Brain & Language 122 (2012) 179–189

Contents lists available at SciVerse ScienceDirect

Brain & Language

journal homepage: www.elsevier.com/locate/b&l

Decomposing animacy reversals between agents and experiencers: An ERP study

Nicolas Bourguignon [a,b,*], John E. Drury [c], Daniel Valois [a,b], Karsten Steinhauer [b,d,*]

[a] Department of Linguistics, University of Montreal, Canada
[b] Centre for Research on Brain, Language and Music, Montreal, Canada
[c] Department of Linguistics, Stony Brook University, USA
[d] School of Communication Sciences and Disorders, McGill University, Canada

ARTICLE INFO

Article history:
Available online 12 June 2012

Keywords:
ERP
Semantic P600
N400
Language processing
Verbal aspect
Thematic roles
Cross-linguistic differences
Psych-verbs
Animacy

ABSTRACT

The present study aimed to refine current hypotheses regarding thematic reversal anomalies, which have been found to elicit either N400 or – more frequently – "semantic-P600" (sP600) effects. Our goal was to investigate whether distinct ERP profiles reflect aspectual-thematic differences between Agent-Subject Verbs (ASVs; e.g., '*to eat*') and Experiencer-Subject Verbs (ESVs; e.g., '*to love*') in English. Inanimate subject noun phrases created reversal anomalies on both ASV and ESV. Animacy-based prominence effects and semantic association were controlled to minimize their contribution to any ERP effects. An N400 was elicited by the target verb in the ESV but not the ASV anomalies, supporting the hypothesis of a distinctive aspectual-thematic structure between ESV and ASV. Moreover, the N400 finding for English ESV shows that, in contrast to previous claims, the presence versus absence of N400s for this kind of anomaly cannot be exclusively explained in terms of typological differences across languages.

1. Introduction

In recent years a growing industry has arisen in language ERP research around the study of so-called THEMATIC REVERSAL ANOMALIES (henceforth TRA, see Kuperberg, 2007 and Bornkessel-Schlesewsky et al., 2011 for an overview). For example, consider the syntactically well-formed sequence *For breakfast the eggs would only eat* ... (from Kuperberg, Sitnikova, Caplan, & Holcomb, 2003). Here the main verb (*eat*) requires a subject noun phrase (NP), which can be mapped to the thematic role of the AGENT of the eating event, which presupposes this NP should pick out an animate entity. Although the relevant NP would make a perfectly acceptable direct object in this case (*eggs* can *be eaten*), since it occupies the canonical subject position it clashes with the animacy requirements of the verb, resulting in a clear intuitive sense of deviance.

The interest of TRA paradigms relates to the information they may bring regarding the factors that modulate two prominent types of ERP components: the N400 (Kutas & Hillyard, 1980) and late positive-going deflections often grouped together under the label of P600 effects (Osterhout & Holcomb, 1992). In particular, earlier days of language ERP research were marked by a rigid alignment between N400- versus P600-effects and lexical/semantic versus syntactic aspects of language processing, respectively. TRA studies of the sort illustrated above have played a role in rethinking this dichotomy. Notably, given that animacy is usually viewed as a conceptual-semantic rather than a structural construct and that semantic anomalies typically yield N400 components, "semantic P600"[1] effects observed in sentences such as *the eggs would eat...* indicate that the traditional alignment of syntax to the P600 and semantics to the N400 must be reevaluated. The present article contributes new ERP data that we argue to be relevant in refining recent hypotheses formulated in this perspective.

1.1. New challenges in TRA research

A wide range of accounts have been offered to address the nature of sP600 effects of TRA in English (Kim & Osterhout, 2005; Kuperberg, 2007; Kuperberg et al., 2003) and Dutch (van Herten, Chwilla, & Kolk, 2006; see also Kuperberg, 2007 and Bornkessel-Schlesewsky & Schlesewsky, 2008 for extensive reviews). However, recent research brings two additional puzzles, the second of which can be viewed as a starting point for our present investigation.

* Corresponding authors. Addresses: Département de linguistique et de traduction, Université de Montréal, C.P. 6128, Succursale Centre-ville, Montréal, QC, Canada H3C 3J7 (N. Bourguignon), School of Communication Sciences and Disorders, McGill University, 1266 Pine Avenue West, Montreal, QC, Canada H3G 1A8 (K. Steinhauer).

E-mail addresses: nicolas.bourguignon@umontreal.ca (N. Bourguignon), karsten.steinhauer@mcgill.ca (K. Steinhauer).

[1] The term "semantic P600" is sometimes used interchangeably with "Late Positivity" depending on the choice of authors. For the sake of consistency, the label "sP600" will be used in this text whenever appropriate.

0093-934X/$ - see front matter Crown Copyright © 2012 Published by Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.bandl.2012.05.001

First, there are reasons to believe that there may be nothing particularly special about thematic reversals and late positive-going (sP600-like) ERP effects. Though less widely advertised, manipulations introducing conceptual semantic anomalies that have no obvious connection with thematic reversal have been shown to elicit biphasic N400/P600 patterns (see Steinhauer, Drury, Portner, & Walenski, 2010, and Stroud & Phillips, 2012), suggesting that P600 effects and other late positivities should be driven by broader information processing resources. Within the context of the sP600 debate, such domain-general interpretation of the sP600 is entertained by van Herten et al. (2006) and van de Meerendonk, Kolk, Vissers, and Chwilla (2008). These authors hold that sP600-effects are, on a par with other positivities such as the P300 (specifically the P3b; see Donchin & Coles, 1988), indexes of monitoring conflicts or discourse updating, presumably pushed around by task effects, sentential lead-in context and/or saliency of violation (see also Kuperberg, 2007). This proposal comes to be consistent with Bornkessel-Schlesewsky et al.'s (2011) latest view of late positivities as indexes of binary categorization of well-formedness.

The second puzzle lies in the fact that the pattern of sP600 does not hold consistently across languages: TRA also elicits monophasic N400 effects in Mandarin Chinese and Turkish (Bornkessel-Schlesewsky et al., 2011) and biphasic N400/late positivities in German (Schlesewsky & Bornkessel-Schlesewsky, 2009). Also, research *within* specific languages (e.g., Icelandic in Bornkessel-Schlesewsky et al., 2011) suggests that ERP responses to TRA can differ according to verb type: While verbs relying on case marking for subject identification elicited a biphasic N400–sP600, those for which subject identification depends on word order rather elicited only a sP600. Considering the properties that characterize individual languages, Bornkessel-Schlesewsky et al. (2011) conclude that the elicitation of N400s or sP600s largely depends on word order flexibility: Whereas N400 effects are expected to be absent for TRA in "sequence dependent" languages or verbs relying on rigid word order, such as English, Dutch and certain Icelandic verbs, they are predicted to occur in "sequence independent" languages or verbs for which case marking is the prime factor of subject identification[2]. This conclusion draws on the broader idea that languages differ in their reliance on various types of cues to determine verb-argument relationships such as case marking, animacy, definiteness, and so on (*cf.* MacWhinney & Bates, 1989). Within the framework of Bornkessel-Schlesewsky and Schlesewsky's extended Argument Dependency Model[3] (eADM, cf. Bornkessel & Schlesewsky, 2006, 2008, 2009), sequence-independent languages would be expected to elicit N400s for thematic reversals during a processing step that their model refers to as COMPUTE LINKING (see below). Their most recent suggestion is remarkable in three ways: (a) Whereas most other approaches have attributed variability in ERP patterns across TRA studies to different item materials and task requirements, this new perspective introduces typological differences among languages as a main source for systematic ERP differences. After decades of replicating apparently monolithic ERP components such as 'lexico-semantic' N400s and 'syntactic' P600s cross-linguistically, we may have reached a point where genuine typological dissimilarities can be linked to distinct psycholinguistic processes – and traced with distinct ERP profiles. (b) Another important aspect of Bornkessel-Schlesewsky et al.'s proposal is that the mystery of 'semantic P600s' (versus semantic N400s) may in the end be solved in terms of a dichotomy which seems to resemble the traditional N400/P600 divide: Depending on the target language, TRA may elicit N400s whenever *lexical* processing is required, and P600s if either structural processing or 'categorization' is sufficient. (c) In their 2011 paper, Bornkessel-Schlesewsky and colleagues localize the relevant criterion for eliciting TRA-related N400s at the distinction between 'sequence-*dependent*' and 'sequence-*independent*' languages (largely operationalized in terms of free word order and case marking). Precisely this criterion also allowed them to create a corresponding verb contrast in Icelandic that replicated both 'typological' ERP profiles within the same language.

