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Syntax, concepts, and logic in the temporal dynamics of language comprehension: Evidence from event-related potentials

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A B S T R A C T

Logic has been intertwined with the study of language and meaning since antiquity, and such connections persist in present day research in linguistic theory (formal semantics) and cognitive psychology (e.g., studies of human reasoning). However, few studies in cognitive neuroscience have addressed logical dimensions of sentence-level language processing, and none have directly compared these aspects of processing with syntax and lexical/conceptual-semantics. We used ERPs to examine a violation paradigm involving "Negative Polarity Items" or NPIs (e.g., *ever/any*), which are sensitive to logical/truth-conditional properties of the environments in which they occur (e.g., presence/absence of negation in: *John hasn't ever been to Paris*, versus: *John has *ever been to Paris*). Previous studies examining similar types of contrasts found a mix of effects on familiar ERP components (e.g., LAN, N400, P600). We argue that their experimental designs and/or analyses were incapable of separating which effects are connected to NPI-licensing violations proper. Our design enabled statistical analyses teasing apart genuine violation effects from independent effects tied solely to lexical/contextual factors. Here unlicensed NPIs elicited a late P600 followed in onset by a late left anterior negativity (or "L-LAN"), an ERP profile which has also appeared elsewhere in studies targeting logical semantics. Crucially, qualitatively distinct ERP-profiles emerged for syntactic and conceptual semantic violations which we also tested here. We discuss how these findings may be linked to previous findings in the ERP literature. Apart from methodological recommendations, we suggest that the study of logical semantics may aid advancing our understanding of the underlying neurocognitive etiology of ERP components.

1. Introduction

The present investigation used event-related potentials (ERPs) in a sentence reading/judgment study examining the temporal dynamics of syntactic, conceptual semantic, and logical semantic/pragmatic dimensions of language processing. The first two of these have been extensively studied with ERPs: linguistic violations such (1b) and (1c) (Table 1) are well-known to respectively elicit (e)LAN/P600 and N400 effects (see Kutas, van Petten, & Kluender, 2006 for review). Although in earlier years these qualitatively distinct ERP-profiles were claimed to index syntactic ((e)LAN/P600) versus semantic (N400) processing, more recent work has shown this simple correspondence to be unsustainable (see Bornkessel-Schlesewsky & Schlesewsky, 2008; Kuperberg, 2007 for reviews). More specifically, it has become clear that other ERP components can reflect semantic processing in the absence of N400-type effects. For example, P600-effects have been shown in connection with verb-argument animacy violations and implausible sentences (Kim & Osterhout, 2005; Kolk, Chwilla, van Herten, & Oor, 2003; van Herten, Kolk, & Chwilla, 2005).

Though there can be little doubt that the N400 is connected with semantic processing, it would be rather surprising if this single ERP response was somehow connected to *every* dimension of the processing of meaning. In fact, already in Fischler, Bloom, Childers, Roucos, and Perry (1983) it was shown that the N400 appears to be insensitive to truth-value distinctions and negation, a result which has been replicated using a wide variety of different types of manipulations (Katayama, Miyata, & Yagi, 1987; Kounios & Holcomb, 1992; Lüdke, Friedrich, De Filippis, & Kaup, 2008; though see Nieuwland & Kuperberg, 2008).

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Table 1
Contrasts examined in the present study.

(1a)	√ Bill enlarges Lynn's pictures of the sunset WELL-FORMED CONTROL
(1b)	* Bill enlarges Lynn's justice of the sunset CONCEPTUAL SEMANTIC ANOMALY
(1c)	* Bill enlarges Lynn's of pictures the sunset PHRASE-STRUCTURE VIOLATION
(2a)	√ *S* Derek *doubts* that Roger ever drinks cognac [+LICENSOR/+NPI]
(2b)	* Derek *thinks* that Roger ever drinks cognac [−LICENSOR/+NPI]
(2c)	√ *S* Derek *doubts* that Roger often drinks cognac [+LICENSOR/−NPI]
(2d)	√ *S* Derek *thinks* that Roger often drinks cognac [−LICENSOR/−NPI]

Note: √: acceptable; *: unacceptable. NPI licensing/non-licensing context differences are indicated in italics (*doubt, think*). See Table 2 for example sentences illustrating the full range of NPI/non-NPI target words and Licensing/Non-Licensing contexts included in the present study. Target NPI/non-NPI words are underlined (ever, often). Previous studies have either analyzed contrasts similar to (2a) vs. (2b), or similar to (2b) vs. (2d). See main text for discussion.

Viewed together, the range of findings above paint a more diverse picture than has been assumed in the past about the ways different dimensions of the processing of "meaning" might be handled by the human brain and reflected in ERPs.

The central concerns of the present inquiry have to do with what we will refer to as "logical semantic" aspects of language processing. Our primary aim was to determine whether ERPs might distinguish logical semantic from syntactic and/or conceptual level semantic processing (we will unpack the logical/conceptual distinction below). We tested previously well-studied cases of syntactic and conceptual semantic violations (1b/c, Table 1) alongside another type of linguistic deviance: cases of "unlicensed" Negative Polarity Items (NPIs; see (2a/b), Table 1).

NPIs include words like *any* or ever, collocations like *at all*, and idioms like *lift a finger*. These expressions manifest a type of context sensitivity which has been argued in the linguistics literature to be best understood in logical semantic terms (see Giannakidou, in press for reviews; Tovena, 2001). More specifically, NPIs must occur in the scope of (i.e., be structurally subordinate to) a LICENSING element, a prototypical example of which is negation (e.g., *John hadn't* ever *been to Paris* versus *John had* *ever *been to Paris*; note: here and throughout, * marks unacceptability).

However, the inventory of NPI-licensors is considerably broader than just negation (see Table 2). A prominent proposal in the formal semantics literature is that NPIs are licensed in DOWNWARD MONOTONIC contexts (Ladusaw, 1979). The concept of monotonicity pertains to entailment patterns involving subset/superset relationships. To illustrate, first observe *that John arrived late* entails that *John arrived*. In contrast, under negation this entailment flips: *John didn't arrive* entails that *John didn't arrive late*, and not vice-versa. In the former case, the inference runs asymmetrically from a subset (*late-arrivers*) to a superset (*arrivers*): this is "upward" monotonicity (or "upward entailment"). In the latter case, the direction of entailment reverses, running asymmetrically from superset (*arrivers*) to subset (*late-arrivers*). This is "downward" monotonicity ("downward entailment"). This can be visualized set-theoretically as in Fig. 1 (top panel).Downward monotonicity is not just a property of negation or negative elements. To illustrate, in Fig. 1 we also show three different combinations of upward and downward entailment patterns involving three different English quantifiers, *every, some*, and *no*. The important point is that the patterns of upward/downward monotonicity (left-hand panel of Fig. 1) track the distribution unacceptable/acceptable uses of NPIs (here illustrated with the English NPI *ever*—see right-hand panel of Fig. 1).

However, it is well-known that the generalization regarding downward monotonicity and NPI-licensing is imperfect. For example, *yes/no-questions* are neither upward *nor* downward monotonic, but nonetheless this environment licenses NPIs (e.g., *Did John* ever *go to Paris?*). One general class of theoretical responses to such facts in the linguistics literature has been to attempt to maintain a logical/truth-conditional account and extend the characterization of the class of NPI-licensors in ways that maintain downward monotonicity as a principled sub-case (e.g., see Giannakidou, 1998; Rothschild, in press; von Fintel, 1999). Setting these subtleties to the side, what is clear is that the study of the processing of these expressions with ERPs offers the promise of uncovering insight into the brain mechanisms underlying logical semantic level processing. Our central mission was to investigate whether the processing of violations of this kind can be *distinguished* from violations involving (i) syntax or (ii) conceptual dimensions of semantics (see below regarding the logical/conceptual distinction).

1.1. *Previous findings*

Several studies have used ERPs to examine NPI licensing (beim Graben et al., 2007; Saddy, Drenhaus, & Frisch, 2004; Shao & Neville, 1998; Drenhaus, beim Graben, Saddy, & Frisch, 2006; Drenhaus, Blaszczak, & Schutte 2006; Drenhaus, Frisch, & Saddy

Table 2
NPI licensing (critical) and non-licensing (control) contexts.

Licensor type	Licensor	Non-Licensor	Example
Negation	*don 't/doesn 't/didn 't haven 't/hasn 't*	*do/does/did have/has*	They really don't/do believe that John ever/often goes camping.
Doubt	*doubts*	*thinks*	Mick doubts/thinks that any/all of the students passed the exam.
Universal quantifier	*every*	*eight*	Every/Eight pupil(s) who ever/often got sick went to the hospital.
Yes/No question	yes/no question	corresponding declarative	Has Sally/Sally has bought any/all of the items for the party?/.
Probability	*rarely/hardly*	*sometimes*	It hardly/sometimes rained at all/this year despite the forecasts.
Possibility	*whether*	*that*	Angela hopes to determine whether/that brain waves ever/often indicate specific mental states.
Temporal order	*before*	*after*	Before/After Mark began to write at all/this year, he received his advance.
Existential	*without*	*with*	Karen bought the computer without/with any/all of its software pre-installed.

Note: The NPI/non-NPI types were evenly distributed across the Licensing/Non-Licensing Types (see main text).

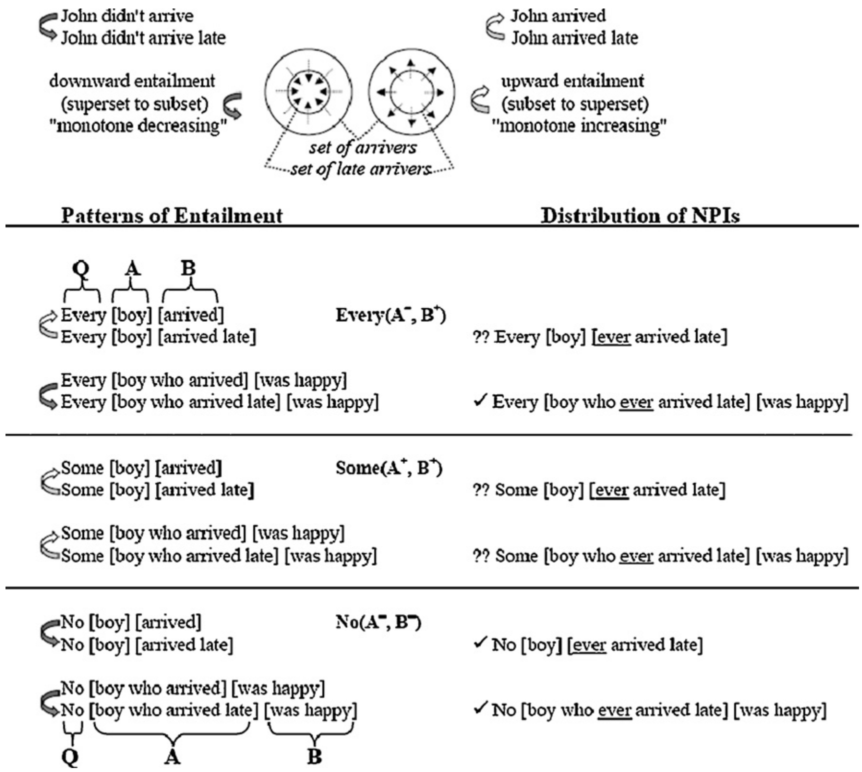

Fig. 1. Monotonicity and NPI-licensing properties of EVERY, SOME, and NO. We assume here a view of quantifiers as predicates of sets (see Barwise & Cooper, 1981). On this view a quantifier Q takes two arguments, its "A"-argument or *restriction* and its "B"-argument (here: the main predicate). Thus, for example, in *Every boy arrived*, *every* is the quantifier, its restriction (A-argument) is the associated noun (*boy*), and the predicate *arrived* is "B-argument". Satisfying the truth conditions for EVERY(A, B) would involve checking to see whether the set of entities that are *boys* is a subset of the set of entities that *arrived* (formally: EVERY(A, B) *is true iff* $A \subseteq B$). These three different quantifiers manifest different patterns of upward and downward monotonicity over each of their two arguments (illustrated by the upward and downward arrows connecting the example sentences in the left-hand panel above). *Every*, for example, is *downward* monotonic over its "A"-argument and *upward* monotonic over its "B"-argument (we mark this as EVERY(A_-, B_+), with the "−/+" marking downward/upward monotonicity, respectively), and this is evident both in the entailment patterns and in the distribution of NPIs (compare left and right panels above). In contrast, *some* is uniformly upward monotonic and cannot license an NPI in either position, and *no* is uniformly downward monotonic and uniformly licenses NPIs.

2005; Xiang, Dillon, & Phillips, 2009).[2] A consistent finding has been late positive-going deflections strongly resembling P600 type effects. However, studies have differed in the presence/absence of additional negative-going ERP effects, with one study showing a prior LAN effect (Shao & Neville, 1998) while others have found N400s (Drenhaus et al., 2005; Drenhaus, beim Graben et al., 2006; Drenhaus, Blaszczak et al., 2006; Saddy et al., 2004) or just P600s (Xiang et al., 2009). These studies differed considerably in their aims, materials and experimental designs, behavioral task, and test language (English vs. German), any of which could have contributed to these inconsistencies (see Section 4). Resolving these differences is important for our understanding of what kinds of processing different ERP components index, and what kinds of patterns be might reliably associated with processing of NPI-licensing violations. In this connection a number of further details of findings emerging from these studies are relevant here (and see Section 4).

First, the initial Shao and Neville study also examined cases of contradiction (e.g., *Jane* **does not eat any meat at all**, *instead she eats only* √ **rice**/#**beef** *and vegetables*) which elicited a P600-like effect and a subsequent late left anterior negativity (henceforth we refer to this as a "P600/L-LAN" pattern). The presence of P600 effects for this case and in studies of NPI-licensing is in line with a growing literature (alluded to above) demonstrating that this component is not uniquely tied to syntactic aspects of processing. This is particularly clear for Shao and Neville's contradiction case, where nothing goes wrong in the syntax proper. Further, it is important to note that on some linguistic analyses, unlicensed NPIs are anomalous because they result in contradictions (Chierchia, 2006—see Section 4).

