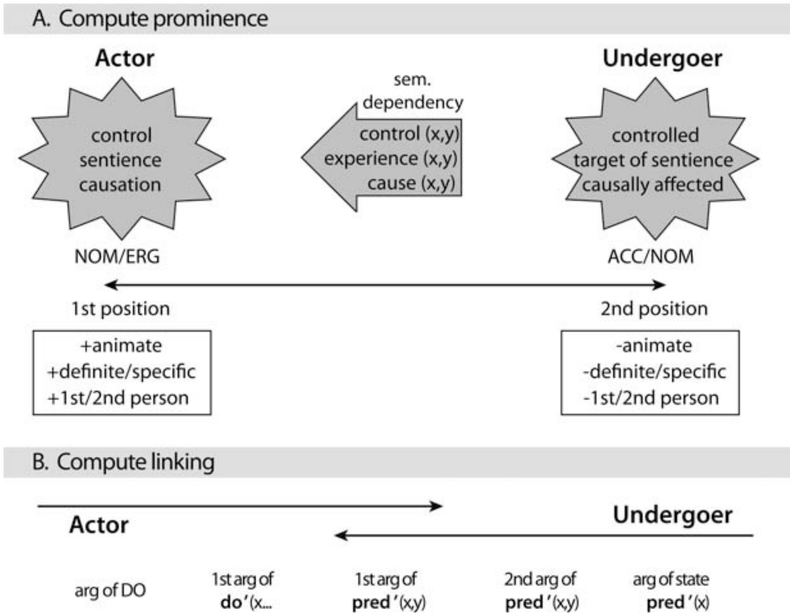

Fig. 5. An illustration of the representational assumptions about the generalised roles actor and undergoer within the eADM. Part (A) depicts the prototypical role properties, their correlates in the domain of prominence information, and the semantic dependency between undergoers and actors (cf. Primus 1999). Part (B) shows the actor-undergoer selection hierarchy, which shows how role identification and role prototypicality are related to the logical structure of the verb (cf. Van Valin 2005).

Languages differ with respect to how they rank the different dimensions of prominence and as to where they place the cut-off point between role identification and role prototypicality assessment. Consider English as a simple example. Here, role identification is strictly determined by an argument's position in the sentence: *The cricket ball hit Bill* cannot mean that Bill hit the ball in spite of that fact that *the cricket ball* is a non-prototypical actor. (Of course, an initial argument can also be the undergoer in English, for example, in a passive. Here too, however, role identification is accomplished via argument position.) In case-marking languages like German, the situation quickly becomes somewhat more complex, that is, more information types need to be taken into account for role identification. In a transitive German sentence with a nominative and an accusative argument, the argument hierarchy is fixed: the nominative argument must be mapped onto the actor and the accusative argument must be mapped onto the undergoer. In sentences with a nominative and a dative argument, in contrast, the relation is more flexible, that is, both cases can, in principle, map onto either the actor or the undergoer argument (with dative-marked arguments always signalling a deviation from a prototypical actor or undergoer).[8] Under these circumstances, animacy information steps in: with an animate dative and an inanimate nominative [as in example (12)], the nominative is now preferentially mapped onto the undergoer-argument rather than the actor-argument (see Schlesewsky and Bornkessel 2004). Thus, depending on the type of case information available, animacy may or may not be involved in determining role identification. The cut-off point between the information types used for role identification and role prototypicality assessment in the COMPUTE PROMINENCE step may thus vary not only from language to language, but also from construction to construction.

The assessment of role prototypicality in the COMPUTE PROMINENCE step is based on the following assumption: actors are atypical if, for some reason, they are not compatible with the properties listed in Figure 5A (e.g. an actor that is identified as such via case marking or position is non-prototypical if it is inanimate because it cannot, by definition, be sentient or consciously controlling). Undergoers, in contrast, do not have any defining properties of their own (as outlined above). Hence, they cannot be non-prototypical in the same way as actors. They can, however, possess actor properties (e.g. animacy, which entails the capacity for sentience and conscious control, see Holisky 1987; Van Valin and Wilkins 1993; Primus 1999). Under these circumstances, the undergoer competes with the actor, thereby engendering increased processing cost. This assumption is captured by a principle termed 'Distinctness', which is given in (13).

(13) *Distinctness* (Bornkessel-Schlesewsky and Schlesewsky 2008 b,c)
The participants in an event should be as distinct as possible from one another in terms of all available dimensions of prominence.

