Semantic evaluation of syntactic structure: Evidence from eye movements

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Abstract

An eye movement study of temporarily ambiguous closure sentences confirmed that the early closure penalty in a sentence like While John hunted the frightened deer escaped is larger for a simple past verb (hunted) than for a past progressive verb (was hunting). The results can be explained by the observation that simple past tense verbs convey an external viewpoint on an event, which presumably fits best when the event described has an endpoint. A definite description object supplies an endpoint. Consequently, to give up the late closure analysis of the post-verbal object when the verb is in the simple past tense, the processor is abandoning an analysis with semantically-expected properties for one which is not as good semantically. By contrast, a progressive verb denotes an activity which does not require an endpoint and therefore is neutral with respect to whether or not it takes an object.

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Many studies of temporary ambiguities, like the direct object/subject ambiguity in sentence 1, have shown that readers (Frazier & Rayner, 1982), and listeners under prosodically neutral conditions (Kjelgaard & Speer, 1999), initially take the post verbal noun-phrase (NP) to be the direct object of the initial clause.
(1) a. While Mary was mending the sock fell off her lap.
   b. While Mary was mending the sock it fell off her lap.

The degree of difficulty observed in early closure sentences like 1a depends on a variety of factors, including the transitivity preference of the initial verb (Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Pickering, Traxler, & Crocker, 2000), the plausibility of the direct object analysis (Pickering & Traxler, 1998), and the length of the ambiguous phrase (Ferreira & Henderson, 1991). Indeed with long plausible direct objects, the initially assigned thematic role of the ambiguous NP seems to linger in the discourse representation even though the phrase is syntactically reanalyzed as subject (Christianson, Hollingworth, Halliwell, & Ferreira, 2001).

The preference to analyze the ambiguous phrase as a direct object has been interpreted as a tendency of the processor to take the first analysis available, as captured by the late closure (Frazier, 1979) or recency principles (Gibson, 1991). The length and plausibility effects discussed above receive a natural treatment in terms of reanalysis difficulty increasing under conditions when an initial syntactic analysis persists for a long time or when the initial analysis is semantically or pragmatically confirmed.

Our concern in the present article is with preferences resulting from viewpoint (past vs. progressive) and their interplay with syntactic analysis. Events can be viewed from an external viewpoint, as in the past tense (Mary left), or from an internal viewpoint, as an ongoing event/activity in the progressive (Mary was leaving). Viewpoint may interact with the interpretation of a predicate. Consider the optionally transitive verb hunt.

(2) a. John hunted.
   b. John hunted the rabbit.
   c. John hunted rabbits.

2a may receive an eventive (‘episodic’) interpretation. However, since hunted has no natural endpoint, it also seems possible to interpret 2a as John was a hunter. The definite NP in 2b provides an endpoint and the salient interpretation of 2b is an eventive interpretation. Note that a bare plural as in 2c does not provide a clear endpoint, allowing a noneventive interpretation (John was a rabbit hunter). In short, an eventive interpretation, where the sentence describes an episode or isolated event from an external perspective, is more available when an endpoint is provided than when it is not.

While a verb like hunt may not have an intrinsic or natural endpoint, other verbs (like blink) do. The direct object of a verb may supply an endpoint depending on the type of phrase: definite description objects more readily supply an endpoint than bare plurals, as illustrated above. Thus, the entire verb phrase may describe a bounded event, one with a clear endpoint, even if the verb itself does not. Consequently, on the eventive interpretation, the simple past tense example 2a feels incomplete without an endpoint. However, the corresponding past progressive 3 does not. This is because in the progressive aspect, the verb phrase denotes a process or ongoing activity. It does not matter whether the activity has a clear endpoint or not.
(3) John was hunting.

The experiment reported here used sentences like 4:

(4) a. As John hunted the frightened deer escaped through the woods.
   b. As John hunted the frightened deer it escaped through the woods.
   c. As John was hunting the frightened deer escaped through the woods.
   d. As John was hunting the frightened deer it escaped through the woods.