The present study does not address the question of the extent to which sP600 or N400 effects are related to monitoring or task effects. Our main focus is on the possibility, highlighted by Bornkessel-Schlesewsky et al. (2011), that different verb types within a particular language might elicit different ERP responses to TRAs. However, (1) we extend their case-marking account for N400s to a more general 'lexical processing' approach also encompassing thematic contrasts, and (2) test this broader account in a language that – according to Bornkessel-Schlesewsky and colleagues – must be viewed as strictly 'sequence-dependent'. Specifically, we test the hypothesis that N400 effects might also be elicited by TRAs detected on EXPERIENCER SUBJECT Verbs (ESVs) in English as a result of having an aspectual-thematic structure that differs from AGENT SUBJECT Verbs (ASVs) and, therefore, requires additional lexical processing. This inquiry, as we will now discuss, can be expected to help us (i) evaluate the predictive range of Bornkessel-Schlesewsky et al's (2011) claim that word order flexibility ("sequence (in)dependence") is the prime factor determining whether TRAs yield N400-like or sP600-like components, and (ii) examine what role thematic/aspectual structure may play in eliciting different ERP responses to TRA.

ASVs such as *eat* denote events, implying a causal chain of actions or processes with a beginning, a duration and an end, and require that their subject argument be an animate AGENT, often (but not always) intentionally involved in the event. By contrast, the animate subject of stative verbs expressing emotions, as with the ESVs, (e.g., *love*), picks out the center of a psychological experience instead of expressing a complex chain of action. As suggested in previous theoretical and behavioral research (e.g., Gennari & Poeppel, 2003 and references therein), the distinction between events and states at the lexical level appears to yield processing differences at the sentence level. Furthermore, recent MEG studies on psychological predicates point to differences in brain responses as a function of lexical complexity (Brennan & Pylkkänen, 2010). Taken together, these findings suggest that aspectual and thematic differences may have an influence on the detection of TRA.

However, ERP evidence so far suggests that differences in the particular thematic roles assigned by verbs do not in fact modulate ERP responses to animacy violations, at least when they are realized on direct objects in English. Paczynski and Kuperberg (2011) examined ERP responses to animate and inanimate nouns in direct object position (their Experiment 2), where the latter created a selectional violation (*b*-examples in (1) and (2) below). In addition, they manipulated the verb-type (e.g., (1) versus (2)), which either assigned the thematic role of PATIENT to the object (as in (1)), or E*xperiencer* (as in (2)). The type of verb in (2) – so-called EXPERIENCER-OBJECT Verbs (EOVs) – are quite often contrasted to their EXPERIENCER-SUBJECT (ESV) counterparts (on which we focus here). The mapping of the EXPERIENCER role in these two verb types (ESV/EOV) are a mirror image of each other: with EOVs, the EXPERIENCER occupies the object position, while the THEME (also known as SUBJECT MATTER,

[2] Note, however, that it is not obvious from Bornkessel-Schlesewsky et al.'s (2011) report that they adequately controlled for factors that other researchers have suggested may influence the presence/absence of the N400 in thematic reversal anomalies, for example the associative/semantic relatedness of open class items (see, e.g., Stroud & Phillips, 2012; Van Herten et al. 2006). However, we will set this concern to the side for the moment (though see our Material and methods and Discussion below).

[3] See Bornkessel and Schlesewsky (2006) for a detailed discussion of the eADM, and Bornkessel-Schlesewsky and Schlesewsky (2008) for an application of this approach to the sP600 literature.

Table 1
Conditions examined in the present study. Target words for correct/violation conditions are indicated in bold italics and violations are marked by "*"[a]. The left-hand side of the table illustrates the main conditions of interest (ASV and ESV) and the right hand side refers to the complementary EOV condition (see Appendix).

Agent Subject Verbs (ASVs)	
Animate – correct	
The boys have ***eaten*** the fries too quickly	
The student has ***written*** the answer on the form	
The hikers have ***used*** the compass in the forest	
Inanimate – incorrect	
The fries have *__eaten__* the boys too quickly	
The answer has *__written__* the student on the form	
The compass has *__used__* the hikers in the forest	
Experiencer Subject Verbs (ESVs)	**Experiencer Object Verbs (EOVs)**
Animate – correct	Animate – correct
The children have ***loved*** the gifts of the orphanage	The gifts have pleased the ***children*** of the orphanage
The judges have ***despised*** the movies at the festival	The movies have displeased the ***judges*** at the festival
The people have ***admired*** the inventions for a long time	The inventions have fascinated the ***people*** for a long time
Inanimate – incorrect	Inanimate – incorrect
The gifts have *loved the children of the orphanage	The children have pleased the *__gifts__* of the orphanage
The movies have *despised the judges at the festival	The judges have displeased the *__movies__* at the festival
The inventions have *admired the people for a long time	The people have fascinated the *__inventions__* for a long time

[a] See Methods below for details about the stimuli. The materials are available from the first author.

cf. Pesetsky, 1995) is the subject. For ESVs, the Experiencer role is mapped to the subject position (see below, and Table 1)[4].

(1) a. At the homestead the farmer *penalized* the **laborer** for laziness
b. At the homestead the farmer *penalized* the *__meadow__ for laziness
(2) a. At the homestead the farmer *interested* the **laborer** in some work
b. At the homestead the farmer *interested* the *__meadow__ in some work

Intriguingly, Paczynski & Kuperberg's data show only (in)animacy main effects, in particular a biphasic N400/P600 response for the inanimate (1b)/(2b) relative to the animate (1a)/(2a) objects, with no interactions involving verb-type. They take this finding to speak against any account which claims that the animacy of nominal expressions exerts its influence on on-line language comprehension via connections to particular thematic roles.

Here we posed the following question: are ERP responses to TRAs similarly insensitive to the particular identity of thematic roles when animacy clashes are realized on the verb as a result of the inanimacy of a preceding subject noun?

1.2. The present study

1.2.1. Violations on the verb: ASVs versus ESVs

The left-hand side of Table 1 includes the four main conditions of central interest in the present study, realizing a 2 × 2 design with factors Verb-type (ASV versus ESV) and Animacy (i.e., of the subject NP). The right-hand side of Table 1 will be discussed further below (Section 1.2.2).

Above we mentioned the eADM: What would this approach predict for this 2 × 2 design (Verb-Type × Animacy)? If we adopt Bornkessel-Schlesewsky et al.'s (2011) assumptions, we would expect main effects of Animacy only, with no Animacy × Verb-Type interactions, at both the first noun and the main verb, based on the following reasoning. First, given the dominance of word order as a cue in English, the sentence-initial subject NPs in all cases should be mapped to a general Actor role (which subsumes both Agent and Experiencer on their assumptions, see below) during the Compute Prominence step. This, according to eADM, should result in an N400 effect once the subject nouns are encountered, with the inanimate NPs (e.g., *fries*/*gifts*, in Table 1) more negative going than the animate ones (*boys*/*kids;* see also Weckerly & Kutas, 1999). However, though animacy is predicted to influence the Compute Prominence step (which deals with NPs), this should not matter once the verb is encountered, since animacy is assumed not to play a role in the Compute linking step (see in particular Section 4.6.1 in Bornkessel-Schlesewsky & Schlesewsky, 2008). Thus, it is only when Compute Prominence and Compute Linking are integrated that the system should detect a mismatch, resulting in a late positivity. If nothing else is said, this view then predicts that the particular sub-type of thematic role assigned to the subject by the two types of verbs in Table 1 (Agent versus Experiencer) should not influence this pattern at all. So far as we can see, to the extent that other views would make specific predictions about these contrasts, all would agree that the Agent/Experiencer distinction should not modulate the effects arising at the verb position (including e.g., Kuperberg et al., 2003 or Kim & Osterhout, 2005).

