Reading and Listening to Garden-Path PP Sentences in Brazilian Portuguese

Marcus Maia

Department of Linguistics
Federal University of Rio de Janeiro
maiamarcus@gmail.com

Abstract

The present study reports three on-line psycholinguistic experiments investigating syntactic attachment decisions in both silent reading and auditory comprehension of the same set of sentences containing ambiguous adjunct and argument Prepositional Phrases (PP) in Brazilian Portuguese. An eye-tracking experiment shows that both adjunct and argument PPs are preferentially attached to the VP during the reading of sentences fully presented on the screen. Sentences are then examined through a self-paced reading experiment and a self-paced listening experiment, in which speech passages were presented in segments, with participants required to initiate presentation of subsequent segments via a key-press. Equivalent prosodic breaks in auditory presentation and segment boundaries in reading were systematically manipulated in order to assess explicit and implicit prosody effects on attachment decisions. The key results are summarized as follows. Unlike the argument/adjunct condition, which was not immediately accessed by the parser, prosodic breaks and visual segmentations displayed rapid parallel effects on the listening/reading times of critical segments, suggesting that BP subjects treat segment boundaries as signaling prosodic boundaries, as predicted by the Implicit Prosody Hypothesis (Fodor, 1998; 2002), and that both explicit and implicit prosody have markedly significant influences in on-line attachment decisions of both adjunct and argument PPs.

1. Introduction

This article examines the reading and the oral comprehension of Brazilian Portuguese (BP) garden-path sentences containing a Prepositional Phrase (PP) which may present a temporary structural ambiguity, as exemplified in (1) and (2):

(1) O redator escreveu o manual para o professor para o editor da nova série.
"The writer wrote the handbook for the teacher for the editor of the new series"

(2) O contador enviou a carta para o professor para o diretor da faculdade.
"The accountant sent the letter to the professor to the college director".

These sentences contain each three PPs, but only the first and the second PPs are relevant for the study. The first PP in each sentence is temporarily ambiguous between a Verb Phrase (VP) or a Noun Phrase (NP) attachment. Even though both structures are grammatically licensed, Garden Path Theory - GPT (Frazier, 1979) predict preference for VP attachment based on the Minimal Attachment Principle (MA), which postulates that "incoming material should be attached into the phrase marker being constructed using the fewest nodes consistent with the well formedness rules of the language" (cf. Frazier, 1979). Upon encountering the second PP in the sentences, perceivers would typically be garden-pathed, that is, having automatically attached the first PP to the VP, as predicted by the MA, they would have to backtrack and review their initial analysis, attaching the first PP to the object NP, in order to be able to attach the second PP to the VP and rescue the sentences. Note, however, that sentence (1) has a monotransitive verb, whereas sentence (2) has a ditransitive verb. If this information is readily available to perceivers as they parse sentences in comprehension, there might be significant differences in the on-line time course of the processing of the two sentences, since sentence (2) obligatorily subcategorizes an argument PP while sentence (1) only has an optional adjunct PP.

There is an important divide in the Sentence Processing literature concerning the types of information which are immediately available for the parser. On the one hand, structural models such as the GPT, have contended that lexical information other than grammatical categorial labels are only accessed in the interpretation stage of a modular dual stage model, after the syntactic parsing process has taken effect. On the other hand, nonmodularistic models have proposed that the structural analysis of a sentence, if it exists at all, would be dependent on the rapid access to lexical information such as, for example, the subcategorization or theta frames of predicates (e.g. MacDonald, Pearlmutter, &Seidenberg ,1994).

The important question concerning the types of information rapidly available to the human parser has also been investigated with respect to prosody. The seminal study by Lehiste (1973) showing that structural ambiguity could be avoided by prosody has started a productive research program exploring the syntax/phonology interface. For example, one might ask whether the garden-path described for BP sentences (1) and (2) could be avoided if the first PP was grouped in the same prosodic phrase as the object NP, signalling that the second PP would be readily available for VP attachment. Additionally, following the Implicit Prosody Hypothesis (IPH; Fodor,1998;2002), one might also ask whether the corresponding visual segmentations of sentences (1) and (2), chunking the first PP to the NP in each sentence, would also avoid the garden-path in reading.