According to Distinctness, transitive relations are easiest to process when the two arguments do not overlap with respect to actor properties, that is, when the actor is animate and definite and the undergoer is inanimate and indefinite. In addition, Distinctness can derive the preference for intransitive interpretations that have been observed in a number of studies (i.e. the tendency to analyse the first argument as the sole participant in an intransitive event), as the simplest way to be distinct is to be the only argument (for discussion, see Bornkessel-Schlesewsky and Schlesewsky 2008 b,c). When an intransitive reading cannot be upheld (e.g. because the processing system has encountered an initial accusative argument), Distinctness will lead the processing system to assume non-overlapping roles. Because processing problems in the COMPUTE PROMINENCE step engender N400 effects (see Figure 4), this accounts for the N400 effects observed at the position of inanimate actors following undergoers, as the inanimacy of the actor contrasts with the Distinctness-based prediction that the actor will be prototypical.

In principle, this proposal is in line with a number of approaches that have emphasised the role of similarity-based interference in language comprehension, noting that sentences become more difficult to process when arguments have overlapping features (cf. Lewis et al. 2006; McElree 2006; Lee et al. 2007; and the references cited therein). However, due to the generalised role representations assumed here, the Distinctness principle differs from current models of interference during language processing in an interesting way: because of the dependency between actors and undergoers, interference is generally predicted to be 'actor-centred'. Thus, only actor properties are deemed important for generating interference between arguments, rather than all possible sources of similarity between them. This essentially leads to three possible scenarios that may lead to increased processing cost in the COMPUTE PROMINENCE step: (a) a non-prototypical actor; (b) interference arising from two arguments with actor properties; and (c) no arguments with actor properties. The first of these cases is difficult to examine in nominative-accusative languages because of an initial nominative's inherent ambiguity between an S and an A reading (see Figure 1). However, ERP findings from Hindi, a split-ergative language, suggest that clause-initial inanimate ergative arguments (which are unambiguous A arguments) engender N400 effects (Choudhary et al. 2007). Likewise, as discussed in detail above, inanimate actors following undergoers engender N400 effects in German, Tamil, Chinese and English; the findings from Chinese and Tamil further suggest that these effects occur both with an inanimate actor and an animate undergoer (an instance of scenario (b), that is, increased competition for the actor role) and with two inanimate arguments (an instance of scenario (c), that is, no arguments that qualify as prototypical actors). These observations suggest that similar processing mechanisms may be operative for the three scenarios outlined above. Nevertheless, the results from Chinese (Philipp et al. 2008) and Tamil (Muralikrishnan et al. 2008) provide initial evidence for an exceptional status of constructions with two inanimate arguments, which engendered additional effects in both studies. Hence, scenarios (b) and (c) may differ from one another after all – as predicted by the notion that Distinctness effects are 'asymmetric' in the sense that they are actor-centred. However, this assumption requires further empirical investigation. At present, the cross-linguistic data are well-captured by the eADM's claim that increased processing costs in the COMPUTE PROMINENCE step are essentially actor-oriented and manifest themselves in N400 effects.

The representations assigned to the arguments by COMPUTE PROMINENCE are subsequently mapped onto the lexical entry of the verb, once this constituent is encountered (COMPUTE LINKING in Figure 4).[9] The eADM assumes that the verb-specific restrictions on this linking process are encoded in a decomposed lexical representation, the 'logical structure' (LS). The LS representations within the model are adopted from Role and Reference Grammar (Van Valin 2005). For example, the LS of a highly agentive verb such as *kill* is *do'*(*x*, CAUSE (*x*, BECOME(*dead'*(*y*)))), thereby encoding both the number of arguments (two) and their relation to one another (*x* is higher-ranking than *y*). The correspondence between the actor and undergoer roles and an argument's position within the LS is shown in the actor-undergoer hierarchy in Figure 5B (from Van Valin 2005). Crucially, this hierarchy not only governs which positions in the LS may map onto the actor and undergoer roles, but also how prototypical these mappings are. Whereas a verb like *kill* has both a highly prototypical actor (an argument of the activity predicate *do'*) and a highly prototypical undergoer (an argument of *pred'*(*x*)), a stative psych-verb like *love* calls for two less prototypical role assignments [the actor is the first argument of *pred'*(*x,y*), whereas the undergoer is the second argument of *pred'*(*x,y*). On the basis of these representational assumptions, the eADM predicts increased linking costs whenever the assumptions about role identification and role prototypicality made prior to the verb do not straightforwardly map onto the verb's LS. This conjecture is supported by ERP findings from German (Bornkessel et al. 2003b) and Turkish (Demiral et al., in preparation), which have shown early parietal positivities and N400 effects at the position of the verb for a disconfirmation of prior assumptions about role identification and role prototypicality, respectively. We have argued that these findings are best explained via a predictive mechanism, which uses the role representations assigned to the arguments to anticipate properties of an upcoming verb (Demiral et al., submitted for publication). Hence, just like verbs provide rich predictive information about upcoming arguments in languages/constructions in which they are available early (e.g. Altmann and Kamide 1999; Kamide et al. 2003), argument properties constrain predictions about upcoming verbs in verb-final constructions.

