SENTENCE PROCESSING AND DISCOURSE CONTEXT

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▪ ABSTRACT: The time course of sentence comprehension subprocesses is investigated in order to assess whether the parser is strictly syntactic in its early phases or whether semantic, pragmatic and discursive information is quickly accessed in time to influence the syntactic analysis. Two experimental studies are reported testing speakers of Brazilian Portuguese, to assess the effects of discursive context in sentence processing. The first experiment revisits the processing of ambiguously attached Prepositional Phrases and finds effects of the previous discourse only in the final off-line measures, which monitor interpretation. The second experiment uses the eye-tracking technique to gauge the antecedent search for the subject of clauses with inflected infinitive verbs, detecting effects of the previous discourse both in the final off-line measure and in the on-line gaze fixation average times. Possible reasons for differences between the effects of discursive information in the two experiments are discussed.

▪ KEYWORDS: Sentence processing. Discourse effects. Eye-tracking.

Introduction

Fundamentally, what is known today about the processing of human language has been discovered through laboratory experimentation. Comprehension and Production studies, using the experimental method and different techniques and tasks, have allowed psycholinguists to test theoretical hypotheses, carefully controlling independent variables and linguistic materials, in different types of designs, measuring decision rates and reaction or reading and listening times with millisecond precision. Influential models such as the Garden-Path theory (FRAZIER; FODOR, 1978; FRAZIER, 1979; FRAZIER; RAYNER, 1982, among many other studies) could be established by measuring the time course of reading or listening comprehension, in self-paced tests and eye-tracking experiments, which were carefully designed and applied under laboratory conditions.

Experimental studies designed according to the Garden Path theory were able to establish default assumptions and metrics of sentential processing, which had been applied even in the absence of specific discursive or pragmatic contexts. For example, we learn that the parser does not wait for a sentence to end in order to start processing

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phrase structuring that allows its interpretation, that is, the parser is incremental, making quick decisions about the analysis of the linguistic input.

Sentence processing research has been able to advance significantly by experimentally investigating the immediate decisions made by the parser when it is confronted with structurally ambiguous constructs. The classic example of Tom Bever (1970) "The horse raced past the barn fell!" contains a paradigmatic example of the preference of the syntactic processor for simpler structures. Since "raced" can be ambiguously analyzed as simple past or past participle, simple past is preferred. The preferential analysis is the one that analyzes "raced" as the main verb of the sentence, leading to a garden-path effect, when later the reader or the listener finds out the form "fell" in the sentence. It is then necessary to re-analyze "raced" as a participle. As we have seen, in the English language, the nominal form of past participle and the form of simple past are homonymous in regular verbs. Because of this homonymy, there is ambiguity in understanding sentences whose verbs present these forms, and these sentences can be analyzed as both main and subordinate adjective clauses.

The Minimal Attachment Principle predicts that, in such cases, there is a preference for the main clause analysis, computing a smaller number of syntactic nodes than in the attachment of the clause as an adjunct, which would form a complex DP.

In Brazilian Portuguese (BP), the Minimal Attachment Principle was established in Maia *et al*. (2003), among other studies, through questionnaires and self-paced reading tests. In Maia (2013), equivalent garden-path constructions were investigated using the eye-tracking technique. Maia *et al.* (2003) reviewed a study by Ferreira and Clifton (1986), in which the [±animate] feature of the subject DP in English sentences is manipulated in order to determine whether the semantic or thematic information could be quickly accessed by the processing system, and thus avoiding a garden-path effect, comparing these constructions with non-reduced relative clauses, which are taken as baseline controls. The rationale of the study was that the inanimate DPs could not be taken as plausible agents and, in principle, would be able to provide the parser with semantic feedback, preventing it from analyzing the sentence as the main clause. Using the eye-tracking technique, Ferreira and Clifton (1986) found evidence against the immediate use of thematic information by the parser. Below, an example of the sets of phrases studied by them:

(1) The defendant examined by the lawyer was unreliable.
(2) The evidence examined by the lawyer was unreliable.

As discussed in Maia *et al.* (2003), the results presented by Ferreira and Clifton (year) support the claim that the inconsistent meaning in sentences such as in (2), in which the *the evidence* DP is inanimate and cannot take the *examined* form in the agentive sense, would not be enough to block the garden-path effect. The authors found the same reading patterns for the two types of sentences and concluded that readers always pursue the same main clause analysis as predicted by the Minimal

Attachment Principle (FRAZIER, 1979), regardless of the semantic information, in compliance with Frazier's proposal, which establishes this principle as universal and strictly syntactic. The study reported in Maia *et al.* (2003) aimed to assess whether the Minimal Attachment preference also occurs in Brazilian Portuguese since an equivalent homonymy also occurs in this language with some irregular or abundant verbs which have identical participles and third person present tense forms. Thus, sentences as (3) would instantiate cases where the reader/listener would be garden-pathed, if the verb form '*suspeita'* were analyzed as simple present and not as past participle.

(3) Mother suspect of son's murder runs away[1]

The study also manipulated the [± human] features of the subject DP in the clause, aiming at assessing whether the parser could use semantic information in time to avoid the garden-path effect. Off-line and on-line experiments were applied. In both a general preference for the Main Verb interpretation was established, demonstrating the Minimal Attachment Principle. The manipulation of animacy semantic features did not influence the average reading times of the critical segments in the self-paced reading task. Maia (2013) investigated the same question using the eye-tracking technique with similar results, supporting the Minimal Attachment Principle.

Those studies explored one of the central issues in Sentence Processing, namely, the time course of subprocesses of language comprehension. It means determining whether the parser is strictly syntactic and serial in its initial analysis or whether it rapidly accesses parallel semantic, prosodic, pragmatic and discursive information in time to influence the syntactic analysis.

