





Processing of coreferential relations and their relationship with the working memory: the influence of syntactic distance on anaphora processing in Brazilian Portuguese

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Abstract

The aim of the present work was to investigate the processing of coreferential relations, focusing on their relationship with the working memory. In a reading process, it is essential that readers continuously perform mental operations that involve the working memory, such as storing, retrieving, and manipulating information. For this reason, it is understood that the processing of coreference resolution is closely related to the working memory. In this relationship between memory and anaphora resolution, the distance factor between the referent and anaphor can play a significant role as distance increases the processing costs when reading sentences. It is known that the working memory is limited; yet there is still no consensus among researchers regarding the nature of storable items. Moreover, the syntactic node, here taken as a representative of the structure of a phrase, was observed as possible storage and recoverable unit in the working memory. Thus, the objective of the study was to verify whether the syntactic distance factor, embeddings with one and two intervening syntactic nodes, is a storable unit in the working memory, investigating its influence in the processing of different anaphora resolution. The self-paced reading experimental technique was used in an experiment. Seventy participants, all university students, were tested individually and underwent a training session before the task. The results suggest that the syntactic distance is a relevant factor in the working memory with significant differences between conditions with syntactic distance concerning those with linear distance, indicating the formation of chunks. There was an increase in reading times depending on the number of intervening embeddings, and different processing costs for each type of anaphora resolution investigated.

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1. Introduction

Anaphoric coreference is a frequent linguistic resource, both in written and oral language, that ensures structural cohesion and semantic coherence when used in a text and it facilitates mental processing during reading tasks. Coreference can occur in different types of anaphora resolution, such as full pronouns and repeated names, as shown in the following examples:

- 1 **Pronoun** -Eva_i vendeu a casa. A tia achou que **ela**_i estava abatida.
Eva_i sold the house. The aunt thought she_i was dispirited.
- 2 **Repeated name** - Eva_i vendeu a casa. A tia achou que **Eva**_i estava abatida.
Eva_i sold the house. The aunt thought Eva_i was dispirited.

In addition to the type of anaphora resolution, other factors can also interfere in the processing of anaphoric coreference. One of these factors is the distance between the referent and resolution. In this case, a common investigation is the one that is present in some studies that observe only its linear aspect, that is, the distance measured by the number of intervening words between the antecedent and the anaphor (Queiroz & Leitão, 2008; Leitão & Simões, 2011). In the present study, we also analyzed syntactic distance, which has not been widely discussed in studies in Brazilian Portuguese (PB) (except in the study by Lima, 2015). We assume, then, that syntactic distance is superimposed on linear distance, and it is composed of intervening syntactic nodes that correspond to subordinate clauses in the sentence and placed between the antecedent and the anaphor.

The working memory is said to be a brain/mental component that temporarily stores information and it consists of storable and recoverable units. This component is responsible for maintaining information during processing, but it is different from long-term memory, as it retains information for only a few seconds. This component makes it possible for different information, including linguistic information, to be retained long enough for processing to occur.

Regarding anaphora processing, the antecedent must be retained in the working memory until an anaphor is identified in speech or text. At this moment, information related to the antecedent is activated in the working memory, enabling its recovery and consequent connection with the anaphor, thus establishing an anaphoric coreferential relationship. Hence, it may be concluded that processing is directly linked to the working memory, as retention of an antecedent is affected by the working memory, and an antecedent that requires more memory storage capacity will lead to higher processing costs in retention and recovery. Similarly, the processing of different types of resolution may also result in higher or lower processing costs, as they may have differences in the way in which they activate their respective antecedents. In addition, other factors, such as embedding, syntactic parallelism or grammatical features, can also play a decisive role in this process, as they can also result in differences in information storage and retrieval.

The relation between memory and anaphoric coreference, the distance factor, between the referent and anaphor, has been investigated by several researchers (Gordon, Hendrick & Levine, 2002; Leitão & Melo, 2011; Leitão & Simões, 2011; Araújo, 2019) in which linear distance increased processing costs when reading sentences, yielding different results depending on the type of anaphoric coreference. Furthermore, different types of anaphora resolution have presented different processing costs regarding the reading time, which may be higher or lower depending on the type of resolution. According to the Informational Load Hypothesis, proposed by Almor (1999), repeated names are more costly than full pronouns, which have been addressed in different studies (Almor, 1999, 2000). However, few studies have addressed the syntactic distance between the antecedent and anaphora resolution at a sentence level and their processing costs. Therefore, investigating whether syntactic distance, measured in intervening

nodes, interferes with the working memory to the point of influencing anaphoric coreference and whether there are processing differences between linear and syntactic distance is of singular importance. Thus, the present study considered two anaphoric forms, namely: full pronouns and repeated names. These were investigated and compared to each other in experimental sentences. Regarding the syntactic distance factor, we constructed sentences containing 1 or 2 intervening syntactic nodes between the antecedent and resolution in the experimental conditions. We also included control conditions to verify processing differences between syntactic distance and linear distance.

The hypothesis is that working memory is directly related to coreferential processing, and, therefore, can affect it to the extent that the different types of anaphors tested will yield in different reading times, even if they are in same syntactic position and referring to the same antecedent. The coreferential processing is subjected to factors that affect both the storage capacity of working memory and factors that influence the recovery of information in that same memory system. In this sense, we assume in this research that the syntactic distance is a factor that influences coreferential processing, either during online processing of different forms of anaphora resolution, or in the process of offline information retrieval in the working memory triggered during processing. This influence can affect the reading time to a greater or lesser extent when compared with sentences with linear distance.

Thus, the general objective of the study was to evidence the relationships between coreferential processing and the working memory by comparing sentences with linear distance and sentences with overlapping linear and syntactic distance with two types of anaphora resolution to observe the reading time in each type of sentence and possible differences between the anaphors in relation to the capacity for storing and retrieving information from the working memory. With regard to the specific objectives, the aim of the present article was to verify whether the distance between the antecedent and anaphora resolution affects the time that the individual spends to process the anaphoric relationship between the antecedent, pronoun and repeated name. In addition, we sought to verify if the syntactic distance interferes in the interpretation of the different types of resolution and if the interpretation of resolution is correct between the antecedent and resolution, and to show to what extent the intervening syntactic nodes constitute a storable unit in the working memory, thus affecting the processing of anaphoric coreference in adults in BP.

2. Theoretical Background

2.1. Anaphora processing

Leitão (2015) establishes that “anaphora processing deals with how anaphoric relationships occur in terms of cognitive processes (mental/brain)”, and the object of investigation is the functioning of “cognitive relations and the factors that are at stake when we hear or read texts with anaphors”. The study of the specificities related to the linguistic processing of anaphoric forms has helped us to understand how the mind/brain acts when understanding and producing language, and whether there are additional costs to the working memory related to storage, repetition and information recall.

As for reading, these studies have contributed to the perception that anaphors are not only different in their written form or function, but also in terms of processing due to the occurrence of anaphors that require more or less processing costs. These processing differences were evident in several studies, such as those by Simões & Leitão (2014), Leitão (2005), Queiroz & Leitão (2008), Farias, Leitão & Ferrari-Neto (2012) and Lima (2015), in which several types of anaphora resolution were tested and different processing costs pointed to differences in the way they are processed.

Although the types of anaphora differ from the way they are processed, there are still differences among sentences with same anaphors. This is because there are other factors at play in the mental operations underlying coreferential processes. Among them, we can mention the type of anaphoric form, in addition

to structural factors, such as parallelism (Chambers & Smyth, 1998; Yang, Gordon & Hendrick, 1999; Lima, 2014; Barbosa, Gondim & Lima, 2016) or semantics, such as the animacy features of the antecedent (Mak, Vonk & Schriefers, 2002; Leitão, 2010; Cabral, Leitão & Kenedy, 2015). One of these structural factors is the distance between the antecedent and the anaphor that, as pointed out by Leitão and Melo (2011), proved to be significant in some studies (Leitão, 2005; Leitão & Simões, 2011; Vasconcelos & Leitão, 2012). Some theoretical models have been proposed to explain the role of these factors in anaphora processing, thus hypothesizing how these factors influence the process of establishing a connection between the antecedent and anaphor. These models are explained below.