It tested the hypothesis that the presence of a definite description object in a simple past tense clause serves as semantic confirmation of the eventive/external perspective interpretation and thus as semantic confirmation of the late closure analysis in sentences 4a and 4b. In other words, if the speaker/writer has used a simple past tense (external perspective), what is expected is a description of a complete event (one with an endpoint). If an endpoint is provided, this serves to semantically confirm the direct object analysis of the sentence making it harder to give up, especially if this plausible analysis is abandoned for an intransitive simple past analysis, which fails to confirm expected semantic properties of the past tense verb. Consequently revising 4a should be difficult relative to a case like 4c in the progressive where the presence and type of the object does not particularly confirm the initial (late closure) analysis. In 4c the progressive is interpreted as an activity and is semantically neutral about whether this activity does or does not have an endpoint. Thus, in the progressive, the processor is giving up an analysis which is no better semantically than the revised analysis.

We compared the processing of early and late closure sentences where the first clause verb was in the simple past vs. past progressive. Giving up the late closure analysis in the simple past early closure sentence (4a) should be difficult because the first (direct object) analysis supplies an endpoint for the event described in the first clause and, in this sense, the first analysis is semantically confirmed.

1. Method

1.1. Participants

Thirty-two students at the University of Massachusetts community were paid to participate. They were native speakers of English with normal vision, and were naive with respect to the purpose of the experiment.

1.2. Apparatus

Eye movements were recorded by a Fourward Technologies DPI tracker (resolution <10 min of arc) interfaced with an 80486 microcomputer which sampled eye position every millisecond. Viewing was binocular, with eye location recorded from the right eye.

Sentences were presented on an NEC 4FG monitor with up to 80 characters per line; participants sat 62 cm from the monitor (3.8 characters equaled 1° of visual angle). Letters were in lower case except when uppercase was appropriate (sentence beginnings and proper names). Luminance on the monitor was adjusted to a comfortable brightness
and then held constant. The room was dark except for an indirect light source that enabled the experimenter to keep notes.

1.3. Materials

Twenty four experimental sentences (like 4, repeated below) were embedded in 104 fillers. Each experimental sentence began with an initial clause composed of a subject and verb; the verb was either in the simple past tense (a and b below) or the past progressive form (c and d). This was followed by a temporarily ambiguous noun phrase (the frightened deer) that could either be interpreted as the direct object of the preceding verb (b and d) or the subject of a new clause (a and c). The ambiguous noun phrase was not disambiguated until the following verb phrase. Finally, 2–4 words followed before the end of the sentence. Two versions were early closure (EC) and two were late closure (LC); two were simple past tense (SP) and two were past progressive (PP).

(4) a. As John hunted the frightened deer escaped through the woods. (EC-SP)
   b. As John hunted the frightened deer it escaped through the woods. (LC-SP)
   c. As John was hunting the frightened deer escaped through the woods. (EC-PP)
   d. As John was hunting the frightened deer it escaped through the woods. (LC-PP)

The 24 sentences were counterbalanced so that six appeared in each of the four conditions per participant (see Appendix A). To check the assumption that the simple past is most natural with an endpoint (e.g. one supplied by an object) whereas the progressive is neutral about having an endpoint, the initial fragment of the experimental sentences, up to and including the verb, was presented to 19 participants in a fragment completion norming study. The simple past received significantly more transitive completions (50%) than the progressive (40%), \( t(18) = 2.7, P < 0.01 \). In addition, the experimental items were presented with punctuation to 22 participants for plausibility rating on a scale of 1–5 (5 = very plausible). The experimental hypothesis predicts a larger penalty for early closure sentences in the simple past than in the progressive in the eye movement record but not in terms of plausibility of the sentence. In the simple past, the plausibility of the late closure and early closure sentences did not differ (3.6 for late closure sentences and 3.5 for early closure sentences), \( t < 1 \). They also did not differ in the progressive (3.3 for both late and early closure sentences), \( t < 1 \).

1.4. Procedure

For each participant, a bite bar was initially prepared to eliminate head movements and the eye tracking system was calibrated to ensure that accurate records were obtained. Participants read 12 practice sentences followed by the 24 experimental and 104 filler sentences. They were told to read for comprehension so that they could answer an occasional comprehension question.

On each trial, a set of calibration boxes appeared on the monitor. Once the experimenter determined that the participant was fixating appropriately, the sentence was presented on the monitor. When they finished reading the sentence, they pressed a button to end
the trial. A session lasted approximately 45 min (with a brief break halfway through the experiment).

