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# Syntactic and Semantic Predictors of Tense in Hindi: An ERP Investigation

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## Abstract

Although there is broad agreement that many ERP components reflect error signals generated during an unexpected linguistic event, there are least two distinct aspects of the process that the ERP signals may reflect. The first is the *content* of an error, which is the local discrepancy between an observed form and any expectations about upcoming forms, without any reference to why those expectations were held. The second aspect is the *cause* of an error, which is a context-aware analysis of why the error arose. The current study examines the processes involved in prediction of past tense marking on verbal morphology in Hindi. This is a case where an error with the same local characteristics can arise from very different cues, one syntactic in origin (ergative case marking), and the other semantic in origin (a past tense adverbial). Results suggest that the parser does indeed track the cause in addition to the content of errors. Despite the fact that the critical manipulation of verb tense marking was identical across cue types, the nature of the cue led to distinct patterns of ERPs in response to anomalous verbal morphology. When verb tense was predicted based upon semantic cues, an incorrect future tense form elicited an early negativity in the 200-400 ms interval with a posterior distribution. In contrast, when verb tense was predicted based upon morphosyntactic cues, an incorrect future tense form elicited a right-lateralized anterior negativity (RAN) during the 300-500 ms interval, as well as a P600 response with a broad distribution.

## *1.1 Background*

Neurolinguistic research has yielded much insight into the functional status of ERP components associated with sentence comprehension, with particular attention to the electrophysiological consequences of different types of linguistic anomaly. The fact that different types of linguistic errors elicit different responses suggests that the human parser is able to make moderately fine-grained distinctions among the problems that arise in sentence understanding. Previous research has identified ERP components that are characteristically associated with the content of morphosyntactic, semantic, and syntactic errors. For instance, words that are anomalous with respect to morphological or syntactic features have long been recognized to generate the P600 response, a late posterior positivity that generally peaks around 600ms post-stimulus (Friederici, Pfeifer, & Hahne, 1993; Hagoort, Brown, & Groothusen, 1993; Osterhout & Holcomb, 1992), as well as an earlier anterior negativity termed the (E)LAN (Coulson, King, & Kutas, 1998; Friederici et al., 1993; Hagoort, Wassenaar, & Brown, 2003; Lau, Stroud, Plesch, & Phillips, 2006; Neville, Nicol, Barss, Forster, & Garrett, 1991). Semantic anomalies in otherwise syntactically well-formed sentences typically elicit a central negativity around 400ms known as the N400 (Kutas & Hilyard, 1980: Kutas & Federmeier, 2000; Lau, Phillips, & Poeppel, 2008).

There is broad agreement that ERP components such as the LAN, N400, and P600 represent processes that are triggered by the processing of an unexpected linguistic event, albeit with much debate over whether these effects are specific to linguistic stimuli (Coulson et al., 1998; Domahs, Wiese, Bornkessel-Schlesewsky, & Schlesewsky, 2008; Münte, Heinze, Matzke, Wieringa, & Johannes, 1998; Martín-Loeches, Casado, Gonzalo, de Heras, & Fernández-Frías, 2006; Núñez-Peña & Honrubia-Serrano, 2004; Patel, Gibson, Ratner, Besson, & Holcomb, 1998). It has often been suggested that the P600, in particular, reflects processes of error detection and repair (Friederici, Hahne, & Saddy, 2002; Gouvea, Phillips, Kazanina, & Poeppel, in press; Hagoort 2003b; Hahne & Friederici, 1999; Hopf, Bader, Meng & Bayer, 2003; Kaan & Swaab, 2003a). However, it remains unresolved what type of error-related processes these ERP components reflect. In particular, there are least two distinct aspects of error processing that the ERP signal might reflect. The first is the *content* of an error, which is the local discrepancy between an observed form and an expected form, with no reference to why a particular form was expected. The second is the *cause* of an error, which is a context-aware analysis of the source of the expectation that the incorrect word violates.

The main difference between these two aspects of error processing involves the information contained in the error signal. A parser that tracks only error content is somewhat of a 'black-box' system: it can recognize failure, but the reason for failure is not immediately recoverable. Successful diagnosis of an error, however, requires more than simply realizing that something has gone wrong; it requires an analysis of the linguistic constraint that was violated. A parser that only tracks error content would not be able to effectively diagnose errors during comprehension. By contrast, a parser that tracks an error's cause can potentially target particular aspects of a parse for repair by recognizing the source of an anomaly that it encounters. In many models of sentence processing, accurate diagnosis of errors is necessary as a critical step on the road to reanalysis and repair (e.g., Fodor & Inoue, 1994; Lewis, 1998). In contrast, there is less need for accurate diagnosis in parsing models that eschew explicit reanalysis and repair mechanisms in favor of parallel parsing and re-ranking of alternatives upon detection of unexpected input. Previous attempts to distinguish these types of parsing architectures have focused on patterns of easy vs. difficult reanalysis (Gibson, 1991; Meng & Bader, 2000; Sturt & Crocker, 1998), on evidence of the parser's sensitivity to transparent reanalysis cues (Fodor & Inoue, 1994), and on the parallels between ERP responses to garden paths and ungrammaticality (Hopf et al., 2003; Kaan & Swaab, 2003a; Kaan & Swaab 2003b).

In the current study, we examine a verbal configuration in Hindi that is particularly well suited to investigating the nature of the parser's error signals, as it involves a case where the same local discrepancy can arise from two very different sources, one syntactic in origin, the other semantic in origin. This therefore provides a good test of whether ERP responses to linguistic anomalies reflect the cause or only the content of the errors that elicit them. The results have implications for the architecture of the parser and its ability to track information across time, as well as for the functional interpretation of the various error signals reflected in language-related ERP components.

*1.2 Cause and Content in Previous ERP Research*

Previous ERP studies have routinely classified responses to linguistic errors as reflecting morphological, syntactic, or semantic anomalies, but it is more difficult to assess whether specific ERP responses reflect processing of the cause or the content of errors, because these properties are in general strongly correlated. Unsurprisingly, errors involving syntactic discrepancies are typically associated with syntactic constraints, and errors involving semantic discrepancies are typically associated with semantic constraints. In order to address this issue, it is necessary to find cases that dissociate the cause and content of an error, such as a semantic source for a morphological prediction. However such cases have proven to be elusive.

For example, subject-verb agreement errors such as **the man mow the lawn* reliably elicit a P600 response (Gunter & Friederici, 1999; Hagoort et al., 1993; Lau et al., 2006; Osterhout & Nicol, 1999), often in combination with an earlier LAN component (Coulson et al., 1998; Friederici et al., 1993; Gunter, Stowe, & Mulder, 1997; Hagoort & Brown, 2000; Kaan, 2002; Kutas & Hillyard, 1983; Münte, Matzke, & Johannes, 1997; Osterhout & Mobley, 1995). Interpretations of this effect generally associate the LAN/P600 components with the morphological error, but it remains unclear whether the ERP response reflects processing of the cause of the error or only its content. In the context of subject-verb agreement the content of the error is the feature mismatch between the observed bare verb form *mow* and the third-person singular forms required of verbs in that position, e.g., *mows, mowed*. Of course, the requirement for a third person singular verb form reflects a linguistic constraint on subject-verb relations, and this constraint is the cause of the error. Importantly, since both the content (the feature mismatch) and the cause (subject-verb licensing relations) are morphosyntactic in nature, the observed ERP responses are not informative about which aspects of error processing are reflected in the ERP response.