CONSEQUENCES FOR THE LANGUAGE PROCESSING ARCHITECTURE

In the previous section, we introduced the 'centrepieces' of the eADM: COMPUTE PROMINENCE and COMPUTE LINKING. These processing steps jointly ensure that arguments and verbs can be combined to form a sentence-level meaning. Interestingly, the specification of these two crucial mechanisms places further constraints on the overall processing architecture.

A first prerequisite for the applicability of COMPUTE PROMINENCE and COMPUTE LINKING lies in the early identification of word category. For example, in order for prominence scales to become applicable, the word category of the current input item must have been identified and classified as non-predicating (i.e. typically as a noun phrase).[10] This is essential, as prominence computation in the sense described here only applies to arguments and not to verbs. Predicating constituents (typically verbs), in contrast, initiate a linking mechanism by means of which the prominence-based argument hierarchy information that has already been established is mapped onto the lexical argument hierarchy specified by the verb. In this way, a cross-linguistically motivated processing architecture of the type described here crucially requires an initial step of word category assignment (as assumed for other reasons in modular or 'two-stage' processing models, for example, Frazier and Rayner 1982; Frazier and Clifton 1996; see also Friederici 2002). The eADM is thus a 'syntax-first' model. Nevertheless, it crucially differs from classical syntax-first architectures in that the word category-based assignment of constituent structure that is assumed to take place in stage 1 of processing does not serve to determine sentence-level meaning. Thus, in accordance with the interface hypothesis, the interpretive burden on the syntax is reduced considerably within the eADM.

In the latest instantiation of the model, the relationship between stage 1 (WORD CATEGORY IDENTIFICATION/BASIC CONSTITUENT STUCTURING) and stage 2 (COMPUTE PROMINENCE and COMPUTE LINKING) is envisaged as cascaded rather than strictly serial in nature (Bornkessel-Schlesewsky and Schlesewsky 2008a and in press). Thus, while there is a hierarchical organisation of processing stages, there is also a certain degree of parallelism: once enough information has accrued in a certain stage of processing to surpass a particular threshold, the next stage of processing can be initiated (see McClelland 1979 for the proposal of a cascaded architecture for cognitive processing and McElree and Griffith 1995 for a discussion of cascaded vs. serial models of sentence comprehension).

The cascaded architecture straightforwardly derives results like those presented by van den Brink and Hagoort (2004), which are often cited as evidence against an initial stage of word category processing. Using auditory presentation, these authors examined the processing of sentences such as (14).

(14) *Het vrouwtje veegde de vloer met een oude kliederde gemaakt van twijgen.
the woman wiped the floor with an old messed made of twigs

The critical word in (14), *kliederde* ('messed'), induces both a syntactic (word category) and a semantic anomaly: the former due to the use of a participle in a sentence context requiring a noun, and the latter due to the implausibility of wiping the floor with something 'messy'. Crucially, as the word category information was encoded in the suffix *-de*, it only became available to the processing system after the semantic information encoded in the stem. The ERP results showed an N400 with an onset before the acoustic onset of the suffix (the 'word category violation point', WCVP), followed by an early anterior negativity timelocked to the WCVP. On the basis of these findings, van den Brink and Hagoort (2004) argued forcefully against a word category-first view. However, there is another possible explanation: the critical words in this study (e.g. *kliederde*) were compatible with a noun reading until the onset of the suffix, and they were encountered in a sentence context that was highly predictive of a noun (determiner + adjective). In combination, these two properties will have led to the threshold for word category identification in stage 1 being quickly surpassed, thus enabling the comprehension system to proceed to stage 2 and the processing of other information types. Nevertheless, as the evidence for a noun analysis is not completely unambiguous, stage 1 processing continues in parallel with stage 2, subsequently registering an 'error signal' when the WCVP is reached. In contrast, when the word category violation is encountered before the semantic violation in the speech stream, no N400 is observable (Hahne and Friederici 2002), thereby attesting to an asymmetrical relation between the processing stages: stage 1 can 'block' stage 2 of processing, but not vice versa. This notion is effectively captured by the cascaded architecture, while at the same time explaining how the temporal order of ERP effects can be reversed under certain circumstances.