2.1.Theories on anaphora processing

The Centering Theory, originally proposed by Grosz et al. (1983) and further developed by Gordon and Chan (1995), proposes that the reference standards have the fundamental function of establishing coherent discourse. The theoretical model establishes that the totality of entities referred to in a sentence function as discursive centers. Discursive centers are all entities present in a statement, which can be classified into two types: anaphoric centers (backward-looking centers or Cb), which move to connect to a previous sentence, and cataphoric centers (forward-looking centers or Cf), which form a group of entities that act as latent anaphoric centers (Cb) for later utterances.

The Centralization Theory proposes that pronouns are the preferential linguistic unit used as anaphoric centers as they have the function of establishing coherence. The use of the pronoun as an anaphoric center is because this anaphoric form allows its referent to be established based on the structural and semantic aspects of the statements. In contrast, the use of the repeated name as an anaphoric center only carries lexical information and does not need other aspects to establish a connection with its referent in a text.

Thus, studies based on experiments using self-paced reading techniques have shown that the repeated name, when used as an anaphoric center in the sentence, slowed down the reading and comprehension process when compared with pronouns. This effect was called repeated-name penalty and it has been reported by different researchers (Gordon & Chan, 1995; Queiroz & Leitão, 2008; Leitão & Simões, 2011; Vasconcelos & Leitão, 2012).

Although the Centralization Theory explains the differences between anaphora resolution, pronouns, and repeated names, other theories seek to do so by focusing on a different theoretical goal. Opposing to the Centralization Theory, Almor (1999, 2000) proposes the Informational Load Hypothesis, which seeks to explain the difference between processing costs and discursive functions of different anaphors, namely, repeated names and pronouns. The Informational Load Hypothesis argues that the more semantic features contained in the anaphor, the greater the processing cost in terms of the working memory when carrying out coreference. Thus, the repeated-name anaphor would present a greater number of semantic traits to be processed and, therefore, processing would take longer than pronouns. Almor (1999) proposed this hypothesis by carrying out research with Alzheimer's patients and found that problems related to the working memory are due to a mental component responsible for recent information storage. The results from the Alzheimer's patients were compared with individuals in the control group with individuals without any memory problems. The results found by Almor et al. (1999) revealed that Alzheimer's patients had problems establishing coreference with pronouns rather than with repeated names. On the other hand, the individuals in the control group easily established coreference when the anaphor was a pronoun. When observing other aspects of coreference in a subsequent study, Almor (1999) concluded that more specific names, such as proper names, have a higher processing cost than non-specific names. This result suggests that new information is being processed, thus increasing processing costs.

As discussed so far, these theoretical models have shown that the differences between the processing costs of different types of anaphora resolution are associated with the mental load in the working memory. Hence, it may be concluded that the relationship between anaphora processing largely depends on the functioning of the working memory. Some studies have worked along these lines to show how information retention and retrieval processes work in the working memory, as it will be discussed below.

2.2. Working Memory

For a better characterization of memory, we must first differentiate short-term memory from long-term memory and their respective functions. Short-term memory refers to a limited-capacity memory system that holds information in consciousness for a brief period of time, while long-term memory corresponds to a relatively permanent storage of information (Gazzaniga & Heatherton, 2005).

Baddeley and Hitch (1994) proposed a working memory model with initially three components: the phonological loop, the visuospatial sketch pad and the central executive component. In this model, each component has different functions, however, hierarchically, the central executive component is responsible for coordinating the actions of the phonological loop and the visuospatial sketch pad. This working memory model has been recently reformulated by Baddeley (2000) who introduced the fourth component to the model, the episodic buffer. Regarding the components of the working memory, the phonological loop and the visuo-spatial sketch pad have the important function of dealing with verbal information, whether auditory or visual, keeping them active in the memory through constant repetition. According to Baddeley and Eysenck (2011), the loop is “basically a short-term verbal memory model”, and its usefulness ranges from the acquisition of vocabulary by children or adults acquiring another language to facilitating tasks, such as the acquisition of grammar and reading. This component of the model is the most significant for language processing tasks.

Studies carried out in the field of psycholinguistics have sought to highlight how the working memory operates in linguistic processing. Gordon et al. (2002) developed an experimental study to analyze the role of the working memory in relation to its storage capacity, seeking to answer whether syntactic processing has a modular or general nature. According to the authors, these questions are fundamental for understanding the functioning of language in terms of processing. In order to demonstrate how interference affects memory and its resources, which interfere in language processing, the authors resorted to a research methodology that used a memory-load task containing a task that relates the processing of phrases and recall of a list of words. Thus, they proposed the following hypotheses: (i) the existence of competition between external memory load and language comprehension; (ii) a combination of load and NP in the sentence must be detrimental to the understanding of the sentence; (iii) a correspondence between load and NP in the sentence must not interact with the syntactic complexity of the sentence. In terms of comprehension, the results of the experiment by Gordon et al. (2002) revealed a main interaction effect indicating that interference from an external memory load can disrupt sentence processing. This effect seems to demonstrate that memory for processing complex syntactic relations shares resources with the memory used for memorizing a list of words. The reading time results indicate online effects of language comprehension in the syntactic combination between memory load and NPs. The results revealed that as recalling improves, the task of understanding sentences tends to be more affected resulting in poorer performance. Considering the analysis of the results obtained from the memory-load task, the authors concluded that syntactic processing has a specific feature for interpreting sentences, increasing processing costs when sentences are syntactically complex. Thus, Gordon et al. (2002) assume the idea of a highly organized working memory that can undertake tasks such as the efficient retrieval of appropriate information when reading and understanding sentences.

Gilchrist, Cowan and Naveh-Benjamin (2008) conducted a study with adults on the working memory capacity for spoken sentences to investigate if the capacity decreases with aging. The aim of the researchers was to analyze recall and recovery of chunks in the working memory to investigate the effects of aging on the clustering phenomenon, as previous results pointed to a decline in immediate recall in the elderly. The authors developed an experimental design with four different conditions, which included (1) four short sentences, (2) four long sentences, (3) eight short sentences or (4) four random sentences. The stimuli were recorded by a female voice using the Audacity program, and the participants responded to the task by speaking into a microphone. The responses were converted to sound files and saved by the computer program (Gilchrist, Cowan & Naveh-Benjamin, 2008, p. 6-7). The task consisted of carefully listening to stimuli through a headset and verbally recalling what was just heard in any order. According to the authors, each participant informed their responses by speaking into a microphone and they had a period of free recall with a maximum duration of 1 minute, even though they were free to end it before by pressing a key. According to Gilchrist, Cowan & Naveh-Benjamin (2008), the results pointed to a clear difference in the number of clusters that can be stored in the working memory at once according to age. However, there was no age effect in the conclusion sentence, suggesting that, although the elderly may have reduced working memory capacity for chunks, recent linguistic materials maintained an integration of elements that did not differ from young adults. In addition, an age-related decline in the working memory capacity measured in chunks appears to be responsible for language memory deficits, so results with the number of words recalled in general showed that the aging deficit lies in retaining multiple units (in this case, long sentences) when there is a large amount of linguistic material (Gilchrist, Cowan & Naveh-Benjamin, 2008, p. 12).. The researchers shed light on questions regarding the effect of aging on recalling chunks in working memory, but there are still many other aspects that need to be taken into consideration.