In ERP research on garden-path sentences it is similarly difficult to distinguish the contributions of processing the cause vs. the content of errors. Garden-path sentences are sentences that, when processed incrementally, lead the parser to commit to an incorrect parse from which it must subsequently recover (Bever, 1970; Frazier & Fodor, 1978; van Gompel & Pickering, 2007). Garden path sentences have been well-studied in the ERP literature, and they are reliably associated with the P600 component (e.g. Hopf et al., 2003; Kaan & Swaab, 2003a; Osterhout, Holcomb & Swinney, 1994). In these cases contributions to the ERPs of the cause and content of the error are again hard to distinguish. For example, Osterhout and colleagues (Osterhout et al., 1994) compared ERP responses to sentences like those in (1).

(1a) The judge believed the patient was lying.
(1b) The judge charged the patient was lying.

The authors hypothesized that readers made a commitment to a particular syntactic analysis of the postverbal noun phrase, i.e., *the patient*, based upon the most common syntactic subcategorization the verb. For the verb *believe* readers anticipate a clausal complement, whereas the verb *charge* biases readers to expect a nominal complement. Consequently, upon reaching the disambiguating verb *was*, no reanalysis is required in (1a), but the parser has to reanalyze its parse in (1b), leading to a P600 response. In the case of this garden path effect the content of the error is the fact that the current parse presents no possible integration site for the incoming word (the verb *was*). The cause of the error is the mismatch between the preferred subcategorization of the main clause verb *charge* and the incoming verb's need for a subject. Hence, the cause of the error (the verb's subject requirement) and the content (the inability to find a syntactic integration site for the incoming verb) are both syntactic in nature, and so again the ERP response does not help to distinguish the contribution of cause and content to processing of these errors.

Thus, existing findings that associate specific ERP components with the diagnosis of errors leave open the question of whether the parser is sensitive to the cause or just the content of the errors that it detects. This is because it is difficult to determine, based on the response to a single error, which aspects of error processing the ERP response reflects.

A more promising approach in this direction is based on comparing the responses to pairs of closely related errors that are associated with different types of cues. This approach is pursued by Casado, Martín-Loeches, Muñoz, and Fernández-Frías (2005). These authors asked whether different cues to word order in Spanish would be reflected in different ERP components in the case of a word order violation. Casado and colleagues investigated cues that signal the less-common OVS word order (as opposed to the canonical SVO order in Spanish). A non-canonical word order can be signaled either by semantic or by syntactic cues. The semantic cue for OVS sentences consisted of an inanimate initial noun followed by a verb that requires an animate subject. For example, in the sentence *the opera sang the tenor*, a Spanish speaker can infer that he is processing an OVS sentence based upon the mismatch between the initial noun phrase and the semantic requirement that the verb imposes on its subject. The syntactic cue, in contrast, involved the case marking that is required of all animate object noun phrases in Spanish. In the Spanish counterpart of an English sentence like *the poet challenged the novelist,* the object noun phrase must be marked with a preposition, as in *el poeta desafió al novelista*. Hence, if the second determiner bears the correct object case this confirms an SVO analysis, but if it does not bear correct object case, reanalysis to an OVS structure is required. Casado and colleagues found that both types of cues for the non-canonical word order elicited a P600 response, and found no qualitative differences between the two conditions. However, since the content of the two errors tested in that study was fundamentally different, contrasting incorrect verb-argument semantics with incorrect morphological marking, it is unclear whether the findings can distinguish ERP error signals of cause versus content of errors. In order to answer this question, we look to a class of tense errors in Hindi where semantic and morphological information can be used to generate identical expectations about verbal morphology.

### *1.3 Processing of Tense Morphology*

Two different types of anomaly have been classified as tense errors in previous ERP research. The first type of anomaly is true tense errors, typically involving a mismatch between a temporal adverbial and the tense form of a verb. For example, Newman and colleagues (Newman, Ullman, Pancheva, Waligura, & Neville, 2007) investigated responses to missing tense morphology on regular and irregular verbs in sentences such as **Yesterday I slip on ice*. They found that violations of this kind elicited a pronounced LAN effect for regular verbs, followed by P600 effects for both regular and irregular verbs. A similar study by Zhang and Zhang (2008) looked at erroneous aspect markers in Mandarin Chinese, examining the response to a perfective marker when it was preceded by a progressive adverbial. Zhang and Zhang found that aspect errors elicited a slightly left-lateralized, posterior negativity with a latency of 200-400 ms after verb onset, in addition to a significant P600 response. Studies by De Vincenzi, Fonteneau, and Hagiwara (De Vincenzi, Rizzi, Portolan, et al., 2006; Fonteneau, Frauenfelder, &

Rizzi, 1998; Hagiwara, Nakajima, Nakagome et al., 2000) found similar results for Italian, French and Japanese respectively. These studies found that tense errors elicited an early negativity with a central or right-lateralized scalp distribution and a latency of 300-500 ms and a subsequent P600. Whereas the study by Newman and colleagues presented errors that were characterized by the lack of inflectional material in English, the studies on Mandarin, Italian, Japanese, and French presented errors that involved explicit morphological marking of an erroneous tense form, such as past tense verb morphology following a future tense adverbial.

A second class of morphosyntactic error that has been classified as a tense error involves the morphosyntax of auxiliary-verb sequences. Allen and colleagues examined sentences such as **He will stood,* which erroneously include tense morphology on the verb *stand*, in violation of the morphosyntactic requirements of English verb clusters (Allen, Badecker, & Osterhout, 2003). That study found that the erroneous past tense marking elicited a strong posterior P600 component, and no significant negativity. In a study involving a similar type of morphosyntactic mismatch between an auxiliary and a verb, Osterhout and Nicol found similar results in response to sequences like **He can flying* (Osterhout & Nicol, 1999).

It is possible that these two types of tense errors probe different representations and processes. In particular, the studies in English that examined ill-formed auxiliary-verb sequences may not involve tense processing in the same way that true tense errors with mismatched adverbials do. For example, in the study by Allen and colleagues (Allen et al., 2003) the error may simply be a violation of the syntactic subcategorization of the auxiliary *will*. In the current study we focus on tense errors that are specifically due to anomalous tense morphology, rather than on violations of local morphological requirements of the type studied by Allen and colleagues and Osterhout. In Hindi, tense information can be cued by both semantic and syntactic contexts. By examining whether the context of the anomalous tense morphology is reflected in the ERP response to the error, we can better determine whether or not error processing reflects the parser's diagnosis of both the cause and content of errors.

### *1.4 The Current Study*

Hindi provides an opportunity to explore the effects of the cause of errors by examining the licensing of verbal tense and aspect. There are two different ways to generate expectations about verbal morphology in Hindi. The first type of cue is semantic. When a sentence contains a past tense adverbial, Hindi requires a past tense verb (a dependency that is by no means unique to Hindi). The second of type of cue is morphosyntactic in nature. Hindi, like many other ergative languages, including Kurdish, Samoan, and Georgian, (Payne 1997), has an aspect-based split-ergative case system. The typical pattern is that these languages employ a nominative-accusative case marking system in imperfect or non-past tenses, while other tense/aspect combinations employ an ergative-absolutive system (see DeLancey, 1981). Hindi displays ergative-absolutive case marking in clauses with perfective aspect, and nominative-accusative case marking elsewhere.

