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Review

An alternative perspective on "semantic P600" effects in language comprehension

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ABSTRACT

The literature on the electrophysiology of language comprehension has recently seen a very prominent discussion of "semantic P600" effects, which have been observed, for example, in sentences involving an implausible thematic role assignment to an argument that would be a highly plausible filler for a different thematic role of the same verb. These findings have sparked a discussion about underlying properties of the language comprehension architecture, as they have generally been viewed as a challenge to established models of language processing and specifically to the notion that syntax precedes semantics in the comprehension process. In this paper, we review the literature on semantic P600 effects and discuss a number of challenges – both conceptual and empirical – to existing approaches in this domain. We then provide a new perspective on these effects by showing how they can be derived within an independently motivated, hierarchically organised neurocognitive model of language comprehension in which syntactic structuring precedes argument interpretation (the extended Argument Dependency Model, eADM; Bornkessel and Schlesewsky, 2006). In addition to straightforwardly deriving the phenomenon of a "semantic P600," the basic architectural properties of the eADM account for existing empirical puzzles within the semantic P600 literature.

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1. Introduction

One of the most pervasive research questions within the cognitive neuroscience of language has centred around the issue of whether and how the brain distinguishes between "syntax" and "semantics." Whereas the distinction between these two linguistic domains has proved somewhat elusive in terms of the functional neuroanatomy of language processing (see Bornkessel-Schlesewsky and Friederici, 2007, for a review), it was long thought to manifest itself directly in electrophysiological measures. Thus, semantic/conceptual processing costs (during language comprehension and elsewhere) have traditionally been associated with the so-called N400 event-related potential (ERP) component, i.e. a centro-parietal negativity between approximately 300 and 500 ms post critical word onset (Kutas and Hillyard, 1980). Syntactic processing effort, by contrast, was long thought to engender a late parietal positive ERP effect, the so-called P600 (Hagoort, Brown, and Groothusen, 1993; Osterhout and Holcomb, 1992, 1993).

In recent years, however, this rather neat one-to-one mapping between macroscopic linguistic domains and language-related ERP components came to be called into question, as an increasing number of experiments had begun to reveal non-semantic N400 effects on the one hand and non-syntactic P600 effects on the other (see Kutas et al., 2006, for an overview of "unexpected" N400 and P600 effects)."Semantic P600" effects in particular have featured prominently within a larger debate about the architecture of the language comprehension system. Typically, these effects have been observed in response to sentences involving an implausible thematic role assignment to an argument that would be a highly plausible filler for a different thematic role of the same verb (e.g. Hoeks et al., 2004; Kim and Osterhout, 2005; Kolk et al., 2003; Kuperberg et al., 2003). For example, Kim and Osterhout (2005) observed a P600 rather than an N400 at the position of the verb in sentences such as "*The hearty meal was devouring*…." In the literature, sentences of this type are thus often referred to as "semantic reversal anomalies." However, as there is some debate in the literature as to whether it is indeed the reversibility of thematic role assignments that is responsible for the pattern of ERP effects in question (see, for example, Kuperberg et al., 2006; Kuperberg et al., 2007), we will continue to use the more neutral formulation "semantic P600 effects."

A number of different accounts have been put forward in order to explain the occurrence of semantic P600s. Whilst these differ with respect to a variety of specific details, they essentially all agree that semantic P600 effects call into question the dominance of combinatory syntactic processing. By assuming that semantic interpretation need not follow from the syntax, they challenge hierarchically organised models of sentence processing which assign a dominance to syntactic representations (e.g. Frazier and Clifton, 1996; Frazier and Rayner, 1982; Friederici, 2002). They are also problematic for interactive models, in which non-syntactic information types may play a crucial role in selecting one particular reading over another, but these readings are nonetheless associated with different syntactic structures (e.g. Hagoort, 2005; MacDonald et al., 1994; Trueswell and Tanenhaus, 1994; Vosse and Kempen, 2000). For example, Kuperberg (2007, p. 24) notes that "few have entertained the idea that a semantic combination of words can even temporarily challenge an unambiguous and simple, canonical syntax in building up higher-order meaning during online neural processing." We will argue in the following that, to the contrary, hierarchically organised models can go a long way in explaining these kinds of results and that, in doing so, they can even derive several findings that appear puzzling from the perspective of previous approaches. Crucially, however, the prerequisite for such an explanation is that the "syntactic" representations assigned in a first, hierarchically dominant stage of processing are very basic and do not determine argument meaning (Bornkessel and Schlesewsky, 2006). We will thus conclude that, rather than arguing against a particular class of language processing models, semantic P600 effects shed light on the nature of the linguistic representations assigned during online language comprehension.

The remainder of this paper is organised as follows. We first briefly review the existing approaches to semantic P600

effects (Section 2), before describing a number of conceptual and empirical puzzles arising with regard to the semantic P600 literature (Section 3). Section 4 of the paper is then devoted to showing that semantic P600 effects can be straightforwardly derived within an independently motivated, hierarchically organised neurocognitive model of language processing, the extended Argument Dependency Model (eADM; Bornkessel, 2002; Bornkessel and Schlesewsky, 2006; Schlesewsky and Bornkessel, 2004). Section 4.1 briefly describes the model architecture, whilst Section 4.2 shows how this architecture explains both the core findings on semantic P600s as well as the results that were unaccounted for to date. In Sections 4.3 and 4.4, we motivate some of the architectural assumptions drawn upon in Section 4.2 in more detail, before turning to a discussion of "plausibility" processing within the eADM in Section 4.5. Finally, Section 4.6 outlines some of the predictions generated by the model and Section 5 offers some conclusions.

2. Previous accounts of semantic P600 effects

In the following, we will briefly discuss existing approaches to semantic P600 effects. As indicated above, all of these approaches share the assumption that the online computation of sentence meaning is not primarily determined by syntactic representations. This means that, in contrast to standard assumptions, semantic interpretations are not "read off" the structures generated by the syntax. Rather, it is assumed that the outcome of syntactic computation can be challenged by non-syntactic processing of some kind. Beyond this common ground, however, current approaches to semantic P600 effects differ in several respects. For present purposes, we will focus on one major dimension, namely the question of how the various approaches conceptualise the non-syntactic processes that are held responsible for this "challenge." In this regard, three basic classes of models can be distinguished: (a) those assuming a crucial role of plausibility/semantic association; (b) those attributing the phenomenon to thematic processing problems of some description; and (c) those assuming that both semantic association and thematic processing (and possibly further factors) are critically involved. We shall discuss the three types of approaches in turn in the following, noting further differences amongst them along the way. Note also that, throughout this section, we shall use the component nomenclature "N400" and "P600" in a purely descriptive manner (i.e. to refer to all centro-parietal ERP deflections with negative or positive peak latencies of approximately 400 and 600 ms, respectively), though we shall suggest in subsequent sections that different instances of these effects may require distinct functional interpretations.

2.1. *Plausibility/Semantic attraction*

As described above, semantic P600 effects are often observable when a reversed assignment of thematic roles to arguments would yield a correct reading. In keeping with this observation, at least two groups of researchers have invoked this property as the crucial conditioning factor for the observation of a P600 rather than an N400.

One variant of this type of approach was put forward by Kim and Osterhout (2005), who examined sentences such as (1). (Note that, here and in the following, the positions at which the ERP effects of interest were observed are underlined and the ERP effects observed at these positions are given in parentheses).

(1) Example stimuli from Kim and Osterhout (2005)
a. The hearty meal was devouring… (P600)
b. The dusty tabletops were devouring… (N400)

For sentences such as (1a), which Kim and Osterhout (2005) termed "attraction violations," they observed a P600 effect in comparison to both active and passive control sentences. By contrast, "non-attraction violations" such as (1b) yielded an N400 effect. On the basis of these results, Kim and Osterhout (2005) argue that a strong semantic attraction between a predicate and an argument may lead the processing system to analyse a syntactically well-formed sentence as syntactically ill-formed. They therefore adopt a conservative (i.e. syntactic) interpretation of the "semantic" P600, which they analyse as resulting from a syntactic mismatch between the present participle form encountered by the processing system and the semantically based expectation for a past participle (cf. *The hearty meal was devoured*…). From the perspective of this semantic-attraction-based processing account, Kim and Osterhout (2005) argue that, if the evidence is compelling enough, semantic analysis can override syntactic analysis even in unambiguous structures.

A second account which makes crucial reference to plausibility-based processing (in the sense that the most plausible combination of the arguments and the verb may challenge syntax-based sentence interpretation) has been proposed by Kolk, van Herten and colleagues (Kolk et al., 2003; van Herten et al., 2006; van Herten et al., 2005). These authors observed a P600 for Dutch sentences such as (2a), which differ from the stimuli used by Kim and Osterhout (2005) in that they induce a semantic anomaly via the *relation* between the two arguments (i.e. both foxes and poachers can hunt, but only poachers hunt foxes and not vice versa). A control condition similar to Kim and Osterhout (2005)'s "non-attraction violation" (2b) elicited a biphasic N400–P600 pattern when participants performed a judgement task, but only an N400 when participants answered comprehension questions on a certain proportion of trials. By contrast, the P600 for the reversal anomaly in (2a) was unaffected by the task requirements.

(2) Example stimuli from Kolk et al. (2003)
a. De vos die op de stropers joeg… (P600)
the fox that at the poachers hunted
'The fox that hunted the poachers…'
b. De bomen die in het park speelden… (N400–P600; P600 = task-dependent)
the trees that in the park played…
'The trees that played in the park…'

Kolk et al. (2003) and van Herten et al. (2005, 2006) propose that the P600 in sentences such as (2a) results from a conflict between the output of a plausibility-based heuristic (which computes the most plausible relation between the sentential

constituents) and the syntactic analysis. Thus, they essentially agree with Kim and Osterhout (2005) that "semantic" processing (in a very broadly construed sense) can compete with – or even override – the syntax. However, from this perspective, the P600 is not viewed as a correlate of the syntactic mismatch that arises as a result of the semantic strategy, but rather as an index of "conflict monitoring." Further supporting evidence for this perspective was presented by van Herten et al. (2005), who showed that the P600 for sentences such as (2a) cannot be explained by a mismatch between an expected verb form and the verb form actually encountered.