The aspects of memory were addressed in study by Gilchrist, Cowan & Naveh-Benjamin (2009), who investigated the development of the working memory in children using sentences, and it has provided new evidence about the increase in the storage capacity of chunks. The authors reported that aging also promotes the increase in the number of items that can be stored in working memory. The main objective of the study was to analyze the age differences in relation to the number of clusters stored in the working memory, suggesting that storage and phonological testing would be mechanisms that contribute to recalling information, even if the memory capacity is limited. The experimental items included (1) lists with four short sentences, each with an independent clause; (2) lists with eight short sentences; (3) lists with four long sentences, each consisting of two significantly combined clauses; and (4) lists of four random pseudo-sentences with several randomly mixed words (Gilchrist, Cowan & Naveh-Benjamin, 2009, p. 3-4). The lists resulted in four experimental conditions and the stimuli was recorded by a female voice and properly controlled. The experiment was carried out on a computer in which the children heard the stimuli on headphones and record their responses by speaking into a microphone. All participants were given instructions to listen carefully to the sentences and to verbally recall what was heard in any order as soon as requested. The results showed that younger children recalled fewer sentences than older children or adults, however there were no age differences related to the words recovered from the sentences recalled. In this sense, Gilchrist, Cowan & Naveh-Benjamin (2009) argue that the increase in the development in memory time was due to an increasing number of chunks present in working memory with a limited performance for the size of the chunk.

The elements stored in the working memory are decisive for the storage and retrieval of information. When addressing syntactic distance, it is even more relevant. This is because the syntactic node, which represents an entire embedded sentence, can be stored in the memory as a chunk, which would decrease the processing cost, although the linear distance between the antecedent and anaphor increases. What remains, therefore, is whether the most embedded position of the anaphor affects the activation of the referent in the working memory, making it difficult to access and recover information, thus affecting the

establishment of anaphoric coreference. These issues have been investigated in the present study based on the methodology described below.

3. Method

The aim of the experimental task was to verify whether syntactic nodes are storable units in the working memory and if these nodes influence the processing of different forms of anaphoric recovery. We analyzed the processing differences between the conditions, first regarding the type of anaphora resolution and the occurrence of effects such as the repeated name penalty or the informational load hypothesis, and which resolution was more and less costly. In addition to investigating the differences between the sentences with 1 syntactic node and 2 syntactic nodes, we investigated which one would require longer reading time by comparing the control sentences with the experimental ones to reveal the particularities of linear and syntactic distance.

Experiment

The present experiment focuses on the observation of two types of anaphora resolution, namely repeated name and pronoun, which will be analyzed in linear sentences and sentences with linear and syntactic distance, with two distinct types of anaphor distance: short and long.

The initial hypotheses for the self-paced experimental task was to verify if there would be a main effect of distance between the antecedent and anaphor, in which the reading times of the critical segment would be longer in sentences with long-distance anaphors, as proposed by the Informational Load Hypothesis (Almor, 1999). Second, we expected to find a significant effect for embedding. In sentences with syntactic embedding, we expected different reading times for sentences without syntactic embedding due to the formation of memory chunks.

3.1. Participants

A total of 30 subjects (15 male and 15 female), undergraduate students from the Federal University of Paraíba, in João Pessoa-PB, with ages between 18 and 28 years, all native speakers of Brazilian Portuguese and residents of the state of Paraíba, voluntarily participated in the research.

3.2. Materials

The experimental items consisted of 48 sentences, which were divided into 8 experimental sentences, 8 control sentences, and 32 fillers. The independent variables were the type of anaphora resolution (full pronoun and repeated name) and the number of intervening embeddings between the antecedent and anaphor (1 embedding and 2 embeddings). The dependent variables were the reading time of the critical segments (repeated name/pronoun), the number of correct answers and the response time to the control question.

Thus, the 2 x 2 factorial design consisted of four experimental conditions (NR1N, NR2N, PR1N, PR2N) distributed across six lists in a Latin-square design and were administered alternately among the participants. The control conditions (SED1PR, SED1NR, SED2PR, SED2NR) were included in the experiment to compare the total reading times between sentences with linear distance and syntactic distance. The descriptions of the acronyms referring to each of the six conditions and their examples, as well as an example of the control question, are shown below.

Experimental conditions

a. Repeated name + 1 syntactic node (NR1N)

Ana \ pintou \ o vaso. \ A mãe \ notou que \ Ana \ estava \ animada.
Ana painted the vase. The mother noticed that Ana was excited.

b. Repeated name + 2 syntactic nodes (NR2N)

Ana \ pintou \ o vaso. \ A mãe \ relatou que \ notou que \ Ana \ estava \ animada.
Ana painted the vase. The mother reported that she noticed that Ana was excited.

c. Full pronoun + 1 syntactic node (PR1N)

Ana \ pintou \ o vaso. \ A mãe \ notou que \ ela \ estava \ animada.
Ana painted the vase. The mother noticed that she was excited

d. Full pronoun + 2 syntactic nodes (PR2N)

Ana \ pintou \ o vaso. \ A mãe \ relatou que \ notou que \ ela \ estava \ animada.
Ana painted the vase. The mother reported that she noticed that she was excited.

Control question: Who was excited? (ANA / MOTHER)

Control conditions

a. No embedding + Distance 1 + Repeated name (SED1NR)

Ane \ ofereceu \ à avó \ o café \ quente. \ Ane \ andava \ exausta.
Ane offered the grandmother hot coffee. Ane was exhausted.

b. No embedding + Distance 1 + Pronoun (SED1PR)

Biu \ doou \ ao avô \ o aluguel \ da casa. \ Ele \ estava \ alegre.
Biu gave the grandfather the rent for the house. He was pleased.

c. No embedding + Distance 2 + Repeated name (SED2NR)

Mel \ dedicou \ à mãe \ a medalha \ de ouro \ brilhante. \ Mel \ estava \ radiante.
Mel dedicated the shiny gold medal to mother. Mel was overjoyed.

d. No embedding + Distance 2 + Pronoun (SED2PR)

Ian \ vendeu \ ao pai \ um celular \ vermelho \ usado. \ Ele \ andava \ devedor.
Ian sold the old red cell phone to dad. He was in debt.

After reading each sentence, the participants answered a control question about the passage. As an offline measure, the objective of the control question was to check reading attention and to ascertain possible differences in the interpretation of the sentences, depending on the type of anaphor and the number of embeddings. The answers to the questions were distributed interchangeably, preventing a possible response strategy by the participant.

Both the experimental conditions and control conditions were thoroughly reviewed, and the number of syllables, number of segments, and position of critical segments were controlled to obtain a more reliable result during statistical analysis. Table 1 shows the division of the segments in each experimental condition and the anaphoric referents and the anaphors in the experimental passages are in bold.

Table 1 – Examples of sentences for each experimental condition in Experiment 2.²

	S1	S2	S3	S4	S5	S6	S7	S8	S9
NR1N	Edu	chutou	a bola.	O pai	notou que	Edu	estava	contente.	-

²**NR1N** Edu kicked the ball. The father noticed that Edu was happy. **PR1N** Edu kicked the ball. The father noticed that he was happy. **NR2N** Edu kicked the ball. The father stated that he noticed that Edu was smiling. **PR2N** Edu kicked the ball. The father stated that he noticed that he was smiling.

PR1N	Edu	chutou	a bola.	O pai	notou que	ele	estava	contente.	-
NR2N	Edu	chutou	a bola.	O pai	afirmou que	notou que	Edu	estava	sorridente.
PR2N	Edu	chutou	a bola.	O pai	afirmou que	notou que	ele	estava	sorridente.

All experimental passages were divided into segments, both controlled for the number of syllables and letters. Therefore, in the conditions with a syntactic node with 8 segments, the critical segment with the anaphor was placed in S6. In the conditions with two syntactic nodes with 9 segments, the critical segment with the anaphor was placed in S7.