In a nominative-accusative system, the subject of a transitive verb patterns with the sole argument of an intransitive predicate in case and agreement, to the exclusion of the object of a transitive verb. In contrast, in ergative-absolutive systems, the sole argument of an intransitive verb patterns with the object of a transitive verb in case and agreement, to the exclusion of the subject of a transitive verb (see Dixon 1994). For example, In English—a nominative-accusative language—verb agreement and nominative case is controlled either by the subject of a transitive verb (He *sees the girls)* or by the sole argument of an intransitive verb (He *walks*). However in Hindi ergative-absolutive clauses, it is the object and intransitive subject that pattern together for purposes of case-marking and agreement. An example is given in (2). Note that the absolutive case in Hindi is not explicitly marked, and is homophonous with the nominative case. Thus, non-case marked intransitive subjects are not informative with respect to tense or aspect, a feature that is relevant to our experimental design. Only the subject of a transitive clause bears the ergative case marker *-ne.* Crucially, this case suffix *-ne* can never co-occur with present or future tense verbs unless they are also marked for perfectivity*,* and therefore this overt case marker is a reliable cue to verbal aspect. As we shall see below, Hindi speakers overwhelmingly associate ergative case-marked subjects with past tense verbs.

| | | | |
|---|---|---|---|
| (2a) | *Larke-ne* | *roTii* | *khayii* |
| | boy.PL.MASC-ERG | bread.SG.FEM-ABS | ate.SG.FEM |
| | "The boy ate the bread" | | |
| (2b) | *Larkii* | *chalii* | |
| | girl.SG.FEM-ABS | walked.SG.FEM | |
| | "The girl walked" | | |

The ergative suffix may thus be seen as imposing a morphosyntactic constraint on the morphological shape of the verb, as does a temporal adverbial. Crucially, however, the morphological expectation derives in one instance from morphological features (i.e. the ergative case marker *-ne*), and in the other instance from the semantics of a past-tense adverbial.

The cause of an error in tense/aspect morphology can thus clearly be manipulated in Hindi. The current study aims to address two related questions on the processing of cause and content in error diagnosis. First, is the parser able to identify the cause of an anomaly in error diagnosis? Second, to what degree do familiar ERP components reflect the processing of the content of an error versus its cause? Answers to these questions have important implications for both theories of sentence processing and for the functional interpretation of ERP components.

## 2. Methods

### *2.1 Participants*

Twenty-three members of the University of Maryland community participated in this study. Data from four participants were excluded due to high levels of artifacts in the EEG recordings. The remaining 19 participants (6 females) had a mean age of 23.9, and all were healthy, native speakers of Hindi with no history of neurological disorder, and all were strongly right-handed based on the Edinburgh handedness inventory (Oldfield, 1971). All participants were pre-screened prior to the study in order to ensure fluency in reading *Devanagari* characters. All participants gave informed consent and were paid $15/hour for their participation, which lasted around 2½ hours, including set-up time.

### *2.2 Materials*

The main ERP experiment had four conditions organized in a 2 × 2 factorial design that manipulated the type of cue for the tense marker on a clause-final verb (semantic vs. syntactic cue) and the correctness of the tense marker (grammatical vs. ungrammatical). The aim of the study was to determine whether ERP responses to the ungrammatical tense marking differed as a function of the type of cue that predicted the tense marking. Experimental materials were carefully controlled in order to isolate the contribution of the different types of cues to the ERP responses. Example sentences from each condition, with the cue element and critical verb marked in bold, are shown in (3), and the *Devanagari* script form for sample verbs in each condition is shown in Table 1.

(3) a. *Haalanki* ***us bunkar-ne*** *ek baRaa sveTar jaldi* ***bunaa****, lekin grahaak-ne sabhii-ki*
although **that weaver-ERG** one big sweater quickly **wove**, but customer-**ERG** all-of
*kimaat ek-hi dii.*
prices same gave (Syntactic cue-grammatical)
"Although **that weaver wove** one big sweater quickly, the customer paid the same for all of them."

b. * *Haalanki* ***us bunkar-ne*** *ek baRaa sveTar jaldi* ***bunegaa****, lekin grahaak-ne sabhii-ki*
although **that weaver-ERG** one big sweater quickly **will weave**, but customer-**ERG** all-of
*kimaat ek-hi dii.*
prices same gave (Syntactic cue-ungrammatical)
"Although **that weaver will weave** one big sweater quickly, the customer paid the same for all of them."

c. *Haalanki* ***pichle shaam*** *vo rahgiir pathaar ke-upar* ***giraa****,*
although **last night** that traveler stone upon **fell**,
*lekin use choT nahiin aayii*
but to-him injures not happen (Semantic cue-grammatical)
"Although **last night** that traveler **fell** upon a stone, he was not injured."

*d. * Haalanki* ***pichle shaam*** *vo rahgiir pathaar ke-upar* ***giregaa****,*
although **last night** that traveler stone upon **will fall**,
*lekin use choT nahiin aayii*
but to-him injures not happen (Semantic cue-ungrammatical)
"Although **last night** that traveler **will fall** upon a stone, he was not injured."

| Devanagari form | romanized form | morphemes | translation |
|---|---|---|---|
| बूना | *bunaa* | weave-PERF | 'he wove' |
| बुनेगा | *bunegaa* | weave-FUT | 'he will weave' |
| गिरा | *giraa* | fall-PERF | 'he fell' |
| गिरेगा | *giregaa* | fall-FUT | 'he will fall |

**Table 1**: Examples of 3rd person masculine singular verb forms used in the ERP study, shown as presented to participants in Devanagari orthography, along with romanization and translation.

Hindi is a verb-final language and tense markers appear as verb suffixes. Therefore, in order to minimize the risk of wrap-up effects associated with words in sentence-final position (Just & Carpenter, 1980), each violation was embedded in a two-clause structure, such that the critical verb appeared at the end of a sentence-initial adverbial clause rather than in sentence-final position. The adverbial clauses were introduced in equal numbers by each of three subordinators:

*haalanki* (meaning 'although'), *chunki* (meaning 'since', 'due to the fact that'), and *jab* (meaning 'when', 'at the time that'). Each of these subordinators created a clear expectation for a subsequent main clause.

The critical verbs were marked with either past tense morphology (grammatical) or future tense morphology (ungrammatical). Hindi past tense forms are comprised of a verb root and a single agreement suffix, whereas future tense forms are comprised of a verb root with an agreement suffix, an overt tense marker *g*, and a second agreement suffix. Although the verb forms differed between the grammatical and ungrammatical conditions, this difference was identical in the syntactic and semantic cue conditions. Sample verb forms from each condition are shown in Table 1.

The syntactic and semantic cue conditions were configured such that a cue for past tense always appeared in the second word position in the sentence, and the critical verb always appeared in the sixth word position, as shown in (3). The sentences were designed such that in the semantic cue conditions the only tense cue was a past tense adverbial, and in the syntactic conditions the only tense cue was an ergative case marker. Nevertheless, the semantic richness of each target clause was balanced by beginning every sentence with an adverbial. The semantic cue conditions started with a temporal adverb consisting of two words, such as *pichle shaam* ('last night'), *gujre hafte* ('past week'). The syntactic cue condition conditions started with a one-word manner adverb (e.g. *jaldi* 'quickly') that provided no cue to the tense of the verb. Since the syntactic cue for past tense came from ergative case marking on the subject noun, and ergative case is restricted to the subjects of transitive verbs, all target clauses in the syntactic cue condition contained a transitive verb with two arguments. The ergative case-marker *–ne* appeared as a suffix on the subject noun, in second position of the sentence. In contrast, intransitive verbs with a single argument were always used in the semantic cue condition, in order to eliminate the possibility of any tense cue arising from the case marking. Despite this difference, the discourse complexity of the syntactic and semantic cue conditions was balanced by presenting the same number of nouns before the critical verb. In the syntactic cue conditions the nouns were the two arguments of the transitive verb. In the semantic cue conditions the nouns were the subject and a noun in a postpositional phrase.