The IPH has proposed that attachment preferences in silent reading are influenced by prosody. "In silent reading, a default prosodic contour is projected onto the stimulus,and it may influence syntactic ambiguity resolution. Other things being equal, the parser favors the syntactic analysis associated with the most natural (default) prosodic contour for the construction".

The current article sets out to investigate the questions raised above with respect to BP sentences such as (1) and (2), by means of three psycholinguistic experiments. The first experiment uses an eye-tracking protocol to examine fixations and regressive saccadic patterns in the reading of target sentences fully presented on the screen, in order to assess whether the garden-paths predicted above are really instantiated in BP and whether there are on-line differences between adjunct and argument PPs. Experiment 2 uses a self-paced reading task, manipulating two types of segmented presentation of the same sentences as in experiment 1, in order to discover whether visual segmentation cues can be rapidly used by the parser and induce or avoid garden-path effects. Finally, experiment 3 uses a self-paced listening task, manipulating in auditory modality the equivalent visual segmentation conditions tested in experiment 2 to investigate whether there are parallel effects in the reading and the listening of those BP sentences, as predicted by the IPH.

2. The Experiments

The three experiments reported in this section elaborate on findings previously reported in Maia, Lourenço-Gomes & Moraes (2004), who investigated the interpretation in silent reading of prepositional phrases (PP), which can either attach high to the verb or low to the NP. They presented the results of two off-line compatibility judgment experiments in which subjects read ambiguous short or long PP complete or segmented sentences, as exemplified in (3), and judged whether a follow-up sentence corresponding to high or low attachment was an adequate statement about the previous sentence.

(3) O funcionário/localizou/o passageiro/com o celular (de capa dura).
"The clerk/ located /the passenger /with the (hard cover) cell phone"
(a) O funcionário tinha um celular (b) O passageiro tinha um celular.
"The clerk had a cell phone."   "The passenger had a cell phone."

Their results showed that, as predicted by the IPH, there were significant interactions between PP length and acceptance rates for VP and NP attachment. Maia, Lourenço-Gomes & Moraes (2004) first provided independent evidence of Brazilian Portuguese (BP) prosodic patterns in oral production and showed that these patterns can predict attachment preferences in the parsing of sentences in the silent reading of prepositional phrases (PP), which can either attach high to the verb or low to the NP. In the study, 42 short and 42 long PPs with forced low and high attachments were read aloud by 7 speakers and subjected to acoustic analyses. Results indicated a significant longer duration of the stressed syllable of the noun immediately preceding the long PPs than preceding the short PPs, signaling a greater probability of a prosodic break between that noun and the long PPs than for their short counterparts. In order to assess whether pre-PP breaks favor high attachment in silent reading, two speeded compatibility judgment experiments were implemented. In experiment 1, 24 subjects read ambiguous short or long PP complete sentences and judged whether a follow-up sentence corresponding to high or low attachment was an adequate statement about the previous sentence. Experiment 2 used the same technique, except that sentences were presented to another 24 subjects in 4 noncumulative segments, as exemplified by the slashes in (3). There were significant interactions between PP length and acceptance rates for high and low attachment. Segmentation also had a significant

effect. The BP data suggested that small segmentation could provide an excess of cues for prosodic boundaries, in such a way that results were exactly as predicted if readers treated every segment boundary as signaling a prosodic boundary. Note, however, that those were off-line experiments, that is, the end of sentence task could not capture the parsing decisions at the very moment when they were happening. Therefore, even though Maia, Lourenço-Gomes & Moraes's experiments indicated implicit prosody effects in the PP attachment ambiguity resolution in BP, they could not make any statement about the time-course of prosodic access in sentence processing. Additionally, that study did not take into account the PP status as adjunct or argument. Taken together, the experiments reported in this section have the objective to investigate the effects of these two factors in the comprehension of PP sentences in BP, namely, the preference for adjunct and arguments and the implicit and explicit effects of segmentation in on-line tasks.