3.3. Procedures

The participants were individually tested at LAPROL - Laboratory of Linguistic Processing - at the Federal University of Paraíba by an experimenter. Before the experiment, the participants read instructions on the computer screen and were instructed by the experimenter to carry out a previous training session to get used to the experimental task. The training session consisted of six sentences, similar to those in the experiment, and it was closely monitored by the experimenter, who sought to answer any doubts regarding the task. After the training session, the participants began the experimental task without any interventions from the experimenter.

The self-paced reading technique consisted of reading segmented sentences on a computer screen (Lenovo® laptop) using the Paradigm program. The participants controlled their reading pace by pressing the right arrow key on the laptop keyboard. The participants read each a segment of the sentence in a self-paced, non-cumulative reading paradigm.

At the end of each sentence, the participant answered a control question, which was displayed in the center of the screen with two possible answers, that is, the names of two possible referents in the sentence. To choose the alternative, the participant pressed the “S” key on the laptop for the option that appeared on the left corner of the screen, and “L” for the option that appeared on the right corner of the screen. After choosing the answer, the program automatically displayed the subsequent sentence. The mean duration of the task was 10 minutes.

4. Results

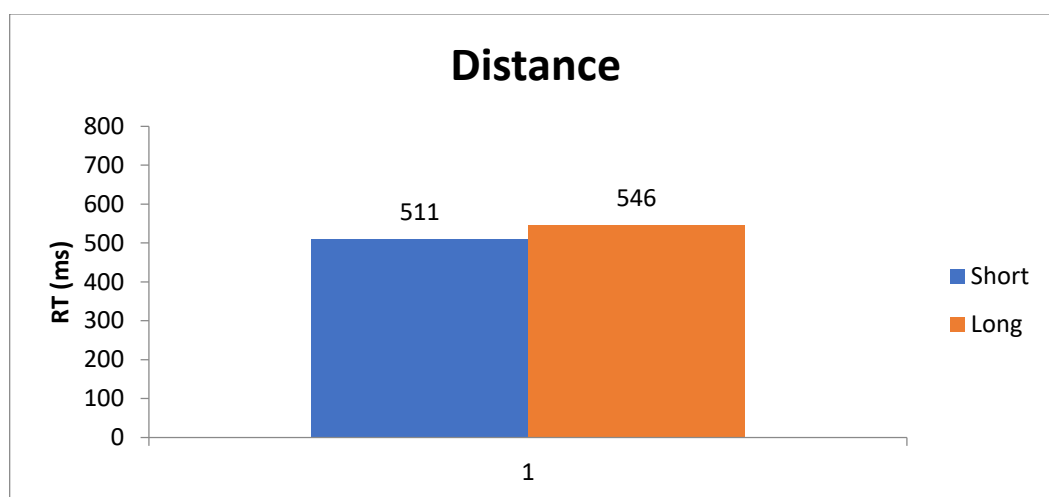
The data collected from the experiment were analyzed using analysis of variance (ANOVA) in 2x2 factorial design. Initially, the data from the critical segment were submitted to statistical analysis considering the type of anaphor (pronoun/repeated name), distance (short/long) and embedding (with/without embedding). Thus, all experimental and control conditions were compared (NR1N, PR1N, NR2N, PR2N, SED1PR, SED1NR, SED2PR, SED2NR) considering the position of the critical segment (anaphor) in each experimental condition.

Table 2 – ANOVA of the critical segment

	<i>Df.</i>	<i>Sum of squares</i>	<i>Mean square</i>	<i>F</i>	<i>P value</i>
Type of anaphor	1	12473.99034	12473.99034	0.60498321	0.437072689
Distance	1	152150.1354	152150.1354	7.379216651	0.006840479
Embedding	1	7089.87387	7089.87387	0.343855858	0.55789228
Type of anaphor: Distance	1	1010.012163	1010.012163	0.048985159	0.824934392
Type of anaphor: Embedding	1	8198.549453	8198.549453	0.397626151	0.528622948
Distance: Embedding	1	201220.9291	201220.9291	9.75912921	0.001894136
Type of anaphor: Distance: Embedding	1	22274.42257	22274.42257	1.080299991	0.299162584
Residue	472	9732044.373	20618.73808		

As shown in Table 2, the ANOVA results of the critical segment revealed a main effect for distance ($p < .05$) and an interaction effect between distance and embedding ($p < .05$). There was no significant effect for type of anaphor or embedding. Graph 1 shows the mean values for the distance factor of the critical segment.

Graph 1 – Reading times of Critical Segment

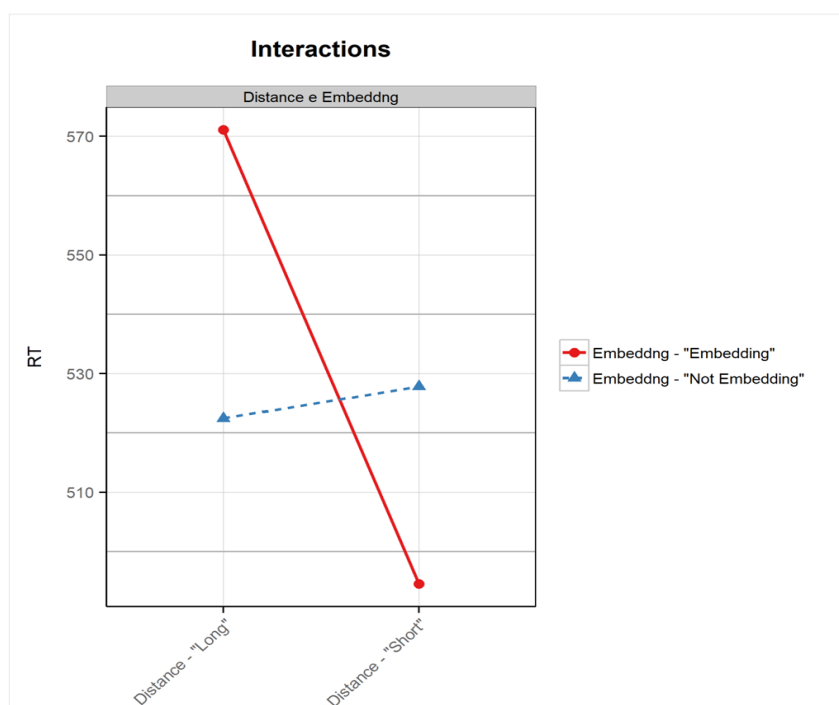


The mean values for the reading time for the distance factor in the critical segment (Graph 1) were longer for sentences with long-distance anaphors (PR2N, NR2N, SED2PR, SED2NR) than those with short-distance anaphors (PR1N, NR1N, SED1PR, SED1NR) during anaphora resolution.

The mean values confirm the main effect of distance and reveals that distance influences the processing time of anaphora resolution, corroborating the Informational Load Hypothesis, proposed by Almor (1999), and the results obtained by Leitão and Simões (2011) on linear distance. However, the present experiment contains sentences with linear distance as well as sentences with overlapping linear and syntactic distances.

As previously mentioned, the ANOVA of the critical segment also revealed an interaction effect between distance and embedding ($p < .05$), as shown in Graph 2.

Graph 2 – Interactions of the critical segment



Although Graph 2 shows three charts on the interaction related to the critical segment, but only the first chart will be considered in the analysis as this is the one that indicates a significant interaction between distance and embedding ($p < .05$). This effect points out that as the distance between the antecedent and anaphor increases, the reading time of the critical segment in sentences with syntactic embedding also increases. On the other hand, the increase in distance between the antecedent and anaphor does not seem to affect the conditions that did not have syntactic embeddings, although there was a slight decrease in the reading time for long-distance anaphors.