By placing the critical verbs in the sixth word position in all conditions it was possible to reduce the risk of ERP differences arising from the ordinal position of the verbs.

The experimental materials consisted of 120 sets of the 4 experimental conditions, which were distributed across four lists in a Latin Square design, such that participants saw 30 examples of each experimental condition. The 120 target sentences were combined with 330 filler items of similar length and complexity. The filler items included examples of correct and incorrect verb agreement, and examples of noun phrase internal agreement errors, such that the anomalies did not consistently appear in the same word position. Across the study as a whole, the ratio of correct sentences to incorrect sentences in each list was 1:1 (225 correct, 225 incorrect).

### *2.3 Sentence Fragment Completion Study*

In order to verify the effectiveness of our syntactic and semantic cues, and to ensure that both cues were equally unlikely to create an expectation for future tense verb forms, we conducted a paper-and-pencil sentence completion task using materials adapted from our target items and fillers. 9 native speakers of Hindi, none of whom participated in the ERP experiment, were given sentence fragments that stopped before the first verb, and were asked to complete the sentence in any way that seemed natural. The fragment completion study included 3 conditions. As in the ERP experiment there was a syntactic condition that provided a tense cue in the form of ergative case marking, and a semantic condition that provided a tense cue in the form of a past tense adverbial. A third condition provided no tense cues. The items in the no-cue condition were created by modifying sentences from the other two conditions to remove the tense cue. The syntactic cue conditions were modified by removing one noun phrase, and leaving just a single noun phrase with no ergative case marker. The semantic cue conditions were modifier by replacing the temporal adverbial with a locative adverbial. 18 sets of 3 items were distributed across 3 lists in a Latin Square design, such that participants saw six items per condition. Target items were combined with 36 filler items to yield a 2:1 filler-to-target ratio.

The results of the fragment completion study are shown in Table 2. There was a bias for past tense verbs in the fragment completions across all conditions, but this bias was absolute in the conditions that contained syntactic or semantic tense cues. 21% of completions in the no-cue condition contained present or future tense verbs, but no completions contained present or future tense verbs in either tense cue condition. Thus, we can conclude that the two types of tense cues create equally strong expectations for past tense (100% of completions), and are equally incompatible with the ungrammatical future tense forms used in the ERP study (0% completions). The only difference between the syntactic and semantic cue conditions was that the ergative case marker in the syntactic cue condition elicited 100% past perfect verb forms, whereas the semantic cue condition elicited a mix of past perfect and imperfect verb forms, consistent with the requirements of Hindi grammar.

| | Future | Present | Past Perfect | Past Imperfect |
|---|---|---|---|---|
| No cue | 3/54 (6%) | 8/54 (15%) | 23/54 (43%) | 20/54 (37%) |
| Semantic Cue | 0/54 (0%) | 0/54 (0%) | 39/54 (72%) | 15/54 (28%) |
| Syntactic cue | 0/54 (0%) | 0/54 (0%) | 54/54 (100%) | 0/54 (0%) |

**Table 2:** Results of the sentence fragment completion task.

*2.4 Procedure*

Participants were comfortably seated in a dimly lit testing room around 100 cm in front of a computer monitor. Sentences were presented one word at a time in black letters on a white background in 30 pt *Devanagari* font. Each sentence was preceded by a fixation cross. Participants pressed a button to initiate presentation of the sentence, which began 1000 ms later. Each word appeared on the screen for 400 ms, followed by 200 ms of blank screen. The 600ms/word presentation rate is slightly slower than the presentation rate most commonly used in ERP studies in European languages, but pre-testing showed that this was the most comfortable rate for the Hindi speakers in the study. The last word of each sentence was marked with a period, and 1000 ms later a question mark prompt appeared on the screen. Participants were instructed to read the sentences carefully without blinking and to indicate with a button press whether the sentence was an acceptable Hindi sentence. Feedback was provided for incorrect responses. Each experimental session was preceded by a 12-trial practice session that included both grammatical and ungrammatical sentences. Participants received feedback and were able to ask clarification questions about the task during the practice session. The experimental session was divided into six blocks of 75 sentences each. Breaks were permitted after each block as necessary.

*2.5 EEG Recording*

EEG was recorded from 30 Ag/AgCl electrodes, mounted in an electrode cap (Electrocap International): midline: Fz, FCz, Cz, CPz, Pz, Oz; lateral: FP1/2, F3/4, F7/8, FC3/4, FT7/8, C3/4, T7/8, CP3/4, TP7/8, P4/5, P7/8, O1/2. Recordings were referenced online to the linked average of the left and right mastoids. An additional electrode was placed on the left outer canthus, and above and below the left eye to monitor eye movements. EEG and EOG recordings were amplified and sampled at 1 kHz using an analog bandpass filter of 0.1-70 Hz. Impedances were kept below 5 kΩ.

*2.6 EEG Analysis*

All comparisons were made based upon single word epochs, consisting of the 100 ms preceding and the 1000 ms following the critical words. Epochs with ocular and other large artifacts were rejected from analysis based on visual screening. Among the 23 participants who were tested, 4 were excluded due to recording difficulties that led to rejection rates exceeding 50%. The total rejection rate among the remaining 19 participants was 18% (range 16%-22% across conditions). The waveforms of the individual trials were normalized using a 100 ms pre-stimulus baseline. Averaged waveforms were filtered offline using a 10 Hz low-pass filter for presentation purposes; however, all statistics were performed on unfiltered data. The latency intervals that were analyzed statistically were chosen based upon visual inspection as well as previous conventions in the ERP sentence processing literature: 0-200 ms, 200-400 ms, 300-500 ms (LAN/N400), 400-600 ms, 600-800 ms (P600), 800-1000 ms.

In the ANOVA, topographically arranged groups of electrodes were defined as follows: left anterior (FT7, F3, FC3), midline anterior (FZ, FCZ, CZ), right anterior (F4, FC4, FT8), left posterior (TP7, CP3, P3), midline posterior (CPZ, PZ, OZ), and right posterior (CP4, P4, TP8). ANOVAs were performed hierarchically, using the within-subjects factors condition, anteriority (anterior/posterior), and laterality (left/midline/right). All $p$-values reported below reflect the application of the Greenhouse-Geisser correction where appropriate, to control for violations of the sphericity assumption (Greenhouse & Geisser, 1959), together with the original degrees of freedom. Due to the large number of possible interactions in this design, we report as significant only those interactions for which follow-up analyses yielded significant contrasts within the levels of the interacting factors.

## 3. Results

*3.1 Acceptability Question Accuracy*

Overall, the accuracy on the acceptability judgment task was 92%. The accuracy scores for individual conditions were as follows: semantic cue grammatical, 91%; syntactic cue grammatical, 94%; semantic cue ungrammatical, 91%, syntactic cue ungrammatical, 92%. A repeated-measures ANOVA revealed no significant differences between conditions in accuracy scores.