In section 2, we briefly review studies that are especially relevant to our research on the influence of the discursive context in sentence processing. Two psycholinguistic studies with speakers of Brazilian Portuguese, to assess the effects of the discursive context in processing, conducted at the Laboratory of Experimental Psycholinguistics (LAPEX - UFRJ / CNPq), are presented in sections 3 and 4, respectively. The first study analyzes the parsing of ambiguously attached Prepositional Phrases and detects effect of the previous discourse only in the off-line measures. The second study addresses the search for antecedent for the empty subject of inflected infinitive verbs, detecting the effect of the previous discourse both in off-line and on-line measurements. Finally, in the last section, we present our final remarks, discussing possible reasons for the differences between the discursive effects in the two experiments.

Sentence Processing and Discourse Context

As reviewed above, sentence processing studies have preferentially focused on experimental investigations of decontextualized utterances; presuppositions and default

[1] In the original: "*Mãe <u>suspeita</u> de assassinato do filho foge."*

principles of sentence processing have been established from on-line and off-line chronometric studies, exploring the access to different types of information, during sentence comprehension. However, in natural situations of verbal interaction, people rarely process decontextualized sentences. Sentences are enunciated and understood in specific pragmatic and discursive contexts. A productive line of research in the interface between the sentence and the preceding discourse in which the target material is produced demonstrates that discursive effects affect memory, with consequences for the analysis and interpretation of the sentence. In a highly cited paper, Sparks and Rapp (2010) review different linguistic cues that influence the activation and deactivation of concepts in memory, affecting language comprehension. According to these authors, these clues can be grouped in lexical, structural and gender-dependent factors.

In addition to the gauging of names and pronouns in the discourse to evaluate their impact on sentence comprehension, connectives have been usually included, among the relevant lexical clues, in order to assess their specific effects on sentence processing, influencing the coherence relations between the relevant segments. Sanders and Noordman (2000) experimentally demonstrate how different types of coherence relationships can affect text comprehension. Also exploring coherence relationships, Spark and Rapp (2010) discuss how text titles influence their reading, reviewing, among others, Hyöna and Lorch (2004), who demonstrate this effect through an eye-tracking experiment. In Brazilian Portuguese, Maia (2008) reports an eye-tracking image monitoring experiment in which 27 subjects were exposed, for 10 seconds, to a series of images containing [human animate], animated human [+ animated + human] elements. The independent variables of the experiment were two, namely: (1) Properties of the stimulus (couple, dog, nothing) and (2) Previous title (house, stones, nothing). The 3x2 experimental design combined the three levels of factor (1) with the three levels of factor (2), producing nine experimental conditions, each of which was tested in three subjects, totaling 27 subjects (9x3). The image presented for the subjects for ten seconds was the picture "Idílio", by Tarsila do Amaral, and the image was manipulated with Photoshop software to generate three levels of independent variable (1). In one of them, the image presented a couple (original image), in a second type, the couple was replaced by a dog, and in the third there was neither the couple nor the dog. Independent variable (2), previous title, consisted of the presentation for five seconds before image display, of one of three screens, containing the title "House on the hill", "Stones in the stream" or no title). The experimental task consisted of observing the image and immediately writing a paragraph, reporting the content of the image observed.

Each version could be preceded or not by written information that remained on the screen for 5 seconds, indicating the title of the image. Each subject then reported what he/she had seen, registering saccadic fixations and movements (on-line measurements), as well as the final report (off-line measurement). The results obtained allowed us to conclude that the previously presented topics (top-down effect), although influencing the off-line measure, do not surpass the bottom-up structural traits in the on-line scan. Structural cues, certainly, also affect the coherence of texts, but, as Sparks and Rapp

(2010) analyze, instead of using lexical items for this purpose, the organizational structure of the text is manipulated to obtain the effects desired(?). In addition to the basic syntactic constituents of the sentence, as subject, verb, object, adjuncts, higher-level structures such as narrative structure, plot, characters are also included in this category, often articulated with spatial and temporal dimensions, as well as with circumstances of cause and purpose, which have an impact on the mnemonic accessibility of textual elements. For example, Rapp and Taylor (2004) report story-based experiments, whose results indicate that accessibility to spatial information would be related to temporal information, and conclude that these dimensions interact, affecting the representation structure in memory.

The clues related to the textual genre constitute a specifically discursive factor. Different types of narrative can produce different types of mental modeling of discourse. As discussed by Sparks and Rapp (2010), the genre "tragedy" usually has an expected final outcome, while the comedy genre is usually more unpredictable. Expositional materials, such as scientific articles, textbooks, newspaper columns, are characterized by a detailed structuring of concepts and facts, triggering more specific and objective analyses of causes and consequences. Violations of expectation in texts impose surprise effects that undoubtedly affect processing. Wolfe (2005), among other works reviewed in Sparks and Rapp (2010), studies the organization of texts, in tests that indicate that the previous and the most recent semantic associations in the structure of a text influence the mnemonic model in a different way.

In general, prior knowledge of the receiver significantly influences the processing of the text. The knowledge of concepts and facts stored in long-term memory affects performance in the reading or listening comprehension of texts, being active, for example, in the construction of connections between concepts, in the interpretation of ambiguous constructions or in the evaluation of the degree interpretive statements. Even recent knowledge, for example, those that can be controlled in materials exposed in experiments often have effects on comprehension tasks. For example, the study by Snyder (2000) controls the presentation of sentences with different types of syntactic islands[2] in questionnaires for judgment, observing an effect of accommodation or satiation by the subjects, as they found instances of these islands in the questionnaire. The islands presented at the beginning were judged to be less acceptable than the islands at the end of the questionnaire, exemplifying a case of more recent experiences already affecting subsequent assessments. In Brazilian Portuguese, the study reported in Barile and Maia (2008) controlled not the presentation of materials in a chronometric experiment of acceptability judgment of sentences with syntactic islands, but the groups of subjects exposed to such sentences. One of the groups consisted of Linguistics students, with explicit knowledge of the grammatical phenomenon of the syntactic

[2] Syntactic islands, first described in Ross (1967) are phrasal contexts that block the extraction of constituents. For example, a question like "What book did John find the teacher who wrote it?" is generally judged as agrammatical, since the constituent 'Which book' would have moved from the position after the verb 'wrote', needing to jump on more than two barriers, according to grammatical theory.

islands, obtained in a Syntax course, part of their curriculum. The other group consisted of Engineering students, without any knowledge of this phenomenon. In the between-group analysis, the difference between the average decision times for the negative assessment of the experimental sentences was significant, demonstrating that the subjects of the Linguistics group, with metalinguistic awareness of island constructions, were more reluctant to reject islands than the Engineering group.