However, an alternative view predicts a different outcome while retaining the potential insight brought forth by Bornkessel-Schlesewsky et al. (2011) regarding N400 effects and the informativeness of various types of cues in sentence processing (both *across* and *within* languages). Their eADM approach assumes the existence of Generalized semantic Roles ("GRs", a.k.a. protoroles or macro-roles, see Van Valin, 2005) of Actor and Undergoer and considers it as a basis upon which the various thematic dimensions vary as a function of verb type (Bornkessel-Schlesewsky & Schlesewsky, 2009). However, eADM does not, to our knowledge, consider whether the more narrow thematic relations these subsume might influence their proposed Compute Linking step in such a way as to yield distinct ERP responses.

Nevertheless, one could easily imagine that the identity of the specific thematic relations subsumed by the Actor/Undergoer GRs could indeed matter, for the simple reason that although the Agent role has a *unique* status as the subject/external argument in English, when this role is present, this is *not so* for the Experiencer role, which can also be mapped to the object/internal position (as with Object-Experiencer verbs like *frighten*, see right-hand side

[4] This intriguing characteristic of psychological predicates has been a major topic of research in theoretical linguistics (Belletti & Rizzi, 1988; Bouchard, 1995; Doron, 2003; Hale & Keyser, 1999; Landau, 2009; Van Voorst, 1992) and still poses many challenges to investigators.

of Table 1, and below). Indeed, on some views (e.g., see Van Valin, 2005) Experiencers are understood to be cross-classified by the Actor/Undergoer distinction (falling across this GR boundary). Put another way, being a verb associated with an Experiencer argument is not *informative* to processing systems in the way that being a verb with an Agent argument is: Whether an Experiencer role can be mapped to the subject/external argument position or not depends on *the identity of particular verbs*. There is no such dependency on the identity of particular verbs at stake when the role involved is an Agent. It thus seems reasonable to hypothesize that the need to narrowly identify the ESVs with a specific sub-class in order to assign the role that results in the subject/verb animacy clash involves fundamentally *lexical* processing. Therefore, on a fairly broad interpretation of N400 effects as reflecting access/retrieval of lexical-conceptual information (see e.g., Lau, Philips, & Poeppel, 2008), the ESV but not the ASV should elicit N400 effects.

1.2.2. The case of EOV

Finally, consider now the right-hand side of Table 1. Though the ASV/ESV contrast was our main focus, one might wish to see whether ESV and EOV might somehow pattern together and contrast in some way with ASV, perhaps as a result of the special status of the former as psychological predicates. However, several aspects of the present study render such comparison problematic (see Section 2.2 for an independent motivation to include the EOV condition in our materials). First, a natural impulse one might have would be to try to round out the conditions in Table 1 into a full $2 \times 2 \times 2$ design, filling in the missing cell. Given that we created our critical ASV/ESV correct/violation pairs by swapping subject and object nouns, what we would need to fill in those cells would be verbs which *permit* inanimate subjects but *demand* animate objects, but which do not involve the assignment of an Experiencer role (but see Paczynski & Kuperberg, 2011 for another approach). As the missing cells in Table 1 suggest, no such cases were included in the study, and in fact it is not obvious what sort of verbs actually *could* permit inanimate subjects while demanding animate objects. It is therefore difficult to conclude with confidence that the ERP response to animacy violations involving EOV would reflect specific properties of this verb type (see, in this connection the discussion in Steinhauer & Drury, 2012 for an illustration of the importance of balanced designs in ERP research). Another issue is that while ERP effects in ESV and ASV appear on the verb itself, they are expected on the object NP in EOV. Not only does this difference introduce potential (and undetectable) confounds related to grammatical class, but the amount of information available at the moment where the violation is detected is not the same between ASV/ESV and EOV. While in EOV *all* arguments have been integrated at the moment the violation occurs, in ESV and ASV only one has. It is therefore impossible to determine the extent to which the ERP effect in EOV indexes a clash involving the Experiencer, the Theme or both thematic roles. However, as our cases do involve a similar (though less well-controlled) contrast as has been investigated in other recent work (i.e., in Paczynski & Kuperberg's study), for sake of completeness we have included a brief analysis and discussion of our EOV conditions as part of an additional 2×2 comparison with ESV in Supplementary material appendix, the result of which we view as of potential interest but, for the moment, inconclusive. Therefore, in the rest of what follows, we concentrate exclusively on our main research question, which deals with the ASV/ESV comparisons involving animacy violations detected on the relevant verbs.

1.2.3. Confounding factors: context and relatedness

Importantly, exploring the hypothesis that the aspectual/thematic properties distinguishing our ASV and ESV conditions, sketched above, requires that we attend to other factors known to influence the elicitation of N400 or sP600 effects (see Methods). Two factors in particular merit brief discussion. The first is the role of sentential lead-in context. TRA sentences used in previous studies often made use of sentential lead-in context prior to the actual violation on the subject noun (e.g., ***Every morning at breakfast***, *the eggs...*). As Kuperberg (2007, Section 3.6) mentions, even small amounts of sentential lead-in context have been shown to play a role in eliciting or suppressing N400 or sP600 components. Assuming this to be the case, sentential lead-in contexts would introduce the risk of interfering with the effects actually elicited by the verbs. As can be seen from Table 1, no such context appeared before the critical elements in our stimuli, namely the subject NPs and the verb.

Another phenomenon to control for was the strength of semantic relatedness (Kuperberg, 2007, Section 3.2.). As has been shown in several previous studies, the degree to which particular arguments are related to the predicate constitutes another potential factor driving the elicitation of N400 or sP600 effects. For example, Kuperberg cites the studies by Kolk, Chwilla, van Herten, and Oor (2003) and van Herten et al. (2006) as evidence for the suggestion that whenever semantic association between arguments and verbs is strong, this would elicit a sP600 and attenuate the N400 component. In order to assign different effects according to differences in verb type and not to differences in relatedness, it was necessary that the degree of relatedness between be similar between ASV and ESV (see details in Section 2.2 below). As in van Herten et al. (2006) and van de Meerendonk et al. (2008), we controlled for semantic relatedness using Latent Semantic Analysis (Landauer & Dumais, 1997; see details in Methods below) in such a way that any differences in ERP responses would be attributable to the distinct aspectual-thematic properties of ESV and ASV rather than semantic relatedness.

2. Materials and methods

2.1. Participants

Twenty right-handed (Edinburgh Handedness Inventory), native English-speaking adults (9 female; mean age = 21.9; age range = 18–37) with normal vision and no history of psychiatric, neurological or cognitive disorders participated after giving informed consent. Participants were paid for their participation.

2.2. Stimuli construction and distribution

Our main goal was to present each participant with 30 grammatical control sentences and 30 ungrammatical TRA sentences in both ASV and ESV conditions (see Table 1). The verbs were selected from Levin (1993). Each of these verbs was combined with plausible pairs of an animate subject NP and an inanimate object NP to create the grammatical control sentences (for matching criteria see below). To rule out any contextual priming effects, no context preceded the subject NP. To allow for tests of animacy/prominence effects on the subject NPs in absence of sentence onset effects, all NPs were lexical nouns preceded by the definite determiner 'the'. In order to avoid confounds with sentence wrap-up effects at any potential target word of interest, object NPs were followed by either prepositional phrases (PP) or adverbial phrases (AdvP), all of which began with a high-frequency function word, resulting in the following sentence template: *The Subject-Noun has/have verb-participle the Object-Noun PP/AdvP* (e.g., 'The hikers have used the compass in the forest.'). The use of the present perfect in ASV and ESV was principally motivated by the need to create naturally sounding sentence materials for both verb types without extensive discourse context, and to ensure that the

presence of a functional category (i.e., the auxiliary *has*/*have*) would minimize carry-over ERP effects between the subject NP (where we expected N400 effects tied to (in)animacy) and the critical verb. Ungrammatical TRA sentences were derived by swapping the (in)animate NPs between the subject and object positions (Table 1). Importantly, for both ASV and ESV, the anomaly occurs on the verb following an inanimate subject NP for both the ASV and ESV conditions, ensuring maximal comparability.

