ERP SIGNATURES OF ATTACHMENT HEIGHT VARIATIONS IN ENGLISH AND SPANISH

by

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ABSTRACT

Previous research suggests that the processing of ambiguous relative clauses and prepositional phrases is language-specific. For instance, when a relative clause can be attached to several nodes in a tree (e.g. in *'the maid of the bride who was on the balcony'*, the relative clause *'who was on the balcony'* can be attached to *'the maid'* or *'the bride'*), English speakers prefer the low node (i.e. *'the bride who was on the balcony'*), while Spanish speakers prefer the high node (i.e. *'the maid who was on the balcony'*) (Cuetos & Mitchell, 1988).

The current thesis aimed to scrutinize the previously claimed asymmetries in the processing of English and Spanish sentences by looking at the detailed time course of parsing. We specifically aimed to test whether any differences between the attachment processes in Spanish and English occur at early stages of the process (i.e. as soon as the words are parsed), or whether the differences observed by previous researchers during off-line tasks (Cuetos & Mitchell, 1988; Fernandez, 2000) depend on post-syntactic strategies. Attachment height variations will be tested by using sentences with relative clauses and prepositional phrases that can have two possible attachment sites (i.e. high and low).

Posterior Negativity effects were found in both high and low conditions in both English and Spanish. Similar effects were found in experiments with relative clause and prepositional phrases. In a cross-language comparison, no significant effects for language were found.

Our contribution to knowledge was twofold. Firstly, it was found that the parser is sensitive to the ungrammaticality and semantic implausibility triggered by both high and low attachments regardless of the language, which means that no attachment site is preferred at an early stage and that parallel parsing occurs in this type of structures. Secondly, native speakers of English and Spanish showed very similar responses to the stimuli, which leads us to the conclusion that the parsing process for these structures is similar in English and Spanish.

These findings could serve as evidence to support parallel parsing models and Construal, which claim that adjunct phrases receive an initial multiple analysis that undergoes disambiguation at later stages (McRoy & Hirst, 1990; Frazier & Clifton, 1996). Moreover, observing similar responses in both English and Spanish at early stages of the parsing processing indicates that the asymmetries observed in attachment height preferences between the two languages in previous studies (Cuetos & Mitchell, 1989; Fernandez, 2002) could be due to post-syntactic factors, such as prosody, which come into play at late parsing stages.

Chapter 1

INTRODUCTION

The current research aimed to examine the previously claimed asymmetries in the processing of English and Spanish sentences by looking at the detailed time course of parsing.   This study specifically aimed to test ambiguous structures involving relative clauses and prepositional phrases with 2 possible attachment sites, which have been claimed to have different parsing preferences in English and Spanish (Cuetos & Mitchell, 1988; Fernandez, 2002). In order to provide a background for the topic at hand, this introduction will present a discussion about the concept of parsing, parsing theories, relative clause attachment, prepositional phrase attachment, the influence of prosody in structural ambiguity resolution, and previous ERP studies related to the topic. Finally, a justification for the current study will be introduced.

1.1. Parsing

When a speaker utters a sentence, he or she must go through a series of processes intended to transform his or her thoughts into language. The speaker's mind must analyze the meaning of his or her thoughts, plan the structure that will be used, come up with the words needed to express the ideas in question, and finally, utter the series of sounds in such words. Then, the listener must decode the information encoded by the speaker in his or her utterance. In order to do this, the listener must put together the structure that the listener intended to convey in the utterance; this process is called 'Syntactic Parsing'.

Several theories have attempted to explain how syntactic parsing occurs in the human mind. The main theories of syntactic parsing can be divided into two groups: serial models and parallel parsing models. These theories will be discussed below.

1.1.1. Serial Models of Parsing

A serial model consists of a series of steps that the parser has to perform in order to build the structure of a sentence. The most widely known serial model of parsing is called the 'Garden Path Theory' (Frazier, 1979). This theory is based on the idea that parsing is a two stage process. During the first stage, the parser analyzes word by word, and builds a structure by adding words to the unfolding sentence structure incrementally. During the second stage, the structure is revised, and if the parser realizes that the previously built structure is wrong, a reanalysis is performed (i.e. the parser builds the structure again). This two stage process can be observed in (1).

(1) *While Sarah was mending the sock fell of her lap*.

When speakers read (1), it is expected that they will initially attach the NP '*the sock*' to the immediately preceding VP '*mending*' because this NP is a plausible object for the VP. Frazier (1979) claimed that when the parser performs this kind of analysis, in which subsequent words are added to the immediately preceding phrases, the parser is executing the 'Late Closure' heuristic. Late Closure tells the parser to keep the last node open, and to attach new phrases to such node. However, Late Closure does not generate the correct structure all the time. For instance, when speakers read the word '*fell*' in (1), the parser immediately realizes that the previously built structure is incorrect because the next word cannot be incorporated. Therefore, the parser must reanalyze the structure. In (1), the verb '*mending*' must be understood as an intransitive verb, and the NP '*the sock*'

should be used as the subject of the verb fell. Doing this reanalysis has a processing cost for the parser, which has been observed as an increase in reaction times and errors of interpretation (Altmann & Steedman, 1988; Britt, 1994; Ferreira & Clifton, 1986; Frazier & Rayner, 1982; Konieczny & Hemforth, 2000; Phillips, Kazanina & Abada, 2005; Pickering & Traxler, 1998; Rayner, Carlson & Frazier, 1983; Trueswell, Tanenhaus & Kello, 1993). According to Frazier (1979), when the parser performs an analysis in which a particular node has to be closed, and the new words are not attached to immediately preceding phrases, the parser is executing the 'Minimal Attachment' heuristic (also called Early Closure), which states that structures should have as few nodes as possible. Minimal Attachment requires the parser to build the simplest structure available even if it means that new words have to attach to higher nodes in the tree as opposed to the immediately preceding ones.

As discussed above, serial models, such as the Garden Path theory, consider that the parser can only build one syntactic structure at a time, and if the wrong syntactic frame for such structure is chosen, it will have a processing cost. However, other models state that the parser is able to build several structures simultaneously. These models will be discussed below.

1.1.2. Parallel Parsing

Parallel Parsing theories are based on the idea that the parser performs multiple structural analyses at the same time. This notion does not contemplate 'reanalysis' (i.e. the parser does not need to tear down an incorrect structure and to build the correct one because all possible structures are built at the first stage).

Several theories describing how parallel parsing is performed have been discussed in previous studies (Traxler, Pickering & Clifton, 1998; Lewis, 2000; Gibson & Pearlmutter, 2000; van Gompel, Pickering and Traxler, 2000; van Gompel, Pickering & Liversedge, 2005; Green & Mitchell, 2006). The current research will focus on the Race-based Parallel Parsing model by McRoy and Hirst (1990), and Construal by Clifton and Frazier (1996) because these two theories make specific predictions about adjunct attachment, which is crucial to the study of attachment height.

1.1.2.1. Race-based Parallel Parsing

McRoy and Hirst (1990) created the Race-based Parallel Parsing model, which is based on the idea that the parser computes several possible structures simultaneously. These structures must compete in a "race" against each other, and the construction that reaches an acceptability threshold first is selected while the others are dismissed. This can be explained by analyzing (2) below.

(2) *The father of the fireman who had a black mustache was fired.*

In (2), the RC 'who had a black mustache', can be attached to the first (i.e. higher) NP '*the father*', or to the second (i.e. lower) NP *'the fireman'*, and both possibilities are semantically and syntactically plausible. However, only one reading is correct (i.e. the intention of the speaker was to say that only one of the two men had a black mustache). Therefore, the parser must select the correct choice, by analyzing non-syntactic factors, such as the context or the prosody of the speaker. This means that the parser, at an initial stage, attaches the RC to both NPs, and later, one attachment is selected, and the other one discarded.

1.1.2.2. Construal

Frazier and Clifton (1996) discovered that the parser does not perform the same kind of analysis when it builds a structure with Primary Relations (i.e. a verb and its arguments), and when it has to incorporate 'Non-primary Relations' (i.e. adjuncts). They claimed that the Garden Path theory required a revision in order to incorporate this distinction. According to them, Primary Relations are subject to the parsing heuristics described in the garden path theory (i.e. Late Closure and Minimal Attachment). This means that when building a structure made out of Primary Relations, one structure is built, and if it is incorrect it must be reanalyzed. As in the example *'When Sarah was mending the sock fell'*, the NP *'the sock'* is immediately analyzed as the object of the VP *'mending'* because here the Primary Relations *'verb'* and *'direct object'* are interacting. In contrast, when an adjunct is identified by the parser, it does not have to be immediately attached to a preferred site, as indicated by a heuristic. Adjuncts have the possibility to associate to several nodes in the three (i.e. to several phrases), and when the parser discovers what the correct reading is (e.g. by using prosody or the context as cues) one of the associations becomes a permanent attachment, and the other one is ignored. This is observed in the example below.

(3)   *The daughter of the secretary who had a black dress was promoted.*

In (3), once the parser identifies the RC *'who had a black dress'* as an adjunct, it is associated to all the possible nodes where it can attach (i.e. *'the daughter'* and *'the secretary'*). When the parser realizes which one is the correct attachment, that attachment is perform and the other association is ignored. This theory implies that no reanalysis is necessary because no structure has to be destroyed and built again, and also, that it has no

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cost for the parser to select between associations. Traxler, Pickering and Clifton (1998) found that no RT delays are generated any of the words of the relative clause (i.e. the speaker continues reading as if the sentence were not ambiguous), which confirmed the lack of cost for the parser when this kind of analysis is performed.

Leaving the parsing theories aside for a moment, the next section will introduce several experiments that have examined how speakers attach relative clauses. These studies incorporated new elements in the study of the parser of ambiguous structures.

1.2. Relative Clause Attachment

In some cases, Relative Clauses (RCs) are found in sentences in which they can be attached to two different nodes in a tree, generating two different semantic readings. An example of this type of ambiguity is exemplified in (4) below.

(4) *Someone shot the maid of the actress who was on the balcony.*

Sentence (4) above is ambiguous because the relative clause (RC) *'who was on the balcony'* can be attached to either the NP *'the maid'* or the NP '*the actress'*. Therefore, the interpretation of the sentence depends on the heuristic that the parser uses to generate the necessary attachments. Choosing the Late Closure heuristic would create a low attachment, which, in turn, would be taken to mean *'the actress was on the balcony'.* This structure is exemplified in the figure below
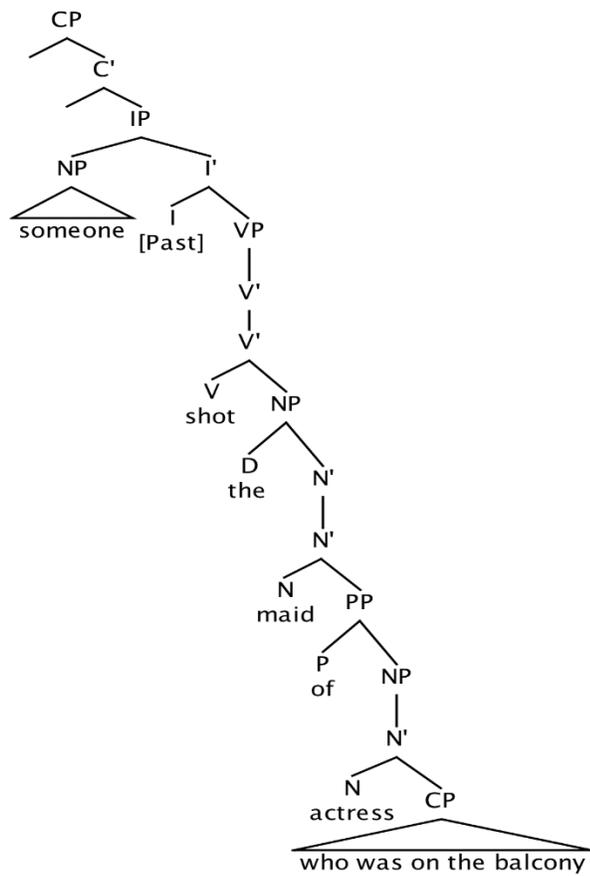
Figure 1.1. Tree diagram of a sentence with a low attachment in a relative clause.

In contrast, if Late Closure is not followed, the parser generates a high attachment (i.e. Early Closure). In this case, the meaning deduced from the sentence would be '*the maid was on the balcony*'. This structure is displayed in figure 1.2 below.
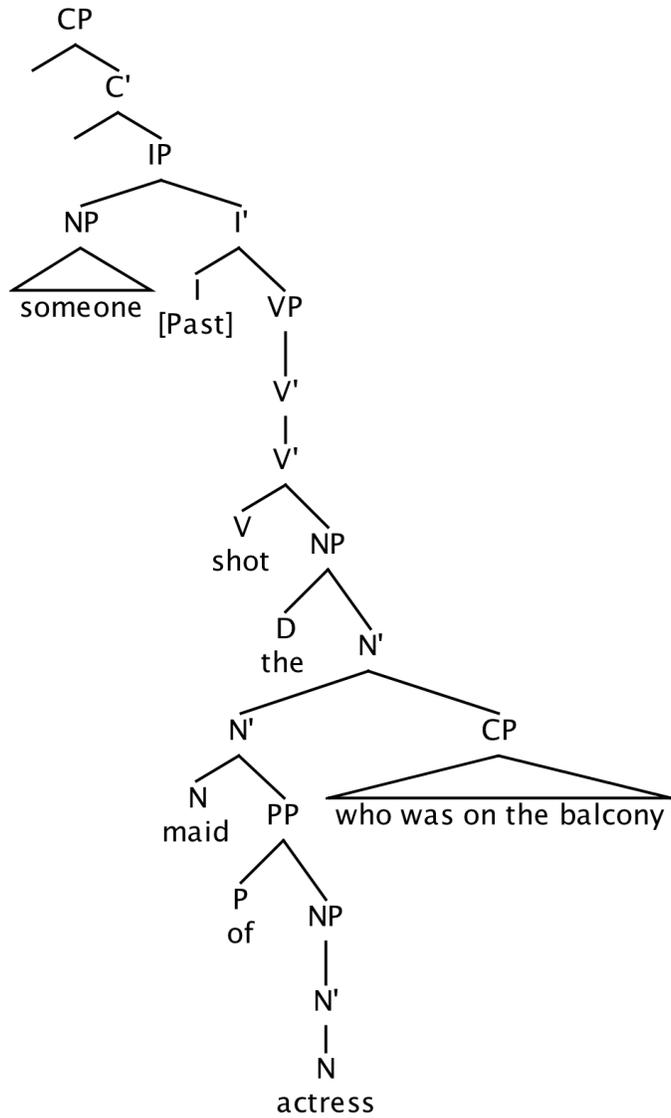
Figure 1.2. Tree diagram of a sentence with a high attachment in a relative clause.

The garden path theory by Frazier (1979) does specify that Late Closure is generally preferred, which would mean that the most common interpretation of (4) would attach the RC to the lower noun, 'the actress' as opposed to the higher noun 'the maid'.

However, the fact that having the RC attach to the higher noun is plausible, and that, in a particular context, the sentence could be used by a speaker to convey the meaning specified in figure 1.2 (i.e. high attachment) and not in figure 1.1 (i.e. low attachment) raises questions about how the parser chooses one heuristic over the other.

More recently, Frazier and Clifton (1996) formulated the Construal theory, which is an improvement to the garden path theory by Frazier (1979). According to Frazier and Clifton (1996), Late Closure and Early Closure only apply to what they called 'primary relations', (i.e. the subject and predicate of a clause, and the complements and obligatory constituents of primary phrases). This means that the general preference for Late Closure applies to verbs and arguments only. In the case of adjuncts, a series of semantic and pragmatic factors capable of overriding Late Closure can come into play. Gilboy, Sopena, Clifton and Frazier (1995) carried out a questionnaire-based study in which they tested whether the preference for high and low attachments was influenced by the ability of a preposition to assign a theta role. They used sentences as (5) and (6) below.

(5) *The tourists admired the museum of the city that they visited in August.*

(6) *The count ordered the steak with the sauce that the chef prepared especially well.*

Gilboy, Sopena, Clifton and Frazier (1995) found out that after subjects read sentence (5) around half of them preferred to attach the RC to the higher noun '*the museum*', and the other half preferred to attach the RC to the lower noun *'the city'*. In contrast, after observing sentence (6), the majority of the subjects preferred to attach the RC to the lower noun '*the sauce'.* This means that preposition '*with*' can block the attachment of the RC to the higher noun. Gilboy et al (1995) argued that this occurred

because preposition *'with'* is capable of assigning theta roles (e.g. instrumental or comitative). This blocking effect is not observed with a preposition that is not a theta-assigner, such as *'of'*.

Additionally, Gilboy, Sopena, Clifton and Frazier (1995) noticed that the presence of a determiner alters subjects' preference for an attachment site. To investigate this, they used sentences like (7) and (8) below.

(7) *They gave me the sweater of cotton that was illegally imported.*

(8) *They gave me the sweater of the cotton that was illegally imported.*

After reading (7), the great majority of the subjects attached the RC to higher noun *'the sweater'*. Note that in (7), the lower noun *'cotton'* does not have a determiner. In contrast, in (8) around half of the subjects preferred to attach the RC to the lower noun and the other half to the higher noun.

Having established the influences of theta-assigning prepositions, and determiners, it is still unclear what happens when these two elements do not come into play (i.e. when a theta-assigning preposition is not present, and when both nouns hold a determiner because, as explained above, the lack of a determiner in one of the nouns can bias speakers towards attaching to the other noun). This case has been studied in cross-linguistic studies, which have found asymmetries in subjects' preferences are language specific. Cuetos and Mitchell (1988) carried out a study in which they asked a group of native speakers of English and group of native speakers of Spanish to provide a semantic interpretation for a sentence containing a relative clause, such as (9) below.

(9) *Someone shot the maid of the actress who was on the balcony.*

Cuetos and Mitchell (1988) found that native English speakers preferred an interpretation consistent with attaching relative clauses as in (9) to the immediately preceding noun. For example, this group of speakers would infer from sentence (9) that the actress was the one on the balcony because they would attach the relative clause 'who was on the balcony' to the immediately preceding NP 'the actress'. In contrast, Spanish speakers preferred to attach relative clauses as in (9) to the higher noun. For instance, after reading (9), they would say that the maid was on the balcony because they would attach the relative clause 'who was on the balcony' to the higher NP 'the maid'. Then, this can be used as evidence to argue that the preference for one type of attachment over the other is language specific. This account of the interaction between attachment sites and the compositional meaning of a sentence is consistent with a "Syntax First" approach, i.e. the idea that syntactic structures are built by the parser before a semantic interpretation is generated (Kako & Wagner, 2001).