This section has established the dichotomy that has characterized the area of Psycholinguistics known as Sentence Processing, already alluded to in the Introduction, which will serve as a reference framework for evaluating the results of the experiments to be reported in the next section, in we which seek to measure effects of the previous discursive context on sentence processing. This area has been marked by an opposition between two classes of incompatible models. On the one hand, models based on the symbolic paradigm, such as the Garden Path Theory - GPT (FRAZIER; FODOR, 1978; FRAZIER, 1979; FRAZIER; RAYNER, 1982), assume a two-stage processor (parsing and interpretation), proposing initial, serial and incremental syntactic analysis, based on simplicity metrics, delaying the access to semantic and pragmatic information for the interpretative, post-syntactic phase. On the other hand, connectionist models, based on the network paradigm, propose that the processor activates multiple sources of information in parallel (MACDONALD; PEARLMUTTER; SEIDENBERG, 1994; TRUESWELL; TANENHAUS; GARNSEY, 1994; TRUESWELL; TANENHAUS; KELLO, 1993) that can compete with one another, producing activations with different weights. The studies reported below will be discussed in the general framework of this dichotomy, especially regarding the temporal course of access to linguistic information during the on-line comprehension of sentences in Portuguese, using chronometric methodologies designed to capture and analyze processes at the moment they are taking place.

Pressuppositional effects in the processing of structurally ambiguous Prepositional Phrases

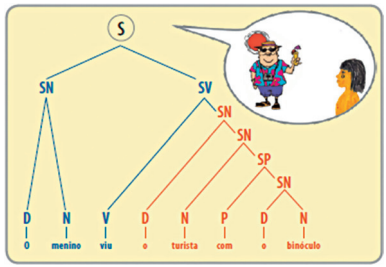
In this section, we will briefly report the study originally published in Maia *et al*. 2003, and also revised in Maia (2013). In this study we investigated a classic type of syntactic attachment ambiguity, as the sentence exemplified in (4) below, in which grammar allows both the attachment of the PP "with binoculars" as an adverbial adjunct, and as an adnominal attachment to the object DP, the tourist:

(4) The boy saw the tourist with binoculars[3]

Note that this sentence allows two syntactic analyses, which respectively produce two distinct interpretations, as illustrated below (MAIA, 2006):

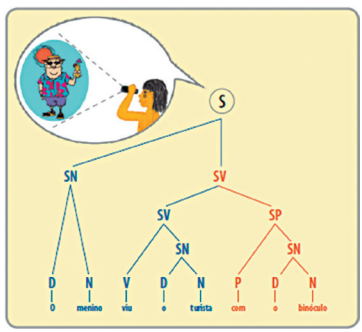
[3] In the original: "*O menino viu o turista com o binóculo."*

Figure 1 – The tourist has the binoculars



Source: Maia (2006, p.98).

Figure 2 – The boy has the binoculars



Source: Maia (2006, p.99).

In English, Clifton, Speer and Abney (1991) use both self-paced reading and eye-tracking techniques to demonstrate a faster preference for the attachment of the PP to the verb than for the attachment to the DP, as predicted by the Minimal Attachment Principle. Crucially for the questions examined in the present article, Maia *et al.* (2003) also included in the test *design*, conditions that aimed at verifying whether attachment preferences could be influenced by the discursive context. The authors manipulated pragmatic presuppositions in order to make PP attachment to DP more or less plausible.

As reported in Maia *et al.* (2003) and revised in Maia (2013), questionnaires were applied to first establish the interpretation preferences of readers between the two grammatically possible analyses. The authors also manipulated the previous context. Forty undergraduate students received two versions of questionnaires containing 20 experimental sentences, as those exemplified below, distributed in a Latin square design among 40 fillers:

Chart 1 – Questionnaire study

1a - Context – Plausible:

Havia um turista no parque. O policial viu o turista com o binóculo.
"There was one tourist in the park. The policeman saw the tourist with binoculars"

1b - Context +Plausible:

Havia dois turistas no parque. O policial viu o turista com o binóculo.
"There were two tourists in the park. The policeman saw the tourist with binoculars"

Quem estava com o binóculo?

Source: Author's elaboration.

The -Plausible context, exemplified in (1a), mentions a single referent, whereas the +Plausible context, in (1b), mentions two referents, intending to increase the plausibility of a DP attachment of the PP. If there were two tourists in the park, it would be more likely to attach the PP to the DP. The results, presented in Table 1 (below), show the answers to the questions computed according to context effects:

Table 1 – Results and percentages per experimental condition

Plausibility	PP to VP	PP to DP
- Plausible	259 / 64,9%	141 / 35,1%
+ Plausible	219 / 54,9%	181 / 45,1%

Source: Author's elaboration.

It should be noted that, even in the + Plausible context, there is no preference higher than 50% for the DP ($p < 0,05$). Nevertheless, context had a robust influence on the answers: In the + Plausible context there was a significant increase in the preference for DP attachment ($t(399) = 2,90$; $p< 0,01$).