Second, the N400 findings (beim Graben et al., 2007; Drenhaus et al., 2005; Drenhaus, beim Graben et al., 2006; Drenhaus, Blaszczak et al., 2006; Saddy et al., 2004) are interesting for several reasons, the most important of which, in our view, is that these effects were found at all. The Saddy et al. study was, to our knowledge, the very first report of an N400 modulation seen in connection with semantic deviance which turns on the properties of a function/closed-class word (German *jemals* = "ever-time"). This is a surprising because: (i) function words typically elicit reduced/attenuated N400s relative to content words (see Brown, Hagoort, & ter Keurs, 1999 for a tabular summary), and (ii) as mentioned above, the N400 appears to be insensitive to truth-value and negation.

Regarding (i): attenuated N400 amplitudes for function words has been suggested to tied to the fact that these elements are "devoid of meaning" (Brown et al., 1999) or "insensitive to meaning" (Van Petten & Kutas, 1991). However, this is perhaps better put in terms of conceptual dimensions of meaning, that is: whatever feature/properties support the individuation of (or relationships between) the semantic content of open-class expressions (i.e., *dog* means DOG, not CAT; *fruit* and *apple* correspond to concepts which manifest a category-exemplar relationship, etc.). That is, though it is reasonable to say that function words characteristically do not involve the encoding of these conceptual kinds of meaning distinctions, they are far from being "devoid of meaning". Functional

[2] There has also been at least one eye-tracking study examining polarity licensing (Vasishth, Bruessow, Lewis, & Drenhaus, 2008). Here we confine our discussion to ERP evidence.

elements rather encode logical semantic distinctions with crucial pragmatic/discourse-theoretic import, including (in)definiteness, quantification, tense, aspect, mood, modality, among others (see von Fintel & Matthewson, 2008 for relevant discussion).

Distinctions that fall under the label of conceptual semantics in the foregoing sense have been shown in numerous ERP studies of language to elicit N400-modulations: deflections of a negative going brain wave with a centro-parietal scalp distribution that peaks about 400 ms post-stimulus onset (see Kutas & Federmeier, 2000 for a review). Conceptual-semantic incongruities (e.g., (1b) in Table 1) reliably elicit larger N400 amplitudes (Kutas & Hillyard, 1980), which may be understood as a special case of (un)predictability, as N400 amplitude inversely correlates with Cloze probability in absence of anomaly (Kutas & Hillyard, 1984). N400-type effects appear to arise largely in virtue of associative links between words/concepts that also manifest independently of syntactic structure. For example, in lists of paired words, priming reduces N400 amplitude (Bentin, McCarthy, & Wood, 1985; Rugg, 1985) in ways that moreover seem to not differ from N400 modulations seen in sentence-context (Kutas, 1993). Modulations of the N400 are not, however, restricted to just word and sentence-level processing, as they also appear in connection with anomalies arising at the level of discourse representation (Federmeier & Kutas, 1999; Nieuwland and Van Berkum, 2006).

At present it remains an open question whether or to what extent N400 effects may index the activity of brain systems supporting lexical (access/retrieval) versus post-lexical (integration) processes (see Lau, Phillips, & Poeppel, 2008 for discussion) or, for that matter, whether the existing range of N400 findings can be taken to speak against the viability of theoretical lexical/post-lexical distinctions (Coulson & Federmeier, in press). However, in a recent review, Lau et al. (2008) consider relevant data from the existing N400 ERP literature alongside neuropsychological and fMRI findings, arguing that the full range of available data are best understood on the view claiming that the N400 indexes the access/retrieval (pre-activation) of lexical/conceptual information. Adopting this latter perspective allows us to make sense of both point (i) (above), namely the insensitivity of this ERP component to truth-value and negation (e.g., if semantic integration proper occurs downstream of time-windows where N400s modulations are typically detected) and (point (ii)) the typical finding of attenuated/absent N400 effects for function words (e.g., if N400s primarily reflect *conceptual* level information, which function words arguably do not carry).

It is the foregoing considerations that make the N400 findings (e.g., in Drenhaus, beim Graben et al., 2006; Drenhaus, Blaszczak et al., 2006; Saddy et al., 2004) for unlicensed NPIs both surprising and important, given that these elements are members of the function/closed-class vocabulary and that their distribution appears to be governed by the presence/absence of particular kinds of inferential (entailment) properties driven by superordinate logical operators. That is, the conditions involved in NPI-licensing do not appear to be conceptual in nature, so we might expect their processing to involve the action of systems of the brain distinct from those underlying N400 activity.[3] Given the mix of results that have been found in studies of NPI-licensing (sometimes a LAN, sometimes an N400, sometimes neither), it remains an open empirical question whether N400 modulations are part of a reliable ERP-profile for encounters with unlicensed NPIs in specific, and in connection with logical/truth-conditional semantic deviance more generally.

Two further important points about previous ERP studies of NPI-licensing motivate the present inquiry. First, with only one exception (Saddy et al., 2004), previous studies have either analyzed only NPI/non-NPI differences in non-licensing environments (Shao & Neville, 1998) or Licensing/Non-Licensing differences for single NPIs (all the other studies). Both of these strategies make it difficult to reach clear conclusions regarding which of the reported findings can be attributed directly to the NPI-licensing violations *per se*, as opposed to effects that may be generally driven by either lexical (NPI/non-NPI) differences or by the contextual manipulations (Licensing/Non-Licensing), that is: independent of the violation. We return to this important point below.

Second, most previous studies have either not included or not reported analyses of additional violation types replicating previously well-established findings alongside the critical NPI-licensing conditions. For example, LAN effects in connection with morpho-syntactic violations are typically small, transient, and not always reliably found across studies (see Hinojosa, Martin-Loeches, Casado, Munoz, & Rubia, 2003; Vos, Gunter, Kolk, & Mulder, 2001 for review). Thus, if LAN-effects could be shown within participants for other (e.g., syntactic) types of violations in the absence of such effects for unlicensed NPIs, this would be reasonably strong evidence that the systems underlying such effects are not implicated logical semantic deviance. Conversely, the finding of a LAN/P600 effect for unlicensed NPIs (Shao and Neville, 1998) suggests that a direct comparison with cases of syntactic violations would be valuable.

At stake here is what ERPs might contribute to our understanding of the respective neurocognitive mechanisms and temporal dynamics of (morpho-)syntactic versus conceptual-semantic versus logical-semantic dimensions of processing (*and*, what the study of logical semantics might teach us about the etiology of ERP components).

Thus far, what has *not* been shown is whether ERPs can distinguish, within participants, the processing of the kinds of logical-semantic information thought to be crucial in theories of NPI-licensing from *both* conceptual semantic and syntactic level processing. Given that prior studies have yielded a mix of findings, some of which include ERP effects commonly connected with (morpho-)syntax (e.g., LAN/P600) and others finding N400-type effects, the present lack of any demonstration that these cases can be distinguished from syntax and conceptual semantics is an important issue to address. Again: this is the primary aim of the present study.

Thus, alongside our critical NPI-licensing manipulations (see (2a–d) in Table 1), we also tested phrase-structure and conceptual semantic violations (i.e., (1a–c) in Table 1, modeled after stimuli used in Neville, Nicol, Barss, Forster, & Garrett, 1991). A second, equally important aspect of the present study was to deploy the full 2 × 2 design (NPI vs. non-NPI × Licensing vs. Non-Licensing) necessary to statistically tease apart effects which may be tied to *just* lexical or to *just* the contextual manipulations from ERP effects attributable to the NPI-licensing violation itself.

A third set of important features of the present study involves the choices of NPIs/non-NPIs and Licensing/Non-Licensing environments to be tested. Here we followed Shao & Neville by testing three NPIs (*ever, any*, and *at all*) and three non-NPIs (*often, all, this year*). However, instead of manipulating the presence/absence of a single licensor-type (as in almost all the other studies), we included eight different pairs of Licensing/Non-licensing contexts (Table 2). These features were incorporated in order to avoid repetition effects and

[3] However, the issues are more delicate than suggested in our main text discussion. There are studies which have shown that some of the same kinds of manipulations of properties of word stimuli which effect the N400 for content words (e.g., frequency, predictability) do so for function words in qualitatively similar ways (DeLong, Urbach, & Kutas, 2005; Münte et al., 2001; see also Osterhout, Holcomb, & Swinney, 1994 for a case of an N400 triggered by a function word in an argument structure violation).

also to expand the external validity of our findings (but see below for a possible disadvantage of this approach).

1.2. Predictions

Syntactic violations (1b) were expected to replicate the pattern of three ERP effects reported in Neville et al. (1991), that is: (i) a very early left anterior negativity (their "N125", often interpreted elsewhere as an "eLAN" effect, e.g., Friederici, 1995, 2002), (ii) a subsequent left lateralized negativity (300–500 ms) with a temporal/parietal scalp distribution, and (iii) a broadly distributed positive deflection (a member of the P600 family). There were several important reasons for adopting Neville et al.'s particular syntactic violation paradigm. First, given the previous findings of effects (i) and (ii), their inclusion in the present study offered the potential to directly compare such effects with possible LAN-type negativities which at least one study (Shao & Neville, 1998) found for unlicensed NPIs. That is, if unlicensed NPIs give rise to LAN effects in the present study, we may still find that this type of violation is nonetheless distinguishable from syntactic/phrase-structure violations either in terms of the timing or distribution of left and/or anterior negativities in the 300–500 ms range *or* in terms of the presence/absence of very early (e.g., N125/eLAN) effects. Second, given that LAN effects are not always reliably found for (morpho-)syntactic violations across studies, not much could be concluded should such effects not materialize in the present study for unlicensed NPIs *unless* we were also able to replicate the Neville et al. findings (i.e., the presence of left lateralized negativities for phrase-structure violations, but not for unlicensed NPIs in the same participants and experimental session, would allow stronger claims about the latter).

Similar logic extends to the inclusion of the conceptual semantic anomalies (which we also based on Neville et al.'s 1991 stimuli). As noted above, NPI-licensing violations have also been found (in the German studies) to elicit N400 effects. Should we find N400 effects here for unlicensed NPIs, these effects could be directly compared to conceptual-level effects on this ERP component. Finally, given that P600 type effects have been reliably found across previous studies of NPI-licensing, we expected to find this type effect for the NPIs in non-licensing versus licensing environments, but not for the comparable contrasts of non-NPIs.

Note that the inclusion of multiple previously untested types of NPI-licensor combinations (Table 2) may be viewed as a potential weakness in our design. That is, potential gains in *generality* may be offset by the obscuring of important more narrow differences. Specifically, different types of NPI-licensor combinations might be expected to be handled in distinct ways by human sentence processing mechanisms. However, in our view, the main interest of NPI-licensing phenomena from the perspective of cognitive electrophysiology lies in the possibility that the apparent diversity of licensing elements is in fact *only apparent* and that this surface diversity disguises underlying general (logical semantic) aspects of language processing (even if disagreement exists in the linguistics literature – and it does – regarding the details; see Giannakidou, in press). If particular ERP effects – whether P600s or LANs or N400s (or some other effects) – are part of a processing profile associated with the failure to license NPIs *generally*, then we should find them here.

2. Methods

2.1. Participants

Twenty-four right-handed, monolingual native English speaking adults (half female; mean age = 21.0, SD = 3.1) with normal vision and no history of psychiatric, neurological or cognitive disorders participated after giving informed consent. Subjects were paid for participation.

2.2. Materials

The critical conditions involved four types of stimuli (Table 1): sentences containing an NPI in an NPI-licensing context (2a); the critical violation condition, where an NPI occurred in a non-licensing context (2b); and control sentences with a non-NPI in either (2c) a licensing context or (2d) a non-licensing context. Sentences were created from 8 pairs of licensing/non-licensing contexts (Table 2) and 3 NPI/non-NPI target pairs (*ever/often*, *any/all*, *at all/this year*), yielding 24 different context-target word combinations.

Each subject saw two examples of each of these 24 combinations in each of the four NPI sentence conditions (licensing/non-licensing, NPI/non-NPI), for a total of 192 sentences; i.e., 2 examples × 24 combinations × 4 conditions). In order to avoid repetition effects, a total of 768 (192 × 4) different actual sentences was created and evenly distributed across four different lists, such that each subject saw a given sentence in only one of the four conditions (counterbalanced across subjects).

Note that of the four NPI/non-NPI, Licensing/Non-Licensing conditions, only condition (2b) contained violations. In order to globally balance the correct/violation proportion, we included 192 additional sentences in each list with the reverse proportion of correct and violation sentences. Of these, 96 were the phrase-structure/conceptual-semantic violations (48 of each) serving as our "control" violations (1b/c, Table 1), and 48 were well-formed control sentences (1a, Table 1). The critical violation sentences for the phrase-structure and conceptual semantic conditions were modeled closely after those used in Neville et al. (1991), and either involved a simple word-order flip (1a/1c, Table 1), or swapping in a noun which created a conceptual incoherency with the main verb (1a/1b, Table 1). An additional 48 filler sentences containing verb inflection violations (part of a separate study) were included, resulting in 384 total items per list (50% containing violations). These additional stimuli were created in 4-tuples following the same logic as the NPI-licensing materials just discussed, so that only one member of each matched 4-tuple was seen by a given participant. Each of the four lists was subjected to a pseudo-randomization procedure to avoid proximal repetitions of similar sentence types. Finally, four reverse-order lists were also created, resulting in eight lists total. Thus each of the eight total presentation lists was seen by 3 of the 24 subjects.