The conflict monitoring hypothesis was explored further by van Herten et al. (2006), using sentences such as those in (3).

(3) Example stimuli from van Herten et al. (2006; Experiment 1)
a. De ladder die op de schilder klom… (P600)
the ladder that on the painter climbed…
'The ladder that climbed the painter…'
b. De appel die in de boom klom… (N400–P600)
the apple that in the tree climbed…
'The apple that climbed the tree…'

In their first experiment, van Herten et al. (2006) replicated the P600 effect for reversible sentences such as (3a), but observed a biphasic N400–P600 pattern for non-reversible sentences such as (3b). The latter result initially appears surprising from the point of view of the conflict monitoring hypothesis, because both a plausibility-based heuristic and the syntactic analysis should come up with an implausible reading.[1] However, van Herten et al. (2006) argued that a substantial number of their critical items indeed contained highly plausible fragments (such as "climb a tree" in 3b) and that, in these cases, a conflict with the implausible syntactic representation may occur. To test this idea, the authors conducted a second experiment in which they explicitly manipulated the semantic association between the object and the verb in implausible sentences such as (4).

(4) Example stimuli from van Herten et al. (2006; Experiment 2)
Jan zag…
Jan saw…
a. …dat de olifanten de bomen snoeiden… (P600)
…that the elephants the trees pruned…
'…that the elephants pruned the trees…'
b. …dat de olifanten de bomen verwenden… (N400–small P600)
…that the elephants the trees caressed…
'…that the elephants caressed the trees…'

Sentences including a highly plausible fragment (such as 4a) induced a P600, whereas sentences without such a fragment (like 4b) elicited an N400 and only a very small P600. Van Herten et al. (2006) argue that this result strongly supports the proposal that "semantic P600" effects reflect the conflict between the output of a plausibility-based heuristic and the syntactic analysis.

2.2. *Thematic processing*

A second class of approaches to semantic P600 effects assumes that these are somehow related to thematic processing effort. However, as one of these proposals also attributes an important role to further factors (Kuperberg, 2007), we will only discuss the thematically based approach that was put forward by Hoeks et al. (2004) in this section.

In an ERP experiment on Dutch, Hoeks and colleagues examined the following sentence types:

(5) Example stimuli from Hoeks et al. (2004)
a. De speer heeft de atleten geworpen. (P600)
the javelin has the athletes thrown
'The javelin has thrown the athletes.'
b. De speer heeft de atleten opgesomd. (N400–P600)
the javelin has the athletes summarised
'The javelin has summarised the athletes.'
c. De speer werd door de atleten geworpen.
the javelin was by the athletes thrown
'The javelin was thrown by the athletes.'
d. De speer werd door de atleten opgesomd. (N400–P600)
the javelin was by the athletes summarised
'The javelin was summarised by the athletes.'

The sentence conditions in (5) manipulated both the semantic association between the verb and the arguments (5a/c vs. 5b/d) and whether the syntactic structure was strongly (5c/d) or weakly (5a/b) constraining. As the preceding discussion would lead one to expect, semantic reversal anomalies such as (5a) elicited a P600 rather than an N400 effect. By contrast, Hoeks et al. (2004) observed N400 effects for the two conditions without a semantic relation between the verb and the arguments (5b/d). These N400s were followed by P600 effects that were less pronounced than those for (5a). However, as the experiment employed a plausibility judgement task, these "additional" positivities were likely task related (see the discussion of 2b above and Section 4.2).

Hoeks et al. (2004) argue that the absence of an N400 in sentences like (5a) provides evidence for an underspecified message-level representation. They propose that such an underspecification arises under conditions of increased thematic processing cost, as caused, for example, by the presence of an inanimate subject in an active sentence such as (5a). From this perspective, the P600 at the position of the verb is viewed as a correlate of thematic role assignment costs.

2.3. *A dynamic interaction of thematic, semantic memory-based and further factors*

A further approach to semantic P600s which attributes a crucial role to thematic processing was proposed by Kuperberg

[1] Note that the positivity cannot be attributed to task requirements (as would appear to be the case for 2b; see Section 4.2 for a more detailed discussion), because the study did not employ a judgement task. Rather, participants answered content questions about the sentences *after* the experimental session.

(2007). She assumes a comprehension architecture in which a syntactic, a thematic and a semantic memory-based[2] processing stream all proceed in parallel and interact with one another. Of these "multiple independent but interactive streams of language processing" (Kuperberg, 2007, p. 40), the first two are described as combinatorial in nature (i.e. involving the "combination of words through algorithmic mechanisms to build up higher-order meaning"; Kuperberg, 2007, p. 37), whereas the latter draws upon the information encoded in a semantic network (i.e. semantic associations, but also categorical relations etc.). Notably, adopting similar assumptions to those proposed independently within the eADM (Bornkessel, 2002; Bornkessel and Schlesewsky, 2006; Schlesewsky and Bornkessel, 2004), thematic processing is described as a combinatorial semantic process that can apply independently of syntactic information and that is also distinguishable from semantic information proper (i.e. drawing upon only a restricted set of semantic features such as animacy). In Kuperberg's model, the parallel processing streams begin to apply within the time window of the N400, with a continued application assumed throughout the P600 time window. In particular, the P600 is described as the outcome of a conflict between the representations built up by the parallel processing streams. For a somewhat more precise illustration of Kuperberg's line of argumentation, consider the following sentences (from Kuperberg et al., 2007):

(6) Example stimuli from Kuperberg et al. (2007)
   a. Every morning at breakfast the eggs would eat… (P600)
   b. Every morning at breakfast the boys would plant… (N400)
   c. Every morning at breakfast the eggs would plant… (P600)

Example (6a) illustrates a typical semantic reversal anomaly, i.e. an animacy violation involving a semantically associated argument. Sentences of this type engendered a P600 effect in comparison to a plausible control. By contrast, results for sentences like (6b) replicated the finding of an N400 effect for semantically unrelated implausible sentences. (Note that this distinction was also observed in several previous experiments by this group using similar stimuli: Kuperberg et al., 2006; Kuperberg et al., 2003). Perhaps most importantly, sentences which induced an animacy violation via a semantically unrelated argument (6c) also showed a P600 rather than an N400. Kuperberg (2007) explains this pattern of results by assuming that the P600 reflects a mismatch between the output of the two combinatorial processing streams: whereas the syntactic stream leads to an Agent (or Causer/Effector) interpretation for the inanimate subject, the thematic stream associates it with a Theme interpretation. In her terminology, the P600 thus reflects a "continued combinatory analysis" (Kuperberg, 2007, p. 37). This explanation holds for both (6a) and (6c), as both involve an animacy violation. In addition, Kuperberg and colleagues assume that sentences of this type (6a/c) do not engender an N400 because semantic integration is "blocked" by the detection of the (animacy-based) thematic processing problem: "once the thematic role violation was detected (reflected by the early part of the P600), participants may not have engaged in further attempts to semantic/pragmatically integrate the meaning of the verb into its preceding context (reflected by the attenuation of the N400)" (Kuperberg et al., 2007, p. 235). In (6b), by contrast, there is no thematic conflict (there is no animacy violation), but rather a mismatch within the semantic memory-based stream, which is reflected in an N400. Kuperberg (2007) further suggests that, under certain circumstances, P600 effects may arise as a consequence of mismatches between the semantic memory-based stream and the syntactic structure, e.g. in the case of completely impossible interpretations, and that the likelihood for such effects may also be increased by particular contextual circumstances or experimental tasks.

2.4. *Influences of discourse context*

Finally, and on a somewhat more phenomenological note, it should be mentioned that seemingly semantic P600 effects have also been observed as a function of discourse context. A finding which is often discussed in this respect stems from Nieuwland and van Berkum (2005), who examined the processing of animacy violations in short stories such as (7).

(7) Example story (English translation of Dutch original) from Nieuwland and van Berkum (2005)

A tourist wanted to bring his huge suitcase onto the airplane. However, because the suitcase was so heavy, the woman behind the check-in counter decided to charge the tourist extra. In response, the tourist opened his suitcase and threw some stuff out. So now, the suitcase of the resourceful tourist weighed less than the maximum twenty kilos. Next, the woman told the tourist/suitcase…

Whereas animacy violations as in the last sentence of (7) elicited an N400 out of context, they engendered a P600 in a story context that was related to the inanimate entity (as in example 7). This finding has been taken to suggest that semantic P600 effects (with a concomitant absence of an N400)

[2] Note that we do not differentiate between semantic memory and plausibility information (in the sense of an "asyntactic" plausibility heuristic) when discussing Kuperberg's model. As the following passage from Kuperberg (2007) makes clear, the two information types appear to be closely intertwined in her approach, though the precise relationship between them is not entirely clear:

> Exactly how this semantic memory-based processing operates is unclear. One possibility is that there is a continuous comparison between the semantic relationships between incoming content words and those relationships that are stored within semantic memory, to determine whether or not there is a match or a mismatch. Another possibility is that the meanings of the verb, argument(s) and other content words are first combined through pragmatic or inferential heuristic mechanisms into tentative propositions (a 'quick and dirty' means of deriving the gist of a proposition) and that it is the *plausibility* of this proposition as a whole that is then evaluated against real-world knowledge that is stored within semantic memory (Kuperberg, 2007, p. 37).

may also be brought about by means of contextual information (see, for example, Kuperberg, 2007).

Interestingly, the situation that arises at the position of *the suitcase* in (7) is highly reminiscent of the well-known phenomenon of reference transfer. Consider the sentence in (8):

(8) Example of reference transfer (from Nunberg, 1979; cited from Culicover and Jackendoff, 2005)

[One waitress says to another:]
The ham sandwich over in the corner wants another coffee.[= The *person contextually associated with a* ham sandwich wants another cup of coffee.]