*3.2 Event-related Potentials*

Figure 1 shows topographic scalp maps that reflect the mean difference between the grammatical and ungrammatical tense conditions for 200 ms intervals following presentation of the critical verb in both the syntactic and semantic cue conditions. The grand average waveforms at the critical verb for the semantic and syntactic conditions can be seen in Figures 2 and 3, respectively. Visual inspection suggests an early negativity in both conditions, followed by later posterior positivities at around 600ms. However, the timing, amplitude, and scalp topography of these effects differed across conditions. In the semantic cue conditions the negativity obtained during the 200-400 interval and showed a posterior scalp distribution. In contrast, in the syntactic cue conditions, the negativity showed a later and more anterior distribution, with a peak at around 400 ms. The late positivity in both the syntactic and semantic cue conditions showed the characteristic timing and posterior scalp distribution of a P600. However, visual inspection suggests that the positivity was longer lasting and had a greater amplitude in the syntactic cue conditions. These findings were tested statistically using a repeated measures ANOVA at a number of successive time intervals.

The results of the overall ANOVA are summarized in Table 3. Consistent with the results of visual inspection, reliable main effects of grammaticality were found in the 200-400 ms interval, the 300-500 ms interval, and the 600-800 ms interval. There were interactions of the grammaticality factor with the topographic factors anteriority and laterality in the 600-800 ms interval, continuing to the 800-1000 ms interval in the case of the grammaticality × anteriority interaction, reflecting the posterior focus of the P600. Crucially, we also found interactions involving both grammaticality and cue-type in addition to the topographic factors in the 600-800 ms and 800-1000 ms intervals. These interactions indicate that the grammaticality manipulation had a different effect in the two levels of the cue-type factor at certain scalp locations. Further analyses were conducted in order to better understand these differential effects.

| Overall ANOVA | 0-200ms | 200-400ms | 300-500ms | 400-600ms | 600-800ms | 800-1000ms |
|---|---|---|---|---|---|---|
| *gram* (1,18) | - | 4.655* | 4.426* | - | 5.006* | - |
| *cue* (1,18) | - | - | - | - | - | - |
| *gram x cue* (1,18) | - | - | - | - | - | - |
| *gram x ant* (1,18) | - | - | - | - | 19.887*** | 5.025* |
| *gram x lat* (2,36) | - | - | - | - | 4.534* | - |
| *gram x lat x ant* (2,36) | - | - | - | - | - | - |
| *cue x ant* (1,18) | - | - | - | - | - | 3.460† |
| *cue x lat* (2,36) | 4.190* | 2.924† | 3.754* | 3.069† | - | - |
| *cue x ant x lat* (2,36) | - | - | - | - | 5.407** | - |
| *gram x cue x ant* (1,18) | - | - | - | - | - | - |
| *gram x cue x lat* (2,36) | - | - | - | - | 4.954* | 10.410** |
| *gram x cue x ant x lat* (2,36) | - | - | - | - | - | 3.771* |

**Table 3:** ANOVA *F*-values at the critical verb for all time windows, with the four factors *grammaticality, cue, anteriority, laterality*.
Symbols indicate *p*-values: † $.05 < p < .1$; * $.01 < p < .05$; ** $.001 < p < .01$; *** $p < .001$

Separate ANOVAs were conducted within each level of the cue-type factor, with the factors grammaticality, anteriority and laterality as within-subjects factors. These analyses were followed with additional analyses of the effects of grammaticality at individual topographic regions of interest. The results for the syntactic cue conditions are shown in Table 4. These analyses revealed that the negativity reached significance only in the 300-500 ms interval in the right anterior region. In contrast, the late positivity was very reliable and broadly distributed across posterior regions, with marginal effects in the left and mid anterior regions.

| Syntactic Cue | 0-200ms | 200-400ms | 300-500ms | 400-600ms | 600-800ms | 800-1000ms |
|---|---|---|---|---|---|---|
| *gram* (1,18) | - | - | - | - | 9.384** | - |
| *gram x ant* (1,18) | - | - | - | - | 20.835*** | - |
| *gram x lat* (2,36) | - | - | - | - | 2.664† | - |
| *gram x lat x ant* (2,36) | - | - | - | - | 2.650† | - |
| Anterior | | | | | | |
| *left gram* (1,18) | - | - | - | - | 3.679† | - |
| *mid gram* (1,18) | - | - | - | - | 3.432† | - |
| *right gram* (1,18) | - | - | 4.704* | - | - | - |
| Posterior | | | | | | |
| *left gram* (1,18) | - | - | - | - | 13.631** | - |
| *mid gram* (1,18) | - | - | - | - | 16.458** | - |
| *right gram* (1,18) | - | - | - | - | 12.853** | - |

**Table 4**: ANOVA *F*-values at the critical verb for all time windows within the syntactic cue conditions, with the three factors *grammaticality, anteriority, laterality*.
Symbols indicate *p*-values: † $.05 < p < .1$; * $.01 < p < .05$; ** $.001 < p < .01$; *** $p < .001$

Table 5 shows the results of statistical analyses of the effects of the grammaticality manipulation in the semantic cue conditions. In contrast to the syntactic cue conditions, the negativity elicited by a semantically cued error was significant in the 200-400 ms interval, and showed a posterior rather than an anterior distribution. Although the semantic cue conditions showed a posterior positivity in the 600-800 ms interval, as in the syntactic cue conditions, the effect was only marginally significant and was observed only at the posterior midline region. This suggests a smaller amplitude and much narrower topographic distribution than the positivity observed in the syntactic cue conditions.

| Semantic Cue | 0-200ms | 200-400ms | 300-500ms | 400-600ms | 600-800ms | 800-1000ms |
|---|---|---|---|---|---|---|
| *gram* (1,18) | - | - | - | - | - | - |
| *gram x ant* (1,18) | - | - | - | - | 4.223† | - |
| *gram x lat* (2,36) | - | - | - | - | 2.770† | - |
| *gram x lat x ant* (2,36) | - | - | - | - | - | - |
| Anterior | | | | | | |
| *left gram* (1,18) | - | - | - | - | - | - |
| *mid gram* (1,18) | - | - | - | - | - | - |
| *right gram* (1,18) | - | - | - | - | - | - |
| Posterior | | | | | | |
| *left gram* (1,18) | - | 3.960† | - | - | - | - |
| *mid gram* (1,18) | - | 4.504* | - | - | 3.336† | - |
| *right gram* (1,18) | - | 5.146* | - | - | - | - |

**Table 5**: ANOVA *F*-values at the critical verb for all time windows within the semantic cue condition, with the three factors *grammaticality, anteriority, laterality*.
Symbols indicate *p*-values: † $.05 < p < .1$; * $.01 < p < .05$; ** $.001 < p < .01$; *** $p < .001$

Finally, in order to directly compare the amplitude of the P600 in the syntactic and semantic cue conditions we performed an additional analysis that followed a procedure used by Hagoort (2003a). ERP waveforms were re-baselined relative to a 350-450 ms interval, in order to minimize potential confounds due to differences that existed prior to the P600 interval. Table 6 shows the mean voltage differences (and standard errors) between the ungrammatical and grammatical conditions, for both the syntactic and semantic predictor conditions at each posterior region of interest in the 600-800ms interval. Pairwise t-tests on the difference scores revealed that the P600 was larger in the syntactic cue conditions than in the semantic predictor condition at all posterior regions (left: $t(18) = 2.98$, $p < 0.01$, midline: $t(18) = 2.44$, $p < 0.05$, and right: $t(18) = 2.27$, $p < 0.05$).

| μV | Syntactic | Semantic |
|---|---|---|
| Left | 3.73 (±0.59) | 1.33 (±0.59) |
| Midline | 4.41 (±0.71) | 2.05 (±0.55) |
| Right | 3.51 (±0.57) | 1.92 (±0.44) |

**Table 6:** Mean and standard error of the re-baselined P600 effects (obtained by subtracting grammatical from ungrammatical conditions), for all posterior regions between 600-800 ms.