Fernandez (2002) carried out a study to confirm Cuetos's and Mitchell's (1988) findings and also to investigate which heuristic could possibly be used by English-Spanish bilinguals considering that the two languages are supposed to have a different preference regarding heuristics. Fernandez (2002) conducted two experiments. Her first experiment used questionnaires with the same type of sentences used by Cuetos and Mitchell (1988), such as (1), and asked the subjects about the meaning of the sentences. In this part of her research, she confirmed the results from Cuetos and Mitchell (1988), which indicated that native speakers of English preferred low attachments and Spanish speakers preferred high attachments. She also found out that English-Spanish bilinguals

followed the preferences of the language they were tested on at the moment. Thus, they preferred low attachments in English and high attachments in Spanish.

In her second experiment, Fernandez (2002) created a self-paced reading task involving sentences with relative clauses that agree in number with only one of the nouns constituting the possible attachment sites in the main clause. Examples of such sentences appear in (7) and (8) below. The Spanish experiment used direct translations of the English stimuli as in (7a) and (8a) below.

(10) *Patricia saw the teacher of the students that were in the library the other day.*

(11) *Patricia vio al professor de los estudiantes que estaban en la biblioteca el otro dia.*

Patricia saw to-the professor of the students that were in the library the other day.

'Patricia saw the professor of the students that were in the library the other day.'

(12) *Patricia saw the teacher of the students that was in the library the other day.*

(13) *Patricia vio al professor de los estudiantes que estaba en la biblioteca el otro dia.*

Patricia saw to-the professor of the students that was in the library the other day.

'Patricia saw the professor of the students that was in the library the other day.'

In (10) and (11), the verb 'be' appears in plural form ('were'); thus, it agrees with the immediately preceding noun 'the students'. This means that in (10) the relative clause is attached to the lower noun, requiring a low attachment. However, in (12) and (13) the verb 'be' appears in singular form ('was'), which demonstrates that the relative clause is

attached to the higher noun 'the teacher'. According to Fernandez's (2002) predictions if Spanish speakers preferred the high attachment they would have reading delays at 'were' in sentence (10) because this structure holds a low attachment because the form 'were' does not agree in number with the nun in the high attachment. However, these delays would not be present in (12) at the word 'was' because this structure complies with low attachment rules. On the contrary, English speakers, allegedly preferring low attachments, would have reading delays when seeing the singular verb in (12), but not the plural verb in (10), since the plural verb agrees with the lower noun.

Fernandez (2002) found that in this on-line task, both groups behaved equally, and experienced reading delays when parsing sentence (12), in which the verb of the relative clause does not agree with the lower noun. This implies that both English and Spanish speakers initially prefer lower attachments, as observed in this behavioral task. On the other hand, the parsing preferences differ in off-line tasks such as questionnaires; while English speakers continue to prefer low attachments, Spanish speakers change their preferences to high attachments. Fernandez (2002) concluded that attachment parsing was a two-step process. In an initial stage, speakers of both languages preferred low attachments, but a later stage, English speakers would keep their initial attachment while Spanish speakers would recalculate and proceed to attach high. This late stage of the process is captured by questionnaires, which provide the parser with enough time to recalculate structures; this probably happens after the full sentence is parsed, and the speaker has enough information to process the holistic meaning of a sentence, which allows post-syntactic factors, such as prosody to come into play.

Other questionnaires and reaction time studies have also been conducted to evaluate attachment height preferences in other languages, and their findings seem to support the language specificity of this parameter. A preference for high attachments has been observed in speakers of Dutch (Brysbaert & Mitchell, 1996), French (Zagar, Pynte & Rativeau, 1997), Japanese (Kamide & Mitchell, 1999), and Greek (Papadopoulou & Clahsen, 2003). In contrast, low attachments were preferred by speakers of Arabic (Abdelghany & Fodor, 1999), Swedish, Norwegian and Romanian (Ehrlich, Fernandez, Fodor, Stenshoel & Vinereanu, 1999).

While questionnaires and reaction time studies, such as Cuetos and Mitchell (1988), and Fernandez (2002), have proven useful to determine the possible language-specific asymmetries between English and Spanish attachment height preferences, they do not provide any information about the detailed time course of the parsing processing in each language, which could reveal whether the asymmetries found emerge from automatic processing, or from post-syntactic sentence comprehension strategies. Observing the detailed time course of parsing processing can be achieved by measuring brain responses through Event Related Potentials (ERP).

The experiments and questionnaires addressing attachment height preferences in relative clauses conducted so far have not yet provided a reason for the cross-linguistic asymmetries found. One of the explanations given to these asymmetries is that languages that attach high have different syntactic structures from those that attach low. This hypothesis will be discussed below.

1.2.1. The Pseudo-Relative Hypothesis

According to Grillo (2012), the main difference between languages in which high attachments are preferred and languages in which low attachments are favored lies on the types of syntactic structures allowed in those languages. Grillo (2012) suggested that languages with a preference for high attachments allow for a Pseudo-Relative structure that is not available in languages that prefer low attachments. Such claim has been supported by several subsequent studies (Grillo & Costa, 2014; Grillo, Costa, Fernandes & Santi, 2015; Grillo & Turco, 2016). How this Pseudo-Relative structure works can be observed in (14) below.

(14) *Carlos vio a Juan que corria.*

Carlos saw to Juan that ran

'Carlos saw that Juan was running.'

In (14), the subordinate clause *'que corria' ('that ran')* seems to be an RC that attaches to the NP *'Juan'*. If this were true, the meaning of the sentence would be that Carlos saw Juan, who happened to be running. However, native speakers do not assign this interpretation to this structure. The actual reading requires the subordinate clause to be interpreted as a complement clause, attached to the verb *'saw'*. In this case, the NP *'Juan'* is not interpreted as the object of the verb *'saw'*, but as the subject of the verb *'running'*. This type of analysis leads to a semantic reading in which Carlos sees a running event carried out by Juan (i.e. Charles sees John running). This semantic reading corresponds to the interpretation that most native speakers of Spanish give to (14). This structure is not allowed in English (*'Charles saw Juan that run'). According to Grillo (2012), the availability of such structure in Spanish bias speakers towards a high

attachment preference when parsing seemingly ambiguous RCs. This reasoning can be explained by examining (15) and (16) below.

(15) *La sirviente de la actriz corrio hacia el balcon.*

The maid of the actress ran towards the balcony

'The maid of the actress ran to the balcony.'

(16) *El policia le disparo a la sirviente de la actriz que corrio hacia el balcon.*

The policeman CL shot to the maid of the actress that ran towards the balcony.

'The policeman shot the maid of the actress who ran to the balcony.'

In (15), no ambiguity is present. Speakers must notice that the person performing the action described by the verb (i.e. *'running'*) is the maid (higher NP) and not the actress (lower NP). According to Grillo (2012), in (16), the parser acts in a similar way. The ambiguous relative clause is interpreted as a Pseudo-Relative, and the maid, which is in the higher NP, is expected to perform the action shown by the verb in the RC. In other words, the parser would only consider the high attachment as grammatical because the whole complex NP (i.e. '*the maid of the actress*') is considered as the subject of the verb 'ran', and in this way, it would be ungrammatical to have a low attachment (i.e. just as it is ungrammatical to have a low attachment in (15) because this attachment would generate the reading *'the actress ran'*).

Grillo (2012) claimed that all RCs in Spanish are interpreted as Pseudo-Relatives. This preference for Pseudo-Relatives would be a consequence of the application of the

Minimal Attachment principle, described by Frazier and Clifton (1996), which states that the structure with the fewest nodes should be created.

Grillo (2012) also argued that the preference for low attachments in English was due to Late Closure, which states that new structures should be attached to the lowest node available. This heuristic would apply in English in this structure since no rule against attaching to the low node is present in the grammar (i.e. as opposed to Spanish, in which the low attachment would be barred by the Pseudo-Relative).

Note that the formation of Pseudo-Relatives requires the presence of a complementizer, such as *'que'* in Spanish (i.e. *'that'*), which serves as the head of a CP that can be used as a complement clause instead of an RC. This implies that other structures that exhibit attachment height ambiguities, such as prepositional phrases, are not subject to the Pseudo-Relative interpretation. The following section will present a discussion regarding attachment height ambiguities involving prepositional phrases.

1.3. Prepositional Phrase Attachment

Letting relative clauses aside for now, prepositional phrases can also exhibit high or low attachments, in a similar manner to relative clauses. This is observed in example (17) below.

(17) *The man saw the boy with binoculars.*

In (17), the PP *'with binoculars'* can be attached to either the VP *'saw'* (high attachment) or the NP *'the boy'* (low attachment). The preference for one attachment or the other regarding this type of ambiguity has been examined in several studies. Rayner, Carlson and Frazier (1983), conducted an eye-tracking experiment. In which they used a

sentence similar to (17) with two types of completions, one favoring a high attachment, as (18) below, and one favoring a low attachment, as (19) below.

(18) *The spy saw the cop with binoculars, but the cop didn't see him.*

(19) *The spy saw the cop with a revolver, but the cop didn't see him.*

In (19), the PP *'the revolver'* cannot be attached to the verb *'saw'* because revolvers cannot be used as an instrument to see, which means that such PP should have a low attachment (i.e. to the NP *'the cop'*). In contrast, in (18), a high attachment is preferred because the PP *'with binoculars'* can be attached to the verb *'see'* and be used as an instrument. Rayner, Carlson and Frazier (1983) noticed an increase in reading times to the completion favoring a low attachment, as in (19), which implies that subjects preferred the high attachment, and for that reason, processing the low attachment had a cost for them.

Clifton, Speer and Abney (1991) conducted a reaction time study in English, in which they tested sentences with prepositional phrases that were only plausible if attached high or low as observed in (20) and (21) below.

(20) *The saleswoman tried to interest the man in the wallet during the storewide sale.*

(21) *The saleswoman tried to interest the man in his fifties during the storewide sale.*

In (20), the PP *'in the wallet'* should clearly be attached to the VP *'sale'* while in (21), the PP 'in his fifties' should be attached to the NP 'the man'. Results indicate that reaction times increased when the PP had to be attached low, which indicates a preference towards high attachment (i.e. attachment to VP).

Another study by Thornton, McDonald and Arnold (2000) included a self-paced

reading task, which intended to test whether subjects preferred to attach a PP to a verb

(high attachment) or to an NP between the VP and the PP (low attachment). Examples of

the stimuli they used appear below.

(22) VP attachment – short: *The salesman glanced at the customer with suspicion*

and   then walked away.

(23) NP attachment - short: *The salesman glanced at the customer with ripped*

jeans and then walked away.

(24) VP attachment – long: *The salesman glanced at the amazingly rude young*

customer with suspicion and then walked away.

(25) NP attachment – long: *The salesman glanced at the amazingly rude young*

customer with ripped jeans and then walked away.

In (22), the PP must be attached to the VP to be plausible, while in (23), the PP

must be attached to the NP instead. Sentences (24) and (25) are similar to (22) and (23);

however, the NPs located between the VP and the PP are longer in order to test whether

NP length had an impact on attachment preferences.

Thornton, McDonald and Arnold (2000) found that reaction times to the

prepositional phrase increased when subjects read sentences that required NP attachments

(i.e. as (22) and (24) above). This means that subjects preferred to attach PPs to the VP

(high attachment) since PPs requiring to be attached to NPs (low attachments) were

unexpected, as evidenced by an increase in reaction times. Similarly, they discovered that

the tendency to prefer a VP decreased with longer NPs, which means that length has an

impact on attachment preferences. This suggests that prosodic packing plays a role in the

attachment selection process since longer NPs require a different prosodic contour than shorter NPs.

To summarize, the studies reviewed so far support the idea that English speakers prefer to attach PPs to VPs and not to NPs (i.e. high attachments are preferred when VPs are available), which appears to contradict the general preference for high attachments that has been attested in studies in which VPs are not used as possible attachment sites. This implies that parsing preferences might not be universal; the principles followed in VP structures do not necessarily hold when VPs are absent. The preference to attach PPs to VPs has also been attested in French (Frenck-Mestre & Pynte, 1997) and Greek (Katsika, 2008). Note that the studies previously discussed have tested the VP – NP – PP construction, where the VP precedes the NP, and therefore, attaching a PP to the VP requires a higher attachment than attaching to the NP, which immediately precedes the PP. However, the strong preference for VP attachment might not be due to attachment height preferences, but rather to a general preference for VP attachment that overrides other heuristics (e.g. Late Closure). This strong preference to attaching to VPs has been also observed in other studies with constructions different from PPs (Altmann & Steedman, 1988; Ferreira & Clifton, 1986). Therefore, in order to observe full ambiguity in PP attachment height (i.e. without having the interference of VPs), it would be necessary to use a structure in which a PP could attach to two different phrases of the same kind so that VPs would not be preferred by default.

Thornton, McDonald and Gil (1999) conducted a cross-linguistic study, in English and Spanish, in which they tested subjects' reaction time responses to sentences

in which a prepositional phrase could attach to two different noun phrases, as observed in the examples below.

(26) *The computer of an office <u>with a giant screen</u> was bought to speed up work.*

(27) *The computer of an office <u>with few employees</u> was bought to speed up work.*

(28) *The computer of my office <u>with a giant screen</u> was bought to speed up work.*

(29) *The computer of my office <u>with few employees</u> was bought to speed up work.*

Note that sentences above have an ambiguous prepositional phrase that starts by *'with'*. As previously stated, 'with' is a theta-assigning preposition, and it can force the parser to attach to a lower noun (e.g. in the phrase *'the maid <u>with</u> the actress that was on the balcony'*, attaching the RC to the lower noun will be preferred). However, preposition 'with' only disables structural ambiguity if it is placed between the two possible attachment sites for the adjunct (i.e. RCs or PPs). For example, in the structure *'the maid of the actress with the bouquet'*, the PP *'with the bouquet'* can be attached either to the high *('the maid')* or to the low node *('the actress')* because these two attachment sites are separated by preposition *'of'*, which does not assign a theta role. In contrast, in the structure *'the maid with the actress with the bouquet'*, the PP *'with the bouquet'* is attached to the low node *('the actress')* because preposition 'with' assigns a theta role to the lower noun *('the actress')*, and this prevents the PP 'with the bouquet' from attaching to a noun placed in a higher position *('the maid')*. Taking this into consideration, Thornton McDonald and Gil (1999) did not use preposition 'with' between the two possible attachment sites in their stimuli. However, 'with' can be the head of the critical PP that can be attached to either a high or a low node as in the examples above (e.g. in (26) *'with a giant screen'* can be attached to either *'the computer'* or *'an office'*. In this

case, *'with'* does not disambiguate the structure because it appears after the two possible attachment sites.

Due to semantic plausibility, in (26) the PP must be attached to the first NP '*the computer'*. In (27), the PP must be attached to the second NP *'an office'*. Sentences (28) and (29) are similar to (27) and (28), but they hold a possessive pronoun instead of the indefinite article in the second NP in order to observe if attachment preferences changed when the lower NP was a more specific entity, and therefore, more difficult to modify. RTs were time-locked to the critical prepositional phrase. The results of this study indicate that English speakers' reaction times significantly increased when the PP needed to be attached to the first NP (high attachment). This implies that English speakers preferred low attachments. In contrast, Spanish speakers showed equal reaction times in both conditions. This means that there is an asymmetry across languages in the attachment height preferences that apply to the PPs of these kinds of sentences. The results found in this study coincide with previous research testing relative clauses since English speakers also prefer low attachments when those structures are used (Cuetos & Mitchell, 1988; Fernandez, 2002). The fact that Spanish speakers show no strong preference for low attachments has also been previously attested in the study of RCs (Cuetos & Mitchell, 1988). However, this study still raises questions about why no preference was shown by Spanish speakers. It is possible that the measurement they used (i.e. reaction times) was not sensitive enough to capture the attachment height preference of these speakers.

1.4. Prosody as a Disambiguating Mechanism

Prosody is used by speakers as a disambiguating mechanism during speech production. The importance of prosody can be observed when speakers produce sentences like (30) below.

(30) *The professor said the student had on socks that did not match.*

When a speaker utters (30), prosody is a crucial feature to determine the meaning conveyed. If the speaker inserts a pause after *'said'*, this sentence would mean that one professor is talking about a student's socks. In contrast, if the speaker inserts a pause before *'said'* and another before *'had'*, this sentence would mean that one student is talking about a professor's socks. As observed in this example, how constituents are attached, and, therefore, the semantic reading assigned to the utterance are determined by the distribution of pauses (Speer & Blodgett, 2006). Prosody has similar effects on ambiguities triggered by attachment height as observed in (31) below.

(31) *Susie learned that Bill telephoned after John visited.*

In (31), the CP *'after john visited'* can be attached to the higher VP *'learned'* or to the lower VP *'telephoned'*, proving two different semantic interpretations. If no pause is inserted, the listener is likely to attach the CP to the VP *'telephoned'*, in which case the sentence would mean that John's visit occurred before Bill's call. If a pause is inserted after *'telephoned'*, the listener will attach the CP to the VP *'learned'*, in which case the sentence would mean that John's visit happened before Susie knew about Bill's call. This example makes clear that prosody has a direct impact on constituent attachment (Carlson, Clifton & Frazier, 2001). Similar effects have been observed in other structures, such as appositives (Briscoe & Buttery, 2007).

Prosody is language-specific, and even in short affirmative sentences, cross-linguistic differences have been attested (Delattre, 1963). Therefore, prosody should be taken into account when analyzing attachment processing cross-linguistically. In the current study, written stimuli will be used in order to control for prosody.

Speakers' knowledge of the prosodic features of their own language can help them make decisions about the holistic meaning of a sentence in off-line tasks even if silent reading is used (Fodor, 2002). However, the interpretation of prosodic features is likely to occur at a late stage of the parsing process as proposed by McRoy and Hirst (1990), and supported by Fernandez (2002) and Thornton McDonald and Gil (1999).

   1.5.   ERP Experiments Related to Ambiguity

This section will introduce ERP experiments that have addressed syntactic ambiguity. These studies will serve as background for the current research.