Reference transfer can be understood as part of a larger class of linguistic phenomena requiring *enriched composition*, i.e. additional inferential processes that are necessary for the computation of an implied meaning (see, for example, Jackendoff, 1997; Pustejovsky, 1995). Previous ERP findings from another situation in which enriched composition is required, namely bridging inferences[3], have revealed that the processing of these types of structures leads to an increased P600 in comparison to previously introduced referents and to an attenuated N400 in comparison to completely new referents (Burkhardt, 2006; Burkhardt and Roehm, 2007). In addition, there is initial evidence to suggest that reference transfer as in (8) also engenders a P600, rather than an N400 (Burkhardt, 2008). Thus, it appears that enriched composition generally correlates with P600 modulations. From this perspective, the absence of an N400 for the "animacy violation" in (7) appears less surprising: when presented in context, *the suitcase* no longer gives rise to a violation but rather leads to increased processing costs due to enriched composition. (Note that, according to Nieuwland and van Berkum's (2005) description of their materials, all of their stories had the same setup of a woman and a man interacting, with the inanimate object that induced the "animacy violation" always related to the man. Thus, the conditions for reference transfer should generally have been met.) We shall return to the issue of how these processing costs for enriched composition might be related to those underlying semantic P600 effects in Section 4.5 below.

2.5. *Summary*

The preceding sections showed that existing approaches to semantic P600 effects offer substantially differing perspectives on the conditions under which seemingly semantic processing problems engender a P600 rather than an N400. Whereas some accounts assume a crucial role of a plausibility heuristic or semantic attraction (Kim and Osterhout, 2005; van Herten et al., 2006), others propose that the critical factor is message-level underspecification due to a thematic processing problem (Hoeks et al., 2004) or that a "continued combinatory analysis" that may be due to either thematic, semantic memory-based or other factors may be crucial (Kuperberg, 2007). Furthermore, the specific functional interpretation of the P600 differs considerably across the different approaches. Whereas Kim and Osterhout (2005) view this component as the correlate of a syntactic mismatch which arises as a result of the strong semantic attraction, Kolk, van Herten and colleagues propose that the P600 reflects the conflict between a plausibility heuristic and the syntactic structure. Finally, whilst Hoeks et al. (2004) attribute the P600 to a somewhat unspecifically defined thematic processing problem, Kuperberg (2007) suggests that it is engendered by a continued combinatory analysis that becomes necessary when there is a conflict between the outputs of the parallel interactive (syntactic, thematic, and semantic memory-based) processing streams.

In spite of the obvious differences between them, all of these accounts have in common that they view semantic P600s as a challenge to existing architectures of language comprehension. For example, van Herten et al. (2006, p. 1194) describe their results as "incompatible not only with syntax-first but also with constraint-based" processing models and as "compelling evidence for the existence of a plausibility strategy." Similarly, Kim and Osterhout (2005, p. 216) conclude that "at least under certain conditions, semantics (and not syntax) is 'in control' of how words are combined during online sentence processing." A very similar idea is put forward by Kuperberg (2007, p. 44), who argues that "the outcome of a semantic memory-based analysis and possibly a semantically-driven combinatorial thematic analysis can, under some circumstances, temporarily dominate online comprehension, even in simple, canonical unambiguous sentences."

3. Semantic P600 effects: conceptual and empirical puzzles

3.1. *A conceptual problem: incremental processing*

Before turning to some empirical puzzles within the literature on semantic P600 effects, we would like to point out a conceptual problem that is inherent to previous discussions of these effects. This problem concerns the relation between the rather verb-centred accounts of semantic P600 phenomena and incremental comprehension. For example, Kuperberg et al. (2003, p. 128) conclude that "animacy information only had a real impact once the verb was presented," which effectively amounts to the claim that the animacy-based thematic assignments assumed in their account take place in a head-driven manner. For a further illustration of the same problem, consider the Dutch sentences in which both arguments appear before the verb (examples 2–5): as there is ample evidence for incremental analysis/interpretation prior to the verb in verb-final constructions (e.g. Aoshima et al., 2004; Bader and Lasser, 1994; Bornkessel et al., 2003; Kamide and Mitchell, 1999), the processing system must already have constructed some kind of sentence-level interpretation before the verb is reached. Hence, even if a

[3] Bridging inferences are required for the interpretation of NPs that do not directly correspond to previously introduced discourse referents, but are inferentially linked to some salient aspect of the current mental model. Consider the following examples (bridged NPs underlined) from Clark (1975):(i) I looked into the room. The ceiling was very high.(ii) I met a man yesterday. The bastard stole all my money.

semantic or plausibility-based heuristic were to apply in parallel with – or even precede – syntactic (or other "algorithmic") processing steps at the position of the verb, these other representations would nonetheless already be available when that position is reached. This issue is acknowledged explicitly by both Hoeks et al. (2004) and van Herten et al. (2006), who invoke Sanford and Sturt's (2002) notion of "shallow processing" as a possible overarching explanation. However, even though there may be evidence for underspecified representations in other domains (e.g. with respect to the resolution of quantifier scope ambiguities), the idea that semantic P600 effects require an explanation in which several information sources apply in parallel and conflict with one another at the position of the verb is clearly inconsistent with the (highly reliable) findings on incremental interpretation in verb-final structures.

However, whilst previous discussions of semantic P600 effects have concentrated on the representations constructed at the position of the verb, this does not imply that existing accounts of these phenomena are necessarily incompatible with incremental interpretation. Yet it also does not appear to be the case that an application of these models' existing assumptions to the pre-verbal domain straightforwardly yields the desired results. Thus, if it is the case that semantic P600 effects are engendered by conflicts between syntactic, thematic and plausibility-based representations (as assumed in one way or another by Hoeks and colleagues, Kolk/van Herten and colleagues, and Kuperberg), this should predict a P600 at the position of the second argument in structures such as those presented by Hoeks et al. (2004) (*The javelin has the athletes…*). Here, both a (animacy-based) thematic processing strategy and a plausibility-based heuristic (if it were construed as applying before the verb) should construct a representation in which the animate argument (*the athletes*) is the Agent and the inanimate argument (*the javelin*) is the Theme. This conflicts with the syntax, which suggests that the inanimate argument thematically outranks the animate argument.

Crucially, however, all existing ERP findings for this type of processing situation (i.e. inanimate Actors acting upon animate Undergoers) have revealed N400 rather than P600 effects. For example, an N400 effect was observed at the position of an inanimate subject following an animate object in German verb-final sentences such as (9) (Frisch and Schlesewsky, 2001; Roehm et al., 2004).

(9) 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.'

At the position of the second argument in the embedded clause in (9), an inanimate nominative (*der Zweig*, 'the twig') engendered an N400 in comparison to an animate nominative (*der Jäger*, 'the hunter'). Following Schlesewsky and Bornkessel (2004), this effect can be explained as follows: when an unambiguously case marked initial object is processed, it is interpreted as an Undergoer. This information is further used for the prediction of a prototypical – and thereby animate – Actor argument. When the inanimate nominative is subsequently encountered, this prediction is not met and an N400 results. Note that the prediction forms an integral part of this explanation as no comparable animacy effect was observed in a study which used the identical lexical material to Frisch and Schlesewsky (2001) and contrasted animate and inanimate nominative arguments in the clause-initial position of sentences otherwise identical to those in (9) (Ott, 2004).

Recent findings from Mandarin Chinese attest to the cross-linguistic stability of this overall data pattern (Philipp et al., 2008). In sentences such as (10), in which the coverb *bèi* unambiguously identifies the first NP as the Undergoer and the second NP as the Actor of a transitive event, inanimate vs. animate Actor arguments engendered an N400. By contrast, there was no ERP difference between inanimate and animate sentence-initial nouns (which were identical to the nouns presented as NP2, thus effectively controlling for lexical factors such as concreteness, frequency etc.). Effects of the lexical–semantic relation/association between the arguments were also ruled out by additional control conditions.

(10) Example stimuli from Philipp et al. (2008)
a. 王子被挑战者刺死了。
wáng zǐ bèi tiǎo zhàn zhě 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.'

Interestingly, Kuperberg (2007) also discusses a similar finding from English, namely an N400 (followed by a P600) for inanimate Agent nouns in the by-phrase of a passive (Paczynski et al., 2006). Kuperberg (2007) presents this finding as evidence for her approach because of the presence of a P600. However, it is not clear why sentences of this type should also engender an N400: as discussed with respect to example (6c) above, the thematic processing problem should be expected to block semantic/pragmatic integration.[4]

In summary, the requirements of incremental interpretation provide an interesting challenge for the accounts presented in Section 2. This appears to be due to the rather

[4] A similar problem arises with respect to animacy modulations in the sentence-initial position in English. Here, Kuperberg's (2007) thematic stream should assign an Agent interpretation to an animate NP and a Patient/Theme interpretation to an inanimate NP. As the latter assignment should conflict with the output of the syntactic stream, a P600 should be expected for inanimate vs. animate arguments in the sentence-initial position. However, this prediction is not borne out by the existing findings on such a comparison: Weckerly and Kutas (1999) observed an N400 for inanimate vs. animate sentence-initial arguments (*The movie…* vs. *The novelist…*). (Note that Kuperberg et al. (2003; 2007) also reported a negativity between 300 and 500 ms for inanimate vs. animate sentence-initial subjects in English.)

verb-centred perspective that these approaches adopt in order to account for the consequences of a strong "semantic attraction" between an argument and the verb or a strong verb-based plausibility bias. Thus, one might either assume that these accounts make no predictions for the pre-verbal domain, thereby severely limiting their scope of applicability, or attempt to extend their predictions to this domain, which leads to several empirical challenges. As we will show in more detail in Section 4 below, we believe that a number of the empirical puzzles currently arising with respect to semantic P600 effects can be overcome if these effects are approached from an incremental perspective.

3.2. *Empirical puzzles*

Having described what we consider to be the biggest conceptual challenge to previous discussions of semantic P600s (i.e. incremental processing), we shall now turn to a number of empirical puzzles arising in this domain. Specifically, we will focus on two basic sets of these problems: those arising within the overall data pattern on semantic P600s, and those posed by data from other domains.