2. Results

Trials with a track loss (5.1% of all trials) were eliminated from further analyses. Data from the following critical regions were analyzed:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

As John| hunted/| was hunting| the frightened deer| escaped/| it escaped| through the woods. Region 1 contained the subordinating conjunction (e.g. *when*, *as*, *because*) and the subject of the subordinate clause. Region 2 contained the verb of the subordinate clause, either in the simple past or the progressive. Region 3 contained the ‘object’ of the previous clause. Region 4, the disambiguating region, contained the verb of the main clause and in the late closure conditions the pronominal subject of this clause. Finally, Region 5 contained 2–4 words that ended the sentence.

Although reading times for all five regions were analyzed, the disambiguating region (Region 4) was of primary interest. The raw reading times for Regions 3–5 are presented in Table 1. For completeness, and to be consistent with most eye movement research (Rayner, 1998; Rayner et al., 1989), the first pass, second pass, and total reading times are presented in the table. However, the measure which we believe is the most important for the question we asked and that we will focus on is the regression-path duration.

### Table 1

Mean go-past, first pass, second pass, and total reading times as a function of tense and sentence type for regions 3–5 in experiment 1

<table>
<thead>
<tr>
<th>Sentence region</th>
<th>3 (the frightened deer)</th>
<th>4 (escaped/it escaped)</th>
<th>5 (through the woods)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SP</td>
<td>PP</td>
<td>SP</td>
</tr>
<tr>
<td><strong>Go-past-regression path</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>721 (711)</td>
<td>717 (703)</td>
<td>541 (553)</td>
</tr>
<tr>
<td>LC</td>
<td>725 (726)</td>
<td>712 (739)</td>
<td>473 (475)</td>
</tr>
<tr>
<td><strong>First pass</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>625</td>
<td>624</td>
<td>370 (−22.84)</td>
</tr>
<tr>
<td>LC</td>
<td>615</td>
<td>638</td>
<td>430 (−46.15)</td>
</tr>
<tr>
<td><strong>Second pass</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>129</td>
<td>112</td>
<td>106 (22.33)</td>
</tr>
<tr>
<td>LC</td>
<td>47</td>
<td>70</td>
<td>74 (−2.49)</td>
</tr>
<tr>
<td><strong>Total time</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>813</td>
<td>787</td>
<td>482</td>
</tr>
<tr>
<td>LC</td>
<td>736</td>
<td>756</td>
<td>510</td>
</tr>
</tbody>
</table>

The reading times are Raw Reading Times. SP, Simple Past Tense; PP, Progressive Past Tense; EC, Early Closure; LC, Late Closure. The values in parentheses for go-past are for those trials with five items eliminated. The values in parentheses for first pass and second pass are deviations from regression for Region 4 (where number of words in the region differed).
Table 2
Mean percentages of regressions into and out of a region as a function of tense and sentence type for regions 1–5 in experiment 1

<table>
<thead>
<tr>
<th>Sentence region</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SP</td>
<td>PP</td>
<td>SP</td>
<td>PP</td>
<td>SP</td>
</tr>
<tr>
<td><strong>Regressions in</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>0.21</td>
<td>0.21</td>
<td>0.13</td>
<td>0.17</td>
<td>0.20</td>
</tr>
<tr>
<td>LC</td>
<td>0.21</td>
<td>0.17</td>
<td>0.11</td>
<td>0.12</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>Regressions out</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>–</td>
<td>–</td>
<td>0.07</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td>LC</td>
<td>–</td>
<td>–</td>
<td>0.07</td>
<td>0.06</td>
<td>0.09</td>
</tr>
</tbody>
</table>

SP, Simple Past Tense; PP, Progressive Past Tense; EC, Early Closure; LC, Late Closure Go-Past. Regressions in include all regressions into a region; regressions out are first pass regressions.

(Konieczny, Hemforth, Scheepers, & Strube, 1997; Liversedge, Paterson, & Pickering, 1998) or go-past time, which represents the time it takes a reader from first entering a region to go past the end of that region with a rightward eye movement (Rayner & Duffy, 1986). What we were most interested in was how long it took readers to get past the disambiguating region of the sentence. Because readers are free to regress as soon as they encounter the disambiguating information, first pass time could easily be compromised by such strategies. Therefore, in studies such as the present one, the go-past measure makes the most sense as the dependent variable. In addition to the reading times, we will also present the number of regressions into and out of a region (Table 2).