A further key architectural claim of the eADM is that prominence information should not be treated on a par with other interpretively relevant information types (e.g. plausibility, world knowledge and discourse context). These types of information are processed in parallel to, but separately from COMPUTE PROMINENCE/COMPUTE LINKING in stage two, before both 'pathways' are mapped onto one another in the GENERALISED MAPPING step of the third and final processing stage. There are several motivations for this assumption. First, the notion of prominence scales is – by definition – restricted to a limited set of information types, namely, those that have been shown to be grammaticality relevant in some language. This empirical/typological motivation is seconded by the theoretical assumption that prominence features such as animacy and definiteness/specificity are directly related to prototypical actor properties. Furthermore, to the best of our knowledge, there are currently no neurocognitive findings that show that world knowledge or discourse context impacts immediately upon sentence-level composition in the sense that is at issue here. Rather, the 'early' effects of all of these information types that have been reported to date (see Hagoort and van Berkum 2007, for a review) can be explained in terms of a dynamic modulation of the mental lexicon. For example, discourse context (and many other influences) impact upon the activation level of individual lexical entries, thereby rendering a word easier or more difficult to integrate. Within the eADM, effects of this type are modelled by means of the PLAUSIBILITY PROCESSING step in stage 2 (thus named for want of a more fitting label). The outcome of this step is integrated with the output of COMPUTE PROMINENCE/COMPUTE LINKING in the GENERALISED MAPPING step in stage 3. See Bornkessel-Schlesewsky and Schlesewsky (2008a) for a detailed discussion of the PLAUSIBILITY PROCESSING step, its status within the overall processing architecture, and the explanatory capacity of these architectural assumptions with respect a range of neurocognitive findings, including 'semantic P600' effects. Furthermore, there is also some converging evidence to suggest that context/world knowledge does not step in until after prominence information has been processed (see, for example, Bornkessel et al. 2003a; Bornkessel and Schlesewsky 2006b, for a delayed impact of context in licensing word order variations; and Bornkessel 2002, for a separation between animacy and world knowledge).

Future Directions

In the preceding sections, we have argued that a prominence-based perspective on incremental sentence comprehension – as advocated within the scope of the eADM – can provide a potentially fruitful approach to psycholinguistic and neurolinguistic findings from a range of diverse languages, thereby helping to shed new light on the cross-linguistic unity and diversity of language processing mechanisms. Nevertheless, there are a number of open questions that will need to be addressed in more detail in future research.

A first important area of investigation concerns the precise specification of prominence information. We have shown that there is currently very good evidence for the assumption of an animacy scale and some initial findings implicating a definiteness/specificity scale. These interact with linear order and morphological case in a way that depends on the particular language being processed. However, it remains to be clarified how many additional prominence dimensions need to be assumed. In addition, the way in which the different prominence scales interact must be spelled out more precisely. In particular, a currently open question is how the language-specific weighting of a particular prominence scale should be derived. Ideally, the prominence interactions in a given language should be derivable from independent evidence, for example, on the basis of corpus studies. To what degree can such independent evidence be obtained?

A second, and somewhat related question concerns the correspondence between language comprehension and language production in the area of prominence information. If the statistical distributions of particular prominence types in large scale corpora are to be used as predictors for the weighting of individual prominence scales during language comprehension, this presupposes a comparable influence of these factors in production and comprehension. However, it remains to be established whether this is actually a valid assumption. Indeed, it has been proposed theoretically (in the framework of bidirectional Optimality Theory) that prominence-based considerations in the domain of object case marking differ from the speaker's and the hearer's perspective (de Swart 2007). Perhaps these 'conflicting interests' might serve to explain some of the controversies that have emerged with respect to the question of how an ideal transitive structure should be defined (Hopper and Thompson 1980; Comrie 1989). However, should production- and comprehension-based considerations differ in this domain, it would certainly lead to a complication of the overall architecture.