3.2.1. *Empirical puzzles within the semantic P600 literature*

A closer look at the literature on semantic P600s reveals several empirical puzzles. The first of these concerns an apparent inconsistency regarding the factors that condition the presence or absence of an N400 (Section 3.2.1.1), whilst the second is tied to the task dependence of P600 effects (Section 3.2.1.2)

3.2.1.1. Lexical–Semantic association and the presence or absence of an N400. When considering the entire set of findings on semantic P600 effects in the literature, the reader will inevitably encounter one major inconsistency between the results of the different groups that have collected data on this topic. Thus, whilst a number of studies have suggested that the absence of an N400 in sentence-level semantic anomalies is crucially conditioned by some form of lexical–semantic association (Hoeks et al., 2004; Kim and Osterhout, 2005; Kolk et al., 2003; van Herten et al., 2006), Kuperberg et al. (2007) provide evidence against this view by showing that non-associated animacy violations only engender a P600. The critical sentence types examined in these studies are repeated in (11) and (12) for convenience.

(11) Examples of sentence types that have engendered N400 effects in the absence of a lexical–semantic association between the argument(s) and the verb
  a. The dusty tabletops were devouring… (N400; Kim and Osterhout, 2005)
  b. De speer heeft de atleten opgesomd. (N400–P600; Hoeks et al., 2004)
  the javelin has the athletes summarised
  c. De bomen die in het park speelden… (N400–P600, P600 = task-dependent;
  the trees that in the park played… (Kolk et al., 2003)[5]

(12) Example of a sentence type that has not engendered N400 effects – but a P600 – in the absence of a lexical–semantic association between the initial argument and the verb
  Every morning at breakfast the eggs would plant… (Kuperberg et al., 2007)

In her review of semantic P600 effects, Kuperberg (2007) interprets this state of affairs as suggesting that neither (animacy-based) thematic processing problems nor semantic associations between the arguments and the verb are sufficient triggers for a semantic P600 (Kuperberg, 2007, p. 35). Rather, she argues that both of these factors increase the likelihood of observing P600 effects. (Additionally, she notes that the likelihood for a semantic P600 is increased by an acceptability judgement task and by the presence of a particular discourse context. We shall return to both of these factors below.)

As we will argue in Section 4.2 below, the apparent discrepancy between the data patterns in (11) and (12) also lends itself to a rather different type of explanation. More specifically, we will suggest that lexical–semantic association typically *does* play a role in engendering semantic P600s, but that the effects of this information type can be "blocked" under certain circumstances (but in a different manner to the blocking envisaged by Kuperberg and colleagues that was discussed in relation to example 6c above).

3.2.1.2. Task dependence and the presence or absence of a P600. A second empirical puzzle arises with respect to the modulation of P600 effects by task demands, which has been observed in a number of studies in the semantic P600 literature. For example, Kolk et al. (2003) observed an N400–P600 pattern for sentences such as (11c) when participants were asked to perform a judgement task, but only an N400 when no judgement was required (see Geyer et al., 2006, for a similar finding). This task dependence is unexpected from the perspective of existing accounts of semantic P600s (though one might perhaps argue that "conflict monitoring" could be construed as a process that is partly influenced by task requirements). For example, Kim and Osterhout (2005, p. 214) comment: "Confusingly, however, the condition [i.e. Kolk et al.'s (2003) sentences like 11c] also elicited a robust P600 effect in the first of their two studies and none in the second."

It is also worth noting that the task dependence of P600 effects which *follow* N400 effects does not appear to extend to the standard semantic P600 pattern, in which there is only a P600 but no N400. Thus, Kolk et al. (2003) observed a P600 for semantic reversal anomalies both when participants performed a judgement task and when they only read the sentences for comprehension. This selective task dependence for P600 effects occurring as part of a *biphasic* pattern appears problematic for the assumption that particular task conditions may *generally* increases the likelihood of P600 effects (Kuperberg, 2007).

[5] Note that this example from Kolk et al. (2003) in fact contains a highly plausible verb phrase. In terms of the additional "partial plausibility" manipulation conducted by van Herten et al. (2006), this sentence would therefore belong to the condition that only elicited a P600 (cf. the discussion of example 4a and Section 4.5 below). Nevertheless, as this is the only example from the condition under consideration that is given by Kolk et al. (2003), we will continue to refer to it in the following discussion.

In contrast to previous approaches, which have (at least implicitly) assumed a unitary interpretation of the P600 effects occurring under these different circumstances, we will suggest in the following that the discrepancy between monophasic semantic P600 effects and P600 effects that appear as part of a biphasic N400–P600 pattern indicates that the two types of positivities require distinct functional interpretations. In particular, the task dependence of the positivity observed in the biphasic pattern suggests that this component indexes a somewhat more general process than its monophasic counterpart.

3.2.2. *Empirical challenges from other domains*

In addition to the empirical puzzles arising within the semantic P600 literature itself, certain aspects of the component interpretations advanced within this literature are problematic from the perspective of findings from other domains. In this section, we therefore briefly discuss a selection of further empirical considerations regarding the interpretation of P600 and N400 effects.

3.2.2.1. The P600 as a correlate of thematic processing?. In Kuperberg's model (and, to some extent, in Hoeks et al's discussion of their findings), it is assumed that thematic processing problems lead to P600 effects (see the discussion of example 6c above). However, this assumption is contradicted by a wide range of ERP findings on the processing of thematic information in languages other than English. For example, Bornkessel et al. (2002, 2003) observed early (200–600 ms) parietal positivities in German sentences requiring a clause-final revision of the thematic hierarchy (i.e. a reversal of Actor/Undergoer assignments to the arguments encountered before the verb). Note that the latency of these effects renders them clearly dissociable from the P600. In a separate set of studies, Frisch and Schlesewsky (2001, 2005) examined the processing of German sentences with two identically case marked arguments. In both verb-final (Frisch and Schlesewsky, 2001) and verb-medial structures (Frisch and Schlesewsky, 2005), these types of "double case violations" were shown to yield an N400–P600 pattern, within which the N400 was interpreted as reflecting a thematic mismatch (in the sense that the identical case marking of the arguments does not allow them to be placed in a thematic hierarchy) and the P600 was classified as the result of a well-formedness problem. Strong converging support for the interpretation of the N400 as a thematic processing problem in these constructions stems from the observation that no N400 effect was observed when one of the arguments was animate and the other was inanimate, thereby allowing for the establishment of a thematic hierarchy (Frisch and Schlesewsky, 2001). By contrast, the late positivity was not modulated by the animacy manipulation, thus suggesting that it does not reflect interpretive processing properties but rather indexes the ill-formedness of the sentences. Similar conclusions were reached by Frisch and Schlesewsky (2005), who observed a modulation of the N400 – but not the P600 – by thematically relevant properties of different case markers. This division of labour between the two components is completely unexpected in Kuperberg's approach, which should predict an animacy-based modulation of the P600.

Furthermore, there is good evidence to suggest that the association between the N400 and thematic processing is in fact very systematic. Recall from Section 3.1 that N400 effects are reliably observed at the position of an inanimate Actor following an Undergoer; this finding appears very stable cross-linguistically, as it has been demonstrated for German (Frisch and Schlesewsky, 2001; Roehm et al., 2004), English (Paczynski et al., 2006; Weckerly and Kutas, 1999) and Mandarin Chinese (Philipp et al., 2008).

When taken together, these findings provide strong evidence for a very different conceptualisation of thematic processing and its relation to ERP components to that put forward by Kuperberg (2007). Note also that the studies discussed above are only a selection out of the full range of published findings calling into question the association between thematic processing and the P600 (see Bornkessel and Schlesewsky, 2006, for an overview).

3.2.2.2. The P600 as a general correlate of conflict monitoring?. The conflict monitoring perspective on the P600 also faces some empirical challenges. As this account views the P600 as a very general correlate of conflict detection (and perhaps conflict resolution), it predicts that conflicts during sentence comprehension should always be accompanied by P600 effects. Whereas this prediction appears to be supported by the traditional association between the P600 and reanalysis effects in garden path sentences (Osterhout and Holcomb, 1992, 1993; see van Herten et al., 2006, for discussion), more recent findings have revealed that reanalysis effects may also be accompanied by N400 effects under certain circumstances. For example, Bornkessel, McElree, Schlesewsky, and Friederici (2004) observed that subject–object reanalyses in German engender N400 rather than P600 effects when the object bears dative case. Note that this effect cannot simply be explained by assuming that a dative is a "lexical" case, because the N400 effects in question were observed relative to a subject-initial control which also involved dative case marking. It also cannot be accounted for by a simple plausibility-based account (for discussion, see Bornkessel et al., 2004, Experiment 3). Rather, it appears that the N400 observed in these studies should be viewed as a correlate of the reanalysis towards a dispreferred object-initial order. (For further converging support, see Haupt et al., 2008; Leuckefeld, 2005; Schlesewsky and Bornkessel, 2006).

In summary, the observation of (monophasic) N400 effects in reanalysis contexts indicates that conflict detection and resolution during sentence comprehension are not invariably accompanied by a P600 effect. This of course does not mean that P600 effects *cannot* be viewed as correlates of conflict monitoring, but only that it is not the case that every conflict engenders a P600. Conversely, though, it must also be acknowledged that the conflict monitoring perspective has the advantage of being able to derive the observation that P600 effects also index conflicts in other language-related domains, e.g. orthographical errors (Vissers et al., 2006).

3.2.2.3. The N400 as a correlate of lexical–semantic/plausibility-based processing cost. Whilst the previous sections were primarily concerned with the functional interpretation of P600 effects, the empirical findings discussed therein also have important consequences for the interpretation of the N400.

These are not straightforwardly compatible with the rather conservative view of this component that is typically adopted by accounts of semantic P600 effects, namely that it indexes increased effort in the processing of lexical–semantic/plausibility information. More precisely, whereas existing accounts of semantic P600 effects have not *explicitly* stated that they assume a one-to-one mapping between the N400 and processes related to lexical–semantic/plausibility information, this does appear to be an implicit assumption of these approaches or it is at least not clear under which circumstances an N400 would be predicted as a correlate of other domains. However, it should be apparent from the discussion in the previous sections that N400 effects are also observable in response to a number of processing problems that are neither lexical–semantic in nature nor plausibility-based. For example, N400 effects reliably occur in response to thematic processing effort (e.g. when an inanimate Actor argument is encountered following an Undergoer). They are also engendered by subject–object reanalyses. The assumption that superficially indistinguishable N400 effects may thus require distinct functional interpretations is supported by the observation that they are associated with different underlying EEG frequency characteristics (Roehm, 2004; Roehm et al., 2007b; Roehm et al., 2004). Hence, an empirically adequate account of semantic P600 effects should acknowledge that N400 effects cannot generally be taken as a diagnostic tool for lexical–semantic or plausibility-based processing.