A series of 2 (tense: simple past vs. progressive) × 2 (closure: early vs. late) ANOVAs were carried out on the data; $F_1$ refers to tests based on participant variability and $F_2$ refers to tests based on item variability. The first pass data did not yield significant results when length differences were accounted for via a deviation from regression measure (Ferreira & Clifton, 1986), but the second pass reading times revealed significant main effects of closure (all ps < 0.05) in each region: early closure sentences resulted in longer second pass reading times in all regions.

2.1. Go-past reading times

There were no reliable differences for the first three regions (prior to disambiguation) in go-past reading times. Table 1 shows that in Region 3, the times are very similar across the conditions. In Region 4, however, there was a significant interaction, $F_1(1, 31)=7.19$, $P<0.05$, $F_2(1, 23)=6.65$, $P<0.05$: in the early closure condition, reading times were significantly longer when the verb appeared in the simple past tense (541 ms) than when it appeared in the progressive form (439 ms), $t_1(31)=2.619$, $P<0.05$, $t_2(23)=2.678$, $P<0.05$. In the late closure conditions, however, reading times were marginally longer when the verb appeared in the progressive form (547 ms) than when it appeared in the simple past tense (473 ms), but only when tested against participants variability, $t_1(31)=−1.713$, $P=0.097$, $t_2(23)=−1.095$, $P=0.285$. The go-past time for Region 5 reflects processing time after any re-reading has been done that is initiated from Region 4,
and here reading times were longer in the early closure than in the late closure conditions, $F_1(1, 31)=12.64, P<0.01$; $F_2(1, 23)=9.14, P<0.01$.

It occurred to us that some of the verbs used might not have been ideal for testing the endpoint hypothesis because they are inherently bounded or because the object does not truly bound the event. To determine whether the verbs have an intrinsic endpoint, the subject and simple past verb of the experimental items were combined with a durative for phrase (Laura read for an hour.) A durative for-phrase requires a process or activity and therefore should be rated unacceptable with verbs that have an intrinsic endpoint. Acceptability was rated by 19 participants on a scale of 1–5 (where 5 is acceptable). As expected, the individual verbs differed but overall the sentences were rated as acceptable with the process/activity reading required for the for phrase. This shows that most verbs in the study did not have an intrinsic endpoint. Excluding the five items with the lowest rating (approached, exited, teased, called, entered) the mean was 4.13. An analysis was then conducted with these five items excluded (they are marked with an asterisk in the Appendix) to insure that the overall pattern was not carried by the least good items. Table 1 presents the go-past reading time in parentheses when these 5 sentences were eliminated. Critically, the data pattern is virtually the same, with the interaction in Region 4, $F_1(1, 31)=10.96, P<0.01$; $F_2(1, 18)=6.41, P<0.05$, and the contrast between the early closure simple past and progressive conditions, 553 ms vs. 424 ms respectively, $t_1(32)=3.45, P<0.05, t_2(23)=2.69, P<0.05$, still significant. The contrast for the late closure simple past and progressive conditions, 475 ms vs. 562 ms respectively, was not significant, both $P$'s $>0.1$. The main effect in Region 5, $F_1(1, 31)=11.56, P<0.01$; $F_2(1, 18)=0.97, P<0.01$, was also still significant.

2.2. Regressions out

In Regions 2 and 3 there were no effects (see Table 2). In Region 4, there were more first-pass regressions out of the region in the early closure (.10) than in the late closure conditions (.03), $F_1(1,31)=10.77, P<0.01$; $F_2(1, 23)=8.16, P<0.01$. In addition, the pattern of regressions out of the verb region was similar to the pattern of means for the go-past measure. There were significantly more regressions out of the early closure condition when the verb appeared in the simple past than when it appeared in the progressive form, $t_1(31)=2.03, P=0.05, t_2(23)=2.42, P<0.05$. In contrast, there were more regressions out of the late closure condition when the verb appeared in the progressive form than when it appeared in the simple past, but this contrast was only significant when tested against participants variability, $t_1(31)=−2.29, P<0.05, t_2(23)=−1.41, P=0.172$. This resulted in a significant interaction, $F_1(1, 31)=6.9, P<0.05; F_2(1, 23)=9.29, P<0.01$. In Region 5, there were more first pass regressions out of the region in the early closure (0.33) than in the late closure conditions (0.23), $F_1(1, 31)=9.59, P<0.01$; $F_2(1, 23)=11.08, P<0.01$.