2.1. The eye-tracking experiment

We monitored participants' eye movements as they read VP NP PP PP attachment ambiguities like (1) and (2), using *Arrington View Point Quick Clamp Eye-tracker,* a corneal reflection and pupil boundary (infrared) system with a temporal resolution of 30Hz (640x 480), which monitored the right eye. Previous research has shown that first pass times reflect early stages of processing during syntactic ambiguity resolution. The objective of the experiment was to measure average fixations during first passing reading in two regions of interest – the first and the second PPs. We also registered regressive saccadic movements to the area of the verb as well as regressive fixations on the verb. If the parser can have quick access to subcategorization frames of verbs, it would be legitimate to expect differences in first pass average reading times across the adjunct/argument condition. Since they are subcategorized, the argument first PP should be more readily integrated into the VP structure than the adjunct first PP. Additionally, the second PP first pass average reading times should be bigger for the argument condition than for the adjunct condition, since in the latter the first PP which is not subcategorized by the verb would be more likely to attach to the object NP and the parser's surprise effect upon encountering the second PP should be smaller for adjuncts than for arguments. On the other hand, if VP attachment preferences do not vary across the adjunct/argument condition, there would be no reason to expect differences in first pass fixations between the conditions. As to second pass measures, if the parser is quickly sensitive to the adjunct/argument difference, more regressive saccades to the verb area as well as higher second pass fixation times on this area should be predicted in the ditransitive condition as a consequence of the stronger garden-path effects caused by arguments.

2.1.1. Participants

Sixteen Speech Therapy undergraduate students with normal vision took part in the experiment in exchange for one point in a Psycholinguistics class. They were all native speakers of BP and entirely naïve as to the nature of the study.

2.1.2. Materials and Procedures

Twenty experimental items were constructed – 10 containing monotransitive verbs such as in (1), and 10 with

ditransitive verbs, as in (2). A computer displayed the materials on a screen 60 cm from the participants'eyes. Participants were told to read sentences carefully, but at a normal rate self monitoring the presentation of the sentences which appeared on a single line in font Times New Roman 28p. A chin rest and a nasal clip were used in order to minimize head movements.

2.1.3. Results

Results are displayed in table 1. A two-way ANOVA by subjects indicated that there were no significant differences in first pass measures across conditions, neither at the first PP region ($F(1,15)=2.58$, $p>0,05$) or at the second PP region ($F(1,15)=1.90$, $p>0,05$). Regressive saccade rates to the verb region were only visually higher, but not statistically robust. On the other hand, average second pass fixations on the verb region were significantly higher for arguments than for adjuncts ($F(1,15)=4..81$, $p<0,001$).

Table 1: *Eye-tracking measures ofVP NP PP PP sentences*

Measures	Condition	
	Monotransitive	Ditransitive
First PP First Pass	1491ms	1508ms ($p>0.05$)
Second PP First Pass	1521ms	1413ms ($p>0.05$)
Verb Second pass	183ms	458ms ($p<0.001$)**
Regressive Saccades to Verb rates	56%	81% ($p>0.05$)

2.1.4. Discussion

Results suggest that the parser does not have early access to subcategorization frame of predicates, adducing evidence in favor of structural, two-stage models of sentence processing, such as the Garden Path theory. Adjunct first PPs are read in average at the same rate as argument first PPs, and the second PPs do not display any differences in average reading times either. Differences between monotransitive and ditransitive sentences do appear, however, in the average fixation times in the second pass on the verb region, after a regressive saccade, suggesting that the recovery of the garden-path is more difficult for arguments than for adjuncts. After being garden-pathed on the second PP region, both in the adjunct and in the argument conditions, the parser selectively backtracks to the verb region in order to check its subcategorization grid and try a cure for the garden-path. As suggested by Fodor & Inoue (1994), the cost of repairing a garden-path must be assigned less to the repair itself than to the difficulty of deducing which changes will be necessary. In the case of the monotransitive verbs, the parser would only have to reanalyze the first PP as modifying the object NP, so that the second PP can then be attached to the VP. In the case of the ditransitive verbs the parser would face a higher repair cost, reflected in the bigger fixation times, since an inspection of the subcategorization grid does indicate that the first PP could indeed be attached to the VP. For that reason the parser would take longer to alter its first analysis of the argument PP, which would not be so readily repaired and attached to the object NP as the adjunct PP.