3.2.3. *Summary*

The purpose of this section was to show that there exist a number of empirical challenges to current perspectives on semantic P600 effects. The discussion revealed that neither P600s nor N400s seem amenable to a unified functional interpretation. Rather, both types of effects can index a number of functionally different processes (which may correlate with different underlying frequency characteristics, as has been demonstrated in the case of the N400). Furthermore, there is an inconsistency within the semantic P600 literature as to which conditions lead to an absence of the N400: semantic association or an animacy mismatch. Though some accounts (Kuperberg, 2007) assume an influence of both factors, they currently fail to make concrete predictions as to the conditions under which one or the other information type determines the observed ERP pattern.

4. An alternative perspective

In this final section, we will describe an alternative perspective on the processing of semantic P600 effects. This account, which is based on the architecture of the extended Argument Dependency Model (eADM; Bornkessel, 2002; Bornkessel and Schlesewsky, 2006; Schlesewsky and Bornkessel, 2004) not only derives the data patterns described above – including the existing puzzles– but also has the additional advantage of being independently motivated. We begin by providing a short overview of the relevant properties of the eADM, before turning to a discussion of how this model derives semantic P600 effects.

4.1. *A short synopsis of the eADM*

In this section, we provide an overview of the relevant architectural details of the eADM (for a detailed description, see Bornkessel and Schlesewsky, 2006; Bornkessel-Schlesewsky and Schlesewsky, submitted). The overall model architecture is illustrated in Fig. 1.

Within the eADM, thematic interpretations – in the form of the generalised thematic roles *Actor* and *Undergoer* – are assigned on the basis of a limited set of cross-linguistically motivated sources of "prominence" information (e.g. morphological case marking, animacy, and definiteness). In this model, thematic information is logically independent of the phrase structure (i.e. of the syntax). This means that the assignment of the Actor and Undergoer roles is not tied to particular structural positions. However, in languages in which linear order is the primary determinant of argument prominence (e.g. English and Dutch), there may be a convergence between the two. Different types of prominence information are summarised in (13).

(13) Different types of prominence information
  a. Primary prominence information
     morphological case marking (German-type languages)
     linear order (English-type languages)
  b. Modulating prominence information
     animacy
     definiteness/specificity
     [+ (presumably) person, topicality]

Prominence information guides argument interpretation independently of the verb by setting up interpretive dependencies between the arguments (*compute prominence* in Fig. 1). In this regard, primary prominence information establishes the basic hierarchy (i.e. which argument is mapped onto the Actor role and which argument is mapped onto the Undergoer role), whereas modulating prominence information determines whether the hierarchy established by the primary prominence information is optimal or not. In an "optimal" hierarchy, the Actor argument outranks the Undergoer argument on all available dimensions of prominence (for converging cross-linguistic evidence, see e.g. Aissen, 1999; Comrie, 1989). However, the precise weighting of a particular information type in determining argument prominence varies from language to language.

The relation between primary and modulating prominence information is particularly clear-cut in languages like English. Here, the argument hierarchy 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 this alternative meaning would circumvent a violation of the animacy scale. In case marking languages, the situation quickly becomes somewhat more complex. In German, for example, the argument hierarchy is fixed in sentences with nominative and accusative case marking (i.e. the nominative argument must be the Actor under these circumstances). In sentences with a nominative and a dative argument, by contrast, the nominative argument can also map onto the Undergoer if the dative argument is animate and the nominative argument is inanimate (see Schlesewsky and

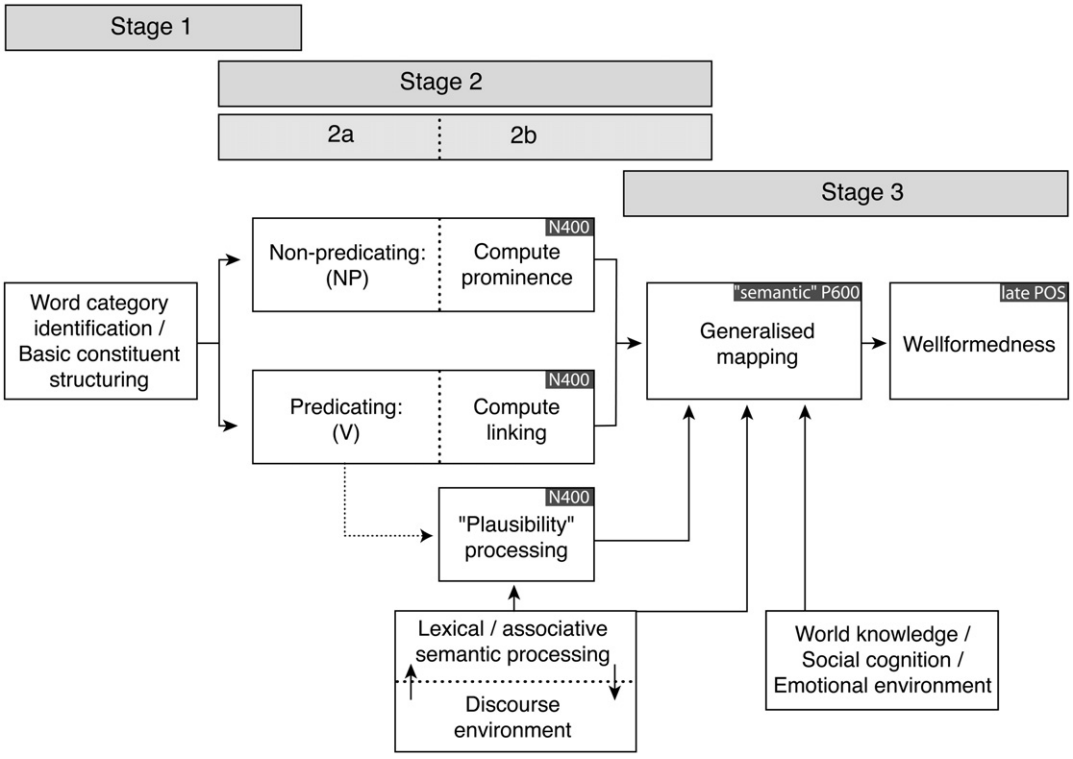

Fig. 1 – Relevant architectural properties of the extended Argument Dependency Model (eADM; Bornkessel, 2002; Bornkessel and Schlesewsky, 2006; Bornkessel-Schlesewsky and Schlesewsky, submitted; Schlesewsky and Bornkessel, 2004) for the modelling of ERP effects in the "semantic P600" literature. For the processing steps relevant to the line of argumentation in the present paper, the corresponding ERP effects are depicted in the figure; note that superficially similar ERP components (e.g. "N400") can index functionally distinct processing steps in this model. Note also that the "plausibility" processing step in stage 2 is *not* responsible for the detection of overall sentence plausibility, but rather serves to determine the most plausible combinations of arguments and verbs in a given sentence (see the text for details).

Bornkessel, 2004). This is the case, for example, in a sentence such as *Der Sängerin gefällt die Arie* ([the singer]$_{DAT}$ pleases [the aria]$_{NOM}$; 'The singer finds the aria pleasing/appealing.'). Thus, under certain circumstances, systems of this type allow prominence information of the "modulating" type to determine the overall argument hierarchy (for further discussion, see Bornkessel-Schlesewsky and Schlesewsky, submitted).

When the verb is reached, the previously processed prominence information is integrated with the verb's lexical requirements in order to "link" an argument to its final interpretation (*compute linking* in Fig. 1). More specifically, the argument is linked to a position within a decomposed semantic structure ("logical structure," LS) stored within the lexical entry of the verb (see Van Valin, 2005, for a theoretical motivation). For example, the (transitive form) of *break* is represented as *do'(x,CAUSE(x,(BECOME(broken'(y)))))*. To achieve a successful interpretation of the sentence *John broke the vase*, the Actor argument *John* must be linked to the *x*-variable in the LS and the Undergoer argument *vase* must be linked to the *y*-argument. The linking process is also crucially influenced by voice, i.e. whereas, in a position-based language like English, the clause-initial argument would be mapped onto the Actor role and linked to the *x*-argument in an active sentence, it would be mapped onto the Undergoer role and linked to the *y*-argument in a passive sentence. (Note also that, as voice simply serves to constrain the mapping between arguments and generalised roles, it is not the case that linking is generally more difficult in passive sentences.)

As should be apparent from the preceding discussion, the eADM differs from other existing neurocognitive models of language comprehension (Friederici 2002; Friederici and Alter 2004; Hagoort 2003, 2005; Ullman 2001, 2004) in that it reduces the interpretive burden that is placed on the syntax. All relational and interpretive aspects of processing (e.g. the establishment of an argument hierarchy or of relations between arguments and the verb) are accomplished by principles that are logically independent of the syntactic structure: prominence computation and argument linking. Hence, syntactic representations *only* encode word categories. This perspective, which is compatible with a variety of theoretical approaches (e.g. Culicover and Jackendoff, 2005; Fanselow, 2001; Van Valin, 2005) stands in contrast to alternative models of the comprehension process, which all – at least to the extent to which they have spelled out their representational assumptions – assume that different argument interpretations (e.g. subject vs. object; Actor vs. Undergoer; or the model-internal equivalents) are associated with different syntactic

structures.[6] This basic underlying philosophy of our model architecture might lead to the impression that we are, in fact, advocating that the form-to-meaning mapping consists almost entirely of heuristics (e.g. an animacy heuristic, a linear order heuristic etc.; see Ferreira, 2003). Insofar as we consider incremental interpretation to proceed completely *independently* of the syntactic structure of a sentence, this is an accurate description of our claims. Crucially, however, we do not consider the influence of these various information types as "quick and dirty" strategies or as "shortcuts to interpretation," as many researchers would assume in the case of true heuristics. Rather, we assume that syntax-independent, prominence-based processes of argument interpretation form an integral part of the form-to-meaning mapping within the language architecture.