In the most plausible condition, there are less pronounced differences in favor of high attachment, computing a significantly higher number of low appositions, which indicates an interaction between the manipulation of the number of referents in the previous context and the choice of the low attachment of the PP, specifying the DP.

However, in a questionnaire study which is restricted to an interpretive evaluation which necessarily takes place after the on-line processing of the sentence, nothing can be learned about the processing phase *per se*. Even though, a significant interaction between the context and the attachment decision was observed, such a difference in interpretation could be reflecting a reanalysis effect, since the on-line processing of the

sentence was not monitored. In other words, the parser could have committed itself to a minimal attachment analysis, and then revised its initial decision to consider the pragmatic factor, namely, the existence of more than one referent in the discourse.

In order to verify if this effect registered in the questionnaire study could also be identified already in the initial phase of the syntactic parsing, an online self-paced reading experiment was performed, which recorded the average reading times of the parts in which sentences were divided, allowing hypotheses to be formulated about the temporal course of processing.

A self-paced reading experiment was designed, in which 24 subjects were asked to read, in a natural and fast manner, two segmented sentences, as indicated by the oblique bars, in the examples below. Each subject was exposed to 16 experimental sentences, presented randomly with 32 distractors, totaling 48 sentences[4]. The experimental sentences were distributed in four conditions; namely, +PL (+ plausible low), +PH (+plausible high), –PL (–plausible low) and –PH (–plausible high).

Frame 2 – Examples of materials in the SPR study[5]

(2a) +PL: There were two tourists in the park./The policeman/saw the tourist /with an open wound.
(2b) +PH: There were two tourists in the park./The policeman/saw the tourist/with the black binoculars.
(2c) –PL: There was a tourist in the park./The policeman/saw the tourist/with an open wound.
(2d) –PH: There was a tourist in the park./The policeman/saw the tourist/with the black binoculars.

Source: Author's elaboration.

After reading each sentence, whose segments were presented in a non-cumulative manner, by pressing the yellow key in the button box[6] connected to an Apple Macintosh computer, there was an interpretation question about the sentence. The question should be answered by pressing either the green key (yes) or the red key (no) in the button box. The experiment intended to test two hypotheses: (a) the Minimal Attachment Principle, which predicts the immediate preference for high PP attachment; (b) the interference of non-structural factors, such as the pragmatic assumption, in on-line processing. Hypothesis (a) would be confirmed if the reading of the PP, presented in segment 4 of

[4] As it is generally the case in experimentation, fillers were included in a proportion of 2/3 of the set of the materials, in order to try to avoid that participants become aware of the questions being tested, which could cause satiation effects and influence results, leading to error.

[5] In the original:
(2a) +PL: *Havia dois turistas no parque./O policial/viu o turista/com a ferida aberta.*
(2b) +PH: *Havia dois turistas no parque./O policial/viu o turista/com o binóculo preto.*
(2c) –PL: *Havia um turista no parque./O policial/viu o turista/com a ferida aberta.*
(2d) –PH: *Havia um turista no parque./O policial/viu o turista/com o binóculo preto.*

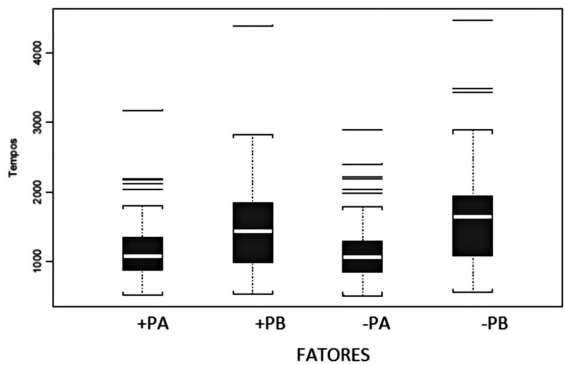
[6] A *button-box* is a device that allows the precise recording of reading or reaction times through button pressing, in psycholinguistic experiments.

each experimental sentence, was slowed under conditions where a low reading was forced than under conditions where high attachment was possible.

This should occur because, being operative in Portuguese, the Minimal Attachment Principle would determine that the attachment of the PP would be initially made, as default, to the VP. Initially committing to this analysis, the readers would enter a garden-path in the sentences in which the reading was forced low, needing to review their initial analyses. Both the surprise effect of being in the garden-path and the revision of the initial syntactic attachment decision would require more mental operations than would be required to process the sentences in which high attachment was admitted, determining the longest reading of PPs in low conditions. Hypothesis (b) would be confirmed if significant differences were detected in PP reading times between + P and -P conditions. For example, the PPs in the -PL condition should record higher average reading times than the PPs in the + PL condition, if the referential presupposition clue was taken into account quickly, just as it appears to have occurred in the off-line task .

As can be seen in the graph below, which indicates the average reading times of the critical segments (segment 4) for each condition, the experiment showed that the Minimal Attachment Principle is also operative in this type of ambiguous structure in Portuguese. The experiment showed that there was no significant interaction between the information regarding the pragmatic assumption and the preferential syntactic apposition of the PP. It should be noted that the conditions under which the low attachment was forced show the highest reading times, as predicted. The crosses -PH x -PL presented significant differences, as did the crosses + PH x + PL. Also the crossing of PH (+ PH and -PH) and PL (+ PL and - PL) was significant, indicating a main effect of the interaction between high or low PP attachment and reading times indicative of the garden-path effect and reanalysis, as predicted. However, the crosses -P x + P are not significant, neither with respect to the crossing of -PH x + PH ($p = 0.8505$), nor with respect to the crossing of -PL x + PL ($p = 0.1244$).

Graph 1 – Average reading times of critical segment 4



Source: Author's elaboration.