2.3. Procedure

Subjects were seated in a dimly illuminated shielded chamber and silently read the 384 sentences displayed in the center of a computer monitor. Sentences were displayed one word at a time (duration = 300 ms; ISI = 200 ms). After each sentence, subjects made an acceptability ('good'/'bad') judgment with a mouse click (left or right, counterbalanced across subjects). Following Neville et al. (1991), subjects were asked to press the 'bad' key if the sentence appeared strange or odd in any way (as illustrated by one morpho-syntactic and one conceptual-semantic example). This task was selected as it was equally compatible with all types of linguistic anomaly without drawing attention to any specific type of violation. Prior to the experiment subjects were given 16 practice items (8 correct and 8 incorrect sentences similar to the filler items). Accuracy feedback was given only during practice. Three evenly spaced breaks divided the experiment into 4 blocks. Testing lasted 2.5–3 h, including preparation and clean-up.

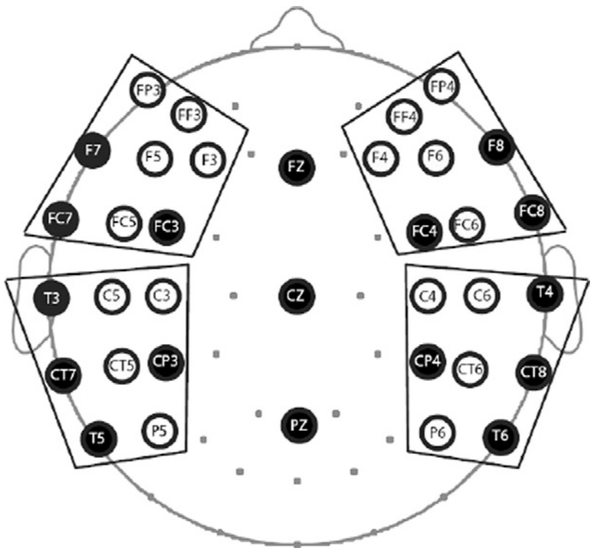

Fig. 2. Regions of interest and midline electrodes used in analysis (note that electrodes marked in black appear in the grand average plots below (Figs. 4 and 5).

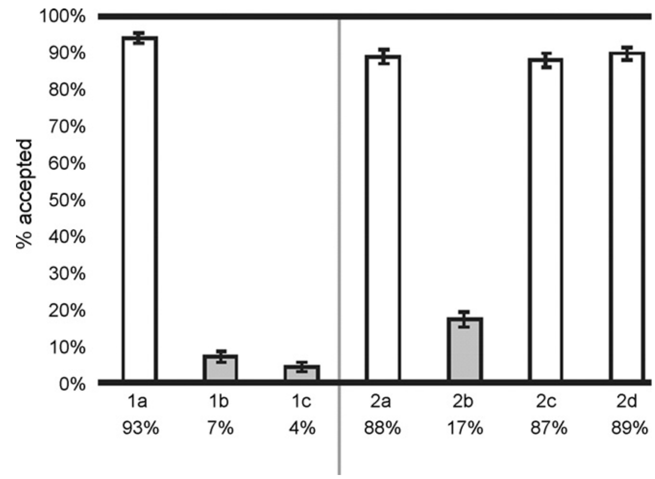

Fig. 3. End of sentence acceptability judgment performance (mean % of acceptance by condition; labels for filler conditions (1)a–c and the critical NPI-licensing conditions (2)a–d correspond to those in Table 1).

2.4. EEG recording and data analysis

Scalp EEG was recorded continuously from 64 cap-mounted electrodes (modified 10/20 system; Electro-Cap International) at a 250 Hz sampling rate (impedances <5 kΩ), referenced to the right mastoid and re-referenced off-line to averaged left-/right-mastoids. Horizontal and vertical EOG was acquired bi-polarly (eye electrode impedances <15 kΩ). The EEG was amplified by Standard Instrumentation amplifiers with a bandpass of 0.01–125 Hz. Trials contaminated with blinks or other artifacts were rejected, resulting in the exclusion of approximately 12% of the data. All channels were low-pass filtered at 60 Hz. For each of the seven conditions (Table 1), single subject waveforms were averaged over 1200 ms epochs following target (NPI/nonNPI) words, with a 200 ms pre-stimulus baseline. The target word for the two-word NPI/non-NPI pair (*at all*/*this year*) was the second word (*all*/*year*).

Based on previous literature and visual inspection of the data, we subjected four 200 ms time-windows to repeated measures ANOVAs (300–500, 500–700, 700–900, and 900–1100 ms post-critical word-onset) with the mean amplitude as the dependent measure. The Greenhouse-Geisser correction for violations of sphericity was applied to all analyses having more than one degree of freedom in the numerator.

For each of the four time-windows, analyses were performed separately for lateral and midline electrodes. Lateral electrodes were grouped into four regions of interest (ROIs) of eight electrodes each, as illustrated in Fig. 2. (Note that a number of more complex statistical analyses were carried out, involving larger numbers of the 64 electrodes we used in our EEG recording; however, in the end these analyses revealed the same pattern of results and did not offer any advantages over the simpler ROI approach taken here.) For lateral electrodes the first-level (global) ANOVAs thus included five factors: ±Licensor (L, 2 levels: non-licensing vs. licensing context), ±NPI (N, 2 levels: NPI vs. non-NPI), Hemisphere (H, 2 levels), and Anterior/posterior (A, 2 levels). The corresponding midline analyses included the factors Licensor, NPI, and Anterior/posterior (3 levels, i.e., Fz, Cz, Pz). Given the aims of our study, the only relevant effects in these first-level analyses are interactions involving *both* Licensor (L) *and* NPI (N) which can moreover be traced to Licensing effects for NPIs. We therefore pursued a hierarchically organized analysis of variance, following-up only for the theoretically relevant L × N interactions.

3. Results

3.1. Behavioral data

The end-of-sentence acceptability judgment task yielded the expected patterns (Fig. 3). A repeated measures ANOVA for the phrase-structure, conceptual semantic violations, and well-formed controls demonstrated the obvious (1a/b/c, Fig. 3) significant main effect of condition [$F(2, 46) = 5147.25$, $p < 0.0001$], and follow-up pair-wise comparisons further showed that the phrase-structure violations were judged acceptable at slightly lower rates (4%) than the conceptual semantic violations (7%) ($F(1, 23) = 7.75$, $p < 0.01$). For the four NPI/non-NPI conditions, a repeated measures ANOVA showed the expected highly significant effects of Licensing [$F(1, 23) = 1272.18$, $p < 0.0001$], NPI/non-NPI [$F(1, 23) = 1323.38$, $p < 0.0001$], and a Licensing × NPI/non-NPI interaction [$F(1, 23) = 1395.44$, $p < 0.0001$]. As hypothesized, pairwise comparisons showed these effects to be driven by the low acceptability rates for the unlicensed NPIs (2b, Fig. 3), whereas none of the three grammatical/acceptable conditions differed from any other (all p's > 0.25). Finally, direct comparisons between NPI violations (2b) and the other violation conditions (1b,c) revealed a significantly higher acceptance rate for NPI violations (all p's < 0.0001).

3.2. Event-related potentials

3.2.1. Licensing/non-licensing effects

Fig. 4 illustrates the ERP patterns for the two licensing conditions separately for NPIs (Fig. 4A) and non-NPIs (Fig. 4B) from −100 ms prior to their onset until 1100 ms thereafter. Two ERP effects attributable to Licensing manipulation emerged for NPIs: (i) a positive-going deflection over posterior electrodes reminiscent of previous P600 findings (henceforth referred to as 'P600-like positivity') which began around 700 ms and persisted to the end of the epoch, and (ii) a subsequent late left anterior negativity (henceforth: 'L-LAN'). In contrast, the wave-forms for the non-NPIs across the Licensing and Non-Licensing contexts were very similar throughout the entire epoch (Fig. 4B), though there was some indication of a small positive-going shift over central parietal recording sites.

Consistent with the visual inspection, there were no critical L × N interactions in either the 300–500 or 500–700 ms time-windows. In the 700–900 ms range, however, we found a significant L × N × Anterior/posterior interaction both in the ROI analysis [F(1,

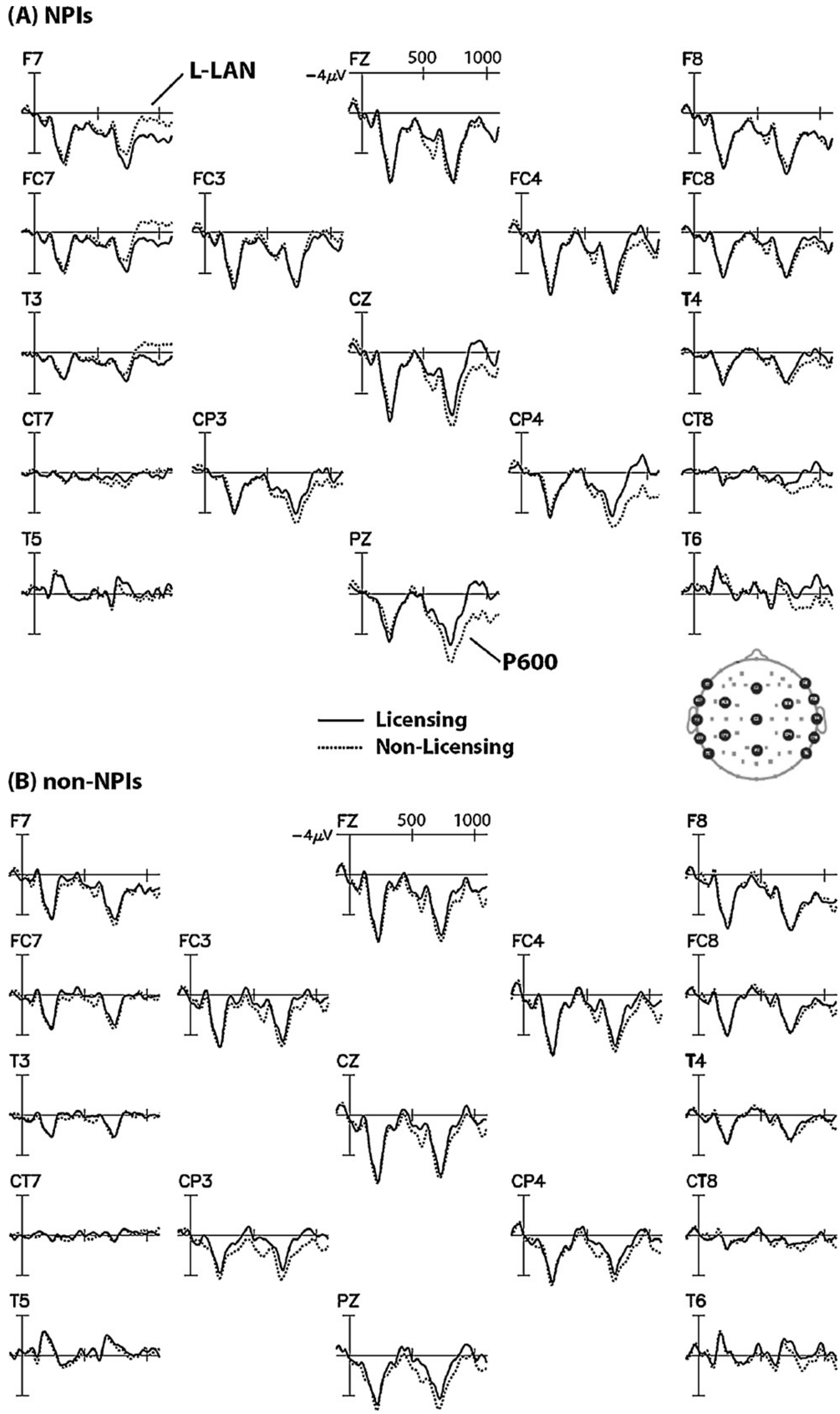

Fig. 4. Grand average waves for (A) NPIs (critical) and (B) non-NPIs (control) in licensing versus non-licensing contexts.

23) = 8.22, $p < 0.01$] and over the midline [$F(2, 46) = 4.65$, $p < 0.05$]. Follow-up analyses showed these to correspond to interactions of Licensing and Anterior/posterior for the NPIs only [ROI: $F(1, 23) = 14.94$, $p < 0.001$; Midline: $F(2, 46) = 6.14$, $p < 0.05$], with no corresponding effects for non-NPIs [*F*s < 1]. These interactions within the NPI contrasts were in turn found to correspond to the posterior P600-like positivity in the Non-licensing condition which yielded a main effect of Licensing averaging over the two posterior ROIs only [$F(1, 23) = 9.74$, $p < 0.01$], as well as at Cz [$F(1, 23) = 8.89$, $p < 0.01$] and Pz [$F(1, 23) = 13.91$, $p < 0.01$] on the midline. However, non-NPIs

also showed a significant effect on the midline, with Non-licensing conditions more positive-going [$F(1, 23) = 4.78$, $p < 0.05$] (a similar trend held in the ROI analysis: [$F(1, 23) = 3.60$, $p = 0.07$]).