An architectural consequence of the eADM's prominence-based perspective on sentence-level interpretation – which derives from cross-linguistic considerations regarding the comprehension process – is that word category processing must precede prominence computation/argument linking. This is essential, as prominence computation according to the scales in (13) only applies to arguments and not to verbs. Verbs, by 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. Thus, prominence computation/argument linking takes place in a second stage of processing, following word category identification and syntactic structure building (which, as described above, only involves a combination of word categories). A second consequence for the overall processing architecture arises from the notion that prominence (and linking-relevant) information only comprises a restricted set of cross-linguistically defined information types. Hence, the architecture must incorporate a processing step that sets in after prominence computation/argument linking and which serves to integrate the resulting representations with other information types like world knowledge (*generalised mapping* in Fig. 1). As will become clear in the following section, these basic tenets of the processing architecture, all of which essentially derive from the cross-linguistic perspective adopted by the eADM, play a key role in our account of semantic P600 effects.

On the basis of these theoretical considerations (i.e. word category processing as a prerequisite for prominence computation/linking; the restricted nature of the information types involved in prominence computation/linking; and the requirement for a mapping between the output of prominence computation/linking and further information types), the eADM posits three processing stages, which are organised in a cascaded fashion (see Fig. 1). (For a motivation of the cascaded processing architecture, see Bornkessel-Schlesewsky and Schlesewsky, forthcoming; Bornkessel-Schlesewsky and Schlesewsky, submitted.) Consequently, the processing steps shown in Fig. 1 are hierarchically dependent on one another. On account of such a hierarchical dependence between a processing step A and a processing step B, a processing conflict in A can lead to a "blocking" of the processing in B.

4.2. *Accounting for semantic P600 effects within the eADM*

Having described the basic architecture of the eADM, let us now turn to the way in which this model can account for semantic P600 effects. A crucial question in this regard concerns the model's treatment of lexical–semantic associations and plausibility information. (Note that we use "plausibility" here as a cover term to refer to all of the information types that are subsumed under the plausibility or semantic-attraction-based heuristics in the models discussed in Section 2, i.e. as a label for a non-combinatorial mechanism that seeks to build up the most plausible combination between the arguments and the verb. We will attempt to establish a more precise definition in Section 4.5 below.) Firstly, it is important to note that plausibility does not influence core processes of argument interpretation (i.e. the assignment of generalised roles) during stage two of comprehension. Rather, the eADM posits that plausibility information is processed in parallel to, but separately from prominence computation/argument linking in this processing stage. This follows directly from the assumption that prominence computation/linking is based on only a restricted set of cross-linguistically motivated information types. The two information sources then interact in the *generalised mapping* step of stage 3 to determine final argument interpretation. Following generalised mapping, the *well-formedness* of the utterance is computed with reference to the communicative task at hand.

The separation between prominence computation/linking and lexical–semantic-plausibility processing within stage 2 is motivated by a number of considerations. Firstly, though both aspects of processing engender N400 effects, these N400s have been shown to be qualitatively different from one another by means of analyses in the frequency domain (Roehm et al., 2007b; Roehm et al., 2004). Secondly, prominence and plausibility correlate with distinct neuroanatomical activation patterns: whereas the processing of prominence information has been associated with the posterior portion of the left superior temporal sulcus and the pars opercularis of the left inferior frontal gyrus (BA44) (see Bornkessel and Schlesewsky, 2006; Bornkessel-Schlesewsky and Schlesewsky, submitted), the processing of lexical–semantic/plausibility information correlates with activation in the mid left superior temporal gyrus and the pars triangularis and orbitalis of the left inferior frontal gyrus (BA 45/47) (see, for example, Friederici et al., 2003; Hagoort et al., 2004). Finally, as proposed in Bornkessel (2002) and Schlesewsky and Bornkessel (2004), there is an asymmetry between prominence-based processing and plausibility processing in that the former can influence the latter but not the other way around. This architectural assumption was motivated by the observation that, in contrast to animacy (i.e. a prominence-relevant feature), plausibility information does not attenuate the processing costs engendered by case-based interpretation conflicts during stage 2 of processing (Bornkessel, 2002; Experiment 6).

[6] Of course, these models differ markedly with respect to the way in which one meaning is selected over the other, i.e. as to whether there is an initial stage of syntactic processing (e.g. Frazier & Clifton, 1996; Frazier & Rayner, 1982; Friederici, 2002) or whether all information types interact from the very beginning (e.g. Hagoort, 2003; MacDonald et al., 1994; Trueswell & Tanenhaus, 1994).

From this overall processing architecture, we can derive the following "ingredients" for the explanation of semantic P600 effects within the eADM:

(a) Steps of core argument interpretation (*compute prominence/compute linking*) do *not* take plausibility into account, but only animacy, voice and other language-specific information types (e.g. morphological case, linear position) relevant for prominence computation (as well as previous prominence assignments and predictions based on them);
(b) The processing of *plausibility* information, which takes place in parallel to core argument interpretation processes, is hierarchically dependent on these processes and can therefore be blocked by them. Note that this processing step essentially amounts to a plausibility heuristic (as also proposed in previous approaches; particularly by Kolk et al., 2003, and van Herten et al., 2005, 2006), i.e. to a non-combinatory assessment of the most plausible relation between the arguments and the verb, with a processing problem only resulting when no plausible relation is available;
(c) *Generalised mapping* leads to an integration of the *linking* and *plausibility* steps and can be blocked by a fatal problem in either of these previous steps;
(d) *Well-formedness* computation is (by its very nature) independent of the success of the previous steps and is therefore not blocked by them; it is also task-dependent.

Within this architecture, the locus of the "semantic P600" is the *generalised mapping* step, which serves to integrate prominence/linking information and plausibility information. In this regard, the eADM converges with other approaches: semantic P600 effects are viewed as resulting from a conflict between different information sources. The absence of an N400 in these constructions is attributable to the semantic association between the arguments and the verb, on account of which no increased processing costs are triggered within the plausibility processing step. When no such association is present, a processing problem is already registered within the plausibility step and an N400 ensues. This N400 may be followed by a late positivity (*well-formedness*) depending on the overall experimental environment. This explanation straightforwardly accounts for the data in Kuperberg et al. (2003), Kim and Osterhout (2005), Kolk et al. (2003), Hoeks et al. (2004) and van Herten et al. (2006).

Consider, for example, the two critical sentence types from Kolk et al (2003), which are repeated in (14) for convenience (with respect to example 14b, see also Footnote 5).

(14) a. De vos die op de stropers joeg…
the fox that at the poachers hunted
'The fox that hunted the poachers…'
b. De bomen die in het park *speelden*…
the trees that in the park played…
'The trees that played in the park…'

In (14a), the processing system assigns the Actor role to the *fox* and the Undergoer role to the *poachers* via their relative linear positions in the sentence (i.e. via the relevant primary prominence information in Dutch; *compute prominence* steps at both NPs). When the verb is reached, these assignments are linked to the verb's LS, namely *do'(x,hunt'(x,y))*. The Actor is mapped to the *x*-argument and the Undergoer is mapped onto the *y*-argument; these assignments are straightforward and no linking problem arises. At the same time, the plausibility of the combination between the arguments and the verb is checked. Here, there is again no problem, because of the semantic association between the arguments and the verb. (Note that this essentially amounts to the assumption of a plausibility heuristic. We will discuss the consequences of such an assumption in more detail below.) Finally, increased processing difficulty ensues in the *generalised mapping* step because the *linking* and *plausibility* steps reached different conclusions with respect to role assignments. Thus, a P600 is elicited. (It is also at this point that the overall ill-formedness or "implausibility" of the sentence is recognised.) In (14b), by contrast, the absence of a semantic association between the subject and the verb leads to a problem being registered in the *plausibility* processing step and, thereby, to an N400. Consequently, *generalised mapping* is blocked because one of its critical information sources failed to generate an input representation. Depending on the experimental environment and the task, a late positivity may be elicited as a consequence of the well-formedness processing step. Hence, Kolk et al (2003) observed a late positivity for this type of sentence only with an acceptability judgement task. Crucially, according to the eADM, this positivity is qualitatively different from that observed (independently of task) for sentences such as (14a).

A very similar explanation can be applied to the sentences examined by Hoeks et al. (2004). The two critical examples of interest are repeated in (15) for convenience.

(15) a. De speer heeft de atleten geworpen.
the javelin has the athletes thrown
'The javelin has thrown the athletes.'
b. De speer heeft de atleten opgesomd.
the javelin has the athletes summarised
'The javelin has summarised the athletes.'

Before the verb is reached, the processing system assigns the Actor role to the *javelin* and the Undergoer role to the *athletes* in both (15a) and (15b). As mentioned above, these assignments are fully determined by linear order in a language like Dutch (or English), i.e. whilst animacy information is used to determine that the Actor argument cannot be a fully prototypical Actor (i.e. one that acts volitionally and is control of the event), it cannot influence the hierarchy itself. Similarly, at the position of the verb, linking proceeds smoothly because of the dominating role of linear order in determining Actor and Undergoer: animacy cannot influence linking in a language of the Dutch/English type. In (15a), there is also no *plausibility-based* problem due to the semantic associations between the arguments and the verb, whereas such a problem does arise in (15b). Hence, (15b) engenders a (plausibility-based) N400, whereas (15a) does not. By contrast, (15a) leads to a *generalised mapping* problem, hence eliciting a P600, and both (15a) and (15b) engender a *well-formedness* problem in the context of the acceptability judgement task. Note that the eADM predicts that a late positivity occurring in the context of a processing problem in both *generalised mapping* and *well-formedness* will

be more pronounced than an effect engendered by a *well-formedness* problem alone, due to a summation of the effects in the two processing steps (Bornkessel and Schlesewsky, 2006, p.804). This hypothesis is in fact borne out in Hoeks et al.'s findings: the late positivity engendered by (15a) was larger than that observed for (15b) (Hoeks et al., 2004, pp. 68–69).

