Processing temporal violations in a language with aspectual markers: An ERP study in Thai
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There are many different ways that reference to the time frame of an event can be expressed which vary from one language to another. Linguistic devices used to encode temporal information include tense, aspect, and temporal adverbs (Klein, 2009). Yet, previous research on the neural correlates of temporal processing has primarily focused on tense. For example, if the time frame is set using a temporal lexical adverb, the corresponding verb inflection must be used for a sentence to be correct. When the adverb and verb inflection do not agree (e.g., ‘Yesterday, I *sail Diane’s boat to Boston.’; Baggio 2008), EEG studies have found a modulation of (LAN+)P600, interpreted as an indication of (morpho)syntactic processing (Bos, Dragoy, Stowe, & Bastiaanse, 2013; Dragoy, Stowe, Bos, & Bastiaanse, 2012; Steinhauer & Ullman, 2002).

However, it is not clear how temporal information is processed in languages that do not use verb morphology for time reference. Consequently, this study aimed to examine whether processing of time reference is different to the morphosyntactic processing of tense in Indo-European languages. We used Thai, as i) it uses aspectual markers to situate events in time rather than morphosyntactic tense markers, and ii) it employs two types of aspectual markers, temporal adverbs and aspectual adverbs, allowing examination of differences depending on which adverb type violations follow.

31 native speakers of Thai (6 males, mean age 31.16) performed a sentence acceptability judgement task on 160 experimental and 80 filler sentences. Each experimental sentence included both an aspectual adverb and a temporal adverb; half began with a temporal adverb, and for sentences with violations, the contrast was apparent on the subsequent presentation of the aspectual adverb, the other half of the sentences had the reverse order (see Table 1). Data were cleaned using automated Independent Component Analysis in EEGLAB and analysed using a cluster-based permutation test (Maris & Oostenveld, 2007).

For sentences with violations at the aspectual adverbs, the difference was most pronounced over the left-lateralized centro-posterior electrode sites ($p = .0399$) between 300-400 ms, but spread over centro-posterior sites ($p = 0.010$) between 400-500 ms (Figure 1). For sentences with violations at the temporal adverbs, a negative centro-posterior cluster in the 400-500 ms time bin ($p = .006$), and a positive cluster in the 600-700 ms time bin ($p = .004$) were detected (Figure 2).

We suggest that, although a positive cluster was observed in sentences with violations at the temporal adverbs, in Thai, time reference may rely more on lexical semantics (indexed by modulation in the 300-500 time window), rather than purely morphosyntactic processes as reported in Indo-European languages. Brain physiology reflects different time reference processing depending on the linguistic devices used for temporal information.
References

![Figure 1](image1.png)  
**Figure 1** The topographic maps display the mean amplitude difference between the ERPs evoked by the aspeutal adverb in correct and violated sentences. Asterisks indicate electrode clusters at which the mean amplitude difference between the two conditions is significant.

![Figure 2](image2.png)  
**Figure 2** The topographic maps display the mean amplitude difference between the ERPs evoked by the temporal adverb in correct and violated sentences. Asterisks indicate electrode clusters at which the mean amplitude difference between the two conditions is significant.

<table>
<thead>
<tr>
<th>Condition</th>
<th>TR in the temporal adverb</th>
<th>TR in the aspeutal adverb</th>
<th>TR in the temporal adverb</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. TempFirst Grammatical (N = 40)</td>
<td>Past</td>
<td>Past</td>
<td></td>
<td><em>peknom</em> por <em>koel</em> tam arhan india tee suan lang baan year-agp father <em>PAST</em> do food india at garden behind home A year ago (last year), father made Indian food at his backyard.</td>
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<tr>
<td>2. TempFirst Ungrammatical (N = 40)</td>
<td>Future</td>
<td>*Past</td>
<td></td>
<td><em>prunnee</em> por <em>koel</em> tam arhan india tee suan lang baan <em>tomorrow</em> father <em>PAST</em> do food india at garden behind home *Tomorrow, father made Indian food at his backyard.</td>
</tr>
<tr>
<td>3. AspFirst Grammatical (N = 40)</td>
<td>Future</td>
<td>Future</td>
<td></td>
<td>por jaa tam arhan india <em>prunnee</em> tee suan lang baan father <em>FUT</em> do food <em>tomorrow</em> at garden behind home Father will make Indian food, tomorrow, at his backyard.</td>
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</table>
| 4. AspFirst Ungrammatical (N = 40) | Past                      | *Future                    |                           | *peknom* por *koel* tam arhan india *prunnee* tee suan lang baan father *PAST* do food india *tomorrow* at garden behind home *Father made Indian food, tomorrow, at his backyard.