Thus, the combined ERP patterns suggest that between 700 and 900 ms there were two distinct types of positivity. First, there was a positive-going deflection for the non-licensing contexts *generally* (note this showed up as a main effect of Licensing in the global ANOVA on the midline [$F(1, 23) = 10.12$, $p < 0.01$]) that was independent of any violation and was elicited even by non-NPIs. Secondly, however, there was a significantly larger (P600-like) pos-

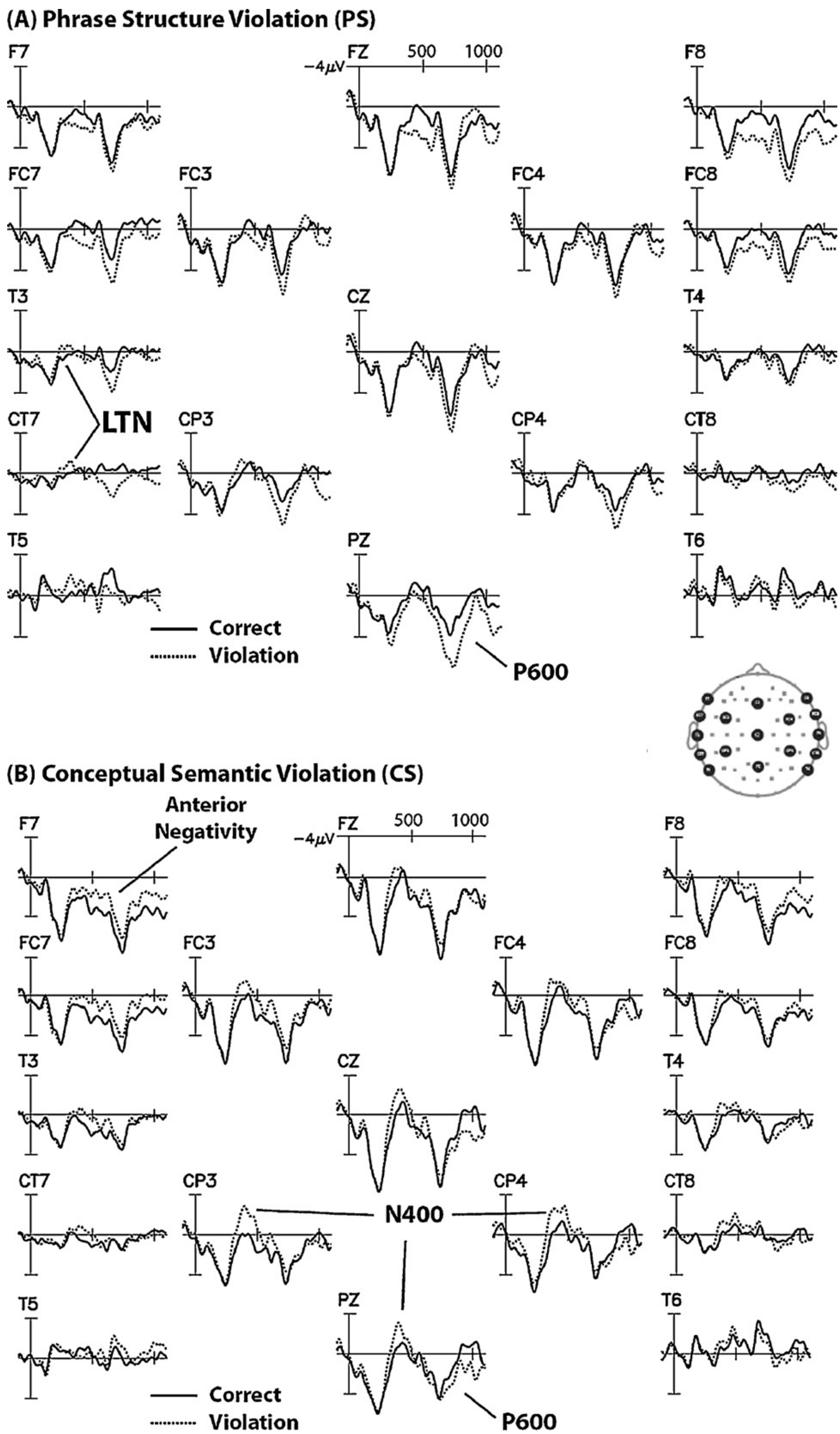

Fig. 5. Grand average waves for (A) phrase-structure and (B) conceptual semantic violations.

itivity *only* for unlicensed NPIs, reflecting the linguistic anomaly in this condition. Further, unlike the licensing main effect (shared positivity across sentence-types), the posterior positivity for NPI violations continued into the subsequent (900–1100 ms) time-window, where it was joined by a second ERP effect.

The 900–1100 ms range was characterized by two concurrent licensing effects in the NPI contrast, while no single licensing effect was observed for the non-NPI conditions. Unlicensed NPIs elicited: (i) the on-going right-lateralized posterior P600-like effect, and (ii) an additional late left anterior negativity (L-LAN). Although each of these effects in itself could be expected to result in a Licensing × AntPost × Hemisphere interaction, in combination they result in a pattern where the unlicensed NPI condition was more negative over the left (LH) than the right hemisphere (RH) across all lateral electrodes (frontally due to the L-LAN, posteriorly due to the P600-like positivity) and more negative at frontal than posterior electrodes (over the LH due to the L-LAN, over the RH due to the positivity). Finally, given that the P600-like positivity was more prominent near midline electrodes than the L-LAN, effects at midline electrodes should be primarily driven by the positivity.

This is exactly the pattern reflected in the global ANOVAs (across all four conditions) as well as in subsequent analyses for NPIs only. First, the global level L × N × A interactions already found between 700 and 900 ms persisted [ROI: $F(1, 23) = 7.34$, $p < 0.05$; Midline: $F(2, 46) = 4.99$, $p < 0.05$]. As expected, this effect continued to drive significant LxA interactions in the NPI analysis [ROI: $F(1, 23) = 14.81$, $p < 0.001$; Midline: $F(2, 46) = 9.30$, $p < 0.01$], and in addition there was a main effect of Licensing over the midline [$F(1, 23) = 6.56$, $p < 0.05$]. Secondly, the global ANOVA additionally revealed a new L × N × Hemisphere interaction over lateral ROIs [$F(1,23) = 5.95$, $p < 0.05$] that was not observed prior to 900 ms and is, therefore, likely to partly depend on the emerging L-LAN. As discussed above, except for the midline effects (which were driven exclusively by the P600-like waveform), both the L × N × A and the L × N × H interactions were likely to be carried by the positivity as well as L-LAN effects.

To resolve these interactions and probe the significance of L-LAN and the posterior positivity independently, we therefore analyzed effects of Licensing on NPIs over each individual ROI. These analyses confirmed a significant negative-going effect over the left anterior ROI [$F(1, 23) = 11.19$, $p < 0.01$] in addition to the P600-like effect which was significant over the right posterior ROI [$F(1, 23) = 14.37$, $p < 0.001$], with no effects over either the left posterior or right anterior ROIs [Fs < 1]. Fig. 4 also illustrates that it was in fact always the unlicensed NPI condition that diverged from the respective other three conditions (licensed NPI and the two non-NPI conditions) which, in turn, did not differ from each other ($F < 1$). In other words, all interactions in the 900–1100 ms time window were exclusively driven by ERP components elicited in the unlicensed NPI condition.

3.3. An early word-class effect

Though we found no L × N interactions in the early (300–500 ms) time-window (where LAN or N400 type effects would be expected) in this range we did find main effects of NPI/non-NPI, in particular N × A [$F(1, 23) = 8.36$, p, 0.01] and N × A × H [$F(1, 23) = 5.19$, $p < 0.05$] interactions in the ROI analyses (with no corresponding effects on the midline). These reflected the finding that non-NPIs were significantly more negative-going over the anterior ROIs [$F(1, 23) = 8.01$, $p < 0.01$], with no significant differences for the posterior ROIs [all F's < 1] (note there were no NPI/non-NPI × Hemisphere interactions within either the anterior or posterior follow-up ROI analyses; see Fig. 6 for a representative left anterior electrode (F7) showing this effect).

3.4. Licensing effects for individual NPIs (any, ever, at all)

In order to examine the consistency of the P600/L-LAN pattern that emerged for unlicensed NPIs, we re-ran the same analyses for these conditions with the additional three-level factor Target-Word (*any*/*ever*/*at-all*). As shown in Fig. 7, the biphasic pattern consisting of a P600-like positivity and an L-LAN was remarkably consistent across each of the three NPIs, and indeed these analyses showed no Licensing × Target-Word interactions in any of the latency ranges examined above (300–500, 500–700, 700–900, 900–1100 ms). However, grand average waves for the Licensing/Non-Licensing contrast for these individual Target-Words appeared to show an effect for the two-word NPI *at all* which was absent for both *ever* and *any*, namely an N400-like modulation, with Non-Licensing conditions more negative-going. Given that N400 effects have been previously reported in connection with unlicensed NPIs, we further probed this apparent effect by looking at narrower latency ranges (300–400 and 400–500 ms). These analyses yielded borderline interactions in the 300–400 ms range of Licensing and Target-word [$F(2, 46) = 2.47$, $p = 0.096$] and LxTxAnterior/posterior [$F(4, 92) = 2.31$, $p = 0.086$]. Analyses at electrode Pz in this 300–400 ms time window revealed significant effect of Licensing for *at all* [$F(1,22) = 6.75$, $p = 0.016$] with the non-licensing condition more negative going, but no significant effects for *ever* [$F < 1$] or *any* [$F(1,22) = 2.36$, $p = 0.139$] (the latter in fact showed a positive-going trend in this latency range).

3.5. Phrase-structure & conceptual-semantic violations

The phrase-structure violations (Fig. 5A) yielded two of the three previously reported (Neville et al., 1991) effects for these contrasts: the left temporal negativity (henceforth: "LTN") and subsequent (P600-like) positive-going deflections (we found no evidence of Neville et al.'s "N125" effect). The conceptual semantic violation elicited an N400 effect which was followed by a subsequent anterior negativity and a late positivity (Fig. 5B). Visual inspection of the grand average ERPs for the phrase structure violation indicated the LTN effect exhibited the same scalp distribution as the corresponding effect reported by Neville et al. (1991) for the same contrast, which reached significance over the left posterior ROI between 300 and 400 ms [$F(1, 23) = 5.34$, $p < 0.05$]. Also in line with Neville et al.'s previous findings was the subsequent positive-going deflection between 500 and 700 ms, as reflected by a main effect of violation at both lateral and midline electrodes [ROI: $F(1, 23) = 6.60$, $p < 0.05$; Midline: $F(1, 23) = 7.95$, $p < 0.01$]. Between 700 and 900 ms, this P600 appeared to dissipate (return to baseline), and only a trend toward a Violation × AntPost interaction over the midline [$F(2, 46) = 3.30$, $p = 0.08$] was found. Given that for this type of violation subsequent words are not matched (see example 1b in Table 1),

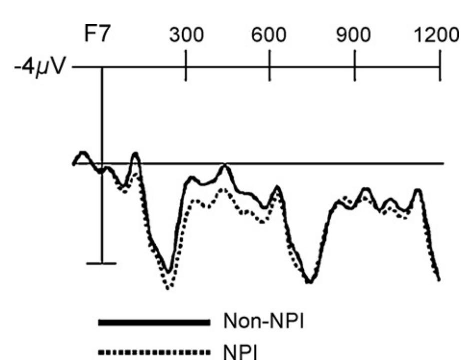

Fig. 6. A (left) anterior negativity for non-NPIs relative to NPIs (averaging over licensing/non-licensing—i.e., a main effect of word-type).

Table 3
Late conceptual semantic effects: individual ROI analyses.

ROI		500–700	700–900	900–1100
Left	Ant	10.40**	6.67*	–
	Post	–	–	–
Right	Ant	4.20*	–	–
	Post	–	–	12.98**

* $p < 0.05$.
** $p < 0.01$.

effects in these later latency ranges are confounded with other factors (e.g., word class), and we do not discuss them here.

The conceptual semantic violations showed a broadly distributed N400 effect in the 300–500 ms interval, yielding a Violation main effect at both lateral and midline electrodes [ROI: $F(1, 23) = 10.93$, $p < 0.01$; Midline: ($F(1, 23) = 6.24$, $p < 0.05$]. Between 500 and 700 ms, a second, more frontal negativity emerged with a distinct scalp distribution from that of the N400 (note the exact onset timing of this effect is not clear, as it may have superimposed the N400 effect in the 300–500 ms window—see Section 4). A Violation main effect was still present in the ROI analysis [$F(1, 23) = 6.34$, $p < 0.05$], but not over the Midline [$F < 1$], and was accompanied by a borderline Violation × AntPost interaction, indicative of the emergence of the anterior negativity [ROI: $F(1, 23) = 4.28$, $p = 0.05$; anterior ROIs: $F(1, 23) = 7.66$, $p < 0.05$; posterior ROIs: $F(1, 23) = 1.51$, $p = 0.23$]. This V × A interaction became significant in the subsequent 700–900 ms time-window [ROI: $F(1, 23) = 4.93$, $p < 0.05$] and persisted into the 900–1100 ms range [ROI: $F(1, 23) = 5.31$, $p < 0.05$]. In this final time-window there was also a borderline Violation × Hemisphere interaction [$F(1, 23) = 4.14$, $p = 0.05$], due to the emergence of a right posterior positivity (significant over the corresponding ROI [$F(1, 23) = 12.98$, $p < 0.01$]), and partly to the fact that the anterior negativity was in this time-window larger over the left than the right anterior ROI (reflected by an anterior VxH interaction [$F(1, 23) = 5.94$, $p < 0.05$]). The pattern underlying these interactions can be more clearly seen in Table 3, where Violation effects are shown for each of the final three time-windows for each of the four ROIs separately.

4. Discussion

NPI-licensing plausibly fits within a larger category of understudied logical semantic/pragmatic level phenomena about which very little is known in terms of underlying neurocognitive processing mechanisms. In terms of event-related potentials, the relevant body of previous findings is inconsistent, so there are no strongly established patterns in the existing literature (i.e., though P600-type effects seem reliable, the presence/absence of additional negative-going ERP effects has varied across studies).

Further, until the present study there was no existing evidence relevant to determining whether the systems of the brain implicated in the processing of unlicensed NPIs are the same, distinct, or overlapping from those which are involved in encounters with either syntactic or conceptual semantic deviance. Finally, previous studies of NPI-licensing have either not included or not reported analyses of relevant control conditions necessary to tease apart genuine violation effects on ERPs from effects more generally tied to either just the lexical or to just the contextual experimental manipulations.