Graph 1 suggests that sentences with B (low attachment) have longer average reading times. An ANOVA[7] with a factor (whose levels were the types of sentences) showed a significant result (F (3,355) = 18,03, p = 0). This means that there are differences in reading times for each type of sentence. Since the sentences with B (low attachment) present longer reading times than the sentences with A (high attachment), the reading times were analyzed, considering the factor with levels A and B, using a 2x2 ANOVA. The results of the analysis with A vs. B and plausibility as factors within subject showed a main effect of A vs. B (high x low attachment), yielding significant results in the ANOVA (F (1,356) = 49.62, p = 0) with sentences A (1148.6ms) showing significantly lower reading times than the B phrases (1563.7ms). The main plausibility effect, in contrast, did not present a statistically significant result (F (1.356) = 1.61, p = 0.21).

These results indicate that the effect of the pragmatic assumption obtained in the off-line experiment did not occur in the syntactic parsing, but only in the interpretive phase of comprehension, suggesting that the parser is impervious to this type of non-structural information. As we shall see, in the next section, however, there is semantic information that, occurring prior to a critical area in the sentence, can, in effect, influence both its interpretation and the reading patterns in on-line measurement.

Semantic effects in the reading and interpretation of subjects of inflected infinitive verbs in Brazilian Portuguese

The report of the following experiment was translated and adapted from Modesto and Maia (2017), presenting an eye tracking study of the reading of sentences containing inflected infinitive verbs in Brazilian Portuguese. In that study, the authors examined the syntactic representation and processing characteristics of null subjects of inflected non-finite sentences in Brazilian Portuguese (BP). After reviewing the relevant syntactic, sociolinguistic, and psycholinguistic literature and discussing the diachronic peculiarities of BP, the authors analyzed the results obtained in the eye tracking experiment, arguing that they show that the controlled interpretation of the subject of the inflected infinitive is not only psychologically real, but also the preferred option in a task where the controlled reading is compared to the arbitrary reading. It is exactly the difference between these two readings, prompted by the context before the sentence in which the inflected infinitive verb was found, which we will focus on in this section.

The eye tracking experiment examined the reading of sentences consisting of a contextualizing subordinate clause, a main clause, and a final clause containing a sentence with a verb in the inflected infinitive. The objective of the experiment was

[7] ANOVA or Analysis of Variance is a statistical test that allows to measure differences between averages obtained for independent variances in an experiment, establishing main effects and interactions.

twofold. First, the authors sought to investigate the effect of mandatory control contexts on sentence processing in relation to contexts favoring indeterminate, arbitrary and referential readings. Secondly, the number agreement between the subject and the verb in the inflected infinitive was manipulated to assess whether the agreement in the singular would totally block a control reading of the sentence or whether a partial control interpretation would still be allowed.

The hypothesis was that the latencies of the first-pass reading measurements (Total Fixation Durations) would be longer in the non-control conditions than in the control conditions, reflecting the higher processing cost of not establishing a local control syntactic relationship, which should be the standard preference in sentence processing. Consistent with the hypothesis that the local control relationship should be preferred as the default in sentence processing, it was also expected that the latencies of the regressive measures for the contextualizing subordinate clauses should be longer in the conditions of non-control interpretation than in the control conditions, reflecting the higher cost of inferential processes vis-à-vis the computation of local grammatical relations. It was also predicted that the questions of interpretation (off-line), which always aimed at the reference of the empty category in the sentence with the inflected infinitive (PRO), should indicate preference for the interpretation of control in the experimental conditions of control, in contrast to the preference for uncontrolled inferential interpretation, under non-control conditions, since the off-line interpretation measure must, in principle, be able to capture post-syntactic integrative processes.

Method

Participants

Forty undergraduate students from the Federal University of Rio de Janeiro voluntarily participated in the experiment, for earning course credit. All were native BP speakers with normal or corrected vision and no history of reading problems.

Materials and Design

A total of 16 sets of experimental sentences as shown in Table 3 were created. Each sentence was followed immediately by an interpretation question that investigated the referent of the empty category in the subject position of the sentence with the verb in the inflected infinitive. Examples of the corresponding questions for the sentences exemplified in Table 3 are shown in Table 4. All experimental sentences consisted of an initial subordinate clause followed by a main clause and a sentence with the verb in the inflected infinitive. There were two independent variables crossing, in a 2x2 design, that is, the control context variable, which had two levels, mandatory

control (O) or no control (N) and number agreement, which could be singular (S) or plural (P). The intersection of these two independent variables, each with two levels, generated four conditions: No Control Plural (NP), Obligatory control Plural (OP), No Control Singular (NS), Obligatory Control Singular (OS). The noncontrol conditions were additionally manipulated in terms of two subconditions: 8 sentences had a referential DP in the subordinate clause, which could potentially be the PRO controller, in the sentence with the inflected infinitive, and another set of 8 sentences did not include such referential DP in the subordinate clause, forcing an exclusively arbitrary interpretation for the PRO.

Obligatory control sentences always contained, in the initial subordinate clause, a verb whose cataphoric subject was the subject DP of the main clause. This DP constituted a semantically plausible subject for all the verbs in the sentence: the verb of the subordinate clause, the verb of the main clause and the inflected infinitive verb in the final clause of the sentence. Uncontrolled clauses, on the other hand, should not allow the possibility that the subject of the main clause could also be the cataphoric subject of the verb of the previous subordinate clause. Uncontrolled clauses always present a subject DP in the main sentence, which for semantic reasons could not be the controller of the empty category PRO in the non-finite clause. In the adjunct clause, in the uncontrolled clauses there was not a semantically plausible DP, neither was there a DP that could plausibly be a distant antecedent to the PRO. The independent variable 'number' included a level at which the DP subject and the main clause verb agreed in the plural (P) and a level at which the subject DP and the main clause verb agreed in the singular (S).