In summary, the independently proposed interplay between *compute linking* and *plausibility processing* in stage 2 and *generalised mapping* and *well-formedness* in stage 3 of the eADM can straightforwardly derive the general processing pattern observed for semantic P600 effects: it accounts for the basic finding of a P600 under these conditions as well as for the absence of an N400 when there is a semantic association between the arguments and the verb. It also derives the occurrence of different positivity effects depending on the experimental task.

At a first glance, the data from Kuperberg et al. (2007) appear to provide a counterexample to our account, as these show only a P600 but no N400 for an animacy violation with a semantically unassociated argument (e.g. *Every morning at breakfast the eggs would plant…*). Here, the *plausibility* processing step should be expected to register a problem, thereby leading to an N400. However, closer consideration of the stimuli used in Kuperberg et al.'s (2007) experiment suggest the following explanation for the absence of an N400 effect in these types of sentences. The vast majority of the stimuli used in this study (approximately 75%) included an auxiliary (like *would*) in front of the critical verb at which the processing conflict was induced. Now recall that, within the eADM, argument *prominence computation* (which is the precursor to linking that takes place before a lexical verb is encountered) is determined by information such as animacy, voice and, in English, linear position of an argument. Furthermore, whereas there might be a general preference for an Actor interpretation of the first argument in English (see Philipp et al., 2008, for discussion), this interpretation is not yet fully fixed by linear order (the primary determinant of argument interpretation in English) at the position of this argument itself. Thus, when the position of the auxiliary is reached, the optimal assumption for the system is that the inanimate first argument is in fact the subject of a passive construction and thereby compatible with an Undergoer interpretation in spite of its sentence-initial position.[7] Note that this assumption of a passive preference under certain thematic conditions is compatible with a number of behavioural observations (e.g. Carrithers, 1989). Thus, *prominence computation* leads the system to expect an infinitival auxiliary (e.g. *be*) in the position following *would*. When a main verb is encountered instead, the prerequisite for *compute linking* is not met; more precisely, linking is not initiated because of the unexpected word category. Crucially, this is not a stage 1 processing problem: from the perspective of the phrase structure, an integration of the new category is straightforwardly possible. From the perspective of linking, by contrast, a fundamental problem arises due to the incompatibility between the representations and predictions established prior to the critical constituent and the category of that constituent. This incompatibility is recognised in stage 2a of processing, in which lexical information relevant for prominence computation and linking is extracted, but no integration between the current item and previously established representations takes place yet (Bornkessel and Schlesewsky, 2006, p. 790). Due to the hierarchical dependency between processing steps, the problem in stage 2a of processing leads to a blocking of the *plausibility* processing step and no N400 is generated. Rather, a standard ERP response to an unexpected category is observed (i.e. a late positivity as in The broker persuaded to sell the stock was sent to jail; Osterhout and Holcomb, 1992; for discussion within the context of the eADM, see Bornkessel and Schlesewsky, 2006, p. 803).

Crucially, this scenario does not apply in the Kim and Osterhout (2005) data. Whilst the structures employed in this study presumably also led to an initial preference for a non-active reading (*The dusty tabletops were…*), the association of the initial inanimate NP with an Undergoer reading is compatible with either passive or middle voice (e.g. *The dusty tabletops were cleaned thoroughly/The dusty tabletops were cleaning easily*). In both cases, the processing system should predict a participle. As this is indeed also the category encountered in the next position, no principled problem arises in stage 2a and *compute linking* can proceed. Similarly, *plausibility processing* is not blocked and an N400 can arise when there is no semantic association. This line of argumentation also holds for the findings from Dutch, none of which induced a category mismatch. (See Section 4.5 for a discussion of why Kim and Osterhout's (2005) sentences engender a P600 in spite of the possibility of a middle interpretation.)[8]

Thus, as the preceding discussion has shown, the architectural assumptions of the eADM, which were independently proposed (beginning with Bornkessel, 2002) in order to explain cross-linguistic aspects of language comprehension, do a good job of accounting for the overall data pattern on semantic P600 effects. Furthermore, and crucially for present purposes, the eADM also serves to shed further light on the two empirical

[7] Of the remaining 25% of Kuperberg et al.'s materials that did not include an auxiliary or a modal, a little over 50% are compatible with a passive reading (e.g. *During recess the classrooms in my school used to…*). Hence, approximately 87% of the overall sentence materials were compatible with a passive reading.

[8] Kuperberg (2007) discusses the possibility that the difference between the results of Kuperberg et al. (2007) and those of Kim and Osterhout (2005) might be due to the additional lead-in context in Kuperberg and colleagues' sentences (e.g. Every morning at breakfast, the eggs …), which was not present in Kim and Osterhout's materials. She suggests that the presence of additional context increases the likelihood of observing a P600, citing preliminary data from sentences without a lead-in context as supporting evidence. A principled explanation for why context might have this kind of influence in the sentences used by Kuperberg and colleagues could be that it renders them close to situations of reference transfer (see Sections 2.4 and 4.5 for discussion). This type of reading is highly accessible, for example, in a sentence such as *When they greeted the queen of England, the trumpets would curtsey…* (from Kuperberg et al., 2006). Assuming that reference transfer does take place in such sentences (and this likely depends on the individual materials), this would, of course, change the linking assumptions of the eADM, as the first NP would then be treated as animate by the linking algorithm.

puzzles that were noted in Section 3.2, namely the absence of an N400 in the non-related animacy violation condition in Kuperberg et al. (2007), and the task dependence of some (but not all) of the positivities observed in the semantic P600 literature. The explanations for these two phenomena lie in the hierarchical dependency between *plausibility* processing and stage 2a (the precursor to *linking* and *prominence* computation) and the task dependence of the *well-formedness* check in stage 3, respectively. In view of the importance of these two architectural assumptions for our line of argumentation, we will discuss them in a little more detail in the following two subsections.

4.3. *Why should the precursor to prominence/linking block plausibility?*

The claim that the processing of plausibility relations based on lexical–semantic associations can be attenuated (or "blocked") by other information types is by no means unprecedented in the neurocognitive literature on sentence comprehension. In a study that independently manipulated sentence-level constraint and semantic association, for example, Coulson et al. (2005, p. 143) observed that "the presence of a sentential context resulted in a dramatic attenuation of the association effect on the ERPs," i.e. on the N400.[9] They further observed an interaction between sentential context and semantic association in a positivity following the N400 (a "late positive component," LPC, in the authors' terms), i.e. the positivity was larger for associated vs. unassociated words in incongruous sentences. Thus, it has been shown that the effect of lexical–semantic associations – as measured by the N400 – can be reduced significantly via the influence of other information types. This modulating influence of discourse is also compatible with the finding that the effects of lexical specifications (like animacy) and their influence on the N400 can be altered by a suitable discourse context (Nieuwland and van Berkum, 2006).

The eADM adds a further dimension to these well-established observations by claiming that plausibility effects based on lexical–semantic associations can also be overridden by linking-related information. This proposal was empirically motivated in Bornkessel (2002) by means of an ERP study which showed that argument interpretation conflicts based on case marking in German cannot be attenuated via plausibility information (i.e. plausibility, unlike animacy, has no effect on argument prominence processing in stage 2). By contrast, the reverse influence does occur, i.e. prominence/linking-related information can modulate a plausibility-related N400. Hence, the relation between the two processing steps is asymmetrical and, in accordance with the basic architectural assumptions of the eADM, the hierarchically dependent processing step (*plausibility*) can be blocked by the hierarchically independent one (*linking*).

Furthermore, there is a theoretical motivation for the ability of *prominence computation/linking* (or rather their precursor in stage 2a) to block *plausibility* processing. This becomes apparent when the function of the plausibility processing step is considered more closely. Whereas all groups that have contributed to the semantic P600 literature to date have essentially assumed that the influence of plausibility is somehow related to lexical–semantic associations (see above), it also appears clear that a "plausibility heuristic" must go beyond pure associations between individual words (see van Herten et al., 2006, for discussion). In this respect, the proposed plausibility heuristics are reminiscent of the *thematic processor* that was put forward by Rayner et al. (1983). It was proposed that this processor, which was thought to operate independently of the syntactic analysis of the sentence "[e]xamines the alternative thematic structures of a word (to compare the relative plausibility of each) and selects the semantically and pragmatically most plausible one" (Rayner et al., 1983, p. 371). Thus, assessment of plausibility depends on *word category* (as it only applies to open class categories such as nouns and verbs) and *thematic structure*. Rayner et al. (1983) argued that this constraint is necessary in order to avoid the (computationally costly) assessment of *all* logically conceivable relations between major phrases. Crucially for present purposes, this proposal (which appears fully compatible with the plausibility-heuristic-based effects in the semantic P600 literature) implies that the (non-syntactic) plausibility assessment is only initiated under certain circumstances. It is thus *dependent* on other aspects of the processing architecture, namely on the information types extracted in stage 2a of processing within the eADM. Only if the prerequisites for linking are met in this step is the plausibility check initiated. Otherwise, it is blocked. Hence, the assumption that the precursor processing step to *compute linking* in stage 2a can block *plausibility* processing is well motivated in both empirical and theoretical terms.

4.4. *Why should the well-formedness check be task-dependent?*

As discussed above, the eADM approach explains the task dependence of the late positive effects discussed in Section 3.2.1.2 by interpreting them as manifestations of the *well-formedness* processing step, which is dependent on the experimental environment and particularly the experimental task.

But why should a *well-formedness* assessment be task-dependent? After all, one might also argue that such as step serves spontaneous self-monitoring during language processing (see, for example, Levelt, 1989) and, as such, is completely task independent. However, in the eADM, the functional significance of the well-formedness step is conceptualised somewhat differently. As argued in Bornkessel and Schlesewsky (2006, p. 805), well-formedness is not viewed as an absolute notion, but rather a task-dependent one. Thus, it was conjectured that the late positive ERP effects observed as correlates of this processing step may be related to the P300 family (see Picton, 1993, for an overview; Osterhout et al., 1996, and Coulson et al., 1998, for a discussion of the relation between the P300 and the P600; and Roehm et al., 2007a, for a recent discussion of the P300 from the perspective of language processing), thereby serving to provide an integration of the

[9] Similarly, using both ERPs and eye tracking, Camblin et al. (2007) showed that the effects of a (coherent) discourse context manifest themselves earlier than the effects of semantic association.

utterance into the overall communicative environment (including the experimental task). In this sense, positivities related to well-formedness contrast with those engendered by generalised mapping, for which we believe – on the basis of the data currently available – that an association with the P300 family is less likely. Given this perspective on the *well-formedness* step, its task dependence and the resulting increased late positivities observed in the context of acceptability judgement tasks are fully predicted by the eADM. By contrast, late positivities in other domains (e.g. in response to orthographical errors; Vissers et al., 2006) currently fall outside of the scope of the model.