The behavioral data of the present study demonstrated that subjects were highly successful in discriminating all types of linguistic anomalies from their respective controls, indicating the compatibility/appropriateness of the judgment task across conditions. Both the slightly enhanced acceptability of conceptual-semantic (7%) versus syntactic phrase structure (4%) violations and the considerably higher acceptability of NPI violations (17%) are in line with previous findings (e.g., Neville et al., 1991: conceptual semantics: 7%, phrase structure: 2%; Saddy et al., 2004: NPI: 13.9%) and are likely to reflect differences in salience/subtlety of the respective anomalies. Thus, there is no indication of any strategy favoring a specific type of anomaly detection. Whereas it is conceivable that employing a judgment task may have led to task-related increased P600-like late positivities (compared to experiments without any tasks), it seems very unlikely that the present task selectively enhanced certain ERP components due to attentional focus on any specific type of linguistic dimension (e.g., Hahne and Friederici, 2002).

The ERP findings of the present study are summarized in Table 4. Here we found that unlicensed NPIs elicited a P600-like effect which was followed by a late left anterior negativity (L-LAN). The posteriorly distributed P600-like positivity emerged in the 700–1100 ms range, while the L-LAN was not detectable statistically until the 900–1100 ms time-window. Although the P600-like positivity occurred somewhat later than the 'standard' 500–700 ms time window for P600 effects used in many studies (e.g., Osterhout & Holcomb, 1992), later time intervals have frequently been used to quantify P600s (e.g., Erdocia, Laka, Mestres-Misse, & Rodriguez-Fornells, 2009; Felser, Clahsen, & Muente, 2003: 700–900 ms; Gunter, Stowe, & Mulder, 1997: 590–980 ms; Hagoort, Wassenaar, & Brown, 2003: 600–800 ms; Münte, Heinze, Matzke, Wieringa, & Johannes, 1998: 600–1200 ms; Newman, Ullman, Pancheva, Waligura, & Neville, 2007: 800–1000 ms). In fact, even studies reporting early onsets around 500 ms often found the largest P600 amplitudes after 700 ms (Kaan & Swaab, 2003). Finally, all previous findings of late positivities in studies on NPI violations (e.g., between 500 and 1100 ms in Shao and Neville; 550–900 ms in Drenhaus et al.) have been interpreted as P600 effects. Therefore, we will follow previous studies and adopt the label P600 for the present posterior positivity as well.[4]

The combined P600/L-LAN pattern was consistent within each of our three NPI sub-conditions (i.e., for ever, *any*, and *at all*) averaging across the eight licensing conditions. Examination of the three different NPIs individually yielded a small additional N400 effect for the two-word NPI *at all* that was absent for *any* and *ever*. In addition, we found ERP effects that were independent of the violation: (i) a late relative positivity for non-licensing versus licensing contexts generally (i.e., present for both the NPIs and, to a lesser extent, for the non-NPIs), and (ii) an early anterior relative negativity for non-NPIs generally, independent of (non-)licensing (note this latter lexical effect is not included in Table 3 summary, though we will discuss its significance below). Phrase-structure and conceptual semantic violations, in contrast, elicited ERP-profiles which were qualitatively distinct both from each other and from NPI-licensing violations. The former partially replicated the pattern reported in Neville et al. (see below), while the conceptual semantic anomalies, in contrast, elicited: (i) the expected N400 modulation, (ii) a sustained anterior negativity (500–1100 ms), and (iii) a late posterior positivity (900–1100 ms). Thus, at the most general level, the central empirical finding of the present study is that syntax, conceptual semantics, and logical semantics yielded qualitatively distinct ERP-profiles. However, before we turn to discuss NPI findings in

[4] An anonymous reviewer notes that it may be inappropriate to refer to the late positivity seen here for unlicensed NPIs as a "P600". Though we believe that the broad family of late positive-going deflections seen in linguistic and other cognitive domains should probably not all be lumped together into one monolithic category, for expository convenience we are following here much previous literature in doing exactly this (i.e., referring to all the late positivities seen in the present study as "P600s", despite their demonstrated timing differences). However, this is hedged throughout (e.g., "P600-type", "P600-related", etc.), and as will become clear in our Discussion, it is likely that the nomenclature will eventually have to become significantly more refined our understanding of these effects deepens.

Table 4
Summary of ERP findings.

Condition		Example	ERP-effects (time)		
Conceptual semantics		1a √. . .enlarges Lynn's photos of. . .		(L)AN[1]	P600
Phrase-structure/syntax		1b *. . . enlarges Lynn's **justice** of. . .	N400	P600	
		1c *. . .enlarges Lynn's **of** photos. . .	LTN		
Logical semantics	[−Licensor/+NPI]	2a √ Derek *doubts* that Roger ever,. . .			
	[+LICENSOR/+NPI]	2b * Derek *thinks* that Roger **ever**,. . .	(N400)[2]	P600	L-LAN
	[+LICENSOR/−NPI]	2c √ Derek *doubts* that Roger often,. . .		P600	
	[−LICENSOR/−NPI]	2d √ Derek *thinks* that Roger often,. . .			

Notes: (1) This effect began as a broadly anterior effect, and subsequently became left later alized as the late positivity emerged. (2) This N400 was only found for one of the three NPIs tested (see main text for discussion); √: acceptable; *: unacceptable.

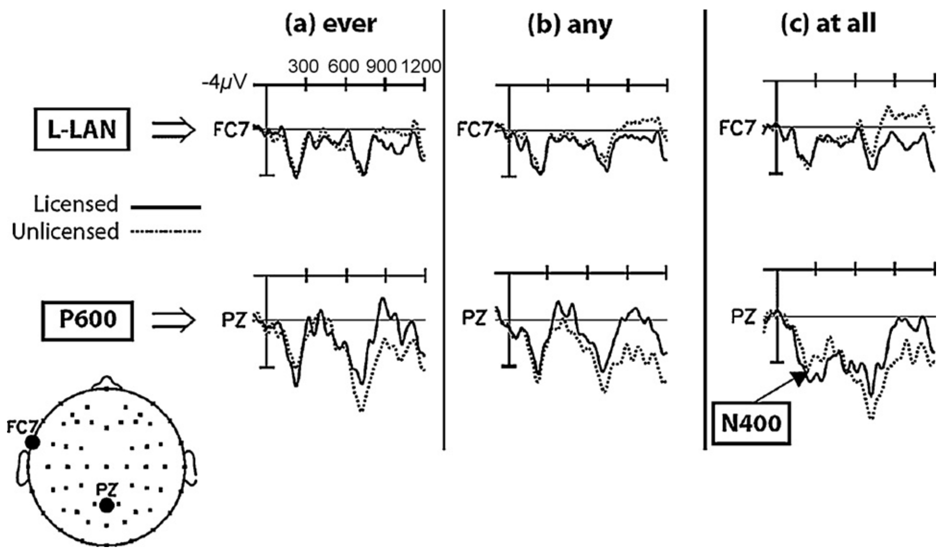

Fig. 7. The P600/L-LAN pattern for the three individual NPIs we tested (*ever, any, at all*) for midline parietal (Pz) and left anterior (FC7) electrodes showing representative effects. Note that *at all* also showed an N400 modulation which was absent for *any* and *ever*.

more detail, a few brief remarks about the findings for the phrase structure and conceptual semantics conditions are in order.

First, it is important to note the ERP pattern found for the phrase structure violations differed from previous reports in that we did not find evidence for the very early left anterior negativity ("N125" or "eLAN") that other studies (including one of our own) have found for this particular type of word order violation. As noted in our Introduction, in the initial Neville et al. (1991) study the pattern that emerged for these cases was threefold: (i) a very early left anterior negativity (eLAN or N125, between 100 and 250 ms), (ii) a second left temporal/parietal negativity (between 300 and 500 ms), and (iii) a late positive-going (P600) effect. However, at least in reading experiments, these very early negativities have not been reliably observed across studies. In line with several other studies (cf., Hagoort, 2003; Newman et al., 2007; Steinhauer, White, & Drury, 2009), we found only the latter two (LTN/P600) effects. However, setting aside the absent eLAN, the pattern of effects found here strongly resembled those that have been previously shown for this type of violation (including the more posterior-temporal scalp distribution of the "LTN" effect (even though some studies have referred to it as a LAN, see Newman et al., 2007).[5]

Second, consider the two less commonly reported effects that emerged downstream of the classical N400 effect for the conceptual semantic violations: (i) the late anterior negativity and (ii) the late posterior positivity. A few general points about these effects should be made. The first is that it is not at all clear whether these effects are unusual, given that the vast majority of past studies which have investigated N400 effects focus on earlier latency ranges (300–500 ms) where N400 effects are reliably found, and do not generally make a practice of inspecting or analyzing later downstream time-windows (e.g., Neville et al., 1991).

A second, complementary point about these two effects is that neither are new. Though we have observed this same pattern of post-N400 ERP effects in a separate study using very similar conceptual violations as were deployed here (Drury, Steinhauer, Pancheva, & Ullman, under revision), we are not the only ones to have found such effects. The later posterior positivity has been

[5] In this discussion we do not take any strong stand on the issue of whether the variety of scalp distributions of negativities (sometimes left lateralized, sometimes broadly anterior, sometimes left and anterior) that have been called "LAN-effects" are all instances of the same underlying phenomenon (thus our more neutral reference to the "LAN-like" posteriorly distributed effect for our phrase-structure violation as a "left temporal negativity" or "LTN"). It is also worth noting that the post-LAN positive-going effects in the present study appear, like in the initial Neville et al. (1991) data, to be a complex effect, with an early more frontal positive peak (~500 ms) followed by a later posterior (central parietal) peak. The timing difference of these two positive-going peaks, though not discussed in Neville et al.'s seminal paper (they focus on the (e)LAN effects) is nonetheless clearly visible in their data), and is easily seen in the present data (compare Fz and Pz in Fig. 5A). We have found this same pattern of an anterior-to-posterior shift in late positive-going deflections for this violation type in a separate study (Drury et al., under revision). These data will be discussed in more detail in a separate report and are not further considered here. Our main interest in this contrast in the context of the present discussion is that this case elicited the left temporal negativity that has been previously reported for this paradigm and others like it targeting syntactic processing.

reported elsewhere for conceptual semantic violations (Friederici & Frisch, 2000; Münte, Heinze et al., 1998; Münte, Schiltz, & Kutas, 1998; Shao & Neville, 1998), and are also seen for other kinds of cases which plausibly require reference to deviance at the syntax/semantic interface (see Bornkessel-Schlesewsky & Schlesewsky, 2008 for a review). Again, this may actually be a regular part of the ERP-profile of this type of conceptual semantic violation: that they have not been more widely reported and discussed may be partly due to the fact that studies targeting the N400 typically confine themselves to analyses of earlier latency ranges. Another potential issue is the inconsistent use of high-pass or band pass filters that systematically remove slow potentials from the EEG signal. The rather low threshold of the band-pass filter used in the present study (0.01 Hz) was unlikely to affect such slow waves.

Regarding the post-N400 anterior negativity, Mecklinger, Schriefers, Steinhauer, and Friederici (1995) report a similar effect following N400 modulations for semantically neutral versus semantically biased verbs in subject/object relative clause ambiguities in German (e.g., schematic English gloss: "This the NP1 that the NP2 VERB Auxiliary"). They attribute this effect to semantic working memory demands (based on its respective absence/presence in "fast" versus "slow" comprehenders—see their paper for discussion). Such late negativities have also been reported for conceptual semantic violations in Friederici and Frisch (2000) (under the label "sentence ending negativity" or "SEN"). However, the late negativity for the conceptual violations in the present study cannot be attributed to sentence-final "wrap-up" type effects, as they occurred here well before the sentence-final words.

Note that it may be that one or both of these post-N400 effects for conceptual anomaly arose in the present study as a function of the acceptability judgment task which participants performed (we return to this general issue below). However, in what follows we now turn to discuss the various sub-components elicited in this study, with our primary focus on the P600/L-LAN pattern for unlicensed NPIs (further discussion and possible interpretations of the post-N400 effects for the conceptual violations will be addressed in this context, see below).

It is first important to note that the P600/L-LAN ERP-profile observed here for NPI-licensing violations may be an instance of a more general pattern. We have also found this same pattern (Drury et al., under revision) for other violations that the linguistics literature links to logical semantics: the so-called "Definiteness Effect" or "DE" in English existential constructions (e.g., *There may be* √ a man/*the man *in the room*; for overview see McNally, in press). Moreover, as noted in our introduction, Shao and Neville (1998) reported a similar P600/L-LAN pattern for cases of contradiction (e.g., *Jane doesn't eat any* **meat** *at all, instead she only eats* #**beef** *and vegetables*).

That these three cases should manifest the same general ERP-profile is difficult to explain without reference to some common underlying mechanism(s) which both link them together *and* distinguish them from both syntax and conceptual semantics. In this connection a number of important questions arise regarding how the present findings relate to similar kinds of effects seen elsewhere, including for other conditions in the present study. More specifically:

1. Are the late P600-like positivities seen for all three types of violations examined here reflective of the same underlying processing, or not?
2. What is the status of the late (left) anterior negative going effects seen in the both the conceptual and logical semantic conditions in the present study? Why should the onset of these effects with respect to the posterior P600 effects differ across the conceptual and logical (NPI-licensing) cases?
3. Finally, what is the status of the marginal N400 effect found here (for *at all*, but not *ever* or *any*) and the N400 effects that have been found in other studies of NPI licensing?

We will address each of these questions in turn.

4.1. P600

The late positivities elicited for all the violations (both syntactic and semantic) tested in the present study adds to the growing body of findings in the literature showing that these effects are not uniquely tied to syntax. Although the positivities seen in the present study may, in fact, represent effects that we might consider assigning distinct descriptive labels to, for convenience here we will refer to all of these deflections as "P600s" or "P600-like" effects (see note 3).