Hopf, Baden, Meng and Mayer (2003) conducted a study in which they tested garden path effects in sentences that started with nouns with ambiguous case (Accusative / Dative). An example of the stimuli they used appears below.

(32) Ambiguous case: *Dirigenten, die ein schwieriges Werk einstudiert haben,*

   kann ein Kritiker ruhig applaudieren.

   Conductors-DAT/ACC who a difficult opus rehearsed have, can a critic

   safely applaud.

   (A critic can safely applaud conductors who have rehearsed a difficult opus.)

(33) Ungrammatical case: *Musiker, die ein schwieriges Werk einstudiert haben,*

kann ein Kritiker ruhig applaudieren.

*Musicians-ACC who a difficult opus rehearsed have, can a critic safely

applaud.

(A critic can safely applaud musicians who have rehearsed a difficult opus.)

(34) Grammatical case (control): *Musikern, die ein schwieriges Werk einstudiert*

haben, kann ein Kritiker ruhig applaudieren.

Musicians-DAT who a difficult opus rehearsed have, can a critic safely

applaud.

(A critic can safely applaud musicians who have rehearsed a difficult opus.)

In all examples above, the verb *'applaud'* requires a dative object (i.e. it works as a benefactive since someone receives the applause). Accusative objects for this verb are judged as ungrammatical. The word *'conductors'* has an ambiguous dative/accusative form; therefore, it can be judged as grammatical if parsed as a dative form, or ungrammatical if parsed as an accusative form. In contrast, the word *'musicians'* has different dative and accusative forms. Hopf, Baden, Meng and Mayer (2003) observed an N400-like response to both ambiguous sentences, as in (32), and ungrammatical sentences, as in (33), when compared to controls, at an early time window, 300-500msec after the critical verb. However, this effect disappeared later (500-700msec) in ambiguous sentences, and remained in ungrammatical ones. Hopf et al. (2003) concluded that when parsing ambiguous cases the parser initially interprets the structure as ungrammatical and quickly reanalyzes, which explains why the effect disappears. The effect continues to be present in ungrammatical structures because even after the parser

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tries to reanalyze the sentence remains ungrammatical. Hopf et al. (2003) considered this

as an evidence to support serial parsing models. Note that this study analyzed

ungrammaticality triggered by the relationship between a verb and its objects, which

Construal labels as primary relations (Frazier & Clifton, 1996). Therefore, Construal

predicts that parsing heuristics would apply in this case, triggering the two-stage process

(i.e. analysis and reanalysis). This is not the case for ambiguous adjuncts such as relative

clauses.

So far, the only ERP study addressing attachment height preferences in relative

clauses was carried out by Carreiras, Salillas and Barber (2004). In this study,

experimenters tested Spanish sentences with relative clauses that could trigger a gender

mismatch if attached high or low, as in the examples below.

(35) *El   criado   de la actriz   que estaba divorciado.*

The servant-MASC   of the actress-FEM who   was   divorced-MASC

'The servant of the actress who was divorced.'

(36) *El   criado   de la   actriz   que estaba   divorciada.*

The servant-MASC of the   actress-FEM who   was   divorced-FEM

'The servant of the actress who was divorced.'

In (35) above, the adjective in the relative clause, 'divorced', does not agree in

gender with the lower NP 'the actress', while it agrees in gender with the higher NP 'the

servant'. In (36), the opposite occurs; the adjective in the relative clause agrees with the

lower noun and not with the higher one. This experiment did not record reaction time

data as EEGs were recorded while stimuli were shown automatically on a screen. A P600

was observed as a response to sentences like (36), in which the high attachment provokes

the gender mismatch, when compared directly to sentences like (35), in which the low attachment is ungrammatical. P600 is associated with reanalysis, and Carreiras, Salillas and Barber (2005) interpreted this response as an evidence for Spanish speakers' preference for high attachments. However, note that the ERP response was obtained by comparing both violations directly (i.e. ungrammaticality in the high attachment against ungrammaticality in the low attachment), and no control condition was added.

At this point no ERP study has assessed attachment height preferences in English, and no study with a control condition has done so in Spanish. Similarity, no cross-linguistic comparison of the ERP responses in English and Spanish has ever been reported. The next section will present a justification for the current study, which will highlight the relevance of this research.

1.6. Justification

A study of attachment height ambiguities using ERPs could help elucidate what happens at early stages of the parsing process, which previous questionnaires and RT studies have not accounted for. According to Osterhout (1994), ERPs have become an essential tool in the analysis of models of language comprehension because they provide information about the neurological activity that occurs in the cerebral cortex during the processing of language stimuli. By observing ERPs, researchers can evaluate speakers' responses towards linguistic stimuli even if such responses are unconscious and not apparent in the behavioral patterns of the individual. Additionally, ERPs serve to observe different time frames in which a neurological response occurs (e.g. at 200msec vs. 400msec), which provides an idea about which specific aspects of language are processed at different times (e.g. responses to phonological stimuli might occur earlier than those to

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syntactic stimuli, etc.). ERP experiments can serve to examine how attachment height preferences work during the real time course of language processing and can, therefore, show whether attachments site preferences change across time.

At this point, no ERP experiment comparing attachment height preferences across languages has been carried out. In order to observe more closely the processing of attachments, it will be necessary to carry out ERP experiments focusing on the detailed time course of the parsing of such attachments. The specific reason why ERP data is important is because it allows for the analysis of the time course of a parsing process. In other words, by observing the electrical changes in a speaker's scalp, different stages of parsing can be documented. For instance, a P600 effect is considered an evidence of reanalysis (i.e. if the speaker attaches to one site, and then self-corrects to attach to another site). Off-line data does not provide this information. For instance, when answering a questionnaire, a speaker can change his/her mind, and this is not recorded in the responses that result from such questionnaires (i.e. subjects' off-line linguistic responses, usually in written form, after reacting to the stimuli). Likewise, reaction time delays only demonstrate that the processing of a particular word was more costly than another at the end point of such process with no additional information available; for instance, no information is provided about what happened in the parser before or after the critical word at which RTs are tested. Studies so far have not captured the early stages of the parsing process (i.e. what occurs in the parser before a behavioral response is produced). An ERP study could provide an insight to these early stages by providing information about what occurs in the brain immediately after the ambiguous structures are processed and before other processes that could be related to language-specific

strategies, such as the analysis of prosody or other post-syntactic elements, come into play. ERPs can be used as a tool to accurately assess the attachment height preferences of a group of speakers because this technique provides information about what is occurring in the brain at the moment of parsing (i.e. during, and immediately after the speaker perceives a word that induces ambiguity or a semantic or syntactic violation) and this can serve to determine whether speakers perform a high or a low attachment by observing whether they perceive violations triggered by performing such attachments.

A study using ERPs in order to observe speakers' responses to PPs in ambiguous structures, such as those described by Thornton, McDonald and Gil (1999), is also needed. The importance of analyzing attachment height with prepositional phrases lies on the fact that these structures are not subject to the Pseudo-Relative theory posited by Grillo (2012). Therefore, analyzing these structures can help elucidate whether the Pseudo-Relative structure that can be assigned to RCs has an impact on parsing, or whether speakers respond in similar ways to different kinds of ambiguous adjuncts (i.e. RCs and PPs).

The current research aims to examine the processes that occur in the brain during the parsing of sentences with different types of attachment height. We aim to map out the detailed early and late time course of English and Spanish processing in order to observe the possible differences that can account for the asymmetry in attachment preferences observed by previous researchers during off-line tasks, and by Fernandez (2002) in her RT study, in which ERPs were not recorded. Attachment height choices will be tested by using relative clauses and prepositional phrases in sentences in which they can have two possible attachment sites (i.e. high and low).

At this point, attachment height preferences have mostly been analyzed through tasks such as questionnaires (Cuetos & Mitchell, 1989), and reaction time experiments (Fernandez, 2002). The only ERP experiment has exclusively covered Spanish, without collecting reaction time data. In this study, only a P600 was detected; early processing as evidenced by N400/LAN was not observed, and late processing, as evidenced by reaction times, was not measured (Carreiras, Salillas & Barber, 2004). Conducting an ERP experiment including reaction time data will allow for the observation of the detailed time course of brain activity triggered by parsing during the processing of sentences requiring low or high attachments in both English and Spanish. This observation will lead to a comparison of this time course of the parsing processing between the two languages, which will serve to identify the existence of differences that could account for the cross-linguistic asymmetry in parsing preferences since these differences could be observed at different stages in the process (i.e. early processing vs. late processing) if such differences exist.

Chapter 2

MODELS OF ATTACHMENT PROCESSING

This chapter will introduce different models of attachment processing based on the findings of previous studies and theories of how the attachment process works. These models are not stated in previous studies, but they are based on the conclusions of such studies or theories. In order to present the models, examples (24) and (25) below, which illustrate different types of attachments, will be used. These sentences have a relative clause that could be attached to two different NPs, one of which would be higher in the tree diagram than the other. However, the morphological agreement between a particular NP and the verb inside the relative clause forces the parser to choose one option over the other in order to preserve grammaticality.

(37) *The man saw the maids of the bride who was on the balcony.*

(38) *The man chased the father of the children who was on the street.*

In (37) above, if the relative clause 'who was on the balcony' is attached high, the sentence becomes ungrammatical since the NP 'the maids' is plural, and the verb 'was' has a singular inflection. If such relative clause is attached low, the sentence is grammatical since the NP 'the bride' agrees in number with the verb. In contrast, in (38), if the relative clause 'who was on the street' is attached high, the sentence is ungrammatical because the NP 'the children' is plural, and the verb 'was' is singular. If such NP is attached high, the NP 'the father' agrees with the verb, which makes the

sentence grammatical. Therefore, we can observe that (37) shows an ungrammatical high attachment while (38) exhibits an ungrammatical low attachment.

2.1. Single Analysis

According to the study by Cuetos and Mitchell (1988) based on questionnaires, English speakers attach low while Spanish speakers attach high. If this hypothesis is true, English speakers should be sensitive to the ungrammaticality in (38), which is only ungrammatical if attached low, and insensitive to the ungrammaticality in (37), which is only ungrammatical if attached high. This means that reaction times to the verb inside the relative clause should be higher in (38) than in (37) for English since the former holds ungrammaticality at their preferred attachment site. Meanwhile, Spanish speakers should be sensitive to the ungrammaticality in (37), which displays a high ungrammatical attachment, while they should be blind to the ungrammaticality in (38), whose attachments they do not prefer. This model does not contemplate reanalysis.

2.2. Late Reanalysis

Fernandez (2002) claimed that English speakers attach low initially and do not reanalyze, which is why in her experiments, English speakers preferred low attachments in both offline (questionnaires) and online tasks (reaction time experiments). In contrast, Spanish speakers follow a different model. According to Fernandez (2002), a Spanish speaker initially performs a low attachment, and after the sentence is completely parsed, reanalysis occurs, and a high attachment is performed. This claim is based on the fact that she observed that in reaction time experiments (on-line) Spanish speakers preferred low attachments, while in questionnaires (off-line), high attachments were preferred. This model is explained in the figure below. The specific time course estimates (i.e. 200msec,

400msec) were not stated by Fernandez, and are merely hypothetical time ranges, whose

purpose is to represent the relative timing of the events that occur during the parsing
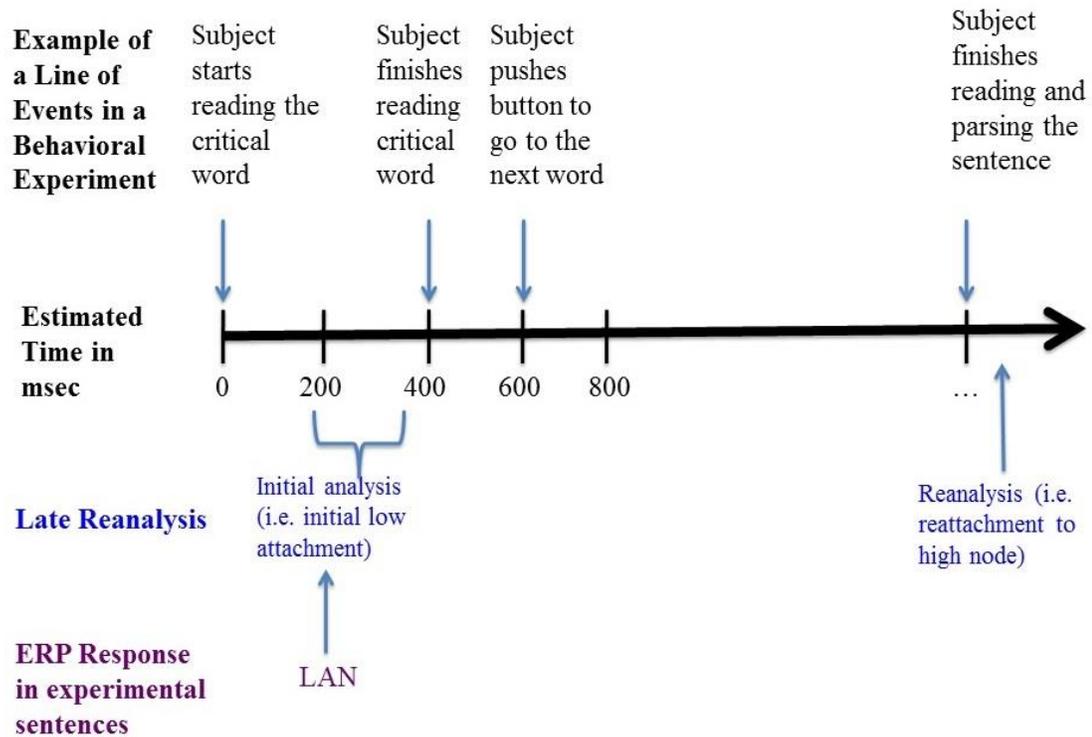
process.

Figure 2.1. Detailed time course of the Spanish speaker's attachment process

according to Late Reanalysis.

As observed in the graph, attachment reanalysis only occurs very lately in the

process, after the whole sentence has been parsed. This reanalysis results from the

application of language specific post-syntactic strategies for sentence comprehension,

which emerge after the sentence is completely parsed and the speaker has the time to

reflect on its meaning to solve possible ambiguities, as claimed by MacWhinney, Bates

and Kliegl (1984).

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If this hypothesis is true, both English and Spanish speakers should be sensitive to the ungrammaticality triggered by the low attachment shown in (38); this sensitivity should trigger an ERP response, probably a LAN response, which is the expected outcome of morpho-syntactic agreement errors, as in the structure generated by the low attachment in (38) (Osterhout, 1994)[1]. Also, both Spanish and English speakers should be blind to the ungrammaticality caused by the high attachment presented in (37) during real time processing (i.e. as attested by online measurements such as ERPs). In this case, the reanalysis carried out by Spanish speakers after reading the whole sentence, which is attested in Fernandez's (2002) questionnaire study, should not generate an ERP response (i.e. no P600 should appear) since ERPs measure the immediate real-time brain responses triggered by the parsing process. In other words, this model predicts that reanalysis would occur after the P600 time window of observation (600-800msec after the critical word), which is why a P600 would not be observed.

2.3. Early Reanalysis

According to Osterhout (1994), speakers can perform reanalysis immediately after their initial analysis (e.g. it can occur around 600msec after the onset of critical words, which is in the time course domain of is in the time course domain of a P600). This means that at the moment of parsing, speakers are able to change the initial interpretation of a sentence and change it to a different one by changing the attachments performed (i.e. this implies that they can change from a low to a high attachment and vice versa). Since reanalysis occurs online, it triggers a P600 response (i.e. a change in voltage in a

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[1] Note that an N400 has been observed instead of a LAN as a response to agreement errors in previous studies (Tanner & Van Hell, 2014).

speaker's scalp, peaking 600ms after the perception of the stimulus of the sentence that triggered reanalysis).

Taking into account Fernandez's (2002) observations that Spanish speakers switch from low to high attachments between online and offline tasks, it is possible that these speakers initially perform low attachments. If attachment ambiguity is observed (i.e. there is a higher available node to which an adjunct can attach), low attachments would be immediately reanalyzed, and transformed into high attachments. In other words, reanalysis can occur much earlier in the process than in the late reanalysis model (i.e. it would occur in the time range in which a P600 can be observed), and that this reanalysis can be captured by an online measurement, such as ERPs. The detailed time course of the analysis performed by a Spanish speaker according to this model is displayed in the figure below.
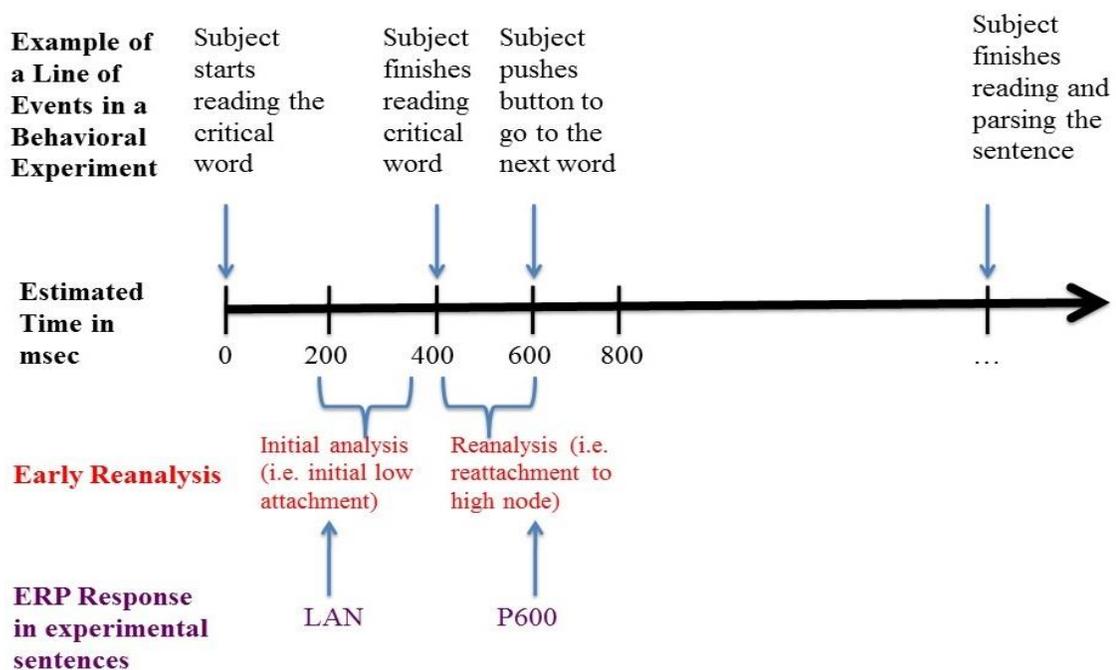
Figure 2.2. Detailed time course of a Spanish speaker's attachment process according to Early Reanalysis.