The verbs of the subordinate clauses, as well as the verbs in the inflected infinitive, were always in the plural. The experimental sentences were distributed in a Latin square, generating four versions of the experiment. In addition, other 32 sentences with different types of structures were created to serve as distractors. For both the experimental items and the distractors, the length of the sentence was controlled to be within a range of 25 to 30 metric syllables. The 48 sentences (16 experimental and 32 distractors) in each version were pseudorandomized to be presented in a fixed order, but always intercalating distracting sentences among the experimental sentences and ensuring that the first and last two sentences were never experimental sentences.

Frame 3 – Examples of experimental sentences[8]

Cond		Subordinate clause (adjunct)	Main Clause	Inflected infinitive verb clause
NP	arb	*Como os feridos foram achados logo*	*os repórteres julgaram*	*Terem salvo muitas vidas*
	ref	*Só quando os bebês foram examinados*	*Os cuidadores perceberam*	*Terem sujado as fraldas*
OP		*Como chegaram logo ao local da queda*	*Os bombeiros julgaram*	*Terem salvo muitas vidas*
NS	arb	*Como os feridos foram achados logo*	*o repórter julgou*	*Terem salvo muitas vidas*
	ref	*Só quando os bebês foram examinados*	*o cuidador percebeu*	*Terem sujado as fraldas*
OS		*Quem salvou muitas vidas? (A) o bombeiro (B) outras pessoas*		

Source: Author's elaboration.

[8] NP arb As the wounded were found soon, the reporters judged having saved many lives
NP ref Only when the babies were examined, the caretakers realized (they) had dirtied their diapers
OP As (they) arrived promptly at the scene of the fall, the firefighters realized (they) had saved many lives
NS arb As the wounded were found promptly, the reporter judged (they) had saved many lives
NS ref Only when the babies were examined, the caretaker realized (they) had dirtied their diapers.
Who saved many lives? (A) The firefighter (B) other people

Frame 4 – Examples of interpretation questions[9]

Cond		Interpretation question	
NP	arb	*Quem salvou muitas vidas?*	*(A) os repórteres* *(B) outras pessoas*
	ref	*Quem sujou as fraldas?*	*(A) os cuidadores* *(B) outras pessoas*
OP		*Quem salvou muitas vidas?*	*(A) os bombeiros* *(B) outras pessoas*
NS	arb	*Quem salvou muitas vidas?*	*(A) o repórter* *(B) outras pessoas*
	ref	*Quem sujou as fraldas?*	*(A) o cuidador* *(B) outras pessoas*
OS		*Quem salvou muitas vidas?*	*(A) o bombeiro* *(B) outras pessoas*

Source: Author's elaboration.

Procedures

A TOBII TX300 eye tracker monitored participants' eye fixations and movements. Subjects viewed the stimuli binocularly on a 23-inch monitor, 65cm apart. The sentences were written in font Courier New 28pt (True Type) and were displayed on the screen in a single line. Before starting the experiment, subjects read instructions

[9] NP arb Who saved many lives? (A) the reporters (B) other people
NP ref Who dirtied the diapers? (A) the caretakers (B) other people
OP Who saved many lives? (A) the firefighters (B) other people
NS arb Who saved many lives (A) the reporter (B) other people
NS ref Who dirtied the diapers? (A) the caretaker (B) other people
OS Who saved many lives? (A) the firefighter (B) other people.

on how to perform the test. Participants were instructed to read the sentences at a very fast pace, but trying to understand the text, as they would be asked to answer an interpretation question at the end of each sentence. By pressing the spacebar on the keyboard, the participants monitored the duration of each sentence on the screen. To ensure a quick reading of the sentences, a timeout of 2 seconds was established, after which the sentence was replaced on the screen by the interpretation question. Participants were then instructed to try to read the sentences as quickly as possible and try to press the keyboard bar before the timeout. Thus, after reading the sentence, the subjects would typically press the bar before the timeout, to call another screen that contained a question with two possible answers, each preceded by (A) and (B). Subjects were instructed to press the key marked with (A) or with (B) on the keyboard. If the subjects took longer than the time limit to press the spacebar, the screen with the interpretation question would appear automatically. A timeout of 5 seconds was set for the interpretation questions screen.

After the instructions there was the calibration phase, which consisted in asking the subject to eye track a red ball moving (bouncing?) around the screen. If the calibration was successful, as indicated by a screen after the calibration session, the experimenter would initiate a training session; otherwise, a recalibration session would take place. The practice session consisted of three sentences that were observed by the experimenter. If the experimenter approved the subject's procedures and he confirmed that he understood the instructions well and could do the experiment, the instructor would start the experiment and leave the room. A complete session usually lasted 25 to 30 minutes.

Results and Discussion

The full results of this study and its respective statistical analyzes are available in Modesto and Maia (2017). In the present article, we intend to focus on the results that are more directly relevant to the topic we are discussing, regarding the influence or not of the discursive context in sentence comprehension.

Next, we present the differences found in the average fixation durations between the sentences in the OP, OS, NP ref, NP arb, NS arb and NS ref conditions, exemplified below:[10]

[10] OP: As (they) arrived promptly to the place of the fall, the firefighters judged having saved many lives
OS: As (they) arrived promptly to the place of the fall, the firefighter judged having saved many lives
NP ref: When the terrorists arrived to the base, the pilots realized (they) were armed.
NP arb: When the data arrived to the base, the scientists realized (they) were in orbit.
NS ref: Only when the babies were examined, the caretaker realized (they) had dirtied the diapers.
NS arb: When the selection was cancelled, the candidate judged (they) were ill intentioned.

OP: Como chegaram logo ao local da queda, os bombeiros julgaram terem salvo muitas vidas

OS: Como chegaram logo ao local da queda, o bombeiro julgou terem salvo muitas vidas

NP ref: Quando os terroristas chegaram na base, os pilotos perceberam estarem armados.

NP arb: Quando os dados chegaram na base, os cientistas perceberam estarem em órbita.