However, as *all* of these ungrammatical TRA sentences started with an inanimate subject NP, there was a risk that participants might use sentence-initial inanimate NPs as a general cue to predict the ungrammaticality even *before* encountering the critical verb. To guard against participants adopting such a processing strategy, we introduced the EOV condition, which – unlike ESV and ASV – is grammatical with inanimate subject NPs and animate object NPs. Thirty EOV were selected (Levin, 1993) that combined well with the NP pairs already selected for the ESV condition. This step was facilitated by the fact that many ESV (e.g., Mary *feared* the storm) correspond to similar EOV (e.g., The storm *frightened* Mary), but with inverted theta role assignment. The ungrammatical TRA condition for EOV was again derived by swapping (in)animate NPs across the subject and object positions. As a result, ungrammatical EOV sentences (e.g., *The children have pleased the *gifts of the orphanage*) had the same NP order as grammatical ESV sentences (e.g., *The children have loved the gifts of the orphanage*). Importantly, whereas TRA effects in ASV and ESV manifest on the verb, TRA effects in EOV sentences are expected to occur on the object NP. Had this been the final design, NPs selected for ESV and EOV would have been repeated twice as often as NPs selected for ASV, causing potential priming effects and other ERP artifacts (e.g., Besson & Kutas, 1993) in ESV and EOV conditions. To guard against this we selected a second set of 60 NP pairs that combined equally well with both ESV and EOV as the initial set of NP pairs. A given participant saw either ESV conditions with the initial NP set and EOV with the second NP set, or *vice versa* (counter-balanced across participants).

To avoid semantic association confounds with our ASV/ESV manipulation, we calculated semantic relatedness between the NPs and the Verbs using "Latent Semantic Analysis" (LSA, Landauer & Dumais, 1997, see http://lsa.colorado.edu/). We used term-to-term comparisons for each of our target (auxiliary +) verb stimuli and the corresponding animate and inanimate subject NPs (e.g., *the fries—have eaten*). Crucially, our materials were extremely well-matched in this respect, yielding nearly identical mean relatedness [$t(88) = 0.30$, $p = 0.98$] for inanimate/AS combinations (mean: 0.318, sd: 0.132) compared to inanimate/ES (mean: 0.319, sd: 0.129). Similarly, the animate/AS (mean: 0.2641, sd: 0.10) and animate/ES (mean: 0.2643, sd: 0.09) combinations were also extremely well-matched in this respect [$t(88) = -0.008$, $p = 0.99$]. Note that, in general, our *inanimate* NPs scored significantly higher ($p < .001$) on these LSA derived semantic relatedness measures than our *animate* NPs. This asymmetry, to the extent that associative/semantic relatedness may matter here (Stroud & Phillips, 2012; van Herten et al., 2006), introduces a bias *against* the possibility of finding an N400, but equally so for *both* of our verb-types (as the violation condition should result in a greater degree of priming of the verb than the control condition, which should be expected to reduce N400 amplitudes). Further, ESV and ASV did not differ in orthographic length ($p > .50$) and frequency (BYU-BNC: The British National Corpus; $p > .50$). Nor did animate and inanimate ESV and ASV Subject NPs differ in frequency (BYU-BNC: The British National Corpus; $p > .50$) or orthographic length ($p > .05$).

A total of four lists was then created (two complementary lists and their respective mirror-image counterparts, thus ruling out any sequence effects) and assigned to participants in a counter-balanced manner. As a result, each subject saw (1) 60 ASV sentences (30 TRA/30 controls), (2) 60 ESV sentences (30 TRA/30 controls) and (3) 60 EOV sentences (30 TRA/30 controls). These conditions were pseudo-randomly distributed and interspersed with 60 sentences of a phrase structure violation condition (e.g., *My father hopes to [grow a tree/*tree a grow] in his yard*; 30 violations/30 controls) and 60 sentences in a semantic anomaly condition (e.g., *The philosopher has interpreted the ideas/*wallpaper* very badly), for a total of 300 pseudo-randomly distributed sentences per list[5]. The 300 items were evenly distributed across 6 blocks of 50 trials each, presented with short breaks of a few minutes between every other block.

2.3. Procedure and behavioral data analysis

Participants were seated in a comfortable chair in a sound-attenuated and electromagnetically shielded booth at a distance of 1 m in front of a computer monitor and were given written instructions before the beginning of the EEG session. Subjects were asked to avoid eye blinks and movements during sentence presentation, their corresponding artifacts in the EEG signal were illustrated on the screen while subjects deliberately moved or blinked their eyes. Each trial started with a fixation cross appearing in the center of the screen for 500 ms, after which sentences were presented word-by-word in an RSVP mode (300 ms presentation plus 200 ms blank screen per word). One second after offset of the last word, a visual response prompt ("GOOD?") required subjects to rate the sentence's acceptability by pressing either the left or right mouse-key. After participants had responded (or the maximal response time of 5 s had elapsed), an eye-blink prompt "(–)" appeared for 2 s, indicating the interval during which blinking was encouraged. This procedure dramatically reduced the occurrence of eye-blink artifacts during sentence presentation (see below). Eight unrelated practice trials (half with linguistic violations) were presented before the actual experiment to familiarize participants with the procedure. The entire session, including electrode placement, breaks, and clean up lasted between 2 and 2.5 h.

2.4. Behavioral data analysis

Acceptability ratings were subjected to a global ANOVA including the factors Verb-Type (2 levels: ASV versus ESV) and Animacy of the subject NP (2 levels: Animate versus Inanimate). Note that for both ASV and ESV, animate subject NPs always correspond to grammatical sentences, and inanimate subject NPs always correspond to ungrammatical (TRA) sentences. Data for the EOV condition can be found in Appendix.

2.5. EEG recording and data analysis

EEG was continuously recorded from 57 cap-mounted Ag/AgCl electrodes (Electrocap International, Inc. Eaton, OH, USA) at a sampling rate of 500 Hz and using an online band-pass filter of 0.05–70 Hz (Neuroscan Synamps2 amplifier, Neuroscan-Compumedics, Charlotte, NC, USA), referenced to the right mastoid. Horizontal

[5] Our pseudo-randomization procedure first evenly distributed the items for each of our critical and filler conditions across the halves of each list, then again into thirds within the halves, and once more into fifths with those thirds, to ensure a smooth distribution of types of stimuli across the recording session. The smallest division of this distribution scheme thus included 1 item from each of our 10 conditions (10 items × 5 × 3 × 2 (halves) = 300 items per list). Those minimal sets of items were then each randomized independently (i.e., each subset of 10 items representing all conditions), and the output was reviewed by hand for all lists to ensure no more than 3 violations or 3 correct sentences occurred in a row, and two items from the same condition were never adjacent in the presentation.

and vertical eye movements and blinks were monitored with electrode pairs placed above/below the left eye (VEOG) and at the outer canthi of both eyes (HEOG). Impedance for each electrode was kept below 5 kΩ.

Offline data preprocessing and averaging was carried out with the EEProbe software package (ANT, Enschede, The Netherlands). First, all channels were subjected to a digital phase-true finite impulse response (FIR) band-pass filter (0.4–30 Hz). Trials contaminated with eye movements and other artifacts (as determined using a 30 μV criterion) were rejected from individual data sets, resulting in the exclusion of 6.7% of the data (with no differences across conditions). Individual average ERPs were computed for each condition at each electrode in epochs from −100 ms to 1100 ms relative to the target word onset, including a 100 ms pre-stimulus baseline. ERP data were analyzed only for trials followed by a correct response in participants' acceptability judgments (response-contingent analyses), thereby excluding a further 9.5% of the trials per condition on average. The resulting subject averages then entered the grand average. To quantify the ERP components of interest, we calculated the average amplitudes in the following time windows, selected based on previous literature and visual inspection of the data: 300–500 (N400), 700–900 and 900–1100 (P600). (For further details and additional time-windows for EOV conditions, see Results and Supplementary material in Appendix).