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In the previous figure, it is possible to see that according to Early Reanalysis, Spanish speakers perform an initial attachment, as soon as they read the word. This initial attachment is quickly reanalyzed and changed. In other words, this model states that both initial analysis and reanalysis occur online (i.e. at the very moment in which the subject is trying to incorporate the word into the sentence that is being parsed).

If this hypothesis is true, Spanish speakers will be sensitive to ungrammaticality in low attachments, as observed in (38). However, they should also show evidence of reanalysis. Since the current research will measure ERPs, the initial sensitivity of low attachments should produce a LAN response (i.e. ERP associated with agreement errors, see Osterhout (1994)) peaking between 300 and 500msec after the onset of the critical word (in this case, the verb triggering morphological disagreement with its subject), and later, 600msec after the critical word, a P600 should be observed (i.e. a P600 is an ERP response associated with reanalysis (Osterhout, 1994)).

2.3.1. Early vs. Late Reanalysis

As previously discussed, Fernandez (2002) found sensitivity to low attachment ungrammaticality in both English and Spanish speakers during reaction time experiments. However, she also discovered that in questionnaires (i.e. off-line measurement), English speakers keep the low attachment that they exhibited at the early only stage, while Spanish speakers switch to a high attachment. This led her to believe that the reanalysis performed by Spanish speakers to switch from a low to a high attachment in an off-line measurement is due to the application of language-specific post-syntactic sentence comprehension strategies which are used after the sentence is parsed, and the speaker has to make a conscious decision about the attachment that is being made (i.e. as in a

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questionnaire in which the speaker is explicitly asked if the relative clause attaches to the higher or the lower noun). However, the Early Reanalysis model does not support this principle. This model states that reanalysis occurs online because this has been attested in previous experiments in which speakers are forced to rebuild the structure of a sentence they are parsing. When reanalysis occurs online, a P600 is observed (Osterhout, 1994). The discrepancy between Early and Late reanalysis can be observed in the figure below. The specific time estimates (i.e. 200msec, 400msec, etc.) are hypothesized time ranges meant to represent the relative timing of the events observed during the parsing process.
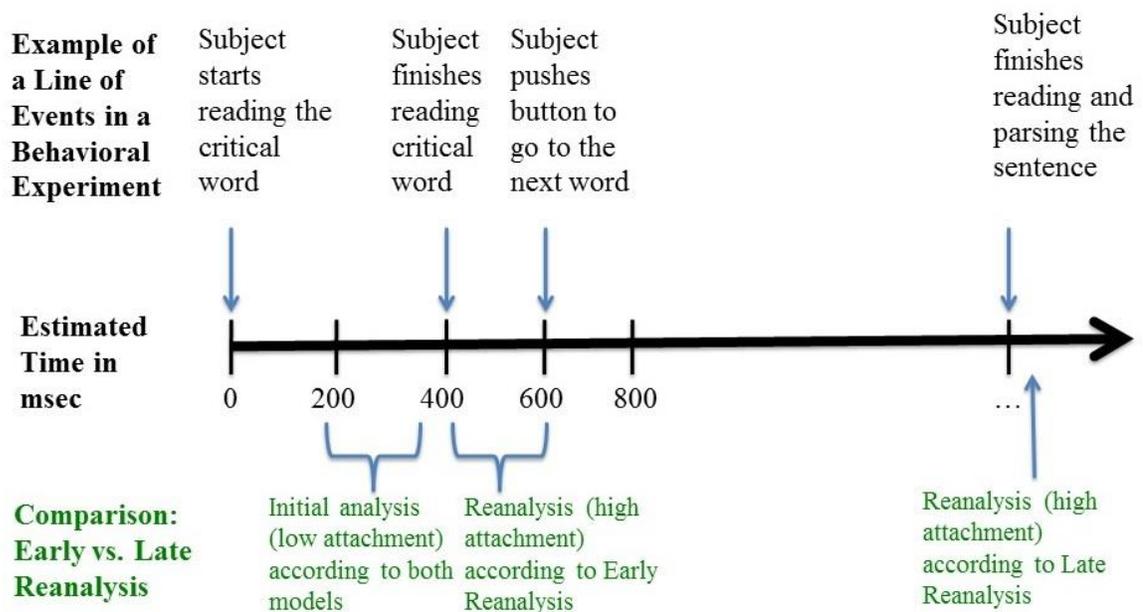
Figure 2.3. Detailed time course of Early vs. Late Reanalysis

Early Reanalysis states that re-attachment occurs immediately after the initial analysis performed by a Spanish speaker. This locates reanalysis at the 400-600msec time window, during which a P600 could be observed. In contrast, in Late Reanalysis, it is

observed that re-attachment is due to post-syntactic mechanisms (i.e. as suggested by Fernandez (2002)), which locates reanalysis after a sentence is parsed, and language-specific elements come into play.

2.4. Parallel Parsing

Different theories regarding the parallel parsing of syntactic structure can be found in the literature (Traxler, Pickering & Clifton, 1998; Lewis, 2000; Gibson & Pearlmutter, 2000; van Gompel, Pickering and Traxler, 2000; van Gompel, Pickering & Liversedge, 2005; Green & Mitchell, 2006). Several models have been designed to describe how the parser processes ambiguous sentences in which the semantic interpretation of the sentence depends on the type of syntactic structure generated (e.g. in the sentence *'Trust shrinks.'*, both *'trust'* and *'shrinks'* can be interpreted as nouns or verbs, generating two different structures with unrelated meanings) (Waltz & Pollack, 1985). Taking into account that parallel parsing theories can account for a wide range of ambiguous structures, the current study will use a parallel parsing model based on McRoy and Hirst (1990) & Construal theory (Clifton & Frazier, 1996) because such studies provide a straightforward account on how adjunct phrases (such as the RCs and PPs discussed in the current study) are parsed in parallel, and how the parsing process they undergo makes them different from complements.

The Race-based parallel parsing model by McRoy and Hirst (1990) states that the parser attaches adjuncts to all possible nodes during an early stage of parsing, which generate competing meanings. This competition is resolved by using post-syntactic language-specific strategies, which can involve prosody or pragmatics. This theory seems to predict that both native speakers of English and Spanish should attach RCs to both

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high and low nodes if such nodes are available. Therefore, there would not be a particular parsing preference at an early stage, and speakers would be sensitive to ungrammaticality triggered by both high and low attachments. If this theory is correct, speakers should show an ERP response to an ungrammatical high attachment (e.g. *"The maids of the bride who was on the balcony.")* as well as to a low ungrammatical one (e.g. *"The maid of the brides who was on the balcony.")*.

The Race-Based parallel parsing model is in line with Construal theory. According to Clifton and Frazier (1996), non-primary phrases (i.e. adjuncts) are subject to an *"underspecified"* analysis (i.e. they are associated to all the possible nodes to which they can attach, without showing preference for any of them during online processing). This underspecification is solved later by a process of resolution, in which nodes compete to satisfy alternative constraints (e.g. semantics, pragmatics). In other words, the parser does not decide immediately where adjuncts are attached; they are associated to all the nodes they could attach to, and during a late processing stage, the sentence is analyzed for morpho-syntactic, semantic, and pragmatic plausibility, and a decision is made about the correct attachment of the adjunct. The time course specified by this model appears in the figure below.
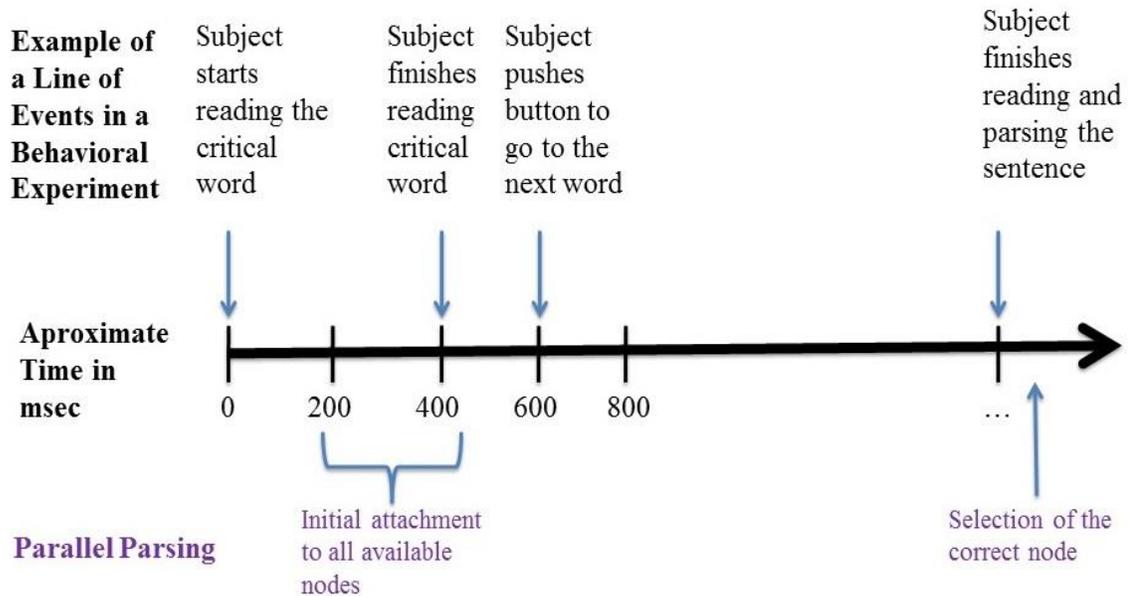
Figure 2.4. Detailed time course of the attachment process according to Parallel Parsing.

Considering this "underspecified" analysis, when a speaker reads sentences like (39) and (40) below. The RC would initially associate to both the higher and the lower noun, and after the sentence is initially parsed, the correct attachment would be deduced from the meaning of the sentence.

(39) *The man saw the maids of the bride who was on the balcony.*

(40) *The man chased the father of the children who was on the street.*

This means that in a sentence like (39), a speaker would initially attach the RC 'who was on the balcony' to both the higher noun *'the maids'* and the lower noun *'the bride'*, and then, after the whole sentence has been initially parsed the resolution process is triggered, and the parser decides that the RC must attach to the lower noun, to preserve the plausibility of the sentence.

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Going back to ERPs, if speakers associate RCs to both high and low nouns in sentences (39) and (40) above, both sentences should trigger a LAN response since in (39) the verb in the RC does not agree with the higher noun, and in (40) the verb does not agree with the lower one. The only way not to observe a LAN response would require the use of a control condition in which both the higher and the lower noun agree with the VP in the RC (i.e. 'the maid of the bride who was) because in such construction syntactic agreement is preserved by both attachments.

Clifton and Frazier (1996) defined construal as a heuristic that was part of the human sentence parsing mechanism, which would apply regardless of the language (i.e. as the garden path does). Therefore, it can be inferred that the association of RCs in (39) and (40) to both high and low nouns would occur in both English and Spanish, and therefore, the same ERP responses would be observed regardless of the language. The concept of construal also implies that the possible asymmetries in attachment height preferences among languages that have been attested in previous questionnaire studies (e.g. Cuetos & Mitchell, (1988)) are not observed during online parsing, but they are rather the consequence of language specific post-syntactic strategies for sentence comprehension, which emerge after the sentence is initially parsed and the resolution process is triggered.

If this hypothesis is true, during online processing, native speakers of both English and Spanish would generate both high and low attachments, which means that they would be sensitive to ungrammaticality in either location. In this case, both languages would be behaving equally during online parsing. After the sentence is fully parsed, post-syntactic elements, such as prosody and contextual cues, would come into

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play. The information provided by these elements would help the parser select one

attachment over the other, and the rejected analysis would be pruned (i.e. cut from the

structure).

In the next two chapters, two studies designed to test the previous models will be

introduced. Each chapter will include a small summary of the predictions that each model

makes regarding the RTs and ERP responses expected for each experiment. Finally, the

models will be revisited in the conclusions, and a discussion about which model made the

correct predictions will be presented.

Chapter 3

STUDY 1: RELATIVE CLAUSE ATTACHMENT

The current study aims to analyze the ERP responses of native speakers of English and native speakers of Spanish to the ungrammaticality triggered by the disagreement between NPs located in low and high nodes and a VP in a subsequent relative clause. This study will collect behavioral responses and EEGs simultaneously as previous studies have done it before (e.g. Van der Meij, Cuetos, Carreiras & Barber (2010)). The collection of behavioral responses does not have an impact on EEG data as observed by (Dimigen, Sommer, Hohlfeld, Jacobs, & Kliegl, 2011).

In this study, a group of native speakers of English and a group of native speakers of Spanish were exposed to the sentences created by Fernandez (2002), in which a relative clause can trigger ungrammaticality when attached to either a high or a low attachment as in the examples below

(41) Ungrammatical High Attachment: *The policeman shot the maid of <u>the brides</u> who <u>was </u>on the balcony.*

(42) Ungrammatical Low Attachment: *The policeman shot <u>the maids</u> of the bride who <u>was</u>*

on the balcony.

In (41), the NP in the low node *'the brides'* disagrees in number with the verb in the RC *'was'*. In (42), the NP in the high node *'the maids'* is the one that disagrees with

the verb in the RC. However, if the opposite attachments are performed (i.e. high in (41) and low in (42)), ungrammaticality is avoided, and sound structures are generated. The current chapter will show a detailed description of this experiment and an analysis of the results.

As observed in chapter 2, previous studies have hinted at the existence of different models of attachment parsing. Such models can be used to make predictions about the ERP responses that a speaker can have when exposed to sentences like (41) and (42). The Single Reanalysis model, based on Cuetos and Mitchell (1988), states that English speakers attach low, and Spanish speakers attach high. The Late Reanalysis model based on Fernandez (2002), states that all speakers attach low by default. The Early Reanalysis model predicts that English speakers attach low, and they do not reanalyze, while Spanish speakers attach low initially and immediately reanalyze, and switch to a high attachment. Finally, the Parallel Parsing model, based on construal and McRoy and Hirst (1990), predicts that during online processing, both English and Spanish speakers attach both high and low, and ambiguities are solved later in a post-syntactic resolution stage. In order to make predictions, we assume that if a speaker peforms a particular type of attachment he or she will show sensitivity to the morpho-syntatic agreement violation, which would trigger a LAN response because this is the most common response for such type of violations (Osterhout, 1994). [2] Predicted responses of English native speakers across conditions are found in the table below.

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[2] Note that an N400 has been observed instead of a LAN as a response to agreement errors in previous studies (Tanner & Van Hell, 2014).

Table 3.1. Predicted ERP Responses of Native English Speakers Triggered by each Type of Relative Clause Attachment as a Function of Model of Attachment Processing.[3]

Condition	English Speaker Response	
	Single Analysis, Late Reanalysis, Early Reanalysis	Parallel Parsing
HAU[4]	No LAN	LAN / RT Delay
LAU	LAN / RT Delay	LAN / RT Delay

Essentially, the predictions about English speaker responses are the same across for the Single Analysis, Late Reanalysis and Early Reanalysis models. It is expected that English speakers will attach low by default, which means that they will be sensitive to the ungrammaticality in LAU sentences. In contrast, they should be blind to ungrammaticality in high attachments, as in HAU sentences, because they do not attach high automatically. However, the Parallel Parsing model predicts a different outcome. According to this model, English speakers should attach both high and low, which means that they should be sensitive to the ungrammaticality in both HAU and LAU conditions. The table below summarizes the predicted responses for native Spanish speakers.

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[3] Note that neither Cuetos & Mitchell (1988) nor Fernandez (2002) makes any explicit predictions about ERPs in any of their papers. The models discussed and the predictions derived from them are an interpretation of what they would find in ERPs considering the conclusions of their studies.

[4] In predicted ERP response tables, the ERP responses attributed to each condition correspond to the comparison between the experimental conditions against the control conditions because voltage variability can only be measured against a baseline (i.e. control condition). For example, ERP responses to HAU sentences correspond to the voltage variability observed as a response to experimental HAU sentences when compared against sentences having the same structure, but with a grammatical high attachment. Please refer to chapter 4 for specific examples of control conditions.

Table 3.2. Predicted ERP Responses of Native Spanish Speakers Triggered by each Type of Relative Clause Attachment as a Function of Model of Attachment Processing.

Condition	Spanish Speaker Response			
	Model A	Model B	Model C	Model D
HAU[5]	LAN/RT Delay	No LAN	P600 only	LAN/RT Delay
LAU	No LAN	LAN / RT Delay	LAN-P600/RT Delay	LAN/RT Delay

The Single Analysis model, based on Cuetos and Mitchell's (1988) findings, would predict that Spanish speakers react to ungrammaticality in relative clauses with high attachments only. In contrast, the Late Reanalysis model, based on Fernandez's findings, favors an early ERP response to ungrammaticality in low attachments only. The Early Reanalysis model predicts that Spanish speakers will react to low attachments, which will trigger a LAN and an RT delay, but an immediate reanalysis (in the 600 to 800msec time window) will also generate a P600. Also, Early Reanalysis considers that Spanish speakers would be initially blind to high attachments (i.e. because they initially attach low), so no LAN response to HAU sentences is expected. However, the reanalysis that occurs to perform a high attachment would generate a P600. Finally, the Parallel Parsing model

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[5] In predicted ERP response tables, the ERP responses attributed to each condition correspond to the comparison between the experimental conditions against the control conditions because voltage variability can only be measured against a baseline (i.e. control condition). For example, ERP responses to HAU sentences correspond to the voltage variability observed as a response to experimental HAU sentences when compared against sentences having the same structure, but with a grammatical high attachment. Please refer to chapter 4 for specific examples of control conditions.

predicts that Spanish speakers perform both high and low attachments, so a LAN response would be triggered in both high and low conditions.