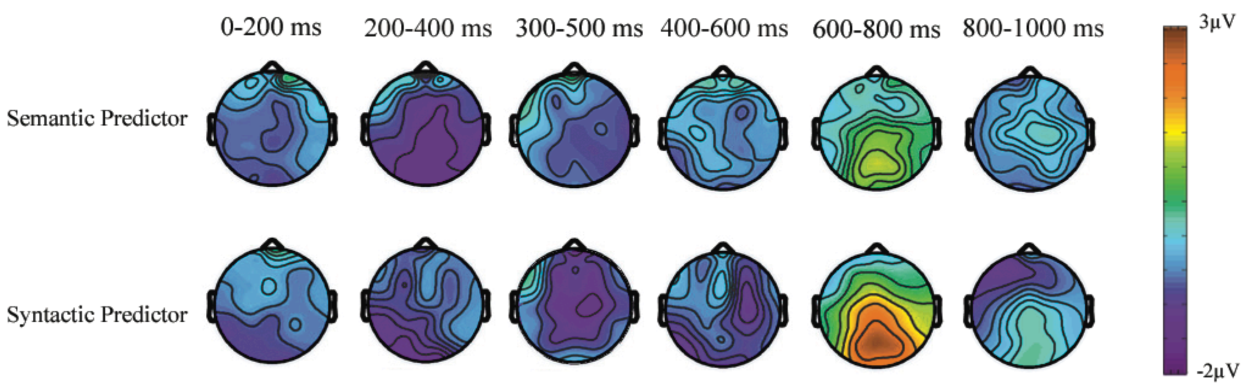


**Figure 1:** Topographic scalp voltage maps, showing the grand average difference between the ungrammatical conditions and the control conditions at successive intervals following the critical verb.

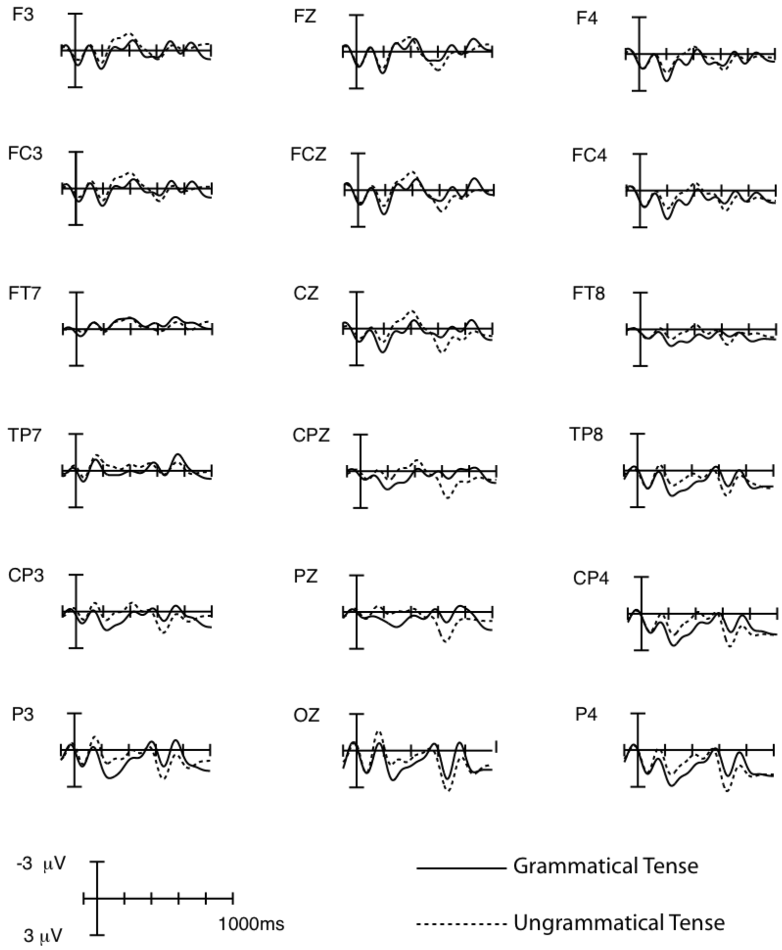


**Figure 2:** Grand average ERP responses elicited by the critical verb in sentences with a semantic cue to past tense (temporal adverb).

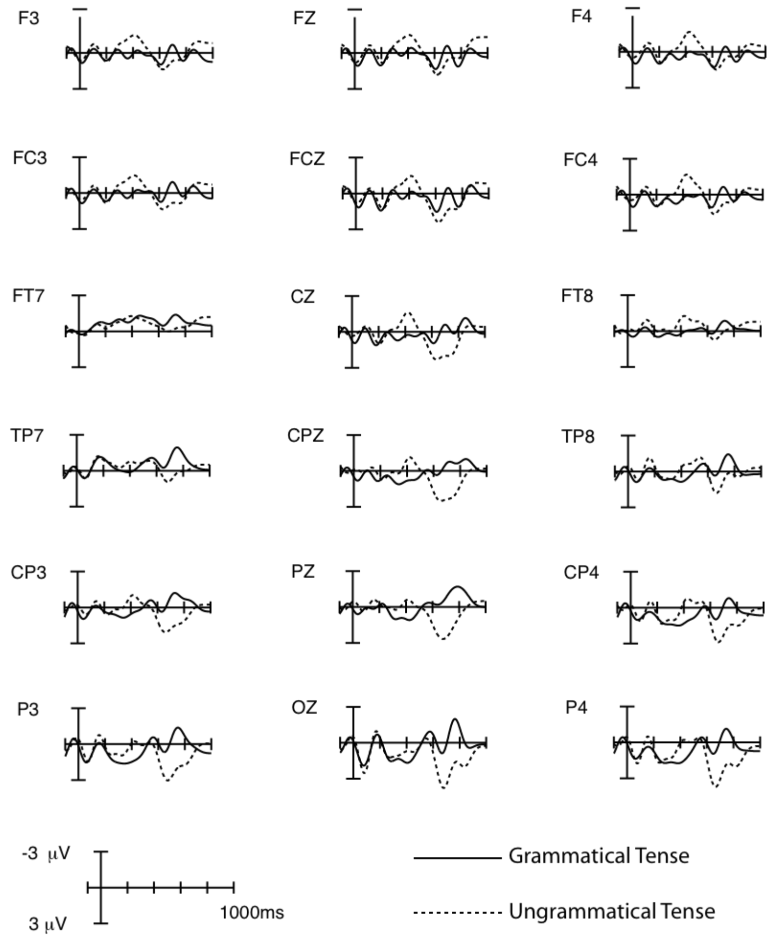


**Figure 3:** Grand average ERP responses elicited by the critical verb in sentences with a syntactic cue to past tense (ergative-marked subject).

## 4. Discussion

### *4.1 Summary of Results*

The current study took advantage of the morphosyntactic properties of Hindi to test whether comprehenders respond differently to errors that are identical in content, but that differ with regard to the source of the expectation that the error is in conflict with. As in English and other languages, past tense adverbials in Hindi (e.g., 'last week') create an expectation for a verb with past tense morphology. The source of this expectation is the semantics of the adverbial. A more distinctive property of Hindi, which it shares with certain other split ergative languages, is that case marking on nouns can also be a reliable predictor of tense/aspect morphology. Hence, tense can be cued by either semantic or syntactic information. The ERP study showed that responses to an identical violation of a tense expectation differ as a function of the source of the tense expectation. Here we discuss the differences in more detail, with particular attention to the question of whether the observed differences are plausibly associated with the syntactic vs. semantic nature of the tense cue. We discuss the implications of these findings for models of parsing.