2.6. Statistical analyses of EEG data

Analogous to the behavioral data, the global ANOVAs for the ERP data included factors Verb-Type (2 levels) and Animacy (2 levels). A total of 43 electrodes were analyzed in each time window separately for lateral and midline electrodes. The midline included the following electrodes: Fz, FCz, Cz, CPz, Pz, POz and Oz, reflected by the factor Anterior-Posterior (7 levels). Lateral electrodes included 36 electrodes (18 over each hemisphere) organized along three columns of six electrodes each: (1) medial (F1/2, FC1/2, C1/C2, CP1/2, P1/2, PO1/2); (2) intermediate (F3/4, FC3/4, C3/4, CP3/4, P3/4, PO3/4); (3) lateral (F5/6, FC5/6, C5/6, CP5/6, P5/6, PO5/6). The global ANOVAs therefore included the corresponding topographical factors: Hemisphere (2 levels), Column (3 levels) and Anterior-Posterior (6 levels). We report only effects that involve the factor Animacy, reflecting the grammaticality of the sentences. Significant interactions ($p < .05$) were followed up with step-down analyses to better understand the underlying pattern. The Greenhouse–Geisser correction for violation of sphericity was applied whenever appropriate; corrected p values will be reported in those cases.

3. Results

3.1. Behavioral data

Participants' acceptability rates for grammatical sentences were 94.6% for ASV and 87.1% for ESV, and their acceptability rates for ungrammatical sentences were 4.5% for ASV and 10.27% for ESV. A repeated measures ANOVA showed the obvious significant main effect of Animacy [F (1,19) = 3932.231; $p < .0001$] and a significant Animacy × Verb-type interaction on participants' acceptability rates [F (2,38) = 62.806; $p < .0001$]. The highly significant main effect shows that subjects had no problems discriminating grammatical from ungrammatical sentences, while the interaction reveals that discrimination was even more successful in the ASV than the ESV conditions. Follow-up analyses further clarified that this overall ASV advantage holds independently for both accepting grammatical sentences [F (1,19) = 15.945; $p < .002$] and rejecting ungrammatical sentences [F (1,19) = 10.925; $p < .005$].

3.2. Event-related potentials

Whereas the behavioral data suggested significant *quantitative* differences between ASV and ESV conditions in an off-line task, the ERPs were expected to reflect the real-time processing of both verb types. In particular, ERPs should reveal if the behavioral differences relied on *qualitatively* similar or distinct cognitive processing mechanisms. We will first present ERP data of the subject NP that may reflect animacy effects equally relevant to both ASV and ESV. We will then turn to the critical verbs to contrast TRA effects for each verb type.

3.2.1. Animacy effects on subject nouns

Fig. 1 illustrates the ERPs from the onset of the subject noun up to the onset of the main verb (1100 ms thereafter), i.e., also including the ERPs elicited by the auxiliary. As can be seen, a broadly distributed N400-like negativity was obtained in the 300–500 ms time range for inanimate relative to animate subject nouns across ESV and ASV sentences. A global ANOVA including ASV and ESV accordingly revealed a main effect of Animacy on the midline [F (1,19) = 14.22; $p < .0014$] and at lateral electrodes [F (1,19) = 13.27; $p < .0018$]. An Animacy × Column interaction [F (2,38) = 8.53; $p = .005$] reflected the fact that the N400 was more prominent near the midline [F1/2 columns: F (1, 19) = 13.99; $p < .0015$] than over lateral columns [F5/6 columns: F = 11.29; $p < .004$]. No statistically significant effects or interactions were observed in the 700–900 ms and 900–1100 ms time-ranges, reflecting the absence of potential effects on auxiliaries immediately preceding the target verbs. The latter finding (absence of differences) is relevant, as it confirms that a 100 ms pre-stimulus baseline for the verb analyses (see below), which is identical to the 900–1000 ms time interval shown here in Fig. 1, is not contaminated by any ongoing effects elicited by the preceding auxiliary (see Steinhauer & Drury, 2012, for discussion of context-driven baseline artifacts in many studies).

3.2.2. Thematic reversal effects on the main verbs

Fig. 2 illustrates the ERPs from the onset of the target verb for ASV (a) and ESV (b), using the 100 ms pre-stimulus baseline just discussed. Most importantly, a broadly distributed N400-like negativity between 300 and 500 ms can bee seen in the ungrammatical TRA condition for ESV (Fig. 2B), but not for ASV (Fig. 2A). This observation was statistically confirmed. Global analyses including these two conditions indicated a significant Animacy × Verb-Type interaction in the 300–500 ms range on the lateral [F (1, 19) = 4.97, $p < .039$] and midline electrodes [F (1, 19) = 4.87, $p < .04$]. Separate follow-up analyses for each verb type revealed a significant effect of Animacy in the 300–500 ms time range for ESV on lateral [F (1, 19) = 5.90, $p < .03$] and midline electrodes [F (1, 19) = 6.02, $p < .03$]. No such effect was obtained in the ASV condition [all Fs < 1].

In the 700–900 ms time range, visual inspection of the data suggested a relatively small sP600-like positivity in both the ASV and ESV violations. Global ANOVAs indicated that this shared effect of Animacy reached statistical significance at lateral electrodes [F (1, 19) = 4.47, $p < .05$], while it was only marginally significant along the midline [F (1, 19) = 4.07, $p = .0713$]. No interactions with Verb-Type were observed either on the lateral or midline electrodes [all Fs < 1]. Although visual inspection of the data suggests a left lateralization of the sP600 effect in ESV relative to ASV, topographical differences were not reflected by any significant effect in this time window [e.g., Animacy × Verb-Type × Hemisphere F (1, 19) = 2.50, $p > .13$].

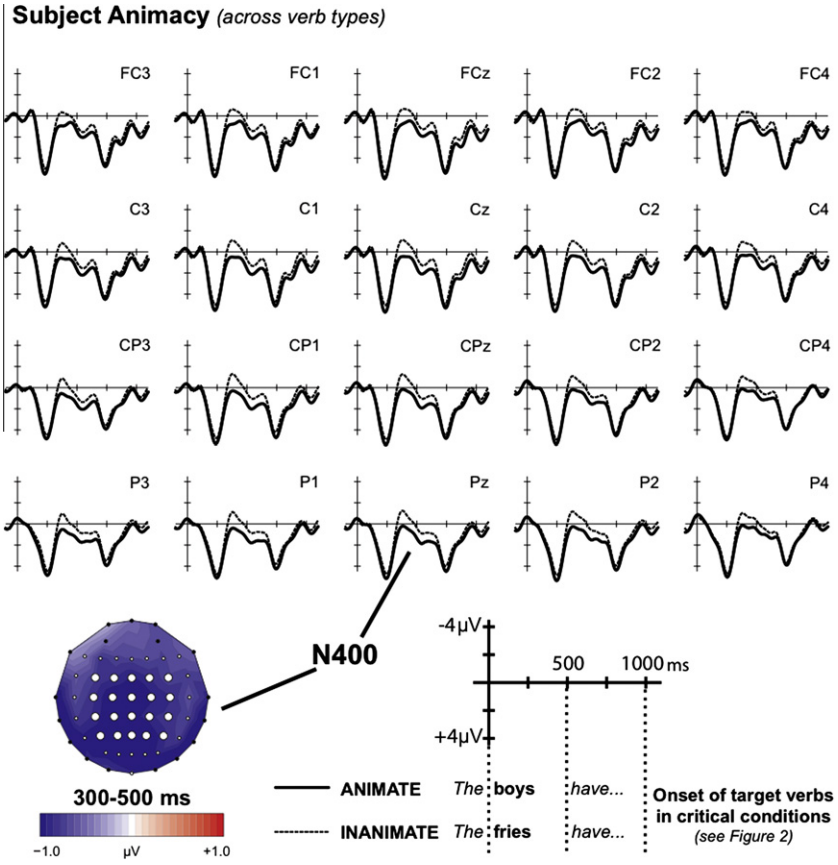

Fig. 1. Grand average waveform and voltage map of the ERPs elicited on the subject of ASV and ESV sentences up until the onset of the target Verbs (ASV, ESV and EOV conditions collapsed). Negativity is plotted upwards. Waveforms are time-locked to the onset of the noun (−100 to 0 ms baseline interval). Inanimate nouns (i.e., ungrammatical sentences, dotted line) elicited a broadly distributed N400 relative to animate nouns (i.e., grammatical sentences, solid line) between 300 and 500 ms. No effects were observed in the subsequent 700–900 and 900–1100 ms time windows, thus ruling out animacy effects on the auxiliary preceding the target verb. As a reminder, animate and inanimate NPs were the same for ESV and EOV.