3.1. Experiment 1A: English Relative Clauses

3.1.1. Method

Subjects

34 native speakers of English from 18 to 26 years of age (mean: 19.41, ±1.43) participated in this experiment. 31 of them were female and 3 male; this gender imbalance is due to the demographics of the University of Delaware (i.e. the Cognitive Science BS program, where most of the volunteers come from has a large female population). 33 were right handed and 1 was left handed. They had normal vision, and no history of language impairment. All subjects were undergraduate students at the University of Delaware. All of them were monolingual speakers of English. Their participation was voluntary, and they received course credit for completing the experiment. Out of the total 34 subjects, 3 of them were excluded due to having too many bad trials (20% of bad trials or more after artifact detection).

Apparatus and Procedure

This experiment was programmed using E-Prime professional 2.0.8.90, running on a Dell desktop PC. RT data was recorded by a PST serial response box. EEG data was acquired by a 128-channel HydroCel Geodesic Sensor Net, with Ag/AgCl electrodes covered by sponges soaked in an electrolyte solution. EEG data was recorded by EGI NetStation software v.4.5. Electrode impedance were lowered below 50Ω prior to data collection. Data were digitized with a 24-bit resolution at 250Hz.

Subjects sat in front of an LCD screen in an electrically shielded, sound treated booth. They had to complete a self-paced reading task in which they read each sentence word by word by pressing a button in the serial box. Subjects were instructed to use their dominant hand. A comprehension question was presented at the end of the sentence, an example of which appears in the next section. The words were presented in yellow Arial 18 font with a black background.

Subjects were instructed to read at a normal pace (i.e. not to fast or too slow). The experiment was divided into two blocks, with a small break in between. Subjects were reminded about keeping a normal pace during the break. This was due to prevent students from reading too fast since the piloting data shows that subjects read each word at a rate of 200 to 300msec if not instructed to read more slowly.

Design and Stimuli

This design uses a single variable with 3 levels, in which two conditions with ungrammaticality triggered by a particular kind of attachment (1- High Attachment Ungrammatical - HAU / 2- Low Attachment Ungrammatical - LAU) are compared to a fully grammatical control condition (3- Control). The complete list of sentences used in this experiment appears as 'APPENDIX A'. An example of experimental and control sentences appears below.

(43) HAU: *The man saw the maids of the bride who <u>was </u>on the balcony.*

(44) LAU: *The man saw the maid of the brides who <u>was </u>on the balcony.*

(45) Control: *The man saw the maid of the bride who <u>was</u> on the balcony.*

(46) Comprehension Question for (44): *Who saw the maid?*

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Although EEG data were recorded throughout the experiment, ERPs were locked to the verb that triggers ungrammaticality when a specific attachment is made (underlined above). Note that the critical verb is kept constant across conditions in order to avoid introducing variance generated by word variations (i.e. the critical verb was always a past tense form of be: was/were). Half of the sentences in each condition had the singular form 'was', and the other half the plural form 'were'. Each subject saw 24 sentences of each kind, for a total of 48 experimental and 24 control trials. 54 sentences were be added as fillers in order to decrease the predictability of the structure in the sentences and to add variety to the stimuli, for a total of 126 sentences in the whole experiment. The experiment was divided into two blocks, with 63 sentences in each block.

After the subject provided a response to the comprehension question, feedback was immediately provided. Comprehension questions, such as (46), never asked the subject to attach the RC to a particular attachment site in order to respond (i.e. the questions used for sentences (43) to (45) never asked *'who was on the balcony?'*). This was done in order not to bias the subject by proving feedback about what the correct response should be. It was necessary to provide feedback in order to make sure that the subject was aware that accuracy was being recorded, and that understanding the sentences was important for the task.

3.1.2. Results

3.1.2.1. Behavioral Results

In this section we will analyze the reaction times in milliseconds to the critical verb, which is underlined in examples (30) through (32) above. Outlier RTs that were faster than 310msec were removed from the data (i.e. this is an approximate projection of

the fastest behavioral reaction possible according to Hawk, Coutout, Holden & Chen (2011)). Similarly, outlier RTs that were slower than 2 standard deviations above the mean for each subject were removed from the data (less than 1% of the data were removed). Table 5.1 below shows the average RT values that were observed in each condition.

Table 3.3. Mean Reaction Times (SD) in msec to the Critical Verb as a Function of Condition in Experiment 1A.

	Condition		
	Control (SD)	HAU (SD)	LAU (SD)
Mean RT	530(212)	540(213)	546(219)
Example Sentence	*...the maid of the bride who **was**......*	*...the maids of the bride who **was**......*	*...the maid of the brides who **was**......*

The data on the table above demonstrate that it took subjects 10msec more to recognize the critical verb in HAU sentences when compared against controls. This difference did not reach significance, *t(30)=0.676, p=0.252*.[6] In contrast, subjects had a 16msec delay when recognizing the critical verb in the LAU sentences in comparison to controls. This difference was significant, *t(30)=1.927, p=0.032.*

The figure below shows a comparison of the mean reaction times across conditions to each of the words in the stimulus sentences from the beginning to the end of

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[6] All p values for t tests are one-tailed. All p values for F tests are two-tailed.

the sentence. From now on, these words will be referred to as "regions". Region #5

corresponds to the critical verb.
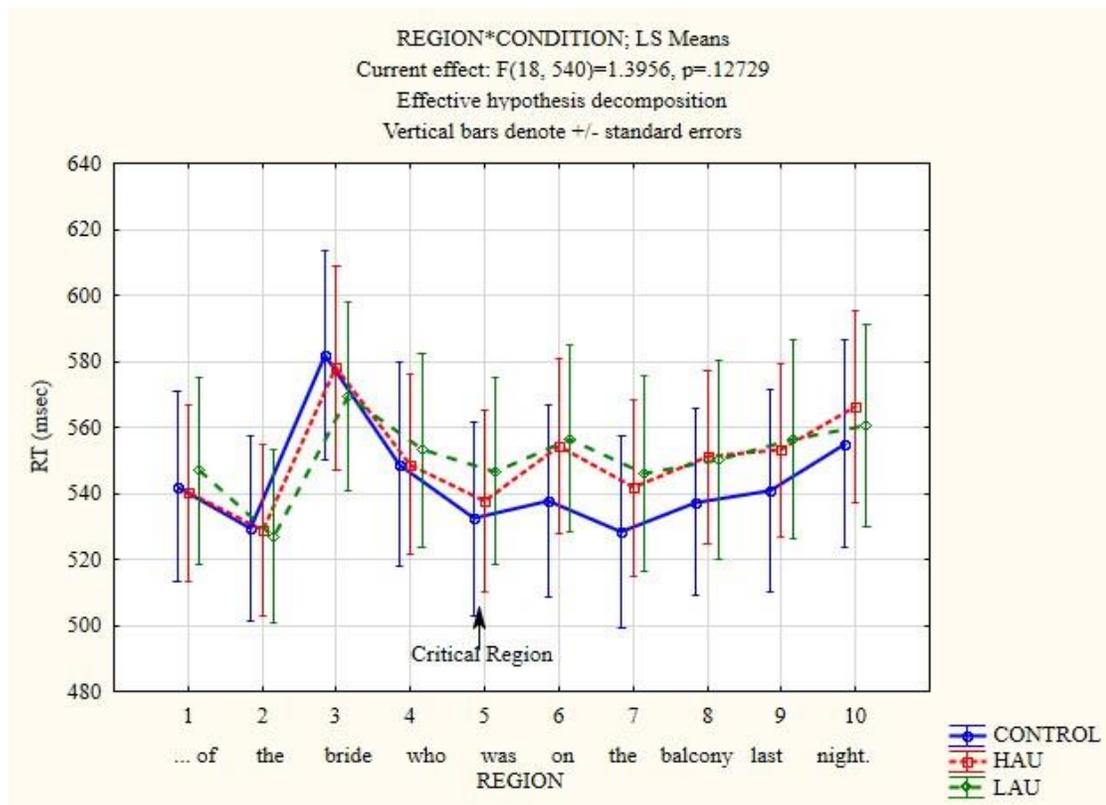
Figure 3.1. Mean Reaction Times (msec) as a Function of Region in the Sentence

in Experiment 1A.

As observed in the figure, differences in reaction times among conditions can be

observed after the critical region (#5), which means that a spillover effect is present (i.e.

reaction times seem to continue to be delayed in HAU and LAU after the critical verb

when compared to the Control condition). This spillover effect is relevant because the

processing of a particular region can be impacted by a processing delay caused by a

preceding region (Vasishth, 2006). A t-test was conducted on the RTs obtained in region

#6, which follows the critical verb. Subjects were 22msec slower in the HAU conditions when compared to controls. This difference was significant; *t(30)=1.962, p=0.030.* RTs at region #6 were 21msec slower in the LAU condition when compared to controls. This difference reached significance *t(30)=2.349, p=0.013.* The significant differences found in region #6 confirm the presence of a spill-over effect.

A repeated measures ANOVA was conducted on the RT data across the 10 word regions observed in the figure. Two within subject factors were considered: Condition (3 Levels: Control, HAU vs. LAU), and Region (10 Levels: the 10 regions observed in the graph above). Results indicate that there was a significant effect for Region; *F(9,270)=6.802, p<0.001.* As observed in the graph, reaction times increase in region 3 (i.e. 'bride'), which corresponds to the noun inside the prepositional phrase that modifies the higher NP (i.e. *'the maid of the bride who'*). This RT increment is observed in all 3 conditions. According to Thornton, McDonald and Gil (1999), this occurs because attaching a PP to an NP (i.e. as in '*the maid of the bride'*) increases processing effort, which translates into an RT delay. No significant main effect for Condition was observed; *F(2,60)=1.057, p=0.353*; and for the Condition × Region interaction; *F(18,540)=1.395, p=0.127.*

3.1.2.2. ERP Results

After continuous EEG data were collected, 1000msec epochs were extracted. Each epoch started 200msec before the critical verb (to allow for baseline correction), and ended 800msec after. An automated procedure to identify bad channels was performed. Any channel with a difference between minimum and maximum voltage of more than 200μ in a moving average of 80 msec was marked as bad. Channels marked

bad in 20% of the data or more were mark as bad in all trials. Bad channels were replaced

by using spherical spline interpolation. Finally, automatic eyeblink subtraction was

performed; single trials were averaged across conditions (Control, HAU, LAU), and all

data were referenced to average voltage by using the ERP PCA toolkit (Dien, 2010). Note

that some previous ERP experiments observing structural ambiguity, such as Carreiras,

Salillas & Barber (2005). have used average mastoid reference; in the current study, it

was observed that there was no noticeable difference in the effects observed on the data if

voltages used average reference or mastoid reference; therefore, the current analysis is

comparable to studies using voltage averaged to linked mastoids.

 Three types of statistical analyses were performed on the EEG data: 1) Global

Analysis, 2) Posterior Region Analysis, and 3) Visual Inspection. No between-subject

factors will be used in this analysis. These analyses are explained below.

 Global Analysis: A repeated measures ANOVA was conducted on the EEG data

from the entire scalp. In order to perform this analysis, the scalp was divided into 4

regions of interest, which were proposed by Dien and Santuzzi (2005). Electrodes were

grouped using 2 spatial factors: anteriority (anterior vs. posterior), and laterality (left vs.

right). The areas covered by these regions are shown in the figure below.

Figure 3.2. Electrode map depicting the distribution of the 8 regions of interest.

For this global analysis, voltage values were averaged across 3 time windows: 200-400msec, 400-600msec and 600-800msec. This distribution will help observe if effects appear at different stages of the parsing process, as opposed to the whole epoch.

Conditions were compared with separate ERP analyses. In other words, only two conditions were compared in each analysis. The factor Condition had 2 level in each of 2 analyses performed: 1) Control vs. HAU, and 2) Control vs. LAU.

To summarize, the repeated measures ANOVA performed on the data for the global analysis had 4 within-subject factors: 1) Anteriority (anterior vs. posterior), 2) Laterality (left vs. right), 3) Time (200-400msec, 400-600msec vs. 600-800msec), and 4) Condition (depending on the specific comparison: Control vs. HAU or Control vs. LAU).

In this analysis, the main effect for Condition will be reported along with any statistically significant interactions between Condition and the other factors.

Posterior Region Analysis: Since the effects observed in the experiments were found in the posterior region, a specific analysis targeting this region will be conducted. It will have the same time windows and condition factors as the global analysis, but only the posterior region of the scalp will be considered, which means that the variable "Anteriority" will not be used. To summarize, this analysis will have 3 variables: 1) Laterality (left vs. right), 2) Time (200-400msec, 400-600msec vs. 600-800msec), and 3) Condition (depending on the specific comparison: Control vs. HAU or Control vs. LAU). As in the global analysis, the main effect for Condition will be reported along with any statistically significant interactions between Condition and the other factors.

Visual Inspection: A set of electrodes located in the particular area of the scalp that appears to have the most prominent effect will be selected as a critical region for analysis. A waveform plot will be provided in order to show a visual representation of the voltage values in the scalp of such region, and a small map of its distribution. This analysis will not include topographical factors. Voltage values will be grouped in 5 time windows (200-300msec, 300-400msec, 400-500msec, 500-600msec, and 600-700msec); this distribution was created in order capture effects that only reached significant in a small time window. Finally, the variable condition will have the same factors explained above. To summarize, this analysis will have 2 factors: 1) Time (200-300msec, 300-400msec, 400-500msec, 500-600msec vs. 600-700msec) and 2) Condition (depending on the specific comparison: Control vs. HAU or Control vs. LAU).

The figure below displays the difference topo plots HAU vs. Control.
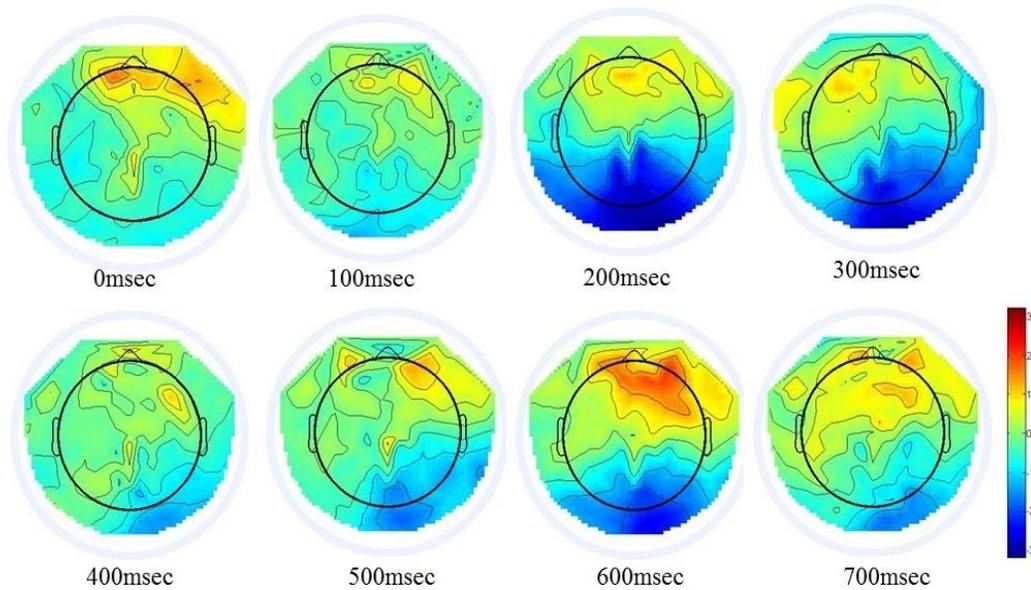
Figure 3.3. English HAU ERP Data. Difference topo plots – HAU vs Control.

The repeated measures ANOVA carried out for the Global Analysis shows that no main effect for Condition was observed; $F(1,30) = 0.067, p=0.796$. The interaction Condition $\times$ Anteriority was significant; $F(1,30) = 8.805, p=0.005$. This interaction stems from a negativity effect observed in the posterior region. The interaction Condition $\times$ Anteriority $\times$ Laterality approached significance. $F(1,30) = 3.556, p=0.069$. This indicates that the effect was probably more prominent in the right side of the posterior region.

Posterior Region Analysis: The repeated measures ANOVA carried out on the voltage values from the posterior region of the scalp indicate that a significant Posterior Negativity effect was observed because the main effect for Condition was significant;

F(1,30) = 8.597, p=0.006. The interaction Condition × Laterality approached

significance; *F(1,30) = 3.335, p=0.077.*

     Visual Inspection: A specific area of the scalp selected by visual inspection was

identified in order to carry out a more in depth analysis. The figure below displays the

map of the selected electrodes, and the waveforms that demonstrate the differences

between the two conditions.
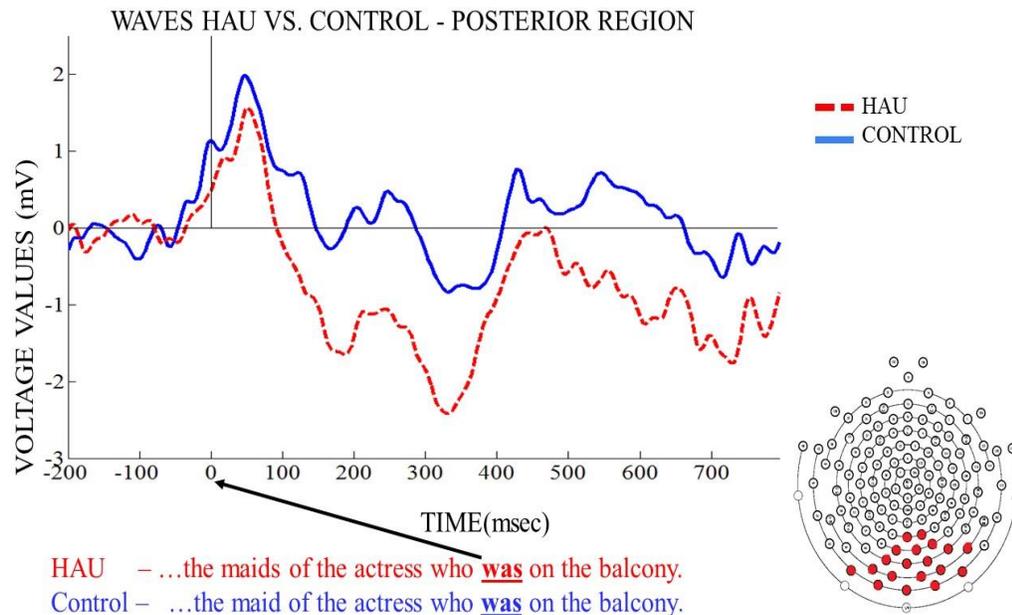
Figure 3.4. English ERP HAU data. HAU vs. Control comparison in a selected area of the scalp. Waveforms of the Posterior Negativity effect (left) and spatial distribution (right).