Along these lines, an interesting behavior was observed regarding the sentences with linear distance when compared with those with overlapping linear and syntactic distance, which confirms our hypotheses that they seem to cause more processing costs. Thus, when it comes to long-distance anaphors, syntactic embedding influences more than linearity.

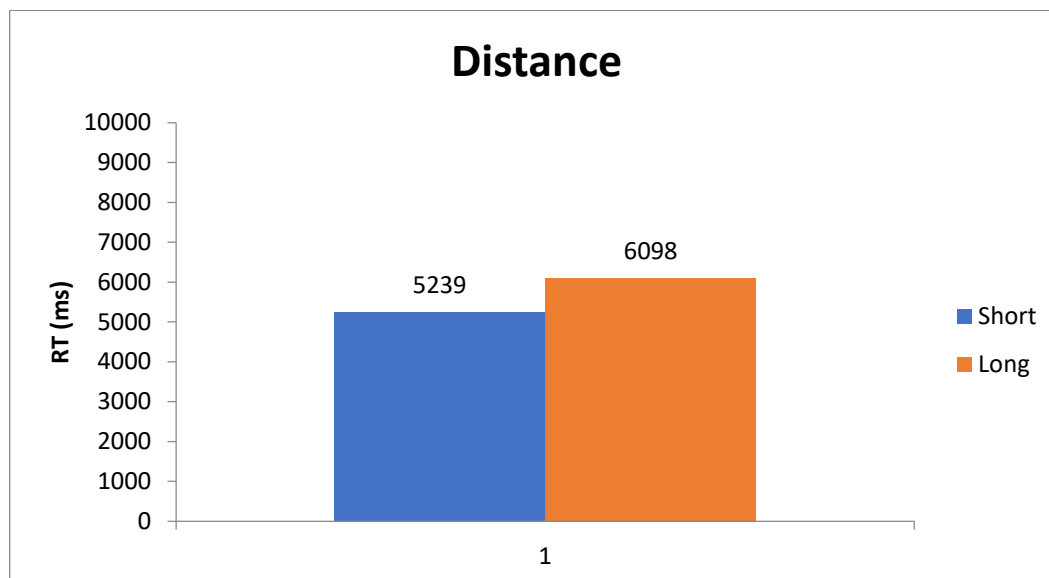
To observe the occurrence of a spill-over effect, we submitted the data referring to the post-critical segment with a verb to statistical analysis. However, we did not find any significant effects in the tested comparisons. Thus, we analyzed the total reading time of sentences.

Table 3 – ANOVA of the fixed effect of total reading time

	<i>Df.</i>	<i>Sum of squares</i>	<i>Mean square</i>	<i>F</i>	<i>P value</i>
Type of anaphor	1	19361357.6	19361357.6	6.250580505	0.012753486
Distance	1	88549319.25	88549319.25	28.58707846	1.39802E-07
Embedding	1	21053155.99	21053155.99	6.796757188	0.009421391
Type of anaphor: Distance	1	2177407.991	2177407.991	0.702949877	0.402218647
Type of anaphor: Embedding	1	4064893.331	4064893.331	1.312301727	0.252558822
Distance: Embedding	1	7745997.237	7745997.237	2.500701672	0.114465422
Type of anaphor: Distance: Embedding	1	22972088.25	22972088.25	7.416261295	0.006703218
Residue	472	1462033931	3097529.514		

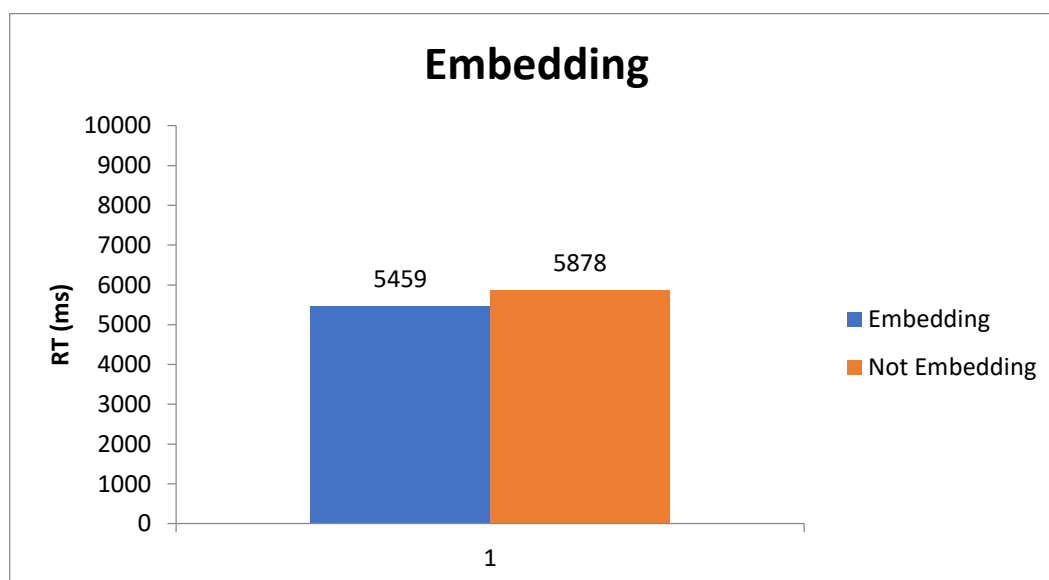
The data of the total reading time of the conditions were submitted to ANOVA (Table 3) that revealed a significantly statistical effect for type of anaphor ($p < .05$), distance ($p < .05$) and embedding ($p < .05$), which will be addressed next.

Graph 3 – Mean values for distance of total reading times



When verifying the mean values of distance for total reading time (Graph 4), there was a difference between the conditions with long- and short-distance anaphors that resulted in a significant distance effect ($p < .05$), as previously reported. Such an effect was expected as long-distance anaphors have a greater number of linguistic segments and the mean reading time tends to increase.

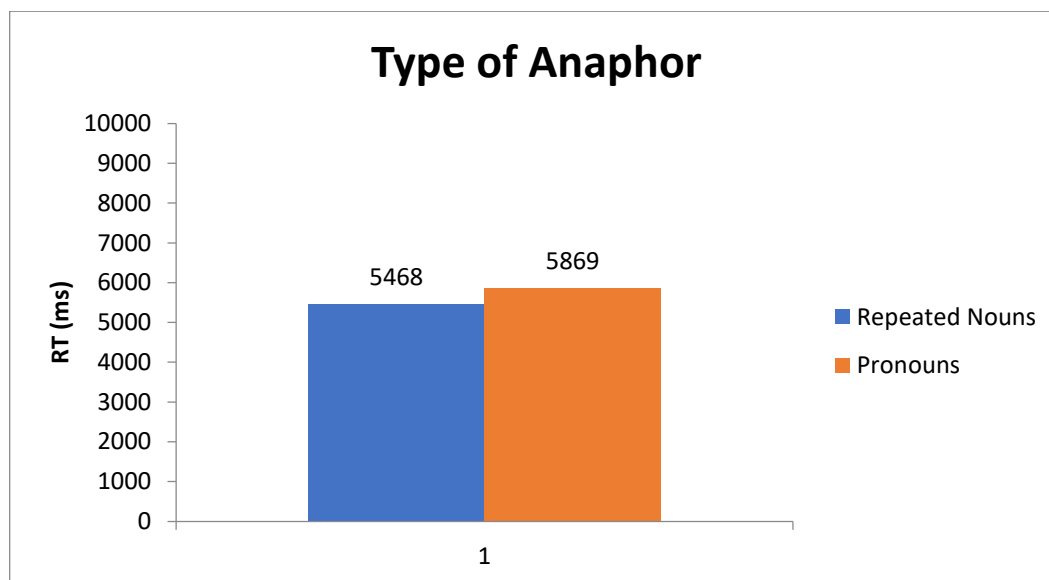
Graph 4 – Mean values of embedding of total reading time



As for the mean values for total reading time (Graph 5) in sentences with syntactic embedding, or syntactic nodes, a main embedding effect ($p < .05$) was observed as they were read more quickly than

those without embedding. In this sense, the data suggests the formation of chunks, as reported by Miller (1956), in the memory through syntactic embedding that allow for faster and more efficient reading.