4. Discussion

In this section we review and discuss the various behavioral and ERP results of the present study, proceeding from what we consider to be their most robust to most speculative implications for the study of TRA. In 4.2 and 4.3 we attempt to formulate a general account of our main findings within the framework of the eADM model (Bornkessel-Schlesewsky & Schlesewsky, 2008). We continue with additional considerations of our results in light of parallel accounts of the sP600 and other theories of language comprehension, suggesting further paths of research on these topics from a neurophysiological point of view (Sections 4.4 and 4.5) and close with a brief survey of limitations in the present study to be addressed in future work (Section 4.6).

4.1. Behavioral data

Despite relatively high levels of accuracy overall (>85%), participants were better at discriminating grammatical and ungrammatical sentences in ASV than in ESV. Given the off-line nature of the task, this difference between conditions was unexpected. However, it may point to differences in the saliency of the violation related to the structural and thematic status of Agents and Experiencers. According to our working hypothesis, Agents are mapped almost by default to the subject argument. As a result, not only do they bear the prototypical role of Actor, but they also occupy the hierarchically highest position in the sentence. Implicit in this argument is the fact that Agents are both sequentially and conceptually more salient than Experiencers, which can occupy either the subject or object position, and whose thematic status gets reevaluated only when the verb is reached. The higher accuracy levels achieved in ASVs relative to ESVs may therefore be explained by the fact that, whereas violations involving the former are sequentially and conceptually straightforward, those involving the latter are less so.

4.2. The subject animacy N400 as an instance of the Compute Prominence step

ERPs analyses for the subject NP revealed a significant N400 for inanimate compared to animate NPs. This effect held equally for subject NPs in ASV and ESV sentences, further strengthening the notion of *systematic* differences. However, since animate and inanimate nouns in our materials were well matched on a number of dimensions, trivial accounts in terms of lexical differences in frequency of occurrence, etc. seem unlikely. An alternative explanation has to do with prominence and is exclusively associated with the thematic role a subject NP typically carries, especially in subject-first (SVO and SOV) languages with strict word order. In fact, our results replicate previous animacy effects for subject NPs in both German (Frisch & Schlesewsky, 2001) and English sentences (Weckerly & Kutas, 1999). Based on such findings, Bornkessel & Schlesewsky's (2006) eADM model assumes the existence of a Compute Prominence step working on a distinction between animate and inanimate feature of sentential subjects (see also Bornkessel-Schlesewsky & Schlesewsky, 2008). In this approach, the N400 essentially reflects increased processing costs due to a

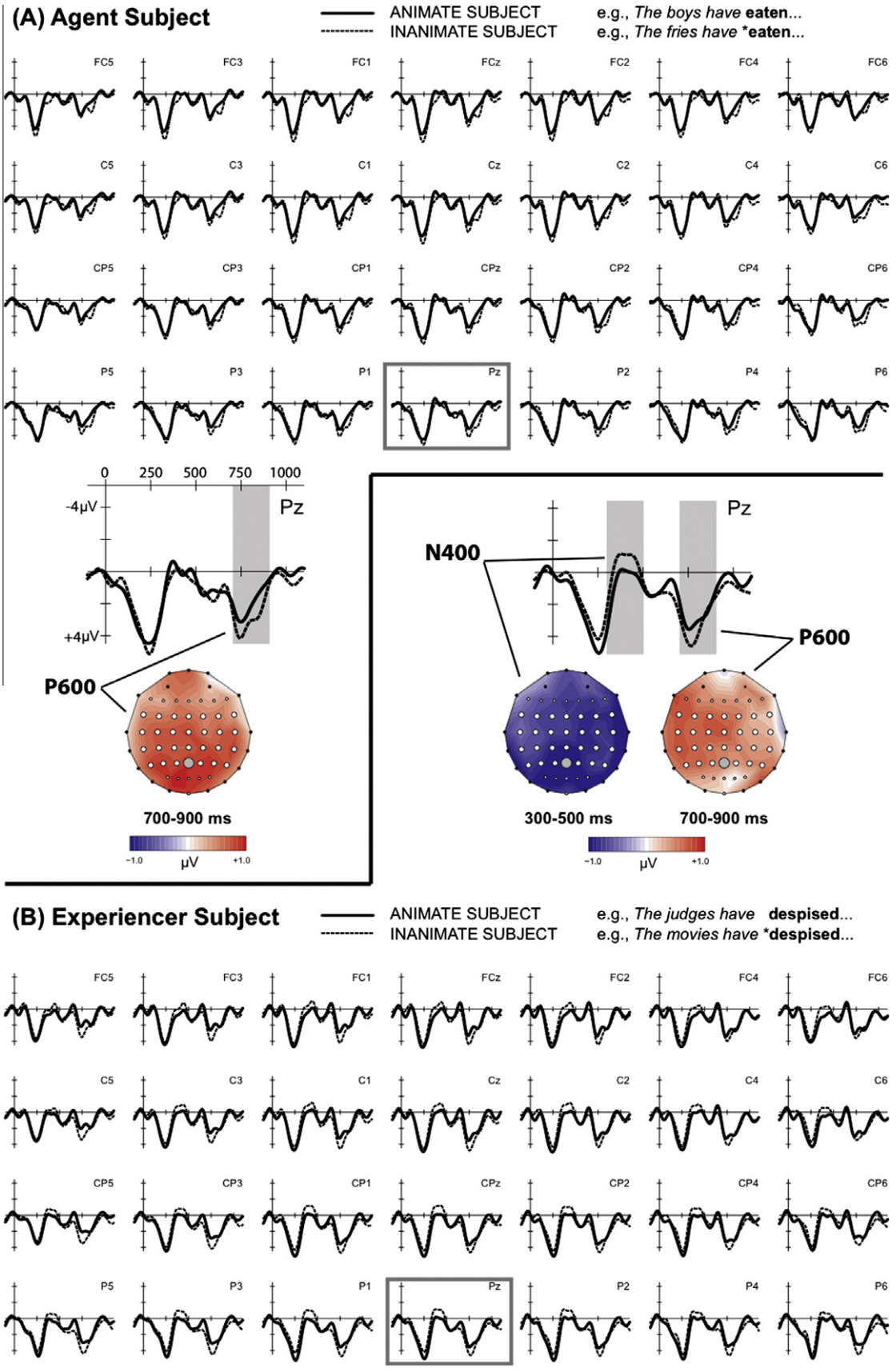

Fig. 2. Grand average waveform and voltage maps of the ERPs elicited on the target verbs of (A) ASV sentences and (B) ESV sentences. Dotted lines represent violations and solid lines represent control sentences. Negativity is plotted upwards. Waveforms are time-locked to the onset of the verb (−100 to 0 baseline interval). Animacy violations elicited a broadly distributed N400 between 300 and 500 ms in ESV but not in ASV. A sP600 was obtained in both ASV and ESV between 700 and 900 ms.

rearrangement of thematic hierarchies. That is, inanimate NPs are less likely to be an Agent, which is the prototypical thematic role associated with Subjects. The replication of such effects in this and other studies (see Kuperberg et al., 2003), where inanimate Subjects elicit larger N400 effects relative to animate Subject NPs, essentially supports the existence of this hypothesized Compute Prominence step in the eADM model. Furthermore, the absence of Animacy × Verb-Type interactions in any time window demonstrates that at this early point in the sentence, ASV and ESV conditions were still processed in the same way.