     HAU stimuli sentences triggered Posterior Negativity. The ANOVA carried out in

the selected region revealed that the main effect for the variable Condition (i.e. HAU vs.

Control) was significant across the 5 time windows examined; *F(1,30)=12.011, p=0.001.*

The interaction between time and condition was also significant, $F(4,120)=1.511$, $p=0.037$. Orthogonal contrasts were performed at each time window, and the average voltage values in microvolts (mV) were calculated. The effect for Condition was significant at the following time windows: 200-300msec: *1.47mV, t(30)=4.288, p<0.001;* 300-400msec: *1.21mV, t(30)=3.469, p=0.001;* 400-500msec: *0.62mV, t(30)=1.734, p=0.047;* 500-600msec: *1.20mV, t(30)=3.526, p<0.001;* 600-700msec: *1.19mV, t(30)=2.648, p=0.007.*

LAU vs. Control

<u>Global Analysis:</u> The figure below displays the difference topo plots LAU vs. Control.
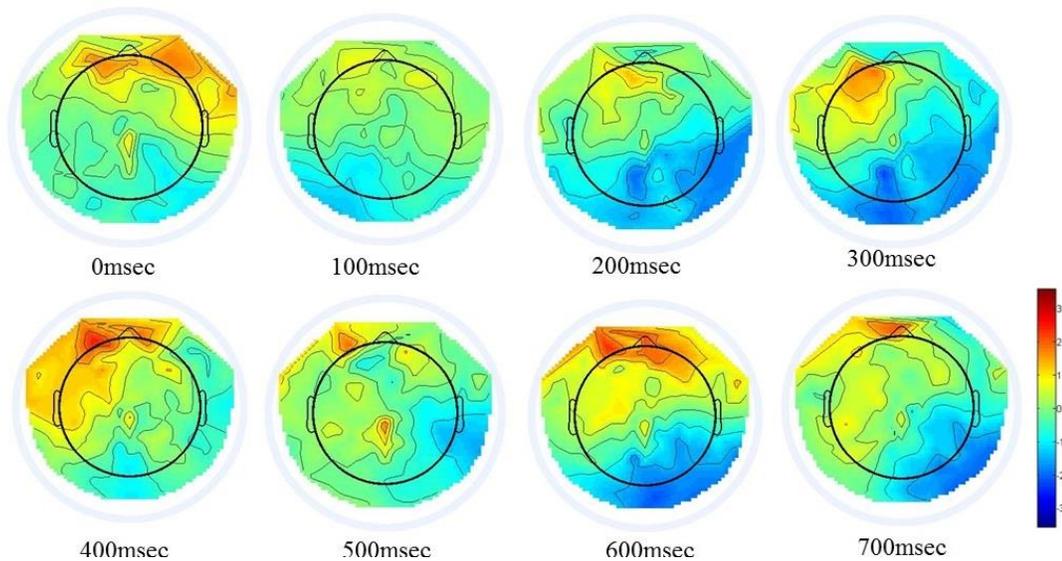
Figure 3.5. English LAU ERP Data. Difference topo plots – LAU vs Control.

The repeated measures ANOVA carried out for the Global Analysis shows that no significant main effect for Condition; $F(1,30) = 0.010, p=0.621$. The interaction Condition $\times$ Anteriority was significant; $F(1,30) = 7.596, p=0.009$, which indicates the presence of the negativity effect in the posterior region. The interaction Condition $\times$ Laterality approached significance. $F(1,30) = 4.095, p=0.051$. This interaction indicates that the effect was located towards the right hemisphere.

Posterior Region Analysis: The repeated measures ANOVA conducted on the voltage values from the posterior region of the scalp indicate that a significant Posterior Negativity effect was observed, as evidenced by a significant main effect for Condition; $F(1,30) = 7.726, p=0.009$. The interaction Condition $\times$ Laterality was also significant; $F(1,30) = 3.335, p=0.077$. This interaction stems from the fact that the effect is localized on the right hemisphere.

Visual Inspection: A specific area of the scalp selected by visual inspection was identified in order to carry out a more in depth analysis. The figure below displays the map of the selected electrodes, and the waveforms that demonstrate the differences between the two conditions.
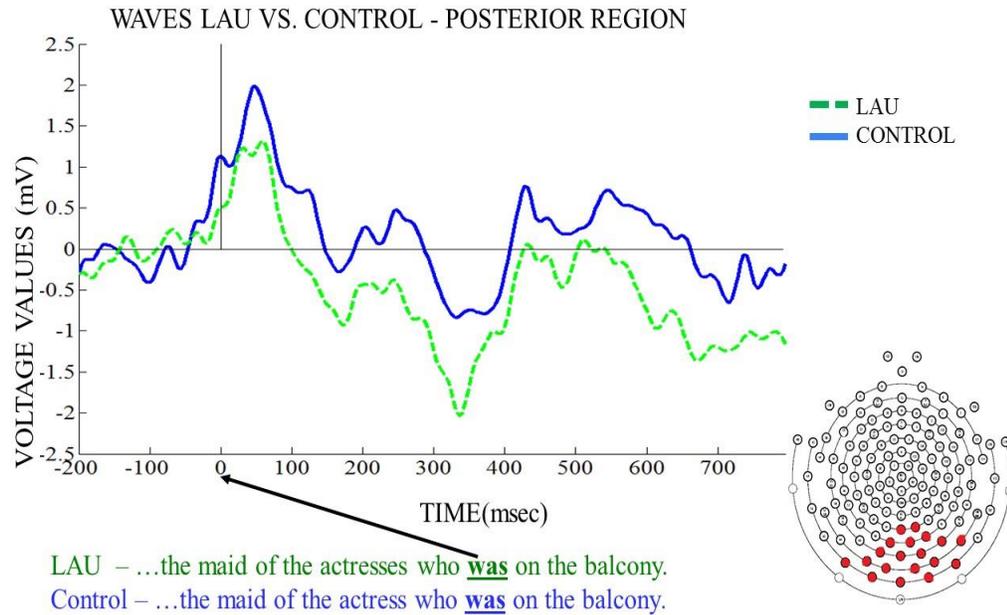
Figure 3.6. English ERP LAU data. LAU vs. Control Comparison in a selected area of the scalp. Waveforms of the Posterior Negativity effect (left) and spatial distribution (right).

LAU stimuli sentences triggered Posterior Negativity. Voltage values. A repeated measures ANOVA demonstrates that the main effect of Condition (i.e. LAU vs. Control) was significant across the 5 time windows from 200 to 700msec after the onset of the critical verb*: F(1,30)=5.149, p=0.030.* Orthogonal contrasts were performed at each time window, and the average voltage values in microvolts (mV) were calculated. The effect for Condition was significant at the following time windows: 200-300msec: *0.83mV, t(30)=2.167, p=0.020;* 300-400msec: *0.75mV, t(30)=1.930, p=0.032;* 400-500msec: *0.58mV, t(30)=1.486, p=0.047;* 500-600msec: *0.64mV, t(30)=1.893, p=0.034;* 600-700msec: *1.08mV, t(30)=2.918, p=0.004.*

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3.1.3. Discussion

Behavioral results demonstrate that an RT delay at the critical verb are only observed in the LAU condition, which is congruent with the results obtained by Fernandez (2002). A spill-over effect after the critical verb is attested in both HAU and LAU conditions in region #6, which follows the critical verb. This spill-over effect is relevant because previous studies have shown that effects in the critical region can transcend in subsequent regions (Vasishth, 2006). This implies that subjects' reactions are delayed by the ungrammaticality in both conditions, even if this delay occurs earlier in LAU than in HAU. RT delays in both conditions suggest that the parser performs both attachments.

ERP results in both conditions show Posterior Negativity. This effect is similar in polarity, and distribution to an N400. This finding is congruent with the behavioral results, and suggests that the parser attaches relative clauses (RCs) to both a high and a low node simultaneously. These findings are congruent with Construal (Frazier & Clifton, 1996) which states that adjuncts, such as RCs, initially receive an "underspecified" analysis, so they can associate to several different nodes. It is also convergent with the parsing principles proposed in the "Race-based Parallel Parsing Model" created by McRoy and Hirst (1990), which proposes that the parser attaches adjuncts to all possible nodes during an early stage of parsing, which generate competing meanings. This competition is solved during a late processing stage, in which the sentence is analyzed for morpho-syntactic, semantic, and pragmatic plausibility, and a decision is made about the correct attachment of the adjunct. This late decision is

probably what previous questionnaire studies (such as Cuetos & Mitchell, 1988) have registered, indicating that English speakers have a preference for low attachments.

3.2. Experiment 1B: Spanish Relative Clauses

Experiment 1B aims to analyze the responses of native Spanish speakers to the ungrammaticality triggered by the attachment of ambiguous relative clauses. In this experiment, a group of native speakers of Spanish was exposed to the stimuli sentences created by Fernandez (2002). An example of such sentences appears below.

(47) *El hombre vio a las sirvientes de la novia que _estaba_ en el balcón esta mañana.*

(The man saw the maids of the bride that _was_ on the balcony this morning).

(48) *El hombre vio a la sirviente de las novias que _estaba_ en el balcón esta mañana.*

(The man saw the maid of the brides that _was_ on the balcony this morning).

In (47), only the low attachment of the RC is plausible (i.e. *'the bride that was on the balcony…'*), as the high attachment yields an ungrammatical structure (i.e. ×*'the maids that was on the balcony…'*). In (48), the opposite is true; while the high attachment is plausible (i.e. *'the maid that was on the balcony…'*), the low attachment is not (i.e. *'the brides that was on the balcony…'*). These stimuli are exact Spanish translations of the English stimuli used in experiment 1A.

3.2.1. Method

Subjects

21 native speakers of Spanish from 20 to 37 years of age (mean: 27.1, ±4.48), 12 female and 9 male, participated in this experiment. 18 subjects were right-handed and 3

left-handed. They were born in the following countries: Argentina (1), Chile (1), Colombia (12), Panama (3) and Spain (4).[7] 14 of them were ELI students at the University of Delaware, who have been living in the United States for less than 6 months; 6 of them were beginning graduate students who had been in the country for less than a year, and 1 of them was a PhD candidate who had been in the US for 4 and a half years. This means that out of the 21 subjects, 20 were present in the US for less than a year before completing the experiment (average length of stay 4.75 months, ±1.92). Due to their short length of stay in the US, it is unlikely that their exposure to English has had an impact on their parsing preferences in Spanish, as suggested by Dussias & Sagarra (2007), who argue that subjects need a long exposure to L2 in order to show interference in their L1 processing. All subjects had normal vision, and no history of neurological conditions or language impairment. They participated in the study voluntarily, and were offered $10 dollars as compensation for their participation. The recruitment process and exclusion criteria used for this experiment were similar to the ones shown in experiment 1. The data from 1 subject was not recorded due to experimental error. 3 subjects were excluded from the data due to too many bad trials (i.e. 20% or more).

Apparatus and Procedure

The apparatus and procedure was exactly the same as in experiment 1A.

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[7] Natives from all Spanish-speaking countries were allowed to participate in this experiment since sociolinguists have argued that the Spanish dialects from Spain and Latin America are highly convergent, and mutually intelligible (Moreno Fernandez, 1990; Hualde, Olarrea, Escobar & Travis, 2010). These characteristics have caused many psycholinguists to treat Latin American Spanish as only one unit (Thorton, McDonald & Gil, 1999; Fernandez, 2002). Additionally, the syntactic variations found across Spanish dialects so far seem not to be related to the structures tested in this study (Zagona, 2002), which allows us to affirm that the possible differences across dialects will not affect the findings of this study. All sentences in the current research are written in a standard variety of Spanish that is used by the mass media in both Spain and Latin America (usually called "Neutral Spanish" or "Panamerican Spanish"). This ensures that the vocabulary was understood by all speakers regardless of their country of origin.

Design and Stimuli

This design uses a single variable with 3 levels, in which two conditions with ungrammaticality triggered by a particular kind of attachment (1- High Attachment Ungrammatical - HAU / 2- Low Attachment Ungrammatical - LAU) are compared to a fully grammatical control condition (3- Control). The complete list of sentences used in this experiment appears as 'APPENDIX B'. An example of experimental and control sentences appears below.

(49) HAU: *El hombre vio a las sirvientes de la novia que <u>estaba</u> en el balcón esta mañana. (The man saw the maids of the bride who <u>was </u>on the balcony.)*

(50) LAU: *El hombre vio a la sirviente de las novias que <u>estaba</u> en el balcón esta mañana. (The man saw the maid of the brides who <u>was </u>on the balcony.)*

(51) Control: *El hombre vio a las sirviente de la novia que <u>estaba</u> en el balcón esta*

mañana. (The man saw the maid of the bride who <u>was</u> on the balcony.)

(52) Comprehension Question for (50): *Quién vio a la sirviente? (Who saw the maid?)*

Although EEG data were recorded throughout the experiment, ERPs were locked to the verb that triggers ungrammaticality when a specific attachment is made (underlined above). Note that the critical verb is kept constant across conditions in order to avoid introducing variance generated by frequency or length variations in the critical word. Each subject saw 24 sentences of each kind, for a total of 48 experimental and 24 control trials. 54 sentences were be added as fillers in order to decrease the predictability of the structure in the sentences and to add variety to the stimuli, for a total of 126 sentences in

the whole experiment. The experiment was divided into two blocks, with 63 sentences in each block.

As in experiment 1A, subjects were given feedback immediately after they responded each comprehension question. These questions did not assess attachment height preferences (i.e. the questions used for sentences (49) to (51) did not ask *'who was on the balcony?'*). This was done in order not to bias the subject by providing a correct response about which type of attachment was correct.

3.2.2. Results

3.2.2.1. Behavioral Results

In this section we will analyze the reaction times in milliseconds to the critical verb, which is underlined in examples (49) through (51) on the previous page. Outlier RTs that were faster than 310msec will removed from the data (i.e. this is an estimate of the fastest behavioral reaction possible according to Hawk, Coutout, Holden & Chen (2011)). Similarly, outlier RTs that were slower than 2 standard deviations above the mean for each subject were removed from the data (less than 1% of the data were removed). Table 1 below shows the average RT values that were observed in each condition.

Table 3.4. Mean Reaction Times (SD) in msec to the Critical Verb as a Function of Condition in Experiment 1B.

	Condition		
	Control (SD)	HAU (SD)	LAU (SD)
Mean RT	575(186)	571(166)	592(213)
Example Sentence	*...the maid of the bride who **was**......*	*...the maids of the bride who **was**......*	*...the maid of the brides who **was**......*

The data above show that RTs were 4msec lower at the critical verb when compared against controls. This difference was not significant; *t(16)=0.960, p=0.175.* Subjects had a 17msec delay when recognizing the critical verb in the LAU sentences in comparison to controls. A t-test indicated that significance was not reached; *t(16)=0.993, p=0.167.*

The figure below shows a comparison of the mean reaction times across conditions to each of the words in the stimulus sentences from the beginning to the end of the sentence. From now on, these words will be referred to as "Regions". The RT data analyzed above corresponds to Region #5, which is the position of the critical verb.
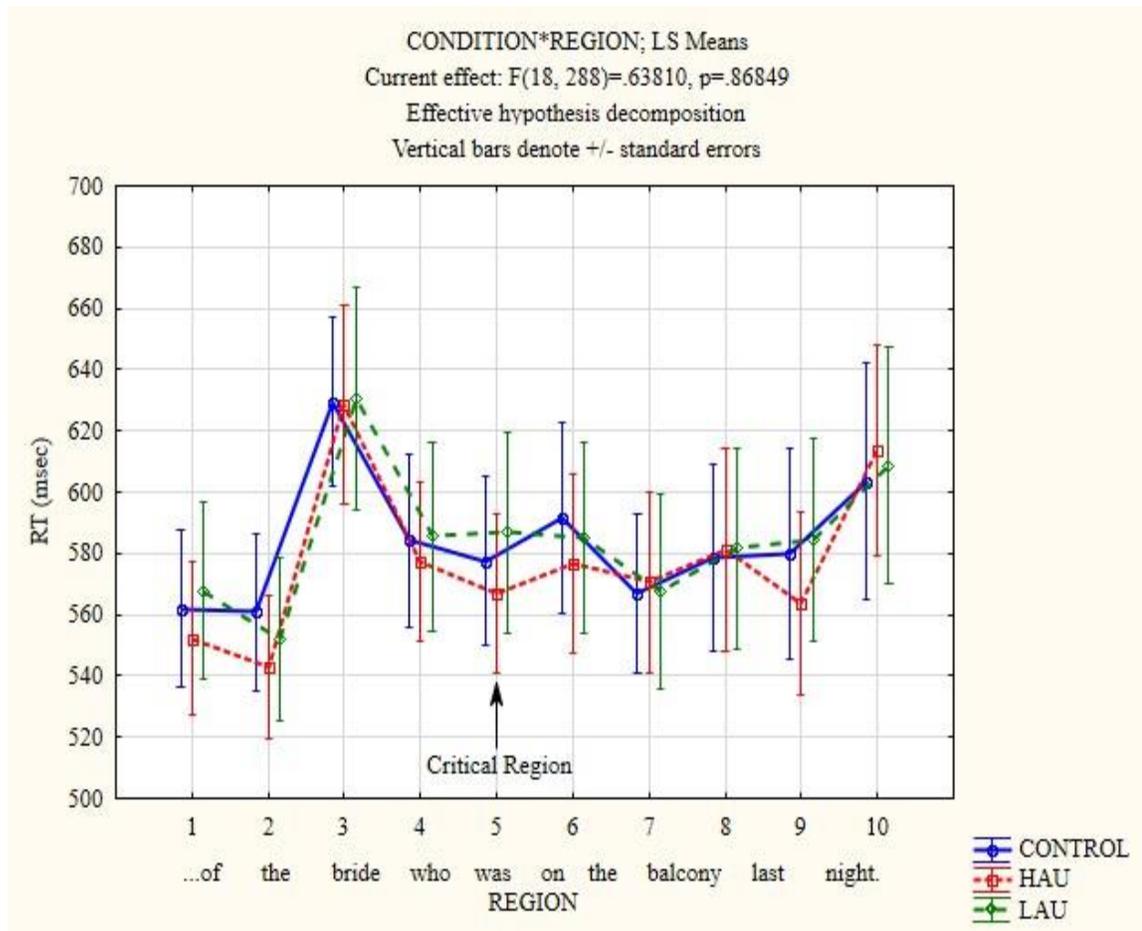
Figure 3.7. Mean Reaction Times (msec) as a Function of Region in the Sentence in Experiment 1B.