Early reports of P600s were arguably tied to syntactic ambiguity and anomaly (Friederici, Pfeifer, & Hahne, 1993; Hagoort, Brown, & Groothusen, 1993; Neville et al., 1991; Osterhout & Holcomb, 1992; Osterhout, Holcomb, & Swinney, 1994). However, very similar kinds of effects are now known to also be elicited in connection with spelling errors (Münte, Heinze et al., 1998; Münte, Schiltz et al., 1998), musical anomalies (Patel, 1998), phonological and prosodic revisions (e.g., Friederici, Mecklinger, Spencer, Steinhauer, & Donchin, 2001; Steinhauer, 2003), and violations created in abstract cognitive sequencing tasks (Lelekov, Dominey, & Garcia-Larrea, 2000; see Kutas et al., 2006 for review). Linguistically such effects do not only occur in connection with syntactic anomaly and ambiguity, but also arise in connection with syntactic complexity (e.g., in establishing the dependency relationships in relative clauses or wh-movement; Kaan, Harris, Gibson, & Holcomb, 2000; Phillips, Kazanina, & Abada, 2005; see also Friederici, Hahne, & Saddy, 2002). P600 effects have also been elicited by thematic anomalies and implausible sentences (Kim & Osterhout, 2005; Kolk et al., 2003; Kuperberg, Kreher, Sitnikova, Caplan, & Holcomb, 2007; van Herten et al., 2005) and are sometimes seen accompanying conceptual-semantic N400s (Münte, Heinze et al., 1998; Münte, Schiltz et al., 1998; Shao & Neville, 1998, and the present study). P600-type effects are also elicited by processing of referential dependencies holding across separate sentences (e.g., Dwivedi, Phillips, Lague-Beauvais, & Baum, 2006; Hammer, Jansma, Lamers, & Munte, 2005).

In sum: the family of P600-like effects appear to reflect processes involving a fairly wide variety of types of information. A broad generalization which may tie them together is that these effects all may be understood reflect the integration/alignment of two or more independently structured or sequentially-ordered bodies of information, thus also reflecting the processing when such cross-domain integrationsfa[i]l. This general view of P600-type effects is clearly gaining ground as the majority perspective in language ERP research judging from the recent literature (see, e.g., Friederici & Weissenborn, 2007; Kuperberg, 2007), for example in the "generalized mapping" component proposed in Bornkessel & Schlesewsky's (2006, 2008) model.

Holding constant this general outlook, the present data suggest that the onset latency of late P600-like effects may reflect the types of information that must be integrated. Our syntactic violation elicited the earliest onset positivity (significant in the 500–700 ms range), followed by the logical-semantic/NPI-licensing case (around 700–900 ms), followed by the conceptual-semantic violation (which did not emerge until the final 900–1100 ms time-window). This ordering of integration effects (syntax → logic → concepts) is consistent with widely assumed views in the linguistics literature. That is, logical semantic composition can reasonably be expected to be reliant (parasitic) on successful syntactic combination, and difficulties in integrating conceptual information should be relative to already established logical semantic relationships (though see our N400 discussion below).

However, it is reasonable to ask what decides whether it is best to understand our P600 effects as reflecting "syntax" versus "semantics"? What *could* decide in principle? A number of factors cloud the issue. Consider the distinction between "syntax" and "logical semantics". Even if we assume that there is such a distinction (i.e., that logical semantics is not "just" an abstract level of syntactic representation) it is not obvious that the same underlying neural circuitry couldn't support both types of processing (i.e., a "combinatorial" processing stream (Kuperberg, 2007), the workings of a general "procedural" system supporting "rule-based" composition (Ullman, 2001), or general structural unification operations (Hagoort, 2005)). Further, it could be that syntactic-level deviance is always attended by disruptions of logical/truth-conditional aspects of semantic composition, especially if the latter is essentially parasitic on the former (i.e., if licit syntactic combination is a prerequisite for composing the corresponding logical semantic level information). These considerations raise the possibility that, in fact, many past "syntactic" P600 findings could rather be interpreted as reflecting the consequences of syntactic violations for logical semantic level composition.

It is also worth asking in this connection a very general question about the time-course of the maintenance of syntactic information proper in on-line processing. Once very early structure-assembly and syntactic category information has been processed, and assuming a rapid, incremental, cascaded mapping to other (more "durable") systems of semantic and discourse-level representation, why should syntactic structure distinctions be maintained in working memory? It may rather be that language processing rapidly makes use of syntactic information but then essentially discards it as information is successfully carried forward (translated) to other (interpretative) levels of processing and memory encoding. If this is correct, then processes such as reanalysis or repair, often suggested to be indexed by P600-type effects in cases of syntactic anomaly or ambiguity, may rather be processes which handle the latter (non-syntactic) types of semantic/discourse representations.

Of course, one way to try to pull apart syntax from logical semantics is to study cases where it can be argued that there is *only* logical semantic level deviance but *no* syntactic level deviance (see Pylkkanen & McElree, 2007, in press for important related discussion). Such cases, we suggest, are represented by precisely the kind of phenomena examined in the present study (NPI-licensing). If we adopt the conclusions of work in linguistic theory which attributes the deviance of unlicensed NPIs to the level of logical/truth-conditional semantics (see Section 1), then it is reasonable to assume that the P600 found here and in all the other studies of NPI-licensing is an effect directly tied to this level of processing, and not to syntax proper. A weaker formulation would suggest that the P600 reflects a mapping/integration problem at the interface between syntactic and semantic representation.

But, if we are right in connecting the pattern found for unlicensed NPIs in the present study (and for the Definiteness Restrictions (DR-)violations in existential constructions found in Drury et al., under revision) with the P600/L-LAN found in Shao and Neville's (1998) contradiction case, this suggests the stronger formulation may actually be correct, that is: nothing goes wrong with the "syntax proper" in Shao & Neville's contradiction manipulation.

Intriguingly, there are views of both NPI-licensing and the DE in existential constructions which can be taken to suggest a more specific generalization connecting all of these findings: they are all instances of logical truth/falsity (i.e., all are abstract cases of either *tautology* or *contradiction*). Chierchia (2006), for example, proposes that unlicensed NPIs result in inconsistent logical representations, specifically: *contradictions*. In Barwise and Cooper (1981) a formal model-theoretic semantics for nominal expressions is developed under which definites and other so-called "strong" quantifiers (e.g., *every, each, most*, etc.) yield tautologies in existential constructions (or, for strong negative quantifiers, e.g., *neither*, contradictions). A more detailed discussion of these accounts is beyond the scope of the present report, and we moreover think some caution is warranted with respect to the possibility of too narrowly (over-)interpreting the small set of presently available empirical findings. We mention this here nonetheless, as we think the convergence of these theoretical characterizations with a common patterning of ERP-profiles across these otherwise superficially diverse cases is striking, and suggests a number of avenues to explore (e.g., examine some of these different contrasts in a within-subjects design, etc.).

If we suppose, along the lines just sketched, that this P600/L-LAN is associated with logical semantic anomaly, and that the P600 part of this pattern reflects a syntax/logical-semantics mapping effect (i.e., detection of some inconsistency in logical-semantic composition given the output of syntactic combinatory processes), what then might the subsequent L-LAN represent?

4.2. L-LAN

Shao & Neville attempt to give a unified explanation for the LAN/P600 effect they found for NPIs relative to non-NPIs in non-licensing contexts and the P600/L-LAN they found for the case of logical contradiction. They suggest that both the negativities trace to increases in working memory burden: encountering an NPI in a non-licensing context triggers a search in working memory of the representation of the previously parsed material for the missing licensing element. The L-LAN effect they find in the contradiction case is offered a similar explanation, that is: working-memory is inspected to verify that the superordinate term (e.g., *meat*—see example in Section 1) was, in fact, actually negated. But as Shao & Neville point out themselves, a unified explanation of these negativities must explain their rather different timing properties.

The results of the present study suggest that Shao and Neville's earlier (300–500 ms) "pre-P600" LAN effect may be traceable to just the difference in the length of the target words they compared (their NPIs were *shorter* than there non-NPIs). Here we found a similar early relative negativity (∼300–500 ms) but in the opposite direction (non-NPIs more negative than NPIs), but again showing a LAN for the *shorter* words (our non-NPIs were shorter than our NPIs). The general patterning of effects across studies (shorter words more negative-going anteriorly) is consistent with word length effects on ERPs demonstrated elsewhere (e.g., Osterhout, Allen, & McLaughlin, 2002). Since we (and all other studies) found no other indication of early LAN effects tied to the NPI-licensing violation itself, it seems likely that there is nothing to explain here: NPI-licensing violations do not give rise to early LAN type effects. Importantly, given that we replicated the (300–500 ms) LAN-like effects reported in Neville et al. (1991) for phrase-structure violations in this study (what we have referred to descriptively as an "LTN"), this conclusion seems reasonable.

But a working-memory based explanation of the L-LAN found in Shao & Neville's contradiction manipulation strikes us as plausible. If correct, this view makes a number of further predictions which are easy to test. In contrast to the more transient early (e)LAN effects seen in connection with (morpho)syntactic violations, slower negative-going waves with (left) frontal distributions have been reported for experimental manipulations believed to involve increases in working memory burden (e.g., in connection with: (i) filler-gap dependencies of varying complexity, Fiebach, Schlesewsky, & Friederici, 2001; Fiebach, Schlesewsky, & Friederici, 2002; King & Kutas, 1995; Kluender & Kutas, 1993; Phillips et al., 2005; (ii) semantic violations involving temporal relationships, mood, and modality (Dwivedi et al., 2006; Münte, Schiltz et al., 1998); (iii) subvocal rehearsal (Ruchkin, Johnson, Grafman, Canoune, & Ritter, 1992) and (iv) mapping relationships between logical semantics and discourse representation (e.g., in reference resolution, see van Berkum, Koornneef, Otten, & Nieuwland, 2007; and in violations of definiteness restrictions in existential constructions, Drury et al., under revision).

The general notion that the L-LAN observed in studies involving logical semantics might be working memory related predicts that separating groups of participants on the basis of independent measures of working memory capacity (e.g., reading span; Daneman & Carpenter, 1980) should yield between-group amplitude differences in these negativities. Also varying task demands could shed light on this possibility (e.g., along the lines of Vos et al., 2001). It also suggests that separating the participants in the present study based on their judgment accuracy might reveal differential effects on the L-LAN (either in effect size, or perhaps onset latency, or both).[6]

In terms of the underlying processes, a working-memory based account of the L-LAN in connection with NPI-licensing could be understood in at least two different ways: (i) search for a licensor and (ii) maintenance of unintegrated material. *First*, the L-LAN may reflect the maintenance/reactivation of the existing representation in order for the parser to engage in the kinds of search processes suggested by Shao & Neville (e.g., for the missing licensor in the case of unlicensed NPIs). This "non-local" account would predict a larger memory load with increasing context (i.e., the distance between NPI and potential licensors in the previous sentence materials).

However, it is worth pointing out that it is not obvious that establishing the link between an NPI and its licensor is a process that is "non-local" in the sense that an actual search for a potential licensor in the sentence materials further upstream needs to be initiated (e.g., analogous to finding an antecedent for a reflexive pronoun; e.g., between "the man" and "himself" in: The man *Mary introduced to Sarah told all the people in the office all about* himself; in fact, Xiang, Dillon, & Phillips, 2009 provide some ERP evidence consistent with a qualitative distinction between NPI-licensing and reflexive binding).

An alternative linguistic account for how NPI licensing may be represented during sentence processing directly leads to the second type of suggested memory load due to unintegrated materials rather than active search. For example, Dowty (1994) proposes a view of syntactic/semantic derivation in which entailment (e.g., monotonicity) properties introduced by logical operators propagate through the structure (essentially marked as features in the structural representation) and thus would be understood to be *locally* visible to computational mechanisms at *any* position in the structure where an NPI needs to be integrated (see also Stabler, 1997 among others for related ideas about encoding logical properties as features marked on structural representations, i.e., what Szabolcsi, 2005 calls "semantically flavored" syntactic features). These "local" and "non-local" views could be understood to make different predictions with respect to the L-LAN effect if it is correct that this relative negativity is indexing an increase in working memory burden. On the "local" view of licensing there should *not* be differential effects of separating NPIs from their licensors by greater numbers of intervening words. For the non-local view, in contrast, the amount of intervening material should matter, as this should effect the complexity of the representation that must be searched for a potential licensor. These issues *may* also relate to the differences across studies of NPI-licensing with respect to the presence/absence of N400 effects (see below).

The L-LAN could also represent a different sort of consequence of the detection of logical semantic anomaly. On this view, the rapid processes by which information is translated from one processing level to the next would encounter a mapping mismatch (e.g., between syntax and logical semantics) or an integration/composition failure (e.g., within logical semantics proper). In either case this could result in the need to maintain representations of incoming material in an unintegrated format, thus imposing an increase in demand on working memory resources. This notion would assimilate well with the finding of sustained negative deflections for filler-gap types of relationships (e.g., wh-movement, object-relative clause, etc., e.g., Fiebach et al., 2001; Kluender & Kutas, 1993) and with the general finding of such effects in connection with rehearsal of words (Ruchkin et al., 1992).

It is interesting to note that we also elicited a late anterior negativity in this study in connection with our conceptual semantic violation. Given its onset and topographical properties, it seems not unreasonable to suggest that this effect is also indexing an increase in semantic working memory burden (in line with the interpretation of a similar effect found in Mecklinger et al., 1995, mentioned earlier). This would be to claim that the anterior negativity seen for our conceptual violations is related to the L-LAN for unlicensed NPIs. Note that the distributional differences (one broadly anterior, the other left lateralized) may simply turn on the timing of the posterior positive-going effects (i.e., due to additivity/cancelation), which arose earlier in the NPI-licensing case than in the conceptual anomaly case. If this is correct, we would need to rather entertain the more general, second interpretation of the L-LAN mentioned above, and we would also predict that this negativity in the conceptual anomaly case should also track individual working memory differences (we are investigating these possibilities).