We focused on two distinct cues to tense/aspect morphology in Hindi: ergative-case marking (the syntactic cue) and temporal adverbials (the semantic cue). An offline sentence fragment completion task confirmed that neither cue creates an expectation for a future tense verb form, and both cues elicited 100% past tense completions. The only difference in the sentence fragment completion results was that the completions in the syntactic condition contained exclusively past perfective verb forms, whereas the completions in the semantic condition included some past imperfective forms. This difference is consistent with Hindi grammar, which strictly links ergative case marking with perfective aspect. However, the fact that speakers in the completion study only ever used the past perfective form, rather than other possible perfective forms, indicates that ergative case marking on a subject noun is treated as a reliable past tense cue by Hindi speakers. Additionally, we can certainly conclude that the simple future tense forms used in the ungrammatical conditions of the ERP study were equally unexpected, irrespective of cue type.

We measured evoked potentials to grammatical and ungrammatical verb forms following both syntactic and semantic tense cues. In the conditions where semantic cues predicted verbal morphology, erroneous future tense verbs elicited an early negativity in the 200-400 ms interval, with a broad posterior distribution. The relation of this negativity to other types of well-known ERP responses, such as the N400 or LAN, is discussed further below. Additionally, a small but reliable P600 response was observed in the midline posterior region during the 600-800 ms interval. In contrast, in the conditions where morphosyntactic cues predicted verbal morphology, anomalous future tense verb forms caused a right-lateralized anterior negativity (RAN) during the 300-500 ms interval and a clear P600 response with a broad posterior scalp distribution. In addition to the ANOVA analyses, a comparison of the amplitude of the P600 response was conducted by measuring the amplitude of the error-related posterior positivity in each semantic cue condition, relative to a 350-450 ms baseline (following Hagoort 2003a). This analysis confirmed that the P600 response was significantly larger and more broadly distributed in the syntactic cue conditions than in the semantic cue conditions. These results demonstrate both qualitative and quantitative differences in the response to the two cue types, despite the fact that the content of the anomalous verbal morphology was identical in both conditions.

These results suggest that the parser is more than a 'black-box' system that is only sensitive to local feature mismatches between correct and incorrect forms. Instead, the results suggest a language comprehension architecture that is able to rapidly recognize (and potentially act upon) different potential error causes. It could achieve this by either (i) carrying forward information about the source of its expectations, or (ii) recognizing errors at separate levels of linguistic analysis (e.g., syntax, semantics, discourse), such that the cause of an error can be inferred based upon the level of analysis that the content is detected.

### *4.2 Relation to Previous ERP Findings*

The current findings extend and corroborate previous ERP findings on the processing of tense anomalies and errors in verbal morphology. The observed ERP response to a tense mismatch in the semantic cue conditions is similar to previous findings about tense and aspect errors that were cued by temporal adverbials (De Vincenzi et al., 2006; Fonteneau et al., 1998; Hagiwara et al., 2000; Newman et al., 2007; Zhang & Zhang, 2008). In each of these previous studies, a negativity was observed with a latency of 200-400 milliseconds, though with differing scalp distributions across studies. In some of these studies the negativity was followed by a relatively modest P600 effect (De Vincenzi et al., 2006; Newman et al., 2007; Zhang & Zhang, 2008). Additionally, the negativity elicited by tense violations differed in both scalp distribution and time course from the N400 responses that were observed in the same participants in more canonical manipulations of semantic anomaly (Hagiwara et al., 2000; Newman et al., 2007; Zhang & Zhang, 2008). Newman and colleagues classified the left-lateralized negativity they observed as a LAN, due to its more frontal distribution. On the other hand, the negativity observed by Zhang and Zhang showed a more posterior, left-lateralized distribution. The negativity observed by De Vincenzi and colleagues showed a right-lateralized distribution that clearly contrasted with the distribution of the LAN elicited by an agreement violation condition in the same study.

In our results the early negativity had a central and posterior distribution, and thus was topographically more similar to the canonical N400 than the LAN. Nonetheless, in light of the consistent finding that standard N400 responses differ from tense-related negativities in within-subjects comparisons, caution is warranted in linking the effect seen in the current study to standard N400 effects. Since the current study focused on the comparison of different cue types, it was not possible to compare the tense-related negativity to the response to more familiar semantic anomalies based upon the lexical content of open class words. If the negativity observed here is instead more related to the processes that elicit anterior negativities in other studies, then the question arises of what aspects of processing the negativity indexes. The LAN is most commonly associated with morphological or syntactic anomalies (Coulson et al., 1998; Friederici et al., 1993; Hagoort et al., 2003). An alternative view, espoused by a number of authors, is that the anterior negativies index working memory load (Kluender & Kutas, 1993; Vos, Gunter, Kolk, & Mulder, 2001). If this is the case, then the negativity observed here might index (unsuccessful) working memory retrieval processes that attempt to link the future tense semantics of the verb with an appropriate reference point in the discourse model.

In the syntactic cue conditions, we observed a right-lateralized anterior negativity, followed by a robust P600 response. Anterior negativities elicited by morphosyntactic anomalies are often left-lateralized (e.g., Friederici et al., 1993; Lau et al., 2006; Neville et al., 1991), but there are also many studies of morphosyntactic anomalies that have elicited bilateral anterior negativities (e.g., Hagoort et al., 2003; Hahne & Friederici, 1999). A right-lateralized anterior negativity (RAN) is not without precedent, however. Right anterior negativities have commonly been elicited by anomalies in music processing (Koelsch & Friederici, 2003; Koelsch, Gunter, Wittfoch, & Sammler, 2004), and by anomalous prosodic contours (Eckstein & Friederici, 2005). Of particular interest is a recent study by Ueno and Kluender (in press) that demonstrated a RAN in response to a morphological anomaly during the processing of Japanese *wh*-questions. In Japanese, *wh*-elements must be licensed by question particles that appear as verbal suffixes, just as ergative case in Hindi requires perfective morphology on the verb. Ueno and Kluender found that when the first verb form encountered after a *wh*-word did not bear a question particle suffix, a RAN was elicited. The presence of a RAN in our results extends this finding to Hindi, and may reflect similarities between the Japanese and Hindi dependencies. Both *wh*-words and ergative case-marked nouns are elements that must be licensed by specific verbal morphology (question particles or perfective marking, respectively). The ergative case marker *–ne* may generate expectations about verbal morphology in a manner similar to Japanese *wh*-words. If this is the case, then the RAN may index the processing demands involved in resolving a morphological dependency between a clause-final verb and its arguments. Clearly, however, more research is needed to determine which dependencies give rise to this effect, as a number of well-studied cases of morphological dependencies between verbs and their arguments (e.g. subject-verb agreement) have not yet been shown to elicit a RAN.