NS ref: Só quando os bebês foram examinados, o cuidador percebeu terem sujado as fraldas

NS arb: Quando o concurso foi cancelado, o candidato julgou estarem mal-intencionados.

Total fixation durations and percentages of decisions in off-line questions can be found in Table 2:

Table 2 – Total fixation durations and percentage of control decisions per condition

Cond	OP	OS	NS ref	NS arb	NP ref	NP arb
Duration	1459 ms	1550 ms	1584 ms	1667	1724	1806
Control Int	83%	62%	24%	29%	28%	36%

Source: Author's elaboration.

The results obtained for the averages of the total durations in the reading of those sentences, by condition, allows us to arrange them according to the following scale in ascending order of average fixation durations, in which significant differences between these durations were found in the statistical analysis.

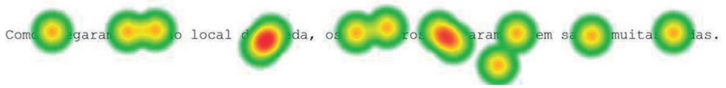
Frame 5 – Ascending ranking of fixation durations per condition

OP < OS < NS ref < NS arb < NP ref < NP arb

Source: Author's elaboration.

Those sentences are now examined in detail. As explained above, the obligatory sentences O always contained, in the initial subordinate sentence, a verb whose cataphoric subject was the DP subject of the main sentence, which constituted a semantically plausible subject for all verbs in the sentence. Having a local controller for the empty category in the subject position of the sentence with the inflected infinitive (PRO have saved many lives), the OP clauses obtained the fastest reading as demonstrated in the heatmap of a typical reading in Figure 3:

Figure 3 – OP: As (they) arrived at once in the place of the fall, the firefighters judged (they) had saved many lives

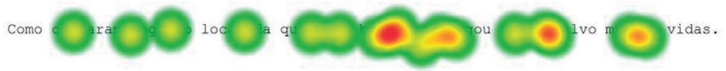


Source: Author's elaboration.

That is, when the processor encounters the DP firefighters, he/she evaluates its referential relevance as the subject of all verbs in the sentence (firefighters arrived, firefighters judged and firefighters saved many lives). This reference analysis has an impact on the reading during its realization, resulting in a resolution of the coreference with ocular fixation times relatively smaller than all other conditions. In the off-line measure, which sought to always probe the possibility of interpretation of control (the firemen saved), this condition obtains the highest rate of control interpretation.

Let us look now the heatmap of a sentence in the OS condition:

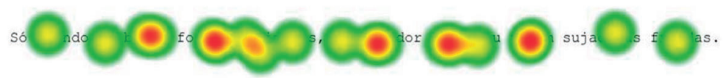
Figure 4 – OS: As (they) arrived at once at the place of the fall, the firefighter judged (they) had saved many lives



Source: Author's elaboration.

The sentences of this condition take significantly longer to read than the OPs, since number agreement is incompatible between the subject DP of the main clause and the inflected infinitive clause. However, partial control is still possible and the coreference in this condition is resolved at shorter reading times than in the N conditions, in which one tries to avoid the relation of control of the empty category in the subject position of the verb in the inflected infinitive. The number mismatch was intended to block the interpretation of the local control requiring, therefore, a more exhaustive visual search for a controller for the PRO. As they do not find a possible local controller in an N sentence, readers should invoke arbitrary reading as a last resort. In any case, this condition obtained the second highest rate of control interpretation, although partial, in the off-line measure. Accordingly, in NS ref, there is a progressive increase in the fixation durations in the reading of the sentence:

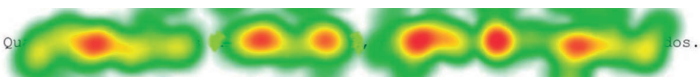
Figure 5 – NS ref: Only when the babies were examined, the caretaker realized (they) had dirtied the diapers



Source: Author's elaboration.

It should be noted that, in this sentence, we tried to block the possibility that the subject DP of the main clause (the caregiver) could not control the empty category in the subject position of the verb in the inflected infinitive through formal resources (agreement mismatch). However, in this condition a plausible DP (the baby) was placed in the subordinate clause to practice the action of the inflected infinitive verb (which had not dirtied diapers), unlike the subject DP of the main clause (the caregiver) that would not be likely to practice this action. This manipulation of plausibility, which is not present in the OS condition or OP condition, required longer fixation times than the previous conditions, indicating that the semantic processing occurred on-line, with consequences also for the off-line interpretive measure, which falls significantly in control percentage. In NS arb, as indicated in the heatmap below, the fixation durations rise even further:

Figure 6 – NS arb - When the selection exam was cancelled, the candidate judged (they) were ill intentioned

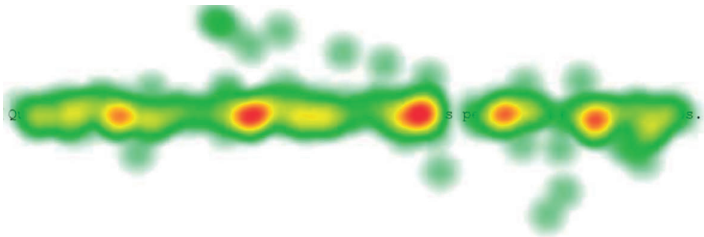


Source: Author's elaboration.

In this case, the number agreement mismatch between the subject DP of the main clause (the candidate) and the verb in the plural inflected infinitive is maintained. However, unlike the NS ref condition, there is no plausible antecedent to control the verb in the inflected infinitive. The search for a referential antecedent causes even longer time periods for the resolution of the coreference in the sentence than in the previous conditions. Finally, the possibility of arbitrary interpretation (other people were malicious) seems to be accessed, as indicated by the low percentage of interpretation of control in the interrogative questions.