Note also that the logical and conceptual anomalies can be distinguished by the temporal ordering of very similar kinds of ERP-effects. That is, the conceptual violations, following the N400-effect, elicit the anterior negativity followed by a later positivity, while the logical-semantic (NPI-licensing) cases show the opposite temporal ordering (posterior positivity followed by anterior negativity). Although some caution is warranted here, this general difference could be taken to suggest that distinctions between these violation types – at least with respect to these later anterior-negativities and posterior-positivities – may rather be best understood *not* so much in terms of separate brain areas/circuits, but rather in terms of different temporal dynamics of the same underlying circuits (see Kuperberg et al., 2003, among others, for some similar suggestions based on fMRI data).

For example, the conceptual anomaly case would be understood on this view to first give rise to access/retrieval difficulties relative to coherent controls, indexed by the N400 difference. This may in turn result in a delay in the integration of information, yielding a temporary increase in working memory burden (along the lines suggested above), indexed by the anterior negativity. Finally, as the relevant conceptual information is retrieved, the system finds that it cannot be coherently integrated, and it would then be this failure that is reflected by the late positivity. However, if this is so, then we might expect to see such effects more generally in connection with conceptual semantic anomalies. That such effects have been infrequently reported may speak against this interpretation, but we wish to stress that this is an empirical issue which requires more careful attention in future studies. Extending data analyses to later time windows beyond the expected N400 latency range and applying high-pass (and band-pass) filters with low thresholds (at least for initial analyses) should clarify the prevalence and functional sig-

[6] Though we have not reported such effects here, we have undertaken these analyses and there is indeed some indication that the anterior negativity does indeed differ between groups binned according to response accuracy. However, we have our doubts that this is the best measure. We are currently engaged in follow-up research involving additional contrasts along with independent assessments of individual working memory differences in order to properly evaluate this possibility.

nificance of these negativities in the near future. Moreover, if we are correct that the anterior negativity (and the L-LAN—see below) may be tied to an increase in working memory burden, assessing the working memory capacity of participants should also shed light on these components.

In contrast, the NPI-licensing violations do not (generally) result in lexical access/retrieval problems, and thus do not (generally) yield an N400 (though see below). Processing systems then attempt to integrate the NPI into the representation, and at this point the logical semantic level deviance is detected, reflected by the positivity/P600. The subsequent (late left) anterior negativity (L-LAN) then reflects the consequences of this integration failure (i.e., having to maintain unintegrated items in memory and/or perhaps "search" of the existing representation for the requisite licensing properties).

Finally, although L-LAN type effects have not been consistently reported in other studies of NPI-licensing, similar kinds of effects have been shown in at least one of the German studies (beim Graben et al., 2007; though unlike the present findings, their late negativities were sentence-final and thus confounded with "wrap-up" effects). It is also possible that either such late effects have been missed in favor of concentrating on analyses of earlier latency ranges, or (if these are indeed working memory related) that they might be inconsistent across subject groups not assessed for working memory capacity. However, these issues correspond to a straightforward empirical agenda for future research in this domain.

4.3. N400

Consistent with other ERP studies of NPI-licensing in English (Shao & Neville, 1998; Xiang et al., 2009) but contra the studies that have been conducted in German (Drenhaus et al., 2005; Drenhaus, beim Graben et al., 2006; Drenhaus, Blaszczak et al., 2006; Saddy et al., 2004), our findings here suggest that N400 modulations are not in general a necessary consequence of encounters with unlicensed NPIs during sentence reading. Though potentially important cross-linguistic (English versus German) differences cannot be definitively ruled out at this point, given that we found a marginal N400 effect for one of the NPIs tested here (*at all*), it appears that a general explanation for the presence/absence of these effects for NPI-licensing violations must be explored relative to other considerations.

What *might* these N400 effects be reflecting? We think the available evidence is in line with a lexical access/retrieval perspective on N400 effects (see Lau et al., 2008), at least with respect to the types of logical semantic manipulations under discussion (if this effect was more broadly about semantic integration, it is unclear why it wouldn't manifest as the most reliable effect across studies—rather, the P600 effect has). There are several possible directions of explanation along these lines that could be pursued including: (i) the complexity of the stored representations of the NPIs that have been tested to date, (ii) Licensor-NPI distance (both linear and hierarchical).

First, one descriptive generalization is that N400 effects for unlicensed relative to licensed NPIs are present only when the NPI is lexically complex: German *jemals* is bimorphemic (*je* + *mals* = *ever* + *time*; note that je can appear in isolation with a meaning equivalent to English "ever") and our two-word case *at all* plausibly must be stored in the lexicon as a unit (associated with its special semantic properties) to distinguish it from other compositional instances of the same pair of words (e.g., *John was* [at [all *of the parties*]]). This line of thinking might be connected to the fact that function words in general elicit reduced or absent N400 activity compared to open-class/content words (see Section 1). It might be that the one-word NPIs tested in the present study (and in Shao & Neville) did not have the requisite "lexical bulk" to elicit an N400 effect. This predicts that testing English NPIs like *anybody/anyone/anything* would reliably yield N400 effects in English (preliminary results from an ongoing follow-up study suggests that this is indeed the case Drury, Dwivedi, & Steinhauer, 2008). This also predicts thatNPI licensing violations in German using just *je* (= "ever") would be expected *not* to elicit N400 effects.

Second, there also appear to have been systematic differences in the linear distance (i.e., number of intervening words) between Licensor and the target NPIs (see Warren, Vasisth, Hirotani, & Drenhaus, 2006 for some relevant behavioral data). In the present study, *any, ever*, and *at all* occurred on average 2, 3, and 5 words (respectively) downstream of their licensors; in the Saddy et al./Drenhaus et al. studies, the NPI occurred approximately 7 words downstream from their licensor (e.g., *No man, who had a beard, was* *ever* *happy*). Note that although there were no differences between target NPIs in the present study (*any, ever, at all*) with respect to the P600/L-LAN pattern, only the NPI that occurred further downstream from its licensor (*at all*) elicited an N400 effect in the present study.

Thus, another descriptive generalization of the range of presently available findings is that the larger distances between licensors and NPIs, the more likely it is to see an N400 effect. This view might be rationalized in accordance with the *local* view of the encoding of monotonicity properties discussed above in connection with the L-LAN. That is, if entailment properties are locally encoded in the ongoing parse such that these properties are "visible" to local syntactic/semantic composition, then perhaps the more prior context that is built-up, the more strongly such properties will be represented. This then might be understood to provide a type of contextual facilitation for the lexical access/retrieval of the NPI (resulting in smaller N400 amplitudes for greater NPI/licensor distances). In contrast, the "non-local" view of licensing discussed above (where the prior context has to be "searched" for an appropriate licensor), interestingly, might be taken to underwrite a complementary view in terms of N400 *increases* for the ungrammatical conditions (i.e., lexical access/retrieval of the NPI is more difficult when more prior context must be searched in order to find an appropriate licensor). Of course, *both* NPI-complexity (e.g., *ever/any* vs. *at all, orje vs. jemals*) and Licensor/NPI distance factors could plausibly matter for N400 effects. Teasing these apart by crossing those factors is a straightforward task for follow-up research.

4.4. Non-violation effects: a methodological lesson for evaluating past and future studies

In addition to the word-length effect discussed above (early LAN-like negativity for shorter words in both Shao & Neville and our study), we also found a main effect of sentence context (a P600-like positivity for non-licensing vs. licensing conditions across NPIs and non-NPIs, thus independent of the NPI violation). This main effect may reflect general integration differences between the sentence structures and is not easy to interpret without further investigations (e.g., we cannot rule out that it was rather the licensing conditions that were more negative-going for non-NPIs, versus the non-licensing conditions being more positive-going).

However, the general significance of this finding (and the early word-length effect) lies in the obvious methodological lesson, which is that pure context (and pure word length) ERP effects *do* occur (whether our particular interpretations here are correct or not). Thus, without appropriate control conditions, ERP-effects due to these factors alone can be erroneously attributed to the NPI violation of interest. Given that our non-licensing conditions in general showed a small late positivity, this means that any prior study which did not include (or did not include analyses of) the relevant control conditions cannot be straightfowardly interpreted as having shown a P600-type effect for NPI-licensing violations. That these late positivities are at least sometimes not detectable using standard averaging techniques (e.g., in Saddy et al., 2004; see Drenhaus, beim Graben et al., 2006; Drenhaus, Blaszczak et al., 2006), further underscores the importance of this methodological point.

5. Conclusion

First, the most consistent finding for NPI violations across studies so far has been the P600, while early effects preceding the P600 (i.e., LANs and N400s) do not seem to reflect reliable NPI violation effects. We have argued that the P600 may reflect an integration or mapping problem at the syntax/logical semantics interface or, perhaps, may index the detection of inconsistencies (e.g., contradictions) at the level of logical semantic representation itself. Second, in our present study as well as some others investigating logical semantics, the P600 was followed by a late LAN (L-LAN). In line with other previous findings in the literature, we have suggested two kinds of accounts that link this component to working memory demands. The combined P600/L-LAN profile seems to confirm previous findings suggesting that non-conceptual – i.e. logical/truth-conditional – dimensions of semantics are processed downstream of the N400 time window (see Katayama et al., 1987, and Lüdke et al., 2008, for compatible findings). Third, we have provided evidence for pure context (licensing) effects as well as target word effects (possibly due to word length differences) that are independent of the licensing violation of interest. Therefore, future follow-up research should deploy designs controlling for these effects or else they will be incapable of teasing out genuine violation effects on ERPs. Further, the finding of ERP effects tied more generally to the licensing/non-licensing distinction points the way towards another path for follow-up research using stimuli without violations (i.e., contrasting the effects that different kinds of logical operators have on ERPs for grammatical sentences).

Finally, we have also suggested here that the value of the study of NPI-licensing (and related kinds of phenomena which may implicate the various interfaces between the lexicon, syntax, logical-semantics, and pragmatics) is that these types of cases have much to teach us about the nature of ERP components. Future work resolving the differences across existing studies promises to aid in our understanding of the linguistic (and possibly more broadly "cognitive") conditions which elicit the kinds of negative (LAN, N400, L-LAN) and positive (P600) shifts in ERPs that we have discussed here. We also believe that further study of these matters should aid in making stronger connections between linguistic semantics and cognitive psychological studies of human reasoning (e.g., especially given the role attributed to monotonicity properties both in theories of NPI-licensing and in some approaches to understanding human reasoning, see e.g., Geurts, 2003; Geurts & Van der Slik, 2005).

However, the most general finding of the present study is that the way that the human brain handles syntactic, conceptual, and logical information can be distinguished *within participants* using event-related brain potentials. Further investigation of these patterns, pursued together, has much to recommend it in terms of the potential to inform both developments in linguistic theory and in our understanding of the underlying etiology of ERP-components connected with language processing.

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References

Barwise, J., & Cooper, R. (1981). Generalized quantifiers and natural language. *Linguistics and Philosophy*, *4*, 159–219.

beim Graben, P., Drenhaus, H., Brehm, E., Rhode, B., Saddy, D., & Frisch, S. (2007). Enhancing dominant modes in nonstationary time seris by means of the symbolic resonance analysis. *Chaos*, *17*, 043106.

Bentin, S., McCarthy, G., & Wood, C. C. (1985). Event-related potentials, lexical decision and semantic priming. *Electroencephalography and Clinical Neurophysiology*, *60*, 343–355.

Bornkessel, I., & Schlesewsky, M. (2006). The extended argument dependency model: A neurocognitive approach to sentence comprehension across languages. *Psychological Review*, *113*(4), 787–821.

Bornkessel-Schlesewsky, I., & Schlesewsky, M. (2008). An alternative perspective on "semantic P600" effects in language comprehension. *Brain Research Reviews*, *59*, 55–73.

Brown, C. M., Hagoort, P., & ter Keurs, M. (1999). Electrophysiological signatures of visual lexical processing: Open- and closed-class words. *Journal of Cognitive Neuroscience*, *11*(3), 261–281.

Chierchia, G. (2006). Broaden your views: Implicatures of domain widening and the "logicality" of language. *Linguistic Inquiry*, *37*(4), 535–590.

Coulson, S., & Federmeier, K. D. (In press). Words in context: ERPs and the lexical/postlexical distinction. *Journal of Psycholinguistic Research*.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior*, *19*, 450–466.

DeLong, Katherine A., Urbach, Thomas P., & Kutas, Marta. (2005). Probabilistic word preactiviation during language comprehension inferred from electrical brain activity. *Nature Neuroscience*, *8*(8), 1117–1121.

Dowty, D. (1994). The role of negative polarity and concord marking in natural language reasoning. *Paper read at proceedings of semantics and linguistic theory IV, at Ithaca, NY*.

Drenhaus, H., beim Graben, P., Saddy, D., & Frisch, S. (2006). Diagnosis and repair of negative polarity constructions in the light of symbolic resonance analysis. *Brain & Language*, *96*(3), 255.

Drenhaus, H., Blaszczak, J., & Schutte, J. (2006). Some psycholinguistic comments on NPI licensing. *Paper read at proceedings of sinn und bedeutung 11, at Barcelona*.

Drenhaus, H., Frisch, S., & Saddy, D. (2005). Processing negative polarity items: When negation comes through the backdoor. In S. Kepser, & M. Reis (Eds.), *Linguistic evidence: Empirical, theoretical, and computational perspectives*. Berlin/New York: Mouton de Gruyter.

Drury, J. E., Dwivedi, V., & Steinhauer, K. (2008). Logical semantics in language processing: An ERP Study. *Journal of Cognitive Neuroscience Supplement*, 249.

Drury, J. E., Steinhauer, K., Pancheva, R., & Ullman, M. T. (under revision). (In)definiteness ERP effects in existential constructions.

Dwivedi, V., Phillips, N. A., Lague-Beauvais, M., & Baum, S. R. (2006). An electrophysiological study of mood, modal context, and anaphora. *Brain Research*, *1117*(1), 135–153.