Both the syntactic and the semantic cue conditions elicited a P600 response, but the P600 was significantly larger in the syntactic cue condition. The P600 has been elicited by a diverse set of linguistic and non-linguistic errors (Hagoort et al., 1993; Kuperberg, 2007; Núñez-Peña & Honrubia-Serrano, 2004; Patel et al., 1998), and it has been linked to processes of error recognition and reanalysis (Friederici et al., 2002; Hagoort, 2003b; Hopf et al., 2003; Kaan & Swaab, 2003a). A number of factors have been shown to influence P600 amplitude, including subcategorization biases (Osterhout et al., 1994), experiment-internal error probabilities (Coulson, et al., 1998; Hahne & Friederici, 1999), the complexity of the processes initiated by the target word (Gouvea et al., in press), and the saliency of the morphological violation (Coulson et al., 1998, Nevins, Dillon, Malhotra, & Phillips, 2007). It is plausible that this last factor may drive the differences that we observed in P600 amplitudes. In the present study there are at least two distinct ways in which a violation in the syntactic cue condition might be termed more 'salient'. One possibility involves the specificity of the expectations that the semantic and syntactic cues generate. Ergative case marking generates a narrow set of expectations about possible verbal morphology, whereas a past tense adverbial is compatible with different past tense completions, as confirmed by the sentence-fragment completion task. Thus, although the probability of the observed future tense form in both the syntactic and semantic cue conditions was zero, comprehenders may have formed stronger commitments to specific verbal morphology in the syntactic cue condition. This in turn could lead to increased saliency in the event of a violation. Alternatively, representational differences between the error in the syntactic and semantic cue conditions may have made the same error more or less salient. In either case, however, the qualitatively different pattern of the other ERP components involved suggests a representational difference between the two conditions. In what follows we discuss possible representational differences that may be responsible for the pattern of results that we observed.

### *4.3 Cause and Content of the Error*

The first possible representational difference between the errors in our syntactic and semantic cue conditions involves the level of representation where the error obtains. We suggested above that the dependency between ergative case marking and perfective morphology is a specific morphosyntactic dependency, possibly analogous to other dependencies such as *wh*-scope marking in Japanese (Ueno & Kluender, in press). This implies that the error in the syntactic cue condition is a failure to build a well-formed morphosyntactic dependency. Detection of this error does not depend on interpretive processes. In contrast, there is no specific morphosyntactic problem in the semantic cue condition. The cause of the error is instead a conflict between the semantics of the future tense verb and the past tense adverbial. Detection of this error may only be possible once a full interpretation of the clause is constructed.

An alternative possibility is that the different ERP responses in the syntactic and semantic cue conditions might reflect differences in the processing of tense and aspect. Strictly speaking, ergative case marking is a cue for perfective aspect, whereas past tense adverbials are cues for past tense. The results of our sentence fragment completion study suggest that for practical purposes speakers treat both cues as effective predictors of past tense, but the grammatical difference must nevertheless be taken seriously. Based on behavioral evidence it has been proposed that tense and aspect are processed in qualitatively different fashions (Dickey, 2000). Tense has been described as a type of anaphoric relation between a specific time point highlighted by a clause and a 'reference point' in the existing discourse model, and this anaphoric character is absent in many characterizations of aspect. However, the tense/aspect difference is unlikely to be the direct cause of the differences observed in the current study, for a number of reasons. First, it is important to distinguish grammatical aspect and lexical aspect (or *Aktionsart*), and the interpretation of grammatical aspect has been argued to always implicate a temporal 'reference frame' (Comrie, 1976; Kazanina & Phillips, 2007; Reichenbach, 1947; Smith, 1991). Second, existing electrophysiological evidence does not appear to distinguish aspect and tense violations: similar ERP responses are elicited by violations of aspect (Zhang & Zhang, 2008) and violations of tense (Fonteneau et al., 1998; Newman et al., 2007). Third, our fragment completion results suggested that Hindi speakers treat ergative case marking as a predictor of both tense and aspect, although this is not a strict requirement of Hindi grammar.

### *4.4 Implications for Models of Sentence Processing*

There has been long-standing interest in psycholinguistics in the question of how the parser is able to recover from incorrect structural analyses. A growing body of evidence implicating anticipatory structure-building processes in sentence understanding has made this question even more pressing, since anticipatory processes increase the risk of error. Accounts of successful recovery from error fall into a small number of classes. One common view is that that the parser engages in reanalysis, i.e., a specific, error-driven repair mechanism that is triggered when anomalous input is presented (Bader, 1998; Ferreira & Henderson, 1991; Fodor & Inoue, 1994; Sturt, Pickering & Crocker, 1999). An alternative is that the parser does not have specific reanalysis mechanisms, but instead simply reprocesses the input using otherwise normal parsing techniques (Grodner, Gibson, Argaman, & Babyonyshev, 2003). These first two approaches share the assumption that successful recovery from error involves the generation of a novel structure that is different from the one that was being pursued prior to the anomaly. A third approach posits that recovery from error does not really involve generation of novel parses, but instead involves the re-ranking of multiple alternative parses that are pursued in parallel, but with different activation levels (Gibson, 1991; Hale, 2003; Jurafsky, 1996; Levy, 2008; Spivey & Tanenhaus, 1998). Notwithstanding the differences between these accounts, they share a number of common properties. They assume that a dominant parse must be inhibited. They assume that alternative parses must be generated, or must receive heightened activation. These alternative parses presumably can only be generated if the parser is somehow able to inhibit the parsing steps that led the previously dominant parse to be dominant in the first place. Finally, the accounts share the assumption that information in the anomalous word plays a key role in the recovery process.

As already discussed above, if the parser has information about the cause of an error, this offers potentially useful information for correct diagnosis and repair of anomalous input. The parser can use information about the cause of an error to relate information about the content of the error to the space of alternative analyses. Indeed, many models of parsing implicitly or explicitly assume that this sort of information linking error content and alternative analyses is available. The model laid out in Fodor and Inoue (2000) is an example of a parsing model that explicitly adopts this assumption. Fodor and Inoue formalize this mechanism in terms of the *adjust* operation of their parser, which acts to repair one or both of a pair of features that have come into grammatical conflict as a result of an error. When defined in this way, the operation requires that information about the cause of the error be accessible to the parser.

The results of the current study provide evidence that information about the cause of an error is rapidly available to the parser. This is a powerful source of information that could support targeted diagnosis and repair of errors. We should note, however, that the current results do not necessarily suggest one specific model over another, and they are compatible with a variety of different sentence-processing models (e.g., Fodor & Inoue, 1994; Lewis & Vasishth, 2005; Spivey & Tanenhaus, 1998; Sturt & Crocker, 1998). The crucial component of these models for the current results is their ability to ability to diagnose the level of representation at which the error obtains. This is naturally achieved in models that draw a clear distinction between morpho-syntactic and semantic processing, but models that instead encode this distinction implicitly are also compatible with the current results.

The current results are less compatible with models that do not allow the parser to easily recover information on the cause of errors. Most notably, this includes models that encode expectations only in terms of surface forms. A number of models of parsing adopt this strategy (Elman, 1993; Jurafsky, 1996; Levy, 2008; MacDonald, 1994). This viewpoint is perhaps most clearly articulated by Levy (2008), who suggests that a word's conditional probability is the sole determinant of processing difficulty (Levy, 2008: 1132-1133). Under this approach, identical conditional probabilities are expected to elicit identical processing difficulty, even in the situation where they are generated from quite different representations. The current results, however, suggest that forms with identical conditional probabilities induce divergent patterns of processing difficulty. The strong view that conditional probabilities uniquely determine processing difficulty is incompatible with this finding. Instead, the current data suggest that the cause of the error must be encoded and/or recoverable in the course of parsing.

## 5. Conclusion

By looking at ERPs elicited by morphosyntactic and semantic cues to verbal morphology in Hindi, we asked whether information about the cause of errors is recoverable during online sentence comprehension. By showing that Hindi speakers react differently to the same morphological anomaly when the anomaly has different underlying causes, we showed that the parser does indeed have access to information about the cause and the content of errors. This finding lends support to a family of parsing models that exploit this type of information.

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