2.2. The self-paced reading experiment

This experiment has the objective to verify further whether (i) the argument/adjunct status of the PP has an immediate effect on its processing and (ii) the type of segmentation of the sentence influences the on-line processing of the sentence. The independent variables are the type of verb (mono or ditransitive) and the type of segmentation of the sentence which could present the first PP on the same frame as the NP or on a separate frame. The dependent variables are the reading times of the segments (on-line measure) and the accuracy of the interpretation questions. Assuming that subjects can make rapid use of the information provided by the type of segmentation of the sentences, we hypothesize that the second PP in sentences such as (1) and (2) will be harder to process when the first PP is shown in isolation than when the first PP is shown in the same frame as the object NP.

2.2.1. Participants

32 Speech Therapy undergraduate students with normal or corrected eyesight took part in the experiment in exchange for one point in a Psycholinguistics course. As in the previous experiment, they were all naïve as to the nature of the study.

2.2.2. Materials and Procedures

Experimental materials were the same 20 sentences as in the eye-tracking experiment distributed in a latin square design that counter-balanced among subjects versions in which the second PP was presented in the same frame as the object NP (long condition) and versions in which the second PP was presented in isolation (short condition). Targets had their number of syllables carefully controlled and were interspersed among 40 filler items. All sentences were followed by interpretation questions that had two options as an answer. Experimental sentences had questions whose correct answers should be the second PP. For example, the interpretation question for sentence (2) was the BP equivalent of "Whom did the accountant send the letter to?" (A) "the professor" (B) "the director". Subjects called to the screen non-cumulatively, at their own pace, each of the four segments in which sentences were divided by pressing the yellow button in a button-box and answered interpretation questions by pressing the (A) or the (B) button in the same device.

2.2.3. Results

On-line results are displayed in table 2. A two-way ANOVA by subjects indicated that there were significant differences in in the average reading times of critical third segment where the second PP was presented. There is significant main effect of argument status ($F(1,31)=8.81$, $p=0,0001$) and of type of segmentation ($F(1,31)=8.82$, $p=0,0002$) and there is interaction between argument status and segmentation type $F(1,31)=7,81$, $p<0.0001$). The off-line measure indicated error rates significantly bigger for long than for short PP conditions ($t(2,638)=3,243$, $p=0,0012$). Monotransitive sentences also get bigger error rates overall than ditransitive sentences ($t(2,638)=1,972$, $p=0,0491$).

Table 2: Average *reading times of short monotransitive (SM), long monotransitive (LM), short ditransitive (SD) and long ditransitive (LD) segmented sentences*

SM 2474ms O redator escreveu o manual	1539ms para o professor	1656 para o editor	1603ms da nova série
LM 1727ms O redator escreveu	2363ms o manual para o professor	1430ms para o editor	1406ms da nova série
SD 2367ms O contador enviou o manual	1519ms para o professor	2045ms para o diretor	1621ms da faculdade
LD 1860ms O contador enviou	2415ms o manual para o professor	1616ms para o diretor	1392ms da faculdade

2.2.4. Discussion

The fact that significant differences in average reading times are found only in segment 3, where the second PP is presented, is entirely consistent with the eye-tracking results presented above. The longer reading times in segment 3 in conditions SD and SM in contrast with the equivalent segment of conditions LD and LM suggests that there is a rapid access to the segmentation type which allows the parser to avoid the garden-path in the long conditions where the first PP is on the same frame as the NP. Additionally, the contrast between the smaller garden-path on the third segment of SM than on the third segment of SD suggests that the reanalyses of argument PPs were harder than the reanalyses of adjunct PPs, as verified in the eye-tracking experiment.