Graph 5 – Mean values of type of anaphor of total reading time



Another main effect was the type of anaphor ($p < .05$) that showed significantly different mean values between pronouns and repeated-name anaphors when the total reading time of the sentences was observed (Graph 6). Lower reading times were observed in repeated-name anaphora resolution in comparison with anaphoric pronouns, revealing that the PNR (repeated-name penalty) did not occur since it would imply that the repeated-name anaphor would present longer reading times. It is important to highlight that these data refer to an analysis among all conditions in both experimental and control items.

The participants' response time to the control question, which appeared at the end of each passage, was also observed. This was intended to keep the individual focused during reading, in addition to checking which conditions were more costly and which ones took less time. ANOVA was used for comparative analyses between experimental and control conditions.

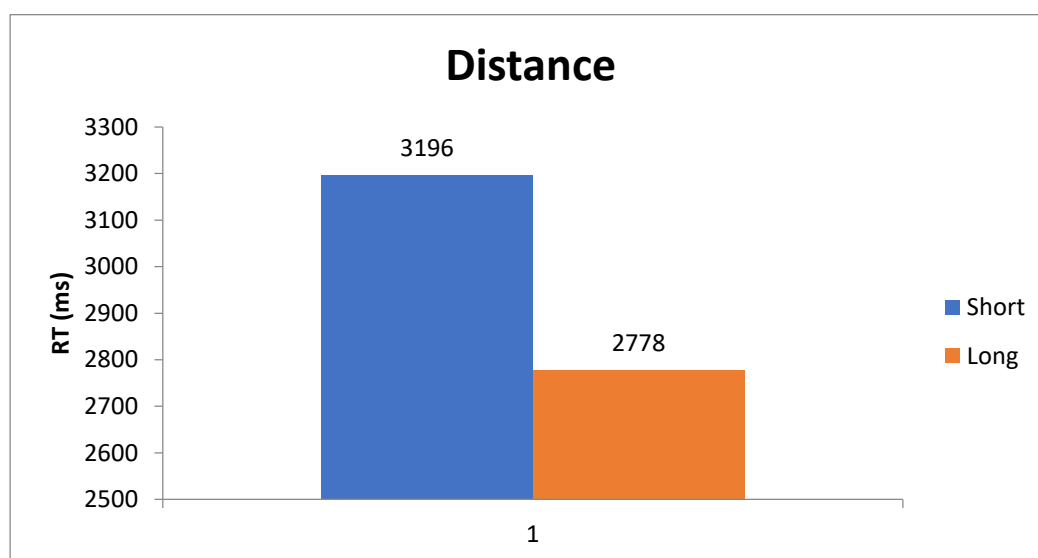
Table 4 – ANOVA of response time to control question

	<i>Df</i>	<i>Sum of squares</i>	<i>Mean square</i>	<i>F</i>	<i>P value</i>
Type of anaphor	1	211967659.3	211967659.3	112.7456416	9.2155E-24
Distance	1	20936477.35	20936477.35	11.13611661	0.000913508
Embedding	1	42006759.51	42006759.51	22.34340403	3.01395E-06
Type of anaphor: Distance	1	808755.6087	808755.6087	0.430177275	0.51222155
Type of anaphor: Embedding	1	103034584.3	103034584.3	54.80411658	6.16175E-13
Distance: Embedding	1	26335743.76	26335743.76	14.00798752	0.000204469
Type of anaphor: Distance: Embedding	1	29136780.54	29136780.54	15.49785957	9.50403E-05
Residue	472	887384503.5	1880051.914		

The ANOVA results of the response time to the control question (table 18) revealed the main effects of distance ($p < .05$), embedding ($p < .05$) and type of anaphor ($p < .05$). There were also interaction effects

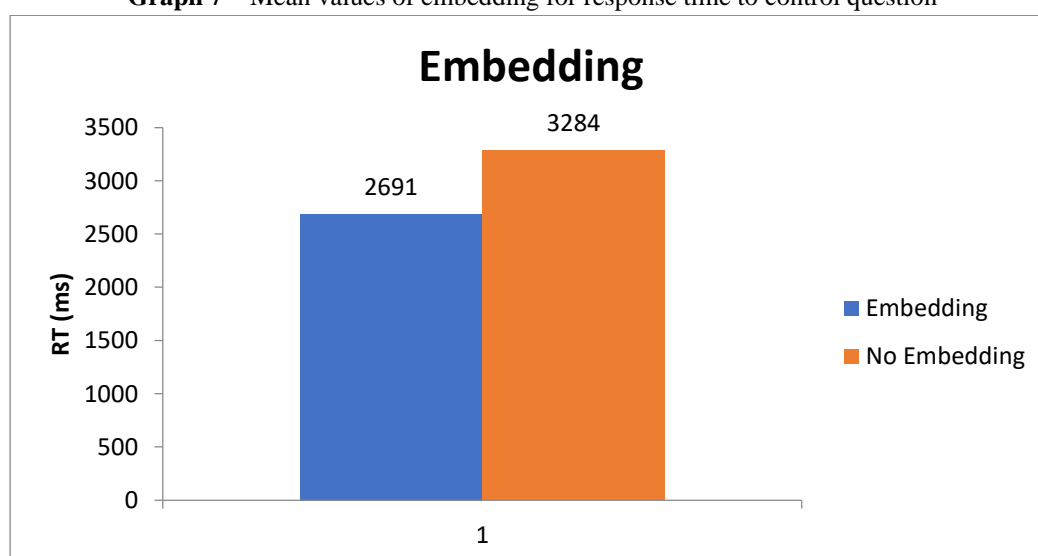
for type of anaphor and embedding ($p < .05$) and distance and embedding ($p < .05$), which will be described and discussed below.

Graph 6 – Mean values of distance for response time to control question



Observing the distance factor (Graph 7), there is a significant increase in the response time to the control question when in conditions with short-distance anaphors, that is, those that had 1 syntactic node and those that had no syntactic nodes but more elements with the same amount of syllables. This result was not foreseen, and it points to a possible facilitating factor for participants when answering the control question because of the structure of sentences with long-distance anaphors as anaphora resolution was close to the question.

Graph 7 – Mean values of embedding for response time to control question

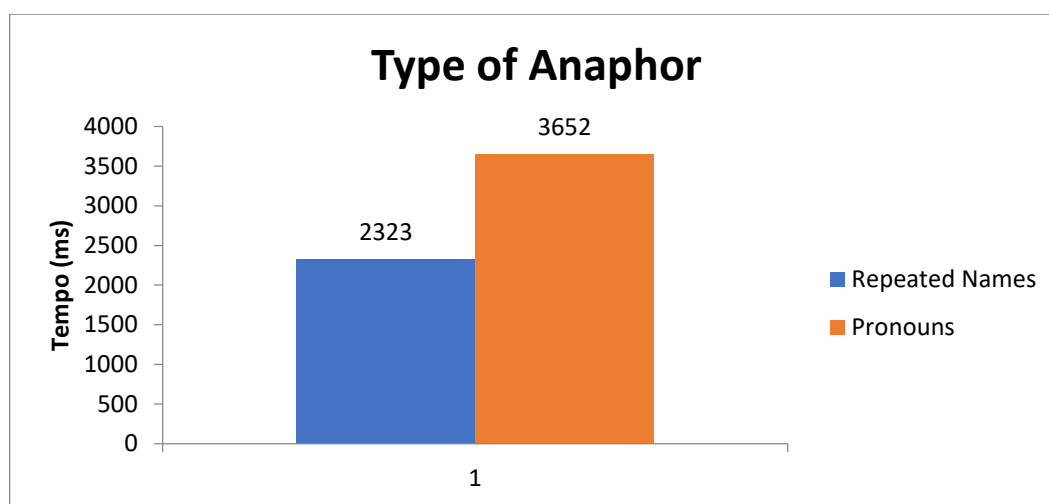


With regard to embedding (Graph 8), a significant effect ($p < .05$) was observed, which shows that sentences without syntactic embedding (SED1PR, SED2PR, SED1NR, SED2NR) were more costly than sentences with syntactic embedding (PR1N, PR2N, NR1N, NR2N).