Third, if we are correct in assuming that prominence information plays a fundamental and universal role in the human language comprehension architecture, the relationship between the linguistic notion of 'prominence' and more general cognitive concepts/mechanisms appears well worth examining. As mentioned briefly above, neuroanatomical findings already offer some indication of an overlap between the prominence-based establishment of an argument hierarchy and the more general inference of agency or interpretation of a goal-direction action. But how close is the correspondence between notions such as 'agency' and 'action' in the linguistic and non-linguistic domains? Which defining characteristics of such notions overlap and which do not? Furthermore, as already suggested by DeLancey (1981), the notions of 'more prominent' and 'less prominent' participants in a linguistic event may be related somehow to the speaker's/hearer's focus of attention and the attention flow within a transitive event. Can this hypothesis be backed up with empirical findings?

Finally, it appears interesting to consider the relationship between the processing mechanisms posited within the eADM and heuristic approaches to sentence comprehension (e.g. Ferreira et al. 2002; van Herten et al. 2006). Should prominence-based interpretation be considered a 'heuristic'? The answer to this question crucially depends on how heuristic processing is defined. In the sentence comprehension literature, heuristics are typically understood as surrogates for a full and accurate analysis of the linguistic input, leading to representations that, in the terminology of Ferreira and colleagues, are simply 'good enough'. In the words of Ferreira and Patson (2007, p. 71), the findings on good enough language processing 'challenge the assumption that the overarching goal of the language comprehension system is to deliver an accurate and detailed representation of the speaker's utterance'. We do not conceive of prominence-based interpretation as heuristically driven in this sense. This is a clear theoretical consequence of reducing the interpretive burden on syntactic structure and rather attributing argument interpretation to a range of information types at the interface between syntax and semantics. From this perspective, there is no clear functional subdivision between those information types that provide a 'detailed and accurate representation' of a sentence and those that serve to construct a 'good enough' interpretation.

In contrast, the eADM's prominence-based approach to sentence comprehension does appear potentially compatible with an alternative conceptualisation of heuristics. At the end of their recent review of good-enough language processing, Ferreira and Patson (2007) conjecture that the use of heuristics in sentence comprehension might be related to Gigerenzer and colleagues' assumption of bounded rationality and the use of heuristics in decision making (e.g. Gigerenzer et al. 1999). From the perspective of this research programme, it is a misconception that '[h]euristics produce second-best results; optimization is always better' (Gigerenzer 2008, p. 21). Rather, heuristics are viewed as adaptive mechanisms that enable quick and effective cognitive processing, even (or especially) under time pressure and in the absence of complete and unambiguous information. This assumption provides a clear parallel to the requirements of online sentence processing: in order for communication to be effective, language must be comprehended rapidly and the ambiguities that abound in natural language must be dealt with efficiently. In this way, the processing preferences and strategies that serve to guarantee incremental interpretation could be viewed as heuristics, as long as they are 'fast and frugal' in the sense that they do not take all possible information sources into account (Gigerenzer and Goldstein 1996). A perspective along these lines appears potentially compatible with the eADM's approach to language comprehension, which is based on the question of how interpretation ('role identification' and 'role prototypicality assessment') is accomplished in the absence of complete information (e.g. in verb-final structures) and assumes that it is based on only a limited set of information types. Indeed, heuristic decision mechanisms might help to provide an answer to the question of how the processing system applies prominence scales to determine role identification and role prototypicality in a given language. This constitutes an important issue for future research.

To conclude, we hope to have shown that concepts from language typology constitute a promising basis for research in the domain of incremental language comprehension. As assumptions of this type not only lead to processing predictions across and within languages but also serve to constrain the overall structure of the processing architecture, we believe that they can provide a fruitful basis for the interpretation and theoretical integration of the ever increasing number of empirical findings from different languages and language families.

Short Biographies

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Notes

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[1] As the absence of increased processing cost for object relative clauses depended on the relation between the animacy status of the head noun and that of the relative clause subject (i.e. the head noun needed to be inanimate and the RC subject animate), Mak et al. (2006) assumed that the processing system may not immediately commit to an analysis. However, the idea that the analysis of an ambiguous argument is delayed until further evidence (e.g. the animacy of a following NP) becomes available is at odds with a number of event-related potential findings that have shown reanalysis costs at the word immediately following the ambiguous argument (e.g. beim Graben et al. 2000; Knoeferle et al. 2008; Demiral et al. 2008). The study by Demiral and colleagues even showed an immediate reanalysis effect following an inanimate ambiguous argument.