4.5. *On the nature of plausibility processing*

A remaining issue concerns the precise specification of the plausibility processing step. Whereas the status of this step within the overall comprehension architecture is clearly specified within the eADM (see Bornkessel, 2002; Schlesewsky and Bornkessel, 2004), model-related research has not as yet concerned itself with its internal workings. Thus, equating this step with a plausibility heuristic is a new assumption and a clearer specification of this mechanism clearly constitutes an important goal for future research. Nonetheless, we can offer some speculations based on the overall architecture of the model and the findings discussed above.

Firstly, recall from Section 4.3 that the we consider a processing mechanism similar to Rayner et al.'s (1983) thematic processor to provide an attractive conceptualisation of the plausibility processing step. Thus, whilst this step may be viewed as a plausibility heuristic, it is not completely unconstrained, i.e. it crucially depends on (linking-relevant) category information and possibly also on the lexical (thematic) properties of these categories. These include both the LS of a verb and further lexical specifications tied to it (e.g. verb-specific restrictions on how the argument slots in the LS can be filled), but perhaps also some further lexical specifications of nouns. These might include qualia properties (Pustejovsky, 1995), which specify, for example, the relation between an object and its parts, the distinguishing features of an object within a broader domain, how the object is created and its purpose/function. The latter property, in particular, might be of crucial importance in engendering semantic P600 effects: in virtually all of the structures in which semantically associated arguments and verbs led to a P600 without an N400, the function quale of the critical argument (or one of the critical arguments) was very closely tied to the meaning of the verb (and its Undergoer role). For example, the notion that a qualia-based link between one of the arguments and one of the argument slots opened up by the LS of the verb might suffice to render "plausibility processing" relatively costless (by serving to determine which argument maps onto which slot) can account for the findings of van Herten et al. (2006; Experiment 2), in which the presence of a plausible VP fragment led to a P600 rather than an N400.

Though speculative at present, the notion that the *plausibility* processor is responsible for an assessment of qualia properties in parallel with argument linking would provide an independent motivation for the assumption of this processing step. Thus, qualia properties (or similar information types) are independently required for other aspects of the comprehension process, for example in sentences involving enriched composition, e.g. argument coercion as in *The boy began the book* (see Pustejovsky (1995) and Jackendoff (1997), for a theoretical discussion of these types of sentences). Indeed, initial MEG evidence suggests that enriched composition yields distinct neurocognitive correlates from pure plausibility violations (Pylkkänen and McElree, 2007): this is expected in terms of the present account, in which the increased processing costs for sentences requiring coercion would result from a mismatch between the output of linking and (qualia-based) "plausibility processing" within the generalised mapping step. An explanation along these lines could also derive the P600 effects observed in response to other types of enriched composition (see Section 2.4).

Furthermore, an implementation of enriched composition along these lines could account for the observation of P600 effects in Kim and Osterhout's (2005) data in spite of the possibility of a middle reading (e.g. *The dusty tabletops were cleaning easily*; see the discussion in Section 4.2). As proposed by Van Valin and LaPolla (1997, pp. 416–417), a middle construction requires a particular LS structure, which deviates from the LS that would be lexically stored for the verb *clean* (akin to *be'([[do'(ø,ø) CAUSE[BECOME[clean'(y)]][easy']*) . Thus, in order to derive the LS required for the middle reading, processes of enriched composition are again required, thus yielding a late positivity as a reflection of *generalised mapping*.

In summary, the notion that the processing step which we have currently termed "plausibility processor" may be explainable in more general terms (e.g. as a compositional process based on qualia properties, lexical specifications of a verb's LS etc.) appears rather promising and can possibly lead to a significant extension of the domain of explanation. Nonetheless, the hypothesised relationship between processing issues related to enriched composition, a plausibility heuristic and the eADM's *generalised mapping* step clearly requires further empirical investigation.

4.6. *Predictions/Future directions*

To conclude our discussion of semantic P600 effects and the eADM, we will now turn to some predictions generated by our account. These concern the cross-linguistic perspective on the one hand and qualitative distinctions between superficially similar ERP components on the other.

4.6.1. *The cross-linguistic perspective*

Recall from Section 4.2 that, in terms of the eADM, animacy mismatches in sentences like *The hearty meal was devouring…* do not lead to problems in the *compute linking* step (which would also be expected to engender an N400). This assumption is motivated via cross-linguistic considerations, which are the heart of the eADM's approach to language comprehension. Thus, one of the most basic claims of the model is that the relevance of individual information types for *prominence computation/linking* differs from language to language. In the case of animacy, the consequences of this assumption are as follows: whilst this feature is universally used for *prominence computation*, it is not always relevant for *argument linking* (i.e. for the mapping of the arguments onto the lexically

decomposed semantic representation of the verb). English provides a good example of this dualism. On the one hand, the role of animacy as a prominence-determining feature in English is evidenced by a range of findings (e.g. Chen et al., 2006; Traxler et al., 2002; Traxler et al., 2005; Weckerly and Kutas, 1999). On the other hand, we concur with previous approaches that animacy is not a determinant of argument linking in English (e.g. Culicover and Jackendoff, 2005; MacWhinney et al., 1984; Van Valin, 2005). Hence, animacy per se can never determine the thematic interpretation of an argument, i.e. its interpretation as an Actor or Undergoer. Rather, it only influences the "goodness of fit" between an argument and the role that it bears (see the discussion of primary and modulating prominence information above). Hence, inanimate arguments that are designated Actors by means of their linear position engender N400 effects as a result of this *prominence* mismatch. When the verb is encountered, by contrast, animacy is not used to determine *argument linking*, since this is completely dependent on linear position in a language of this type. Therefore, there are no linking-based N400 effects due to animacy in English (or Dutch).

This account therefore clearly predicts that the "semantic P600" in sentences of the type discussed here should not be a universal phenomenon. Rather, in languages in which animacy may play a role in argument linking, similar sentence types should engender N400 effects (and no task-independent P600 effects, since generalised mapping will be blocked). However, in contrast to traditional assumptions, these N400s will be linking-related rather than plausibility-based. Whether this prediction is indeed borne out will need to be examined in future research.

4.6.2. *Qualitative distinctions between superficially similar ERP components*

Throughout the discussion in the preceding sections, the reader will have noted that the eADM assumes a many-to-one mapping between language comprehension steps and language-related ERP components (see Bornkessel and Schlesewsky, 2006, p. 805, for discussion). For example, *prominence computation/argument linking* and *plausibility processing* both correlate with N400 effects, but these are assumed to be qualitatively distinct. As described in Section 4.2, there is some initial evidence in favour of this assumption, e.g. from frequency-based measures. However, it has not yet been tested empirically in relation to the sentence types of concern to the present discussion. Thus, a clear – and testable – prediction of the eADM's approach to semantic P600 effects is that the *plausibility-based* N400 which occurs in sentences with semantically unassociated arguments and verbs should be distinct from N400 effects observed as correlates of *argument linking* or *prominence computation*.

A second prediction concerns the different types of late positive effects. As noted in several places throughout the preceding discussion, we assume a distinction between *generalised mapping* (which is responsible for generating the "semantic P600") and the *well-formedness* check. Some initial empirical evidence for this distinction was described in Bornkessel and Schlesewsky (2006). However, as for the N400 effects discussed above, our account clearly predicts that the two types of positivities observed in the semantic P600 literature should be distinguishable (e.g. in terms of frequency characteristics).

5. Conclusions

In this paper, we have argued that the effects in the literature on semantic P600s can be derived within an independently motivated, hierarchically organised neurocognitive model of language comprehension, the extended Argument Dependency Model (eADM: Bornkessel, 2002; Bornkessel and Schlesewsky, 2006; Bornkessel-Schlesewsky and Schlesewsky, submitted; Schlesewsky and Bornkessel, 2004). Importantly, these seemingly "unexpected" P600 effects follow directly from the assumptions of the model, which were motivated with reference to very different processing questions. Hence, the component interpretations assumed are compatible with a much broader range of findings. The model additionally has the advantage of overcoming apparent contradictions between previous findings (i.e. the problem of whether semantic relatedness or an animacy mismatch is the crucial factor conditioning the absence of an N400). It further makes the interesting prediction that semantic P600 effects should be subject to cross-linguistic variation.

Notably, the line of argumentation advanced here from the perspective of the eADM does not mean to imply that previous approaches to semantic P600 effects are entirely incorrect. To the contrary, there are some interesting degrees of overlap between these and our model. In particular, the notion of a conflict between different information types (as assumed by Kolk, van Herten and colleagues and, to some degree, by other approaches as well) is highly compatible with the assumption that semantic P600 effects are engendered by the generalised mapping step within the eADM, as this step serves to integrate distinct sources of information with one another. Our model differs from previous approaches, however, with respect to the question of how this conflict comes about within the overall processing architecture (though this, of course, does not undermine the general compatibility with overarching conflict-based perspectives on the semantic P600). Furthermore, like previous accounts of semantic P600 effects, the eADM's approach also makes reference to a plausibility heuristic. However, as this processing step is embedded in a hierarchical processing architecture, it only applies under certain circumstances. Furthermore, we have suggested that the "plausibility processor" may be motivated in more general terms, e.g. with reference to a check of lexical LS specifications/qualia properties that is initiated in parallel with argument linking (and thereby is also blocked under circumstances in which linking cannot take place).

In summary, by illustrating how semantic reversal anomalies/semantic P600s can be modelled within the eADM, we have shown that a hierarchically organised incremental processing model – together with a rather different conception of autonomous thematic processing ("prominence"/"linking") – can go a long way indeed in accounting for these seemingly unexpected language-related ERP effects.

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