In the NP ref condition, the agreement between the subject DP of the main clause and the inflected infinitive verb seems to make the search for a local controller even more costly because it is misleading. Thus, the initial search for a local controller is discarded because it is not semantically plausible. The search then proceeds to find a possible controller in other areas of the sentence, finding greater semantic plausibility in the subject DP of the subordinate clause. Again, there is a semantic effect on the on-line measure. Fig. 7 shows the heatmap of a NP ref. sentence.

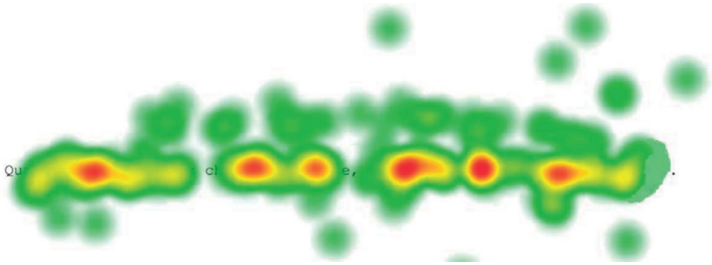
Figure 7 – NP ref: When the terrorists arrived at the base, the pilots realized (them) to be armed



Source: Author's elaboration.

Finally, Figure 8 illustrates the heatmap of an NP arb sentence, which demands the longest average fixations of all conditions, since there is no semantically plausible DP in the sentence that could be the appropriate controller for the PRO. The arbitrary interpretation of the PRO is the most costly for the processor because it requires intense visual scanning in the search for a plausible DP. The parser resorts to an arbitrary interpretation only when this search proves fruitless.

Figure 8 – NP arb: When the data arrived at the base, the scientists realized (they) were in orbit



Source: Author's elaboration.

Final remarks

In the present article, we sought to review the role of discursive context in sentence processing. Two experiments were presented with on-line and off-line measurements in which pragmatic or semantic plausibility factors were manipulated. In the first experiment, it was observed that the construction of the syntactic tree in the parsing process was not affected by manipulated assumptions, which sought to influence the attachment rates of a PP to the local DP and not to higher VP. The results of the self-paced reading study, as seen, did not indicate that the manipulated presuppositional factors were accessed in time to influence the sentence syntactic analysis, and it was

only in the final measure, in the post-parsing interpretive phase, that an influence of pre-sentence presuppositions was observed. In the second study, on the other hand, it was possible to observe effects of the semantic reference of DPs in on-line, as well as in off-line measurements. As discussed in the previous section, the semantic plausibility that a DP could be selected by a verb as its agent determined significant differences in the visual scan of the sentence, with consequent differences in the mean times of ocular fixation in reading.

Before concluding, we shall suggest a possible explanation for this apparent conflict in the access to discursive semantic and/or pragmatic information by the syntactic processor. As we have seen, the field of sentence processing has been characterized by structural models such as the GP theory, which proposes that the initial analysis of the sentence is not influenced by semantic factors, in contrast to more interactive models that admit the influence of semantics already in the initial analytical processes.

In addition, we also speculate whether an evaluation of these models based on the two studies reported in this article is inconsistent or inconclusive, not allowing proof or rejection of either type of model. A closer comparative analysis of the two experiments presented here may offer reasons to assess this contradiction as only apparent, as indicated above. It should be noted that in the first experiment what is at stake is the construction of the syntactic tree by the parser, which offers a rapid analysis to be interpreted in a second more integrative moment of comprehension, when the interpretation of the sentence is made, precisely considering the syntactic structure composed by the parser. The initial syntactic analysis is proven to be rapid, performed on a millisecond scale. In order to achieve this speed, it is necessary to restrict the information that is initially accessed, and then revise the initial analysis, if necessary. The initial analysis must therefore be restricted to the minimum information needed to build the tree. On the other hand, in the second experiment, there is no syntactic tree construction, but the establishment of semantic references and coreferential relationships. As evaluated by Nicol (1988), in his seminal work about the sub-area of anaphoric coreference, it would be possible to think that the establishment of coreferential relations is an intermediate module between the structural syntactic analysis and the interpretative processes, in sentence comprehension. By all means, in order to process these relationships, it is necessary to inspect the structure, evaluating, for example, syntactic licensing, such as those proposed in the Binding Theory (CHOMSKY, 1981), but it is necessary to go beyond this structural inspection, in order to satisfy the interpretability of the sentence. If such an architecture of the processes of language comprehension is true, there is no longer any reason to believe that the two experiments are contradictory: the influence of the discursive context is not observed in the on-line capture of the initial tree-building syntactic analysis, but can be observed in on-line measurements, in the establishment of referential and co-referential relations that intermediate the structural processes and the interpretative phases of sentence comprehension.

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MAIA, M. Sentence processing and discourse context. **Alfa**, São Paulo, v. 63, n.3, p.565-588, 2019.

- *RESUMO: Investiga-se o curso temporal dos subprocessos da compreensão de frases, procurando-se determinar se o processador é estritamente sintático em sua análise inicial ou se já acessa informações de natureza semântica e discursiva a tempo de influenciar a análise sintática. São reportados dois estudos com falantes de português brasileiro, para aferir efeitos de contexto discursivo no processamento. O primeiro revisita o processamento de Sintagmas Preposicionais ambíguos e encontra efeito do discurso prévio apenas nas medidas finais, que monitoram a interpretação. O segundo usa a técnica de rastreamento ocular (eye-tracking) para aferir a busca de antecedente para o sujeito de oração com verbo no infinitivo flexionado, encontrando efeito do discurso prévio tanto na medida final ou off-line, quanto na medida on-line. Discutem-se possíveis razões para as diferenças entre os efeitos de informações discursivas nos dois experimentos.*

- *PALAVRAS-CHAVE: Processamento sintático. Efeitos do contexto discursivo. Rastreamento ocular.*

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