The result suggests that the embedding/syntactic node can facilitate not only total reading time, as previously reported, but also when answering questions, while sentences with linear distance, that is, without embedding, demand more time to be resolved. The formation of chunks in the working memory (MILLER, 1956), which help organization and concatenation of information syntactically embedded at the time of reading, may be a possible explanation for the facilitating factor when answering the control question.

It must also be pointed out that an unwanted ambiguity effect occurred, mainly in the control conditions, in which it was not possible to ascertain which answer was in fact the correct because the referents were of the same gender. This was only noticed during statistical analyses.

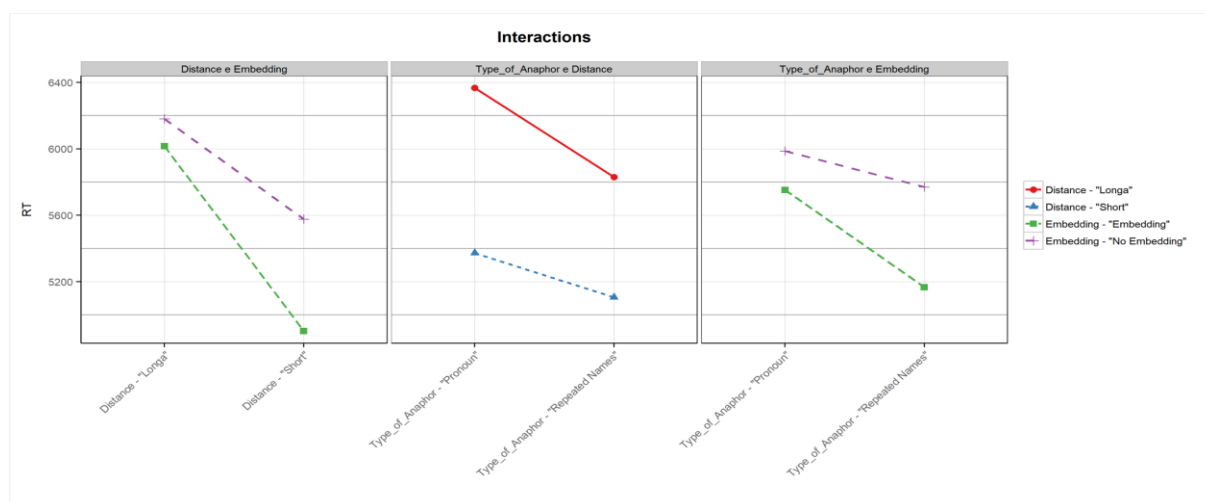
Graph 8 – Mean values of type of anaphor for response time to control question



Regarding the type of anaphor (graph 19), a significant effect was observed ($p < .05$) indicating an increase in the response time for the conditions with the anaphoric pronouns. A shorter response time was observed in conditions with repeated names. We attribute this result due to the proximity between the repeated name, anaphor, and the control question. As they were read in a short time, the participant could probably remember the answer more easily, thus reducing resolution time.

In addition to the main effects, we observed the effects of interaction between the variables obtained by ANOVA, as shown in Graph 9.

Graph 9 – Interactions for response time to control question



Significant interactions regarding the response time to the control question (graph 20) occurred between type of anaphor and embedding ($p < .05$) and distance and embedding ($p < .05$).

The first effect points to a facilitation of syntactic embedding due to the anaphoric pronoun. Analyzing the graph, the trends are reversed: resolution time of the repeated name increased in the sentences with syntactic embedding, however response time decreased when the anaphor was pronoun, facilitating resolution. Regarding sentences without embedding, the repeated name presented shorter response time, unlike the pronoun which had a high cost, as the individual needed more time to respond, which can be caused by a greater load of information in memory. Such data are in line with the results reported by Lima (2015), suggesting that syntactic embedding has an important role in co-referentiality, influencing the type of anaphora resolution, even during an offline task.

The second effect refers to distance and embedding ($p < .05$), however the graph shows that there is no crossing of trends. Even so, response time for sentences with syntactic embedding were shorter for both long- and short-distance anaphors. The same did not occur in sentences without embedding since resolution time significantly increased, particularly in conditions with short-distance anaphors.

In addition to the critical segment, the post-critical segment, the total sentence reading time and the response time to the control question, the rate of correct answers to the control question was submitted to statistical analysis to observe differences among the variables and conditions. It is important to point out that we considered the first referent of the sentence as the correct answer, even though it seemed ambiguous due to the use of referents of the same gender. For this, a binomial regression model was used, and the results are shown in the tables below.

Table 5 – Coefficient estimates for correct answers to control question

	<i>Estimate</i>	<i>Standard deviation</i>	<i>Wald test</i>	<i>P value</i>
Intercept	4.781590162	0.565234784	8.459476132	.05
Type of anaphor Pronoun	-2.480939071	0.487492395	-5.089185173	.05
Distance: long-distance	0.419348951	0.326289528	1.285205057	0.1987
Embedding: no embedding	-1.647306649	0.378503133	-4.352161195	.05

The coefficient estimates for correct answers to the control question (Table 6) indicated a significant effect for type of anaphor-pronoun ($p < .05$), in which the conditions with the anaphoric pronouns induced more errors than the conditions with repeated names. There was also a significant effect for embedding - without embedding ($p < .05$), in which the conditions without embedding, that is, those with linear distance, induced more errors than those that with linear distance and syntactic overlapping. Again, sentences with linear and syntactic distance are processed differently from those with linear distance. The organization of the sentence in syntactic embeddings seems to facilitate the short-time response to answer the question in an offline task as well as correctness.

Table 6 – Odds ratio for correct answers to control question

<i>Variable</i>	<i>Category</i>	<i>Odds ratio</i>	<i>Lower threshold</i>	<i>Upper threshold</i>
Type of anaphor	Pronoun vs repeated name	0.083664622	0.032180114	0.217518466
Distance	Long distance vs short distance	1.520971006	0.802384972	2.883095875
Embedding	No embedding vs embedding	0.192567864	0.091706762	0.404358208

As for the odds ratio for correct answers to the control question (Table 6), the results show that there are more chances of success for conditions with repeated-name anaphors than with anaphoric pronouns. As for embeddings, there are more chances answering the question correctly in conditions with syntactic embedding than in those without.

Table 7 – Likelihood-ratio test (LRT) of correct answers to control question

<i>Variables tested</i>	<i>Test statistics</i>	<i>Df</i>	<i>P value</i>
Type of anaphor + Distance + Embedding	65.22376	3	4.50E-14

In sum, the binomial regression model also revealed significance in the likelihood-ratio test ($p < .05$), showing that our variables were significant for the model (Table 7). The data support the performance of the variables in the phenomenon studied, confirming the importance of the research.

5. Discussion

In general, the main objective of the experiment carried out in this study was to provide evidence about the relations between coreferential processing and the working memory. Thus, we developed an individual, non-cumulative, self-paced reading experimental task by controlling stimuli and the execution of the task.