4.3. Presence/absence of N400 effects at the main verb

The main goal of the present study was to investigate the possibility that TRA might yield distinct ERP responses according to verb type. This was supported by the main finding: animacy reversals elicited an N400 at the position of the critical verb in ESV but not in ASV. To the extent that we have succeeded in ruling out other potentially confounding factors[6], this seems to be an effect that no current accounts would have predicted. Importantly, that no N400 was elicited by ASV violations in the absence of sentential lead-in context indicates that the lack of N400s in TRA (here and in previous studies) cannot be simply due to contextual priming effects. On the other hand, an N400 effect was elicited by ESV violations, even though the two verb conditions were well matched in terms of semantic associations between words, and both lacked any lead-in context. This pattern underlines Bornkessel-Schlesewsky et al.'s (2011) observation that reversal anomalies are not necessarily reflected by a monophasic sP600. However, it also extends (and relativizes) their claim that the presence versus absence of N400s is primarily driven by "sequence-dependency", as both ASV and ESV were presented in English.

This leaves us with an account of our effect in light of a difference in thematic/aspectual structure. As sketched in Section 1.2 above, Experiencers can be viewed as differing from Agents in that they do not uniquely map to a single syntactic position and that they fall across the Generalized Roles of Actors and Undergoers. Whereas in English Agents (setting aside the presence of passive voice) uniformly take the subject/external position in the sentence, Experiencers can either occupy the subject or object position depending on the type of (psychological) verb that selects them. As a result, what matters most in ESV is the proper *lexical identification of verbs*[7]. On any broad view connecting lexical access/retrieval to the N400 (Lau et al., 2008), such an effect observed on the verb of ESV sentences in TRA may be readily accounted for (in addition, we find that this interpretation has much to recommend it in terms of generality and simplicity).

4.4. sP600 effects

A shared sP600 effect appeared between ESV and ASV between 700 and 900 ms, mainly at lateral electrodes. Although a significant main effect at lateral electrodes, this sP600 was however smaller than in previous studies investigating TRA. We believe that the somewhat weak amplitude of the sP600 effect observed in the present study deserves consideration along two lines of inquiry pointed out in Kuperberg (2007). As outlined in Section 1.2.3, there is some evidence suggesting that sentential context may influence the elicitation of the sP600[8]. The lack of sentential lead-in context in our stimuli might explain the relatively low amplitude of the sP600 observed in our analyses, which would provide further information about the role played by sentential context in influencing the sP600 amplitude. On the other hand, Kuperberg (2007, Section 5.1) also mentions how variability in top-down working memory and/or cognitive control might influence brain responses to animacy violations. van Herten et al.'s (2006) monitoring hypothesis of the sP600 similarly entails that differences in monitoring capacities may correlate with differences in ERP responses, a hypothesis that has received increasing empirical support. For instance, a recent study by Nakano, Saron, and Swaab (2010) studying the role of working memory capacity in sentence processing showed that, whereas high-span participants elicited a clear sP600 in response to animacy violations (e.g., *The box is* ****biting*** *the mailman*), low-span participants rather showed an N400. Although the role of working memory capacity, context and differences in verb types have so far not been considered together within the framework of the sP600 debate, there are reasons to believe that these factors interact with one another in the incremental steps of sentence comprehension. A study recently started in our lab has been designed to explore whether working memory capacity may differentially affect the processing of TRA in ASV and ESV conditions. All that said, the small amplitude of the sP600 effects in the present study may instead (or in addition) be due to the fact that these violations were less salient that others that were included as fillers, including word category and lexical-conceptual semantic violations (see Methods; for effects of filler sentences on ERP patterns in experimental conditions see Mecklinger, Schriefers, Steinhauer, & Friederici, 1995; Steinhauer, Mecklinger, Friederici, & Meyer, 1997 and Friederici, Mecklinger, Spencer, Steinhauer, & Donchin, 2001; for discussion see Steinhauer & Drury, 2012).

4.5. Implications for eADM

We believe to have shown that recent predictions for TRA within the framework of the eADM (Bornkessel-Schlesewsky et al., 2011) are partly problematic and partly supported by our data. Given that ESV elicited N400s in a language that must be viewed as strictly 'sequence-dependent' (English), the proposed typological dichotomy in terms of reliance on word order cues seems too strong. On the other hand, the involvement of lexical processing may be key to our understanding of when TRA do and do not elicit N400s. Our data demonstrate that, in addition to case marking, at least thematic and aspectual differences between verbs need to be considered. Moreover, regarding the N400 effect for ESV but not ASV anomalies, we conceive that the architecture of the eADM could accommodate the main findings in the following way: the eADM's Compute Prominence step works on a first-pass Actor-Undergoer distinction while the Compute Linking step would proceed to a more fine-grained analysis of thematic relationships based on the verb's logical structure (see Bornkessel-Schlesewsky & Schlesewsky, 2009). Interpreting the case of ESV into the premises of eADM therefore supports a two-step analysis of thematic relationships, whereby the prototypical roles assigned by Compute Prominence may be reanalyzed as Experiencers. Understood in eADM's terms, our main finding therefore suggests that the initial assignment of thematic roles by Compute Prominence can be subsequently refined by Compute Linking. And, contra earlier discussions of the eADM

[6] One could argue that the significantly higher semantic relatedness between verbs and inanimate (as compared to animate) nouns may have contributed to the lack of an N400 in the ASV condition (see Methods). However, this difference in semantic relatedness was exactly the same for ESV and ASV conditions and should therefore have affected the N400 in both verb conditions to the same extent.

[7] These matters obviously connect to the special status of Experiencers that has been the topic of extensive research on the syntax and aspect of psychological verbs (see Belletti & Rizzi, 1988; Bouchard, 1995; Doron, 2003; Hale & Keyser, 1999; Landau, 2009; Van Voorst, 1992). It also relates to the relevance of Agency and Experience as prime distinctive features of human cognition (Gray, Gray, & Wegner, 2007) and how these may map to human sentence comprehension.

[8] As noted by one of the reviewers, the effects of sentential lead-in context noted by Kuperberg (2007) may be restricted to the *semantic* P600, since large P600 effects have been observed in morphosyntactic mismatches without substantial lead-in context (e.g., see Barber & Carreiras, 2005).

which suggested that the operations involved in COMPUTE LINKING should not be expected to drive the elicitation of N400 effects for animacy violations in languages (like English/Dutch; Bornkessel-Schlesewsky & Schlesewsky, 2008, p. 67) where linear order is a dominant cue, our findings suggest instead that such effects can indeed manifest in such languages.

4.6. Limitations

Since the present research is the first to report different ERP responses to TRA according to verb-type in English (see Bornkessel-Schlesewsky et al., 2011 for Icelandic), it is worth pointing out two potential limitations. First of all, it appears that the use of the present perfect in the present study varies depending on whether the verb is ESV or ASV, therefore introducing a potential confound related to aspect. Indeed, whereas the present perfect in ASV can have either a resultative or universal reading (compare *The boys have **finally** eaten their fries* and *The boys have **always** eaten fries*), it has a mainly universal reading when used with ESV (and other stative verbs, compare *The children have **?finally**/**always** loved the gifts of the orphanage*). Within the context of research on the interaction between aspect and verb type in on-line sentence processing (see Brennan & Pylkkänen, 2010 for a recent MEG study of aspect and psych-verbs), we think it relevant to further explore the effects that aspectual manipulations might have on the elicitation of ERP responses to TRA. Another limitation has to do with the presence of task demands introduced by participants' acceptability judgments. Both the monitoring approach to sP600 effects (e.g., van Herten et al., 2006) and the most recent eADM account for these positivities suggest that grammaticality tasks may play a major role factor in eliciting sP600-like effects. It therefore seems important to see if the differences between ESV and ASV can be replicated the absence of overt judgment tasks[9].

5. Conclusion

In the context of research on the sP600, the present study investigated the extent to which different thematic roles in sentential subject position, in particular A*gents* versus E*xperiencers*, influence the processing of TRA as reflected in distinct ERP responses. The main finding of the present study was an N400 response to ESV that was absent in ASV. Furthermore, a shared sP600 was observed in both conditions. We proposed an analysis of the N400 within the framework of Bornkessel & Schlesewsky's (2006) eADM's Compute Linking step of language comprehension and argue that more fine-grained thematic distinctions can be observed also at this stage of sentence processing. Besides the potential implications that such findings may bring in the modeling of language comprehension, we discussed the importance of considering factors such as sentential context, monitoring capacities or task requirements in eliciting N400 and sP600 effects in TRA. For the time being, our hope is to have shown that thematic or aspectual considerations must be taken into consideration.