2.3. Regressions in

Whereas the regressions out data are based on first pass regressions, the regression in data represent all regressions into a region. There were no significant effects in Regions 1
and 2. However, readers did regress into Regions 3–4 more often in the early closure (.185 for Region 3 and 0.21 for Region 4) than in the late closure conditions (.06 for Region 3 and 0.135 for Region 4): Region 3, $F_1(1, 31)=21.53, P<0.01; F_2(1, 23)=22.76, P<0.01$; Region 4, $F_1(1, 31)=8.84, P<0.01; F_2(1, 23)=7.36, P<0.05$.

3. Discussion

The central finding of the experiment is that tense and sentence structure interacted in Region 4 (where the sentence was disambiguated): the cost for processing early closure structures compared to late closure structures was much larger in the simple past conditions than in the past progressive conditions. The difference in the percentage of regressions out of Region 4 (where the sentence structure first becomes clear) between early closure and late closure was larger in the simple past tense condition than in the past progressive condition.

Interestingly, the Region 4 go-past data showed a significant interaction due largely to the relatively fast reading time in the early closure past progressive condition. The early closure progressive sentences were fast, not only relative to their simple past counterparts, but also relative to the progressive late closure sentences. If the advantage of the early closure relative to the late closure sentences continued into Region 5, this might suggest that no late closure error had been made in the progressive forms. However, given the pervasive late closure advantage in the second pass data and the go-past data in Region 5, it is quite clear that readers were garden-pathed even in the progressive sentences. The finding of an early closure penalty in Region 5, but no difference between the simple past and the progressive in this region, suggests that the progressive helped readers in the early stages of diagnosing the error, but did not help in later stages of revising the incorrect analysis of the early closure sentences (e.g. in Region 5). It is possible that the reanalysis performed in Region 5 is concerned with the thematic role adjustments entailed by the syntactic reanalysis.

The distinction between simple past tense and past progressive is primarily one of viewpoint. The same real world event can be presented with an external viewpoint (when Rita washed the clothes...) or with an internal viewpoint (when Rita was washing the clothes...). Given this, what the present results suggest is that viewpoint influences sentence processing very rapidly and not just at some late interpretive stage of language processing. Instead, the formal distinction between simple past and past progressive informs the processor’s ongoing assessment of the goodness of its current analysis, strongly supporting the general claim that interpretation of a sentence proceeds incrementally.

Acknowledgements

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Appendix A. Experimental sentences

1. As John hunted/was hunting the frightened deer escaped/it escaped through the woods.
2. When Anne visited/was visiting the British relatives were moving/they were moving to London.
3. When Rita washed/was washing her favorite sweater was torn/it was torn to shreds.
   *4. As Jason entered/was entering the old house groaned/it groaned and a beam fell.
   *5. When the soldiers approached/were approaching the wheat field separated/it separated and enemy troops appeared.
6. When Joan left/was leaving her old boyfriend stalked/he stalked her for two months.
7. While the assistant measured/was measuring the delicate fabric ripped/it ripped and frayed.
8. When Greg returned/was returning the new jaguar was operating/it was operating smoothly.
9. Because Cecelia baked/was baking the delicious homemade bread was served/it was served at breakfast.
10. Even when Todd cleaned/was cleaning the small kitchen smelled/it smelled like old garbage.
    *11. When the pretty assistant called/was calling the young plumber was usually/he was usually available immediately.
    *12. Because Tim teased/was teasing his younger sister left/she left the room angry.
13. Because Grandma knitted/was knitting wool sweaters would appear/they would appear under the Christmas tree.
14. Because Keith grilled/was grilling large steaks were done/they were done to perfection.
15. Because Maria read/was reading the financial news was always/it was always at her fingertips.
    *16. Just as Kathy exited/was exiting the old theater went/it went up in flames.
17. As Sam pounded/was pounding the thin metal ripped/it ripped and broke into pieces.
18. When Sonya painted/was painting the kitchen walls were covered/they were covered in obvious drops.
19. As Lisa typed/was typing the eviction notice was/it was cancelled.
20. When Tina supervised/was supervising the night crew was/it was very efficient.
21. As Gary watched/was watching the drunken workmen stumbled/they stumbled off the platform.
22. When the sheriff patrolled/was patrolling the whole area was/it was very safe.
23. When Mr. Ozawa conducted/was conducting the symphony orchestra was lit was at its peak.
24. When Molly sang/was singing the drinking songs sounded/they sounded like opera.

References