Because a spill-over effect was observed in experiment 1A, the RTs obtained in region #6, which follows the critical verb, were tested for significance. Subjects were 8msec faster in HAU when compared against controls. This difference was not significant; *t(16)=0.982, p=0.171*. Subjects were 2msec faster in LAU when compared against controls. This difference was not significant; *t(16)=0.433, p=0.336*.

A repeated measures ANOVA was conducted on the RT data across the 10 word regions observed in the figure. Two within subject factors were considered: Condition (3 Levels: Control, HAU vs. LAU), and Region (10 Levels: the 10 word regions observed in the graph above). Results indicate that there was a significant effect for Region; $F(9,144)=8.006, p<0.001$. As in experiment 1A, reaction times increase in region 3 (i.e. 'bride'). This RT delay, according to Thornton, McDonald and Gil (1999), is due to the fact that attaching a PP to an NP (i.e. as in '*the maid of the bride'*) increases processing effort. No significant main effect for Condition was observed; $F(2,32)=0.725, p=0.491$; and for the Condition $\times$ Region interaction; $F(18,288)=0.638, p=0.868$.

3.2.2.2. ERP Results

After continuous EEG data were collected, 1000msec epochs were extracted. Each epoch started 200msec before the critical verb (to allow for baseline correction), and ended 800msec after. An automated procedure to identify bad channels was performed. Any channel with a difference between minimum and maximum voltage of more than 200μ in a moving average of 80 msec was marked as bad. Channels marked bad in 20% of the data or more were mark as bad in all trials. Bad channels were replaced by using spherical spline interpolation. Finally, automatic eyeblink subtraction was performed; single trials were averaged across conditions (Control, HAU, LAU), and all data were referenced to average voltage by using the ERP PCA toolkit (Dien, 2010).

The same three types of statistical analysis carried out in experiment 1A were conducted on the data of the current experiment. The global analysis had 4 within-subject factors 1) Anteriority (anterior vs. posterior), 2) Laterality (left vs. right), 3) Time (200-400msec, 400-600msec vs. 600-800msec), and 4) Condition (depending on the specific

comparison: Control vs. HAU or Control vs. LAU). No between-subject factors were

used in this analysis. The Posterior Region analysis had the same factors except for

anteriority. Finally, the Visual Inspection analysis had 5 time windows (200-300msec,

300-400msec, 400-500msec, 500-600msec vs. 600-700msec) and two conditions

(Control vs HAU or Control vs LAU, depending on the comparison).

Control vs. HAU

<u>Global Analysis:</u> The figure below displays the difference topo plots HAU vs.
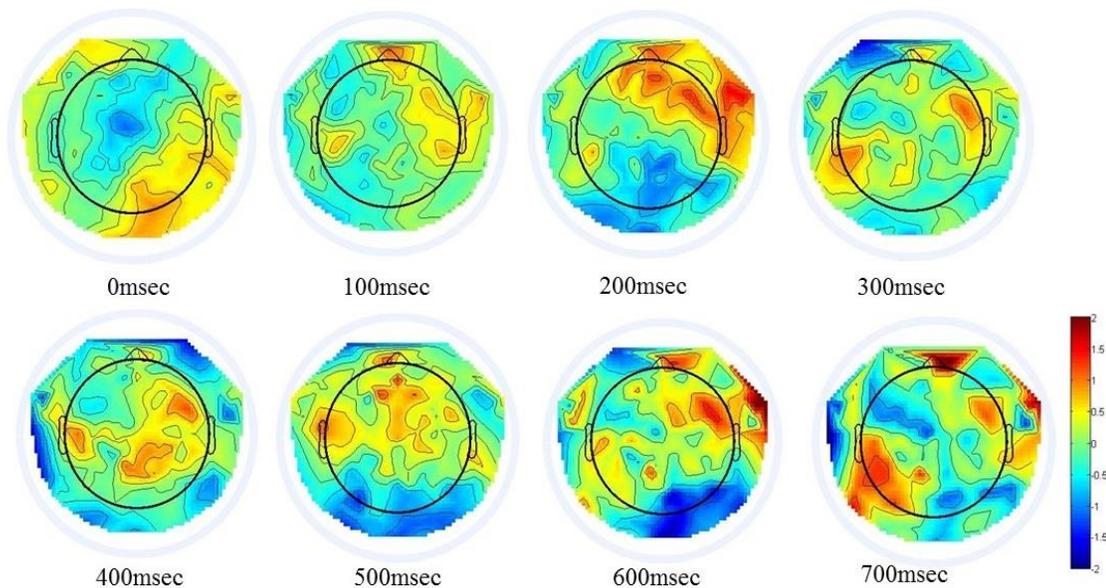
Control.

Figure 3.8. Spanish HAU ERP Data. Difference topo plots – HAU vs Control.

The repeated measures ANOVA conducted for the Global Analysis shows that no

main effect for Condition was observed; $F(1,16) = 0.045, p=0.834$. The 4 way

interaction Condition $\times$ Anteriority $\times$ Laterality $\times$ Time approached significance; $F(2,32)$

= 2.981, p=0.064. This interaction stems from the fact that the effect was observed in the right posterior region, and at a late time window only.

Posterior Region Analysis: The repeated measures ANOVA carried out on the voltage values from the posterior region of the scalp shows that no significant effect for Condition was observed; *F(1,16) = 2.222, p=0.1554.* The 3 way interaction Condition × Laterality × Time was significant; *F(1,16) = 4.658, p=0.016,* stemming from the presence of a negativity effect in the right posterior region at the 400-600 time window.

Visual Inspection: A specific area of the scalp selected by visual inspection was identified in order to carry out a more in depth analysis. The figure below displays the map of the selected electrodes, and the waveforms that demonstrate the differences between the two conditions.
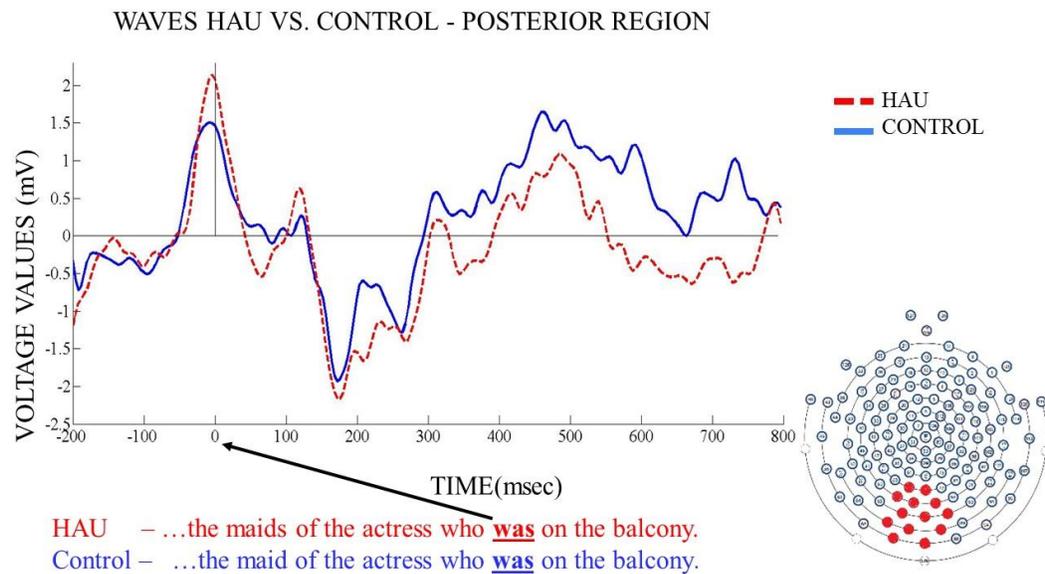
Figure 3.9. Spanish ERP HAU data. HAU vs. Control comparison in a selected area of the scalp. Waveforms of the Posterior Negativity effect (left) and spatial distribution (right).

HAU stimuli sentences triggered Posterior Negativity. The ANOVA revealed that the main effect for the variable Condition (i.e. HAU vs. Control) did not reach significance across the 5 time windows examined; *F(1,16)=3.383, p=0.084.* However, orthogonal contrasts indicate that the effect for Condition was significant at the *500-600msec* time window: *1.22mV, t(16)=3.526, p=0.029* The effect approached significance at the 200-300msec time window: *0.83mV, t(16)=1.634, p=0.061.* It did not reach significance at the following time windows: 300-400msec: *0.87mV, t(16)=1.482, p=0.079;* 400-500msec: *0.79mV, t(16)=1.556, p=0.070;* 600-700msec: *1.19mV, t(16)=1.293, p=0.107.*

LAU vs. Control

<u>Global Analysis:</u> The figure below displays the difference topo plots LAU vs. Control.
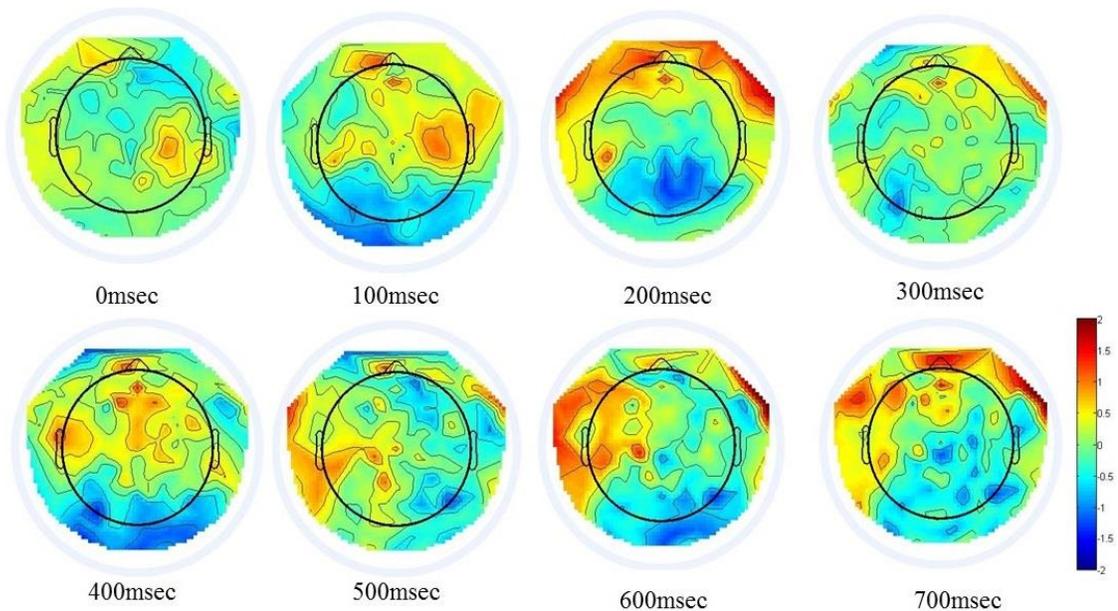
Figure 3.10. LAU ERP Data. Difference topo plots – LAU vs Control.

The repeated measures ANOVA carried out for the Global Analysis shows that no main effect for Condition was observed; $F(1,16) = 0.015, p=0.901$. No significant interactions involving the variable Condition were observed.

Posterior Region Analysis: No significant main effect for condition was observed in the posterior region of the scalp; $F(1,16) = 0.769, p=0.393$. The 3 way interaction Condition × Laterality × Time was significant; $F(2,32) = 3.933, p=0.0029$, stemming from the presence of a negativity effect on the right posterior area of the scalp.

Visual Inspection: A specific area of the scalp selected by visual inspection was identified in order to carry out a more in depth analysis. The figure below displays the map of the selected electrodes, and the waveforms that demonstrate the differences between the two conditions.

WAVES LAU VS. CONTROL - POSTERIOR REGION

LAU – …the maid of the actresses who **was** on the balcony.
Control – …the maid of the actress who **was** on the balcony.
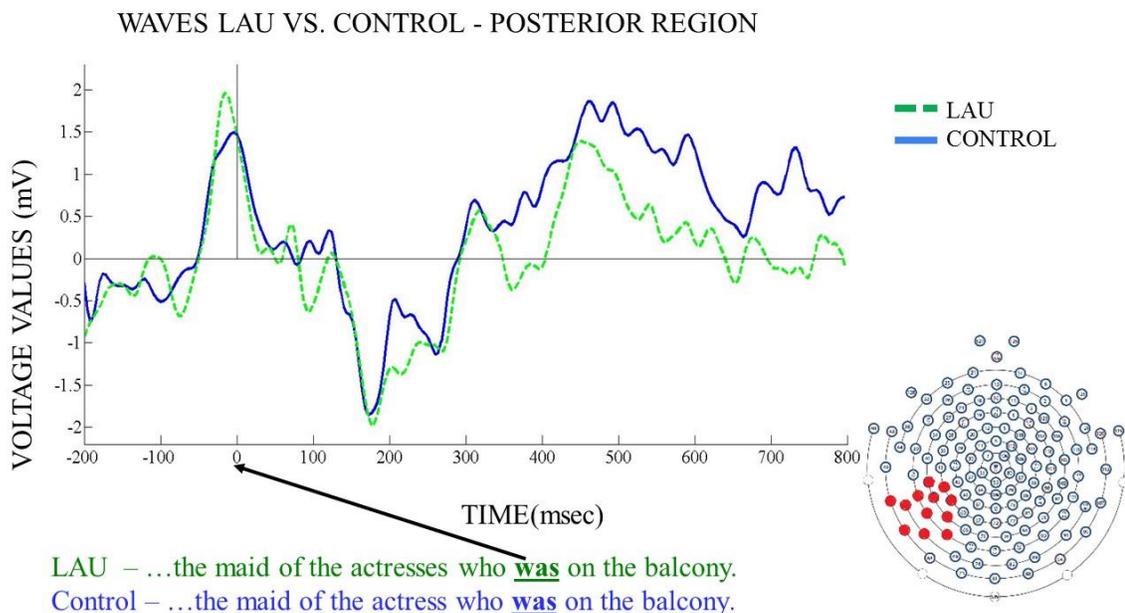
Figure 3.11. English ERP LAU data. LAU vs. Control Comparison in a selected area of the scalp. Waveforms of the Posterior Negativity effect (left) and spatial distribution (right).

LAU stimuli sentences triggered Posterior Negativity. A repeated measures ANOVA conducted on the selected area of the scalp demonstrates that the main effect of Condition (i.e. LAU vs. Control) approached significance across the 5 time windows from 200 to 700msec after the onset of the critical verb: *F(1,16)=4.386, p=0.052.* Orthogonal contrasts were performed at each time window, and the average voltage values in microvolts (mV) were calculated. The effect for Condition was significant at the following time windows: 400-500msec: *0.66mV, t(16)=2.010, p=0.031;* 500-600msec: *1.08mV, t(16)=2.567, p=0.011.* Significance was not reached at the following time windows: 200-300msec: *0.23mV, t(16)=0.744, p=0.234;* 300-400msec: *0.56mV, t(16)=1.510, p=0.075;* 600-700msec: *0.62mV, t(16)=1.278, p=0.110.*

3.2.3. Discussion

Behavioral results demonstrate that an RT delays at the critical verb were not observed in the HAU condition against control or in the LAU condition against control. This might indicate that the ungrammaticality effect perceived is not strong enough to have an impact of reaction times. For this reason, it is not possible to reach a conclusion about attachment height preferences in Spanish relative clauses based only on RTs.

ERP results indicate that Posterior Negativity was observed in both HAU and LAU conditions when compared to controls. These effects were similar in polarity, and distribution to an N400. This finding matches what was observed in experiment 1 with English speakers. The presence of an ERP effect in both HAU and LAU conditions suggests that the Spanish parser attaches relative clauses (RCs) to both a high and a low node simultaneously. These findings are congruent with Construal (Frazier & Clifton, 1996) which states that adjuncts, such as RCs, initially receive an "underspecified"

analysis, so they can associate to several different nodes. It is also congruent with the parsing principles proposed in the "Race-based Parallel Parsing Model" created by McRoy and Hirst (1990), which proposes that the parser attaches adjuncts to all possible nodes during an early stage of parsing, which generate competing meanings. One of the attachments is selected during a late processing stage, in which the sentence is analyzed for morpho-syntactic, semantic, and pragmatic plausibility, and a decision is made about the correct attachment of the adjunct. This late decision is probably what previous questionnaire studies (such as Cuetos & Mitchell, 1988) have registered, indicating that Spanish speakers have a preference for high attachments.

The results of the current study serve as evidence to demonstrate that at an early stage of the parsing process (immediately after perceiving the word), the parser performs both high and low attachments. The same behavior was observed in experiment 1A, in which English speakers participated. This indicates that the parsing of relative clauses occurs in a similar way in English and Spanish.

3.3. Comparison of Relative Clause Attachment across Languages

In this section, a comparison of the results from experiments 1A and 1B will be provided. The data from both English and Spanish speakers will be aggregated in order to observe general averages and perform the statistic calculations to determine whether there was an effect for language.

3.3.1. RT Results

The RT data from English and Spanish speakers was collapsed in order to observe the average. The table below displays the average RT times to the critical verb in the pooled data from both languages.

Table 3.5. Mean Reaction Times (SD) in msec to the Critical Verb as a Function of Condition; Pooled Data from both Languages.