[2] Note that, in spite of the classic correlation between N400 effects and lexical/semantic/plausibility processing on the one hand and P600 effects and syntactic processing on the other, the relatively neat subdivision between 'semantic' and 'syntactic' ERP components does not generally hold. For discussion, see Kutas et al. (2006) and Bornkessel-Schlesewsky and Schlesewsky (2008a) and the references cited therein.

[3] Dyirbal (Northeast Australia), for example, shows an accusative system for first and second person pronouns and an ergative system for all other noun phrase types (see Dixon 1979, 1994).

[4] Even if a sentence such as (3a) is analysed as involving a zero case marker (hence providing a potential syntactic basis for role identification), one would still need to explain why the alternation between zero and overt object case marking is governed by the relative position of the A and P arguments on the animacy hierarchy. Thus, even from this perspective, languages such as Awtuw manifest a 'primacy' of animacy information in role identification that languages like English clearly lack.

[5] An example of a nominative-marked P-argument in German is given in (i):

(i)	Gestern	wurde	dem Jungen	das Fahrrad	gestohlen.
	yesterday	was	[the boy]:DAT	[the bicycle]:NOM	stolen
	'The boy had his bicycle stolen yesterday.'				

In example (i), the inanimate nominative *das Fahrrad* ('the bicycle') is the P-argument, thereby illustrating that the overt morphological case marking of a single argument does not unambiguously determine the argument role of that argument in German. Note, however, that nominative-marked P arguments only occur in sentences with dative-marked co-arguments (see, for example, Wunderlich 1997; Fanselow 2000). Therefore, a nominative following an initial accusative can be unambiguously identified as an A argument.

[6] Note, however that the bèi-construction also differs from 'European-style' passive constructions in that it is traditionally associated with an adversative reading, that is, a reading in which the first NP (the undergoer) is negatively affected by the event described (e.g. Bisang 2006; Chappell 1986).

[7] Note that the eADM's actor and undergoer role concepts combine the assumptions of two distinct theoretical approaches. The labels 'actor' and 'undergoer' as well as the assumptions about how these roles are combined with the lexical information provided by the verb are derived from Role and Reference Grammar (see Van Valin 2005, for the latest version of this grammatical theory). In contrast, the assumptions about prototypical actor and undergoer properties and the semantic dependency between the two roles are adopted from Primus's (1999) development of Dowty's (1991) proto-role approach.

[8] Note that there are essentially two possibilities here. On the one hand, dative arguments may be considered instances of actor or undergoer role concepts (albeit in a non-prototypical instantiation), or they may be modelled as a category of their own (e.g. Van Valin 2005). However, this more fine-grained differentiation is not critical for the discussion at hand. What is most important is that dative case marking generally signals a deviation from the prototypical role concept, both for actors and undergoers.
[9] Within the scope of their 'linking-based checking algorithm', Bader and Bayer (2006) also propose a step of 'argument linking', which serves to map argument and verb representations onto one another. In contrast to the approach pursued here, however, Bader and Bayer assume a classic syntax-first architecture, in which argument interpretation is syntactically determined (i.e. based on 'structure assembly' and syntactic case assignment principles). When the verb is encountered, these syntactically based assignments are used to link the arguments to positions in the verb's argument structure. Animacy only comes into play in a second step, namely, if the syntactic assignments lead to a conflict. From our perspective, this view is difficult to reconcile with the evidence for a direct interaction between features such as animacy and case marking (see the previous sections of this article).
[10] As correctly pointed out by an anonymous reviewer, the category of a word does not always suffice to determine whether it is a predicating or a non-predicating constituent. For example, the noun *professor* is used in a non-predicating sense in *The professor died*, but in a predicating sense in *Bill is a professor*. However, the distinction between a predicating and a non-predicating item can typically be derived by assessing the category of the word in question in relation to the sentence context in which it occurs (i.e. in relation to the sequence of preceding word categories). This is accomplished by stage 1 of the eADM (hence the label 'basic constituent structuring', see Bornkessel and Schlesewsky 2006a, for details).

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