Acknowledgments

We are grateful to Ina Bornkessel-Schlesewsky and Matthias Schlesewsky for valuable discussions of the present research. We also thank two anonymous reviewers for helpful comments on previous versions of this manuscript. The present work was supported by grants awarded to Dr. Steinhauer by the Canada Research Chair program and the Canada Foundation for Innovation (CRC/CFI; Project # 201876), and by a SSHRC grant awarded to Drs. Steinhauer and Drury (#410-2007-1501), entitled 'Locating logical semantics in the temporal dynamics of language comprehension'.

[9] We would like to thank an anonymous reviewer for drawing our attention to this point.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.bandl.2012.05.001.

References

Barber, H. A., & Carreiras, M. (2005). Grammatical gender and number agreement in Spanish: An ERP comparison. *Journal of Cognitive Neuroscience, 17*(1), 137–153.
Belletti, A., & Rizzi, L. (1988). Psych-verbs and -theory. *Natural Language and Linguistic Theory, 6*(3), 291–352.
Besson, M., & Kutas, M. (1993). The many facets of repetition – A cued-recall and event-related potential analysis of repeating words in same versus different sentence contexts. *Journal of Experimental Psychology: Learning, Memory and Cognition, 19*(5), 1115–1133.
Bornkessel, I., & Schlesewsky, M. (2006). The extended argument dependency model: A neurocognitive approach to sentence comprehension across languages. *The Psychological Review, 113*(4), 787–821.
Bornkessel-Schlesewsky, I., Kretzschmar, F., Tune, S., Wang, L., Genç, S., Phillipp, M., et al. (2011). Think globally: Cross-linguistic variation in electrophysiological activity during sentence comprehension. *Brain and Language, 117*(3), 133–152.
Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2008). An alternative perspective on "semantic P600" effects in language comprehension. *Brain Research Reviews, 59*, 55–73.
Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2009). The role of prominence information in the real-time comprehension of transitive constructions: A cross-linguistic approach. *Language and Linguistics Compass, 3*(1), 19–58.
Bouchard, D. (1995). *The semantics of syntax*. Chicago, IL: University of Chicago Press.
Brennan, J., & Pylkkänen, L. (2010). Processing psych verbs: Behavioural and MEG measures of two different types of semantic complexity. *Language and Cognitive Processes, 25*(6), 777–807.
Donchin, E., & Coles, M. G. H. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences, 11*, 357–373.
Doron, E. (2003). Agency and voice. The semantics of the semitic templates. *Natural Language Semantics, 11*, 1–67.
Friederici, A. D., Mecklinger, A., Spencer, K. M., Steinhauer, K., & Donchin, E. (2001). Syntactic parsing preferences and their on-line revisions: A spatio-temporal analysis of event-related brain potentials. *Cognitive Brain Research, 11*, 305–323.
Frisch, S., & Schlesewsky, M. (2001). The N400 reflects problems of thematic hierarchizing. *NeuroReport, 12*(15), 3391–3394.
Gennari, S., & Poeppel, D. (2003). Processing correlates of lexical semantic complexity. *Cognition, 89*, B27–B41.
Gray, H. M., Gray, K., & Wegner, D. M. (2007). Dimensions of mind perception. *Science, 315*, 619.
Hale, K., Keyser, S. J. (1999). Bound feature, merge, and transitivity alternations. In L. Pylkkänen, A. Van Hout, H. Harley (Eds.), *Papers from UPenn/MIT Roundtable on the Lexicon 35*, pp. 49–72.
Kim, A., & Osterhout, L. (2005). The independence of combinatory semantic processing: Evidence from event-related potentials. *Journal of Memory and Language, 52*, 205–225.
Kolk, H. H. J., Chwilla, D. J., van Herten, J., & Oor, P. J. W. (2003). Structure and limited capacity in verbal working memory: A study with event-related potentials. *Brain and Language, 85*, 1–36.
Kuperberg, G. R. (2007). Neural mechanisms of language comprehension: Challenges to syntax. *Brain Research, 1146*, 23–49.
Kuperberg, G. R., Sitnikova, T., Caplan, D., & Holcomb, P. J. (2003). Electrophysiological distinction in processing conceptual relationships within simple sentences. *Cognitive Brain Research, 22*, 117–129.
Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207*(4427), 203–205.
Landau, I. (2009). *The locative syntax of experiencers*. Cambridge, MA: MIT Press.
Landauer, T., & Dumais, S. T. (1997). A solution to Plato's problem: the latent semantic analysis theory of acquisition, induction, and representation of knowledge. *The Psychological Review, 104*(2), 211–240.
Lau, E. F., Philips, C., & Poeppel, D. (2008). A cortical network for semantics: (De)constructing the N400. *Nature Reviews Neuroscience, 9*, 920–933.
Levin, B. (1993). *English verb classes and alternations: A preliminary analysis*. Chicago: University of Chicago Press.
MacWhinney, B., & Bates, E. (1989). *The crosslinguistic study of sentence processing*. Cambridge: Cambridge University Press.
Mecklinger, A., Schriefers, H., Steinhauer, K., & Friederici, A. D. (1995). Processing relative clauses varying on syntactic and semantic dimensions: An analysis with event-related potentials. *Memory and Cognition, 23*, 477–494.
Nakano, H., Saron, C., & Swaab, T. Y. (2010). Speech and span: Working memory capacity impacts the use of animacy but not of world knowledge during spoken sentence comprehension. *Journal of Cognitive Neuroscience, 22*(12), 2886–2898.

Osterhout, L., & Holcomb, P. (1992). Event related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language, 31*(6), 785–806.

Paczynski, M., & Kuperberg, G. R. (2011). Electrophysiological evidence for use of the animacy hierarchy, but not thematic role assignment, during verb-argument processing. *Language and Cognitive Processes, 26*(9), 1402–1456.

Pesetsky, D. (1995). *Zero syntax – Experiencers and cascades*. Cambridge: MIT Press.

Schlesewsky, M. & Bornkessel-Schlesewsky, I. (2009). When semantic P600s turn into N400s: On cross-linguistic differences in online verb-argument linking. In M. Horne, M. Lindgren, M. Roll, K. Alter, J. v. K. Torkildsen (Eds.), *Brain talk: discourse with and in the brain. Papers form the first Brigit Rausing Language Program Conference in Linguistics*. Lund: Bridit Rausing Language Program.

Steinhauer, K., & Drury, J. E. (2012). On the early left-anterior negativity (ELAN) in syntax studies. *Brain and Language, 120*(2), 135–162.

Steinhauer, K., Drury, J. E., Portner, P., & Walenski, M. (2010). Syntax, concept, and logic in the temporal dynamics of language comprehension: Evidence from event-related potentials. *Neuropsychologia, 48*, 1525–1542.

Steinhauer, K., Mecklinger, A., Friederici, A. D., & Meyer, M. (1997). Probability and strategy: An event-related potential study of processing syntactic anomalies. *Zeitschrift fuer Experimentelle Psychologie, 2*, 305–331.

Stroud, C., & Phillips, C. (2012). Examining the evidence for an independent semantic analyzer: An ERP study in Spanish. *Brain and Language, 120*(2), 108–126.

Van de Meerendonk, N., Kolk, H. H. J., Vissers, C. Th. W. M., & Chwilla, D. J. (2008). Monitoring in language perception: Mild and strong conflicts elicit different ERP patterns. *Journal of Cognitive Neuroscience, 22*(1), 67–82.

van Herten, M., Chwilla, D. J., & Kolk, H. J. (2006). When heuristics clash with parsing routines: ERP evidence for conflict monitoring in sentence perception. *Journal of Cognitive Neuroscience, 18*(7), 1181–1197.

Van Valin, R. D. (2005). *Exploring the syntax-semantic interface*. Cambridge, MA: Cambridge University Press.

Van Voorst, J. (1992). The aspectual semantics of psychological verbs. *Linguistics and Philosophy, 15*, 65–92.

Weckerly, J., & Kutas, M. (1999). An electrophysiological analysis of animacy effects in the processing of object relative sentences. *Psychophysiology, 36*, 559–570.