Erdocia, K., Laka, I., Mestres-Misse, A., & Rodriguez-Fornells, A. (2009). Syntactic complexity and ambiguity resolution in a free word order language: Behavioral and electrophysiological evidences from Basque. *Brain and Language*, *109*, 1–17.

Federmeier, K. D., & Kutas, M. (1999). A rose by any other name: Long-term memory structure and sentence processing. *Journal of Memory and Language*, *41*, 469–495.

Felser, C., Clahsen, C., & Muente, T. (2003). Storage and integration in the processing of filler-gap dependencies: An ERP study of topicalization and *Wh*-movement in German. *Brain and Language*, *87*, 345–354.

Fiebach, C. J., Schlesewsky, M., & Friederici, A. D. (2001). Syntactic working memory and the establishment of filler-gap dependencies: Insights from ERPs and fMRI. *Journal of Psycholinguistic Research*, *30*(3), 321–338.

Fiebach, C. J., Schlesewsky, M., & Friederici, A. D. (2002). Separating syntactic memory costs and syntactic integration costs during parsing: The processing of German WH-questions. *Journal of Memory and Language*, *47*, 250–272.

Fischler, I., Bloom, P. A., Childers, D. G., Roucos, S. E., & Perry, N. W., Jr. (1983). Brain potentials related to stages of sentence verification. *Psychophysiology*, *20*(4), 400–409.

Friederici, A. D. (1995). The time course of syntactic activation during language processing: A model based on neuropsychological and neurophysiological data. *Brain and Language*, *50*, 259–281.

Friederici, A. D. (2002). Towards a neural basis of auditory sentence processing. *Trends in Cognitive Sciences*, *6*, 78–84.

Friederici, A. D., & Frisch, S. (2000). Verb argument structure processing: The role of verb-specific and argument-specific information. *Journal of Memory and Language*, *43*, 476–507.

Friederici, A. D., Pfeifer, E., & Hahne, A. (1993). Event-related brain potentials during natural speech processing: Effects of semantic, morphological and syntactic violations. *Cognitive Brain Research*, *1*(3), 183–192.

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*(2), 305–323.

Friederici, A. D., Hahne, A., & Saddy, D. (2002). Distinct neurophysiological patterns reflecting aspects of syntactic complexity and syntactic repair. *Journal of Psycholinguistic Research*, *31*(1), 45–63.

Friederici, A., & Weissenborn, J. (2007). Mapping sentence form onto meaning: The syntax-semantics interface. *Brain Research*, *1146*, 50–58.

Geurts, B. (2003). Reasoning with quantifiers. *Cognition*, *86*, 223–251.

Geurts, B., & Van der Slik, F. (2005). Monotonicity and processing load. *Journal of Semantics*, *22*, 97–117.

Giannakidou, A. (1998). *Polarity sensitivity as (Non)veridical dependency*. Amsterdam-Philadelphia: John Benjamins.

Giannakidou, A. (In press). Negative and positive polarity items: Licensing, compositionality and variation. In C. Maienborn, K. Von Heusinger, & P. Portner (Eds.), *Semantics: An international handbook of natural language meaning*. Berlin: de Gruyter.

Gunter, T. C., Stowe, L. A., & Mulder, G. (1997). When syntax meets semantics. *Psychophysiology*, *34*, 660–676.

Hagoort, P. (2003). Interplay between syntax and semantics during sentence comprehension: ERP effects of combining syntactic and semantic violations. *Journal of Cognitive Neuroscience*, *15*(6), 883–889.

Hagoort, Peter. (2005). On Broca, brain, and binding: A new framework. *Trends in Cognitive Sciences*, *9*(9), 416–423.

Hagoort, P., Brown, C., & Groothusen, J. (1993). The syntactic positive shift (SPS) as an ERP measure of syntactic processing. *Language and Cognitive Processes*, *8*(4), 439–483.

Hagoort, P., Wassenaar, M., & Brown, C. (2003). Syntax-related ERP-effects in Dutch. *Cognitive Brain Research*, *16*(1), 38–50.

Hahne, A., & Friederici, A. D. (2002). Differential task effects on semantic and syntactic processes as revealed by ERPs. *Cognitive Brain Research*, *13*(3), 339–356.

Hammer, A., Jansma, B. M., Lamers, M., & Munte, T. (2005). Pronominal reference in sentences about persons or things: An electrophysiological approach. *Journal of Cognitive Neuroscience*, *17*(2), 227–239.

Hinojosa, J. A., Martin-Loeches, M., Casado, P., Munoz, F., & Rubia, F. J. (2003). Similarities and differences between phrase structure and morphosyntactic violations in Spanish: An event-related potentials study. *Language and Cognitive Processes*, *18*(2), 113–142.

Kaan, E., Harris, A., Gibson, E., & Holcomb, P. (2000). The P600 as an index of syntactic integration difficulty. *Language and Cognitive Processes*, *15*(2), 159–201.

Kaan, E., & Swaab, T. Y. (2003). Repair, revision, and complexity in syntactic analysis: An electrophysiological differentiation. *Journal of Cognitive Neuroscience*, *15*, 98–110.

Katayama, J., Miyata, Y., & Yagi, A. (1987). Sentence verification and event-related potentials. *Biological Psychology*, *25*, 173–185.

Kim, A., & Osterhout, L. (2005). The independence of combinatory semantic processing: Evidence from event-related potentials. *Journal of Memory & Language*, *52*(2), 205.

King, J. W., & Kutas, M. (1995). Who did what and when? Using word- and clause-level ERPs to monitor working memory usage in reading. *Journal of Cognitive Neuroscience*, *7*(3), 376–395.

Kluender, R., & Kutas, M. (1993). Bridging the gap: Evidence from ERP's on the processing of unbounded dependencies. *Journal of Cognitive Neuroscience*, *5*(2), 196–214.

Kolk, H. H. J., Chwilla, D. J., van Herten, M., & 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.

Kounios, J., & Holcomb, P. J. (1992). Structure and process in semantic memory: Evidence from eventrelated brain potentials and reaction times. *Journal of Experimental Psychology: General*, *121*, 459–479.

Kuperberg, G. R. (2007). Neural mechanisms of language comprehension: Challenges to syntax. *Brain Research*, *1146*, 23–49.

Kuperberg, G. R., Holcomb, P., Sitnikova, T., Greve, D., Dale, A. M., & Caplan, D. (2003). Distinct patterns for neural modulation during the processing of conceptual and syntactic anomalies. *Journal of Cognitive Neuroscience*, *15*, 272–293.

Kuperberg, G. R., Kreher, D. A., Sitnikova, T., Caplan, D. N., & Holcomb, P. J. (2007). The role of animacy and thematic relationships in processing active English sentences: Evidence from event related potentials. *Brain and Language*, *100*(3), 223–237.

Kutas, M. (1993). In the company of other words: Electrophysiological evidence for single-word and sentence context effects. *Language and Cognitive Processes*, *8*(4), 533–572.

Kutas, M., & Federmeier, K. D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Science*, *4*(12), 463–470.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science*, *207*(1), 203–205.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature*, *307*(1), 161–163.

Kutas, M., van Petten, C. K., & Kluender, R. (2006). Psycholinguistics electrified II (1994-2005). In M. A. Gernsbacher, & M. J. Traxler (Eds.), *Handbook of psycholinguistics*. New York: Elsevier Press.

Ladusaw, W. A. (1979). Polarity sensitivity as inherent scope relations. *Ph.D. Dissertation*. University of Texas at Austin.

Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics: (de)constructing the N400. *Nature Reviews Neuroscience*, *9*, 920–933.

Lelekov, T., Dominey, P. F., & Garcia-Larrea, L. (2000). Dissociable ERP profiles for processing rules vs instances in a cognitive sequencing task. *NeuroReport*, *11*(5), 1129–1132.

Lüdke, J., Friedrich, C. K., De Filippis, M., & Kaup, B. (2008). Event-related potential correlates of negation in a sentence-picture verification paradigm. *Journal of Cognitive Neuroscience*, *20*(8), 1–16.

McNally, L. (In press). Existential sentences. In C. Maienborn, K. Von Heusinger, & P. Portner (Eds.), *Semantics: An international handbook of natural language meaning*. Berlin: de Gruyter.

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*(4), 477–494.

Münte, T. F., Heinze, H. J., Matzke, M., Wieringa, B. M., & Johannes, S. (1998). Brain potentials and syntactic violations revisited: No evidence for specificity of the syntactic positive shift. *Neuropsychologia*, *36*(3), 217–226.

Münte, T. F., Schiltz, K., & Kutas, M. (1998). When temporal terms belie conceptual order. *Nature*, *395*(6697), 71–73.

Münte, T. F., Wieringa, B. M., Weyerts, H., Szentkuti, A., Matzke, M., & Johannes, S. (2001). Differences in brain potentials to open and closed class words: Class and frequency effects. *Neuropsychologia*, *39*(1), 91–102.

Neville, H., Nicol, J. L., Barss, A., Forster, K. I., & Garrett, M. F. (1991). Syntactically based sentence processing classes: Evidence from event-related brain potentials. *Journal of Cognitive Neuroscience*, *3*(2), 151–165.

Newman, A. J., Ullman, M. T., Pancheva, R., Waligura, D. L., & Neville, H. J. (2007). An ERP study of regular and irregular English past tense inflection. *Neuroimage*, *34*, 435–445.

Nieuwland, M. S., & Kuperberg, G. R. (2008). When the truth isn't too hard to handle: An eventrelated potentials study on the pragmatics of negation. *Journal of Cognitive Neuroscience Supplement*, 213.

Nieuwland, M. S., & Van Berkum, J. J. A. (2006). When Peanuts Fall in Love: N400 Evidence for the Power of Discourse. *Journal of Cognitive Neuroscience*, *18*(7), 1098.

Osterhout, L., Allen, M., & McLaughlin, J. (2002). Words in the brain: Lexical determinants of wordinduced brain activity. *Journal of Neurolinguistics*, *15*, 171–187.

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

Osterhout, L., Holcomb, P. J., & Swinney, D. A. (1994). Brain potentials elicited by garden-path sentences: Evidence of the application of verb information during parsing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(4), 786–803.

Patel, A. D. (1998). Syntactic processing in language and music: Different cognitive operations, similar neural resources? *Music Perception*, *16*(1), 27–42.

Phillips, C., Kazanina, N., & Abada, S. H. (2005). ERP effects of the processing of syntactic longdistance dependencies. *Cognitive Brain Research*, *22*(3), 407.

Pylkkanen, L., & McElree, B. (2007). An MEG study of silent meaning. *Journal of Cognitive Neuroscience*, *19*(11), 1905–1921.

Rothschild, D. (In press). Non-Monotonic NPI-Licensing, Definite Descriptions, and Grammaticalized Implicatures, Proceedings of Semantics and Linguistic Theory XVI, Cornell Linguistics Circle Press: Ithaca.

Ruchkin, D. S., Johnson, R., Jr., Grafman, J., Canoune, H. L., & Ritter, W. (1992). Distinctions and similarities among working memory processes: An event-related potential study. *Cognitive Brain Research*, *1*, 53–66.

Rugg, M. (1985). The effects of semantic priming and word repetition on event-related potentials. *Psychophysiology*, *22*(6), 642–647.

Saddy, D., Drenhaus, H., & Frisch, S. (2004). Processing polarity items: Contrastive licensing costs. *Brain & Language*, *90*(1–3), 495.

Shao, J., & Neville, H. (1998). Analyzing semantic processing using event-related potentials. *Newsletter for the Center for Research in Language*, *11*(5), 3–20.

Stabler, E. (1997). Computing quantifier scope. In A. Szabolcsi (Ed.), *Ways of scope taking*. Dordrecht: Kluwer.

Steinhauer, K. (2003). Electrophysiological correlates of prosody and punctuation. *Brain and Language*, *86*, 142–164.

Steinhauer, K., White, E. J., & Drury, J. E. (2009). Temporal dynamics of late second language acquisition: Evidence from event-related brain potentials. *Second Language Research*, *25*(1), 13–42.

Szabolcsi, A. (2005). *Questions about model theory, proof theory, and semantically flavored syntactic features*. New York University.

Tovena, L. M. (2001). The phenomena of polarity sensitivity: Questions and answers. *Lingua e Stile XXXVI*, (1), 131–167.

Ullman, Michael T. (2001). A neurocognitive perspective on language: The declarative/procedural model. *Nature Reviews Neuroscience*, *2*, 717–726.

van Berkum, J. J. A., Koornneef, A. W., Otten, M., & Nieuwland, M. S. (2007). Establishing reference in language comprehension: An electrophysiological perspective. *Brain Research*, *1146*, 158–171.

van Herten, M., Kolk, H. H. J., & Chwilla, D. J. (2005). An ERP study of P600 effects elicited by semantic anomalies. *Cognitive Brain Research*, *22*(2), 241.

Van Petten, C., & Kutas, M. (1991). Influences of semantic and syntactic context on open and closed class words. *Memory and Cognition*, *19*, 95–112.

Vasishth, S., Bruessow, S., Lewis, R. L., & Drenhaus, H. (2008). Processing polarity: How the ungrammatical intrudes on the grammatical. *Cognitive Science*, *32*(4).

von Fintel, K. (1999). NPI-licensing, strawson-entailment, and context-dependency. *Journal of Semantics*, *16*, 97–148.

von Fintel, K., & Matthewson, L. (2008). Universals in Semantics. *The Linguistic Review*, *25*, 139–201.

Vos, S. H., Gunter, T. C., Kolk, H. H. J., & Mulder, G. (2001). Working memory constraints on syntactic processing: An electrophysiological investigation. *Psychophysiology*, *38*(1), 41–63.

Warren, T., Vasisth, S., Hirotani, M., & Drenhaus, H. (2006). Licensor strength and locality effects in negative polarity licensing. In *CUNY Human Sentence Processing Conference* New York.

Xiang, L., Dillon, B., & Phillips, C. (2009). Illusory licensing effects across dependency types: ERP evidence. *Brain and Language*, *108*, 40–55.