2.3. The self-paced listening experiment

Experiment 2 showed that segmentation type in reading immediately influences PP attachment. Experiment 3 was developed in order to assess whether segmentation effects would also be observed in auditory segmentation of the same sentences. The objective was to test whether visual segmentation was really simulating implicit prosody effects.

2.3.1. Participants

26 Speech Therapy undergraduate students with normal or corrected eyesight took part in the experiment in exchange for one point in a Psycholinguistics course. They were all naïve as to the nature of the study.

2.3.2. Materials and Procedures

Experimental materials were auditory versions of the same 20 sentences as in Experiment 2. Design and procedures were also equivalent to Experiment 2, except that previously recorded sentences were orally presented upon key-press. Durations of critical segment 3 were measured and equalized on the basis of the means at 841ms, using *Speech Analyzer*.

2.3.3. Results

On-line results were strikingly parallel to experiment 2. Average reading times of critical segment 3, where the second PP was presented, are comparatively displayed in graph 1. Comparative t-tests between relevant reading and listening times (short reading x short listening and long reading x long listening) all yield nonsignificant results (p> 0.05) both in the monotransitive and ditransitive conditions.

Graph 1: *Listening times of critical segment 3(2ndPP)*
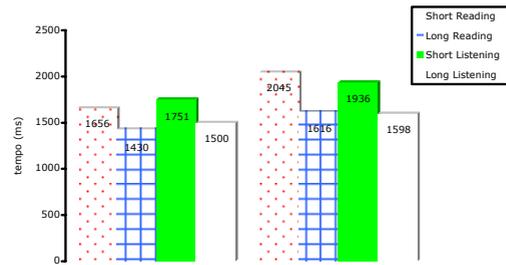
	Monotransitive	Ditransitive
Short Reading	1656	2045
Long Reading	1430	1616
Short Listening	1751	1936
Long Listening	1500	1598

2.3.4. Discussion

Although still preliminary, the comparison of results obtained in the self-paced reading and self-paced listening experiments suggest that (i) prosodic ruptures can be simulated in silent reading based on visual segmentation producing differentiated processing effects; (ii) there seems to be a rapid access to segmentation types which is able to induce a garden-path in the less natural conditions (the short 1st PP) and to avoid it in the more natural conditions (the long 1st PP).

3. Conclusions

Taken together, the three experiments demonstrate that unlike the argument/adjunct condition, which was not immediately accessed by the parser, visual and auditory segmentations displayed rapid parallel effects on the reading and listening times of critical segments, suggesting that BP subjects treat segment boundaries as signaling prosodic boundaries, as predicted by the Implicit Prosody Hypothesis (Fodor, 1998; 2002), and that both explicit and implicit prosody have markedly significant influences in on-line attachment decisions of both adjunct and argument PPs.

4. References

[1] Fodor, J.D., 1998. Learning to parse? *Journal of Psycholinguistic Research*, 27, 2, 285-319.

[2] Fodor, J.D. 2002. Prosodic disambiguation in silent reading. *NELS*, 32.

[3] Fodor, J.D. & Inoue, A. 1994. The Diagnosis and cure of garden-paths. *Journal of Psycholinguistic Research,*23,5,407-434.

[4] Frazier, L. 1979. On Comprehending Sentences: Syntactic Parsing Strategies, PhD dissertation, U.Conn.

[5] Lehiste, I. 1973. Phonetic disambiguation of syntactic ambiguity. *Glossa*, 7, 107-122.

[6] Macdonald, M. C.; Pearlmutter, N.J. & Seidenberg, M.S. (1994). The Lexical nature ofsyntactic ambiguity resolution. *Psychological Review, 101*, 676-703.

[7] Maia, M. Lourenço-Gomes, M.C. & Moraes, J. (2004). Prosodic effects on the reading comprehensionand the oral production of ambiguous relative clauses and prepositional phrases in Brazilian Portuguese. Poster presented at 17th Annual CUNY Human Sentence Processing Conference.College Park, Maryland.