The data were submitted to statistical analysis that suggested that the embedding variable was significant in relation to the critical segment, total reading time, response time and rate of correct answers to the control question. Embedded sentences were read more quickly and led to more correct answers, unlike sentences without syntactic embedding, that is, those with linear distance, that seem to form chunks that facilitate the reading and understanding of sentences.

The variable type of anaphor was not significant in the analysis of the critical and post-critical segment. However, statistical significance was observed when analyzing the data related to the total reading time, response time and rate of correct answers to the control question. There was no evidence of PNR, as the conditions with repeated-name anaphors presented longer reading times than those with anaphoric pronouns. In fact, anaphoric pronouns were more costly when answering the questions, thus inducing more errors.

Regarding distance, in the sentences with short-distance anaphors (conditions with 1 syntactic node or shorter sentence) and long-distance anaphors (conditions with 2 syntactic nodes or longer sentence), significant effects were observed for the critical segment and for the total reading time. We found that shorter reading times were observed for sentences with short-distance anaphors, which corroborates the results obtained by Leitão and Simões (2011) and our hypothesis that distance is a factor that influences processing (Almor, 1999). With regard to the response time to the control question, the conditions with short-distance anaphors presented longer resolution times than those with long-distance anaphors, which suggests a problem related to the proximity of the anaphora resolution to the final question in sentences with distance-long anaphors. There was no significance regarding the rate of correct answers.

Regarding offline processing, the results suggest an influence of the syntactic factor even after processing the anaphoric coreference, which facilitated the short-time response to answer the question as well as correctness.

The results obtained during the analyses shed light on the questions regarding the type of anaphora resolution, demonstrating that there are differences between the anaphors even though being in the same syntactic position, that is, referring to the same antecedent. Likewise, the syntactic distance factor showed significant differences in relation to the linear distance factor, which implies a strategy of grouping information from the verbs in each syntactic node.

Finally, there might have been ambiguity in the interpretation of the control sentences due to the two referents with the same gender. This fact may have caused an unexpected increase in response time for conditions with pronouns in comparison with conditions with repeated names. This result differs from the findings reported by Leitão and Simões (2011) and from the Informational Load Hypothesis (Almor, 1999).

6. Conclusions

The present research, based on the experimental psycholinguistic, sought to investigate coreferential processing and its relation to the working memory by verifying the processing differences between different types of anaphora resolution - repeated names, pronouns and empty categories - and investigating the influence of the syntactic distance factor in intervening nodes in anaphora processing in BP. In addition, we sought to establish a comparison between the syntactic distance and linear distance between the referent and anaphor in the sentence to better understand issues related to the processing cost of the working memory.

According to the literature, anaphoric coreference is an efficient resource in reading as it provides fluidity to the text, and different types of anaphora resolution have shown different processing times when compared in experimental reading tasks, for example. These results refer to the nature of anaphors as some of them carry more information than others.

In addition, other factors can also influence coreferential processing, such as the distance between the referent and anaphor (Almor, 1999), which has been addressed linearly in most studies. This type of factor increases not only the distance between the antecedent of the sentence and its anaphor, but also the time for storing the information in the temporary working memory. There are not many studies that have addressed syntactic distance and linear distance. Therefore, this study sought to investigate distance, since we understand that syntactic nodes influence coreferential processing and behave differently from those with linear distance.

As a working hypothesis, we expected that the working memory would be directly related to coreferential processing by affecting it in different ways, depending on the type of anaphora resolution, even when in the same syntactic position and referring to the same antecedent. We also assumed that the syntactic distance, when overlapping with linear distance, is a factor that influences coreferential processing, either during online processing of different types of anaphora resolution or during offline

retrieval of information in the working memory, as it would influence processing cost to a greater or lesser extent than sentences with linear distance.

The results suggest that the syntactic distance may be a relevant factor in the working memory with significant processing differences in conditions with linear distance in comparison with those with overlapping linear and syntactic distance, indicating the formation of chunks (Miller, 1956) that optimize storage capacity by more effectively promoting information retrieval. There was also an increase in reading times depending on the number of intervening embeddings, corroborating our initial hypotheses and the Informational Load Hypothesis (Almor, 1999), as well as different processing costs for each type of anaphora resolution, as reported by Leitão and Simões (2011).

Some aspects such as the phenomenon of co-referentiality, correlation with the mental component, called working memory by Baddeley and Hitch (1974), and memory measurement tests must be addressed in further studies to obtain more significant and detailed results. These tests would be correlated to observe the phenomenon of co-referentiality in information retention and retrieval tasks.

Despite this, the evidence and results described throughout this study point to the phenomenon of anaphora resolution that varies as factors change, revealing to be sensitive to aspects such as distance between the antecedent and anaphor. At this point, linear and syntactic distances, although in overlapping positions in some situations, seem to act differently when it comes to coreferential processing.

Therefore, we consider the contributions of this research to be important in Brazilian Portuguese in view of the few comparative studies between linear distance and overlapping linear and syntactic distance. We also reaffirm that the phenomenon of coreference is broad and sensitive to several structural and semantic factors in the sentence. Thus, we intend to further and expand discussions on anaphora processing within the scope of experimental psycholinguistics.

7. Ethics Committee Approval

The author(s) confirm(s) that the study does not need ethics committee approval according to the research integrity rules in their country (Date of Confirmation: 21.01.2021).

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Çekirdeksel ilişkilerin işlenmesi ve bunların işleyen bellekle ilişkileri: sözdizimsel mesafenin Brezilya Portekizcesi'nde anafora işleme üzerindeki etkisi

Öz

Bu çalışmanın amacı, işleyen bellek ile ilişkilerine odaklanarak öz-kayı ilişkilerinin işlenmesini incelemektir. Bir okuma sürecinde, okuyucuların sürekli olarak bilgi depolama, geri çağırma ve kullanma gibi çalışma belleğini içeren zihinsel işlemler gerçekleştirilmesi önemlidir. Bu nedenle, çekirdek referans çözümlemesinin işlenmesinin, çalışma belleği ile yakından ilgili olduğu anlaşılmaktadır. Bellek ve anafora çözünürlüğü arasındaki bu ilişkide, referans ve anafora arasındaki mesafe faktörü, mesafe cümleleri okurken işlem maliyetlerini artırdığından önemli bir rol oynayabilir. Çalışma belleğinin sınırlı olduğu bilinmektedir; yine de araştırmacılar arasında depolanabilir öğelerin doğası hakkında bir fikir birliği yoktur. Dahası, burada bir cümlenin yapısının bir temsilcisi olarak alınan sözdizimsel düğüm, çalışma belleğinde olası depolama ve kurtarılabilir birim olarak gözlemlendi. Bu nedenle çalışmanın amacı, sözdizimsel uzaklık faktörünün, bir ve iki araya giren sözdizimsel düğümleri olan gömülmelerin, farklı anafora çözünürlüğünün işlenmesindeki etkisini araştıran çalışma belleğinde depolanabilir bir birim olup olmadığını doğrulamaktır. Bir deneyde kendi hızına göre deneysel okuma tekniği kullanılmıştır. Hepsi üniversite öğrencisi olan yetmiş katılımcı bireysel olarak test edildi ve görevden önce bir eğitim seansına katıldı. Sonuçlar, sözdizimsel mesafenin, parçaların oluşumunu gösteren doğrusal mesafeli olanlarla ilgili sözdizimsel mesafeli koşullar arasında önemli farklılıklar ile çalışma belleğinde ilgili bir faktör olduğunu

göstermektedir. Araya giren gömme sayısına baęlı olarak okuma sürelerinde bir artış ve incelenen her bir anafora çözünürlüęü türü için farklı işleme maliyetleri vardı.

Anahtar sözcükler: Anafora İşleme. Çalışan bellek. Sözdizimsel Mesafe, Brezilya Portekizcesi

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