	Condition		
	Control (SD)	HAU (SD)	LAU (SD)
Mean RT	548(146)	548(136)	561(148)
Example Sentence	*...the maid of the bride who **was**......*	*...the maids of the bride who **was**......*	*...the maid of the brides who **was**......*

A difference of less than 1msec was found between HAU and Control; *t(47)=0.048, p=0.480*. A 13msec delay was found in the LAU condition when compared to controls. This difference was significant; *t(47)=2.174, p=0.018*. A repeated measures ANOVA showed no main effect for Language; *F(1,46)=0.782, p=0.381.* The interaction Language × Condition was not significant; *F(2,92)=0.788, p=0.457.*

The graph below displays the data across conditions in 10 different regions (i.e. words) in the sentence. Region 5 corresponds to the critical verb.
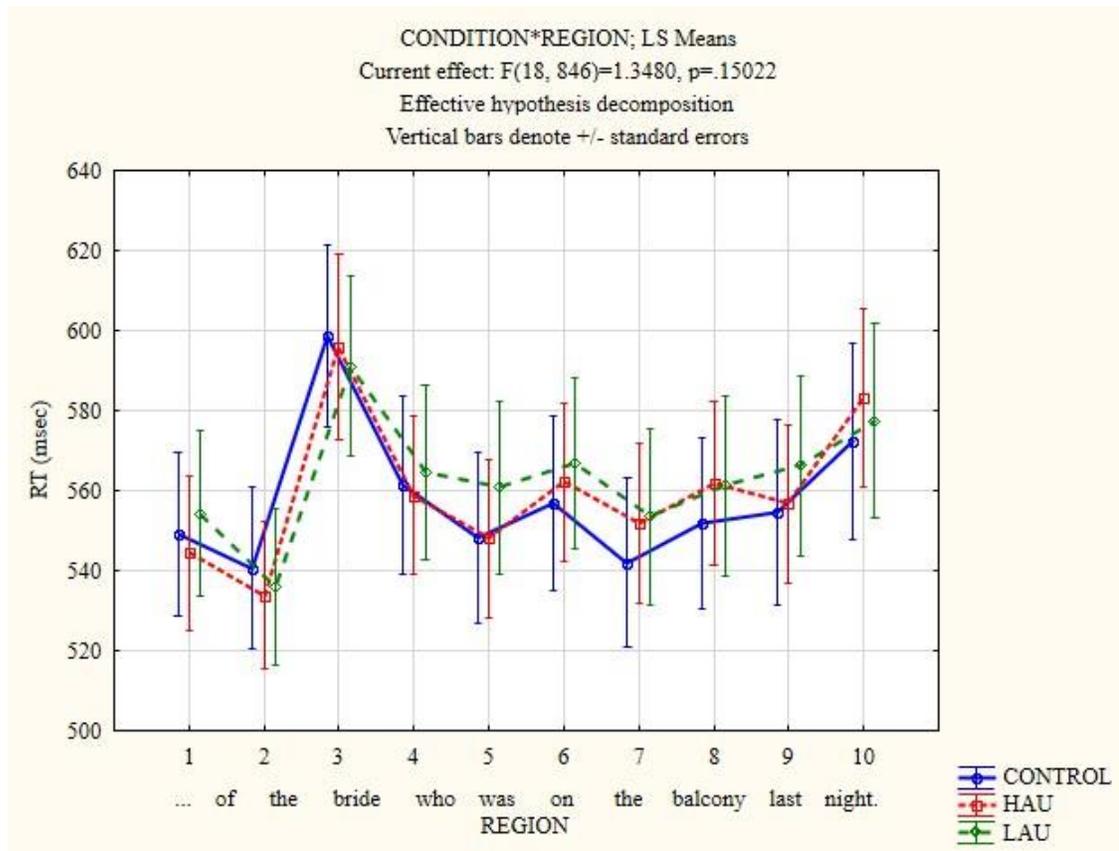
Figure 3.12. Pooled Data from English and Spanish: Mean Reaction Times (msec) as a Function of Region in the Sentence.

RTs to the word immediately following the critical verb (region #6) were examined in order to observe whether a significant spill-over effect was present. RTs to the HAU condition in region #6 were 5msec slower than controls. This difference was not significant; *t(47)=0.685, p=0.249*. A 10msec delay was found in the LAU condition when compared to controls. Significance was not reached; *t(47)=1.338, p=0.094*. A repeated measures ANOVA showed no significant main effect for Language;

F(1,46)=0.664, p=0.419. The interaction Language × Condition was not significant at region #6; *F(2,92)=2.385, p=0.097.*

An additional repeated measures ANOVA was conducted on the RT data across the 10 word regions observed in the figure. Region; *F(9,414)=15.382, p<0.001.* As it appears in the graph, reaction times increase in region 3 (i.e. 'bride'), corresponding to the noun inside the prepositional phrase that modifies the higher NP (i.e. *'the maid of the bride who'*). This RT increase was observed in both experiments 1A and 1B. The RT delay observed at region 3 occurs due to the increase in processing effort caused by adding a PP (i.e. 'of the bride') to the higher NP (i.e. 'the maid), as suggested by Thornton, McDonald and Gil (1999) in their Complex NP study. The Region × Language interaction was not significant; *F(9,414)=1.429, p=0.172.*

3.3.2. ERP Results

The EEG data from both English and Spanish RC experiments was aggregated in order to compute a general average. The same three types of statistical analysis carried out in experiment 1A were conducted on general average. The between-subject factor Language (English vs. Spanish) as added to the three analysis. The global analysis had 4 within-subject factors 1) Anteriority (anterior vs. posterior), 2) Laterality (left vs. right), 3) Time (200-400msec, 400-600msec vs. 600-800msec), and 4) Condition (depending on the specific comparison: Control vs. HAU or Control vs. LAU). No between-subject factors were used in this analysis. The Posterior Region analysis had the same factors except for anteriority. Finally, the Visual Inspection analysis had 5 time windows (200-300msec, 300-400msec, 400-500msec, 500-600msec vs. 600-700msec) and two conditions (Control vs HAU or Control vs LAU, depending on the comparison).

HAU vs. Control

<u>Global Analysis:</u> The following figure displays the difference topo plots HAU vs. Control from the pooled data (English and Spanish combined).
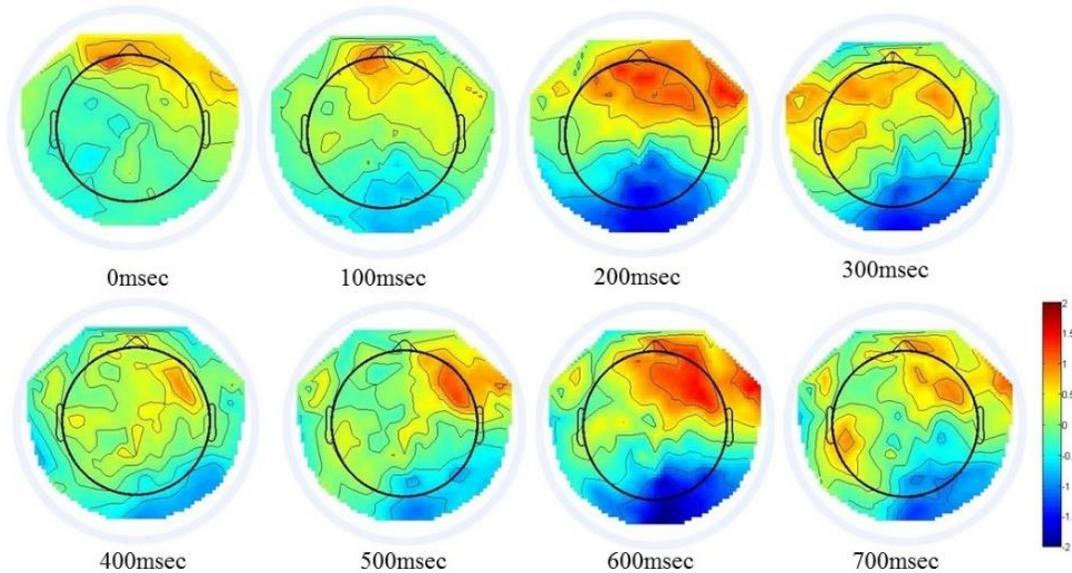
Figure 3.13. Pooled HAU ERP Data. Difference topo plots – HAU vs Control.

The repeated measures ANOVA carried out for the Global Analysis shows no main effect for Condition; $F(1,46) = 0.097, p=0.756$. The interaction Condition × Anteriority × Laterality was significant; $F(1,46) = 6.793, p=0.012$, stemming from a negativity effect on the central-right posterior region of the scalp.

<u>Posterior Region Analysis:</u> No significant main effect for condition was observed; $F(1,46) = 2.291, p=0.136$. The interaction Condition × Laterality reached significance; $F(1,46) = 4.257, p=0.044$, stemming from a posterior negativity effect that was more prominent on the right side of the scalp.

Visual Inspection: A specific area of the scalp selected by visual inspection was identified in order to carry out a more in depth analysis. The figure below displays the map of the selected electrodes (right), and the waveforms that demonstrate the differences between the two conditions.
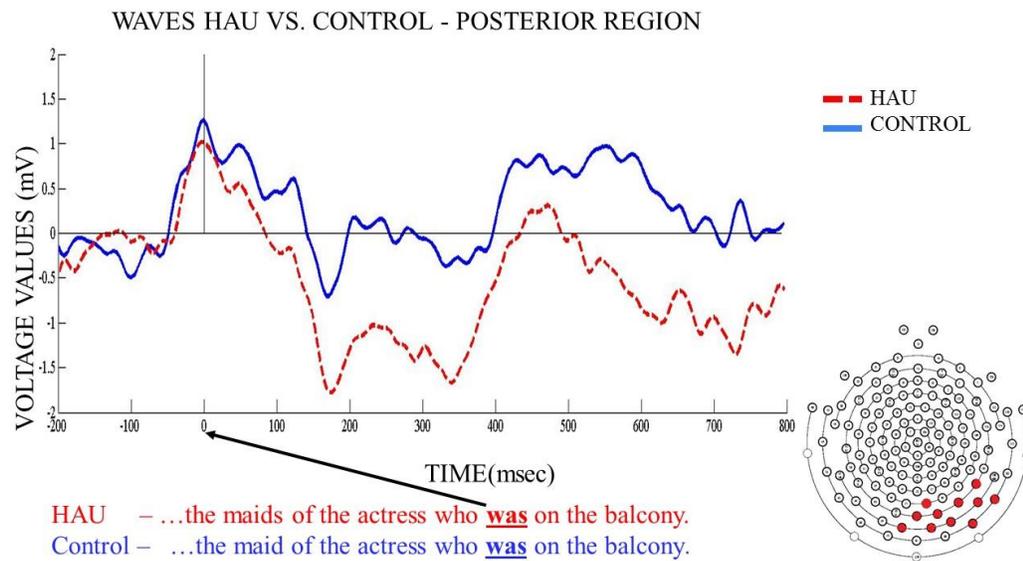
Figure 3.14. Pooled HAU ERP data. HAU vs. Control comparison in a selected area of the scalp. Waveforms of the Posterior Negativity effect (left) and spatial distribution (right).

HAU stimuli sentences triggered Posterior Negativity in the pooled data. The ANOVA revealed that the main effect for the variable Condition (i.e. HAU vs. Control) was significant across the 5 time windows; $F(1,46)=9.336, p=0.003$. There was no significant effect for the variable Language (i.e. English vs. Spanish); $F(1,46)=1.373, p=0.247$. The Condition $\times$ Language interaction was not significant: $F(1,46)=1.662,$

p=0.203. Orthogonal contrasts were performed at each time window, and the average

voltage values in microvolts (mV) were calculated. The effect for Condition was

significant at the following time windows: 200-300msec: *1.23mV, t(47)=3.871, p<0.001;*

300-400msec: *1.06mV, t(47)=3.227, p=0.001;* 400-500msec: *0.66mV, t(47)=2.235,*

p=0.015; 500-600msec: *1.22mV, t(47)=4.063, p<0.001;* 600-700msec: *1.19mV,*

t(47)=2.903, p=0.003.

      LAU vs. Control

      <u>Global Analysis:</u> The following figure displays the difference topo plots HAI vs.

Control from the pooled data (English and Spanish combined).
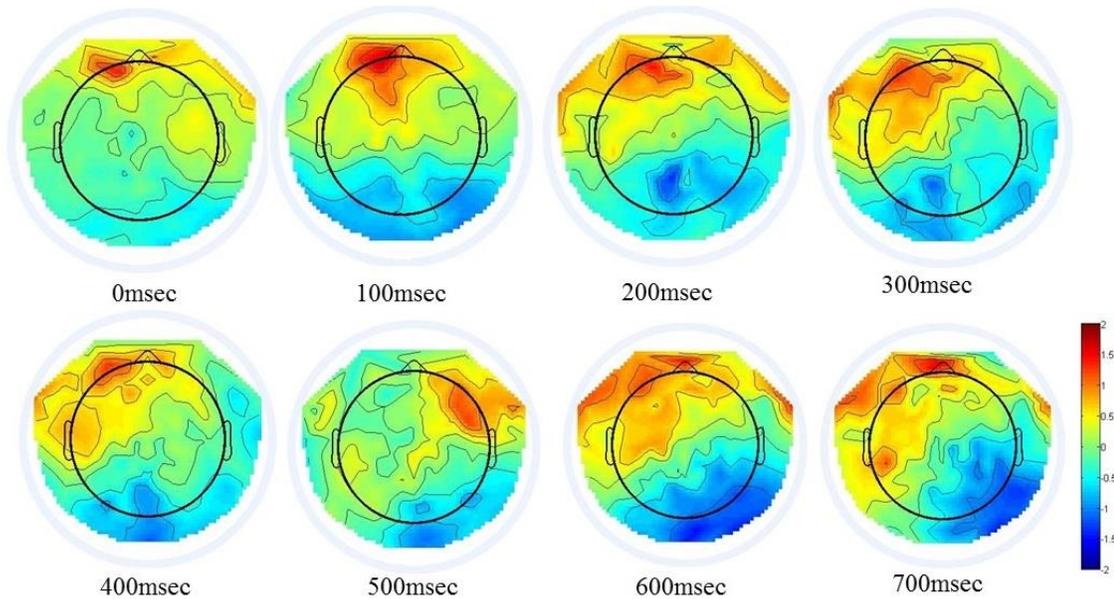
Figure 3.15. Pooled LAU ERP Data from both languages. Difference topo plots –

LAU vs Control.

The repeated measures ANOVA conducted for the Global Analysis shows no significant main effect for Condition; *F(1,46) = 0.079, p=0.779*. The interaction Condition × Anteriority was significant; *F(1,46) = 5.845, p=0.019,* stemming from a posterior negativity effect.

Posterior Region Analysis: A Posterior Negativity effect was observed as a response to LAU stimuli in the pooled data from both languages. A significant effect for condition was observed in the posterior region; *F(1,46) = 5.617, p=0.022*. No significant relevant interactions were observed (including Language related interactions).

Visual Inspection: A specific area of the scalp selected by visual inspection was identified in order to carry out a more in depth analysis. The figure below displays the map of the selected electrodes, and the waveforms that demonstrate the differences between the two conditions.

WAVES LAU VS. CONTROL - POSTERIOR REGION

LAU – …the maid of the actresses who **was** on the balcony.
Control – …the maid of the actress who **was** on the balcony.
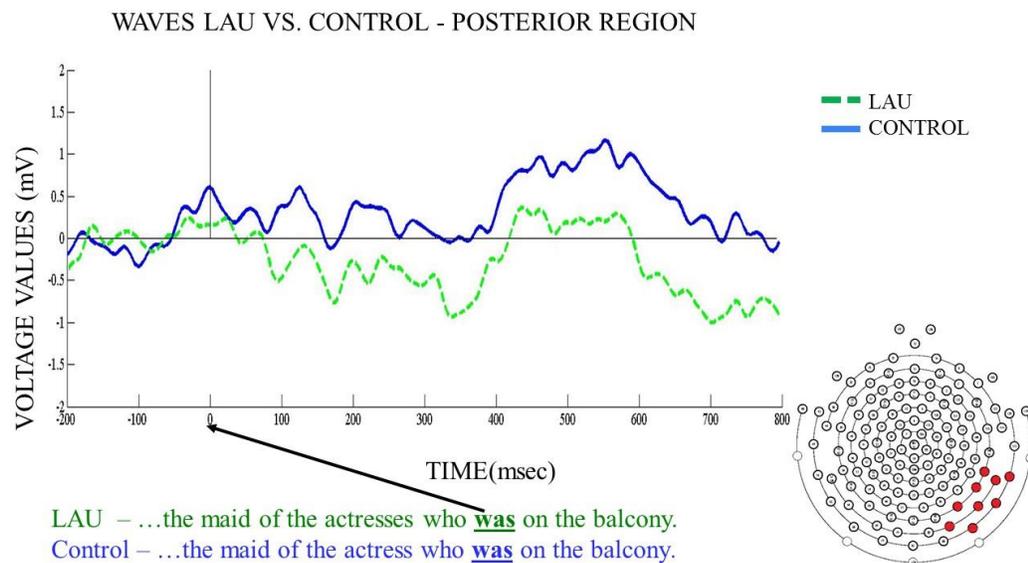
Figure 3.16. Pooled LAU ERP data. LAU vs. Control comparison in a selected area of the scalp. Waveforms of the Posterior Negativity effect (left) and spatial distribution (right).

LAU stimuli sentences triggered Posterior Negativity. A repeated measures ANOVA demonstrates that the main effect of Condition (i.e. LAU vs. Control) was significant across the 5 time windows from 200 to 700msec after the onset of the critical verb: *F(1,46)=8.860, p=0.004*. The main effect for the variable Language (i.e. English vs. Spanish) did not reach significance; *F(1,46)=0.145, p=0.704*. The interaction Condition × Language did not reach significance: *F(1,46)=1.571, p=0.216*. Orthogonal contrasts were performed at each time window, and the average voltage values in microvolts (mV) were calculated. The effect for Condition was significant at the following time windows: 200-300msec: *0.66mV, t(47)=2.556, p=0.007;* 300-400msec: *0.69mV, t(47)=3.112, p=0.002;* 400-500msec: *0.62mV, t(47)=2.595, p=0.007;* 500-600msec: *0.78mV, t(47)=2.939, p=0.003;* 600-700msec: *1.06mV, t(47)=3.732, p<0.001.*

3.3.3. Discussion

No statistically significant results were shown across conditions or languages in the combined RT data. This could be due to the fact that collapsing the subjects across languages increases the variability of the sample, which makes it more difficult to observe the effect across conditions. Having no effect of language is an indication that Spanish and English speakers recognize words at a similar rate.

EEG data displays a significant Posterior Negativity effect in both HAU and LAU conditions when compared against controls. These effects are similar in polarity and distribution to an N400. This demonstrates that English and Spanish speakers generate high and low attachments simultaneously, and for this reason, they are sensitive to ungrammaticality in both attachment sites. These findings support the idea that parallel parsing applies when subjects are exposed to syntactically ambiguous adjuncts, which is

congruent with Construal theory (Frazier & Clifton, 1996), and the Race-based Parallel

Parsing Model created by McRoy and Hirst (1990). It can be concluded that the

attachment of RCs occurs as in the figure below, in which the RC is simultaneously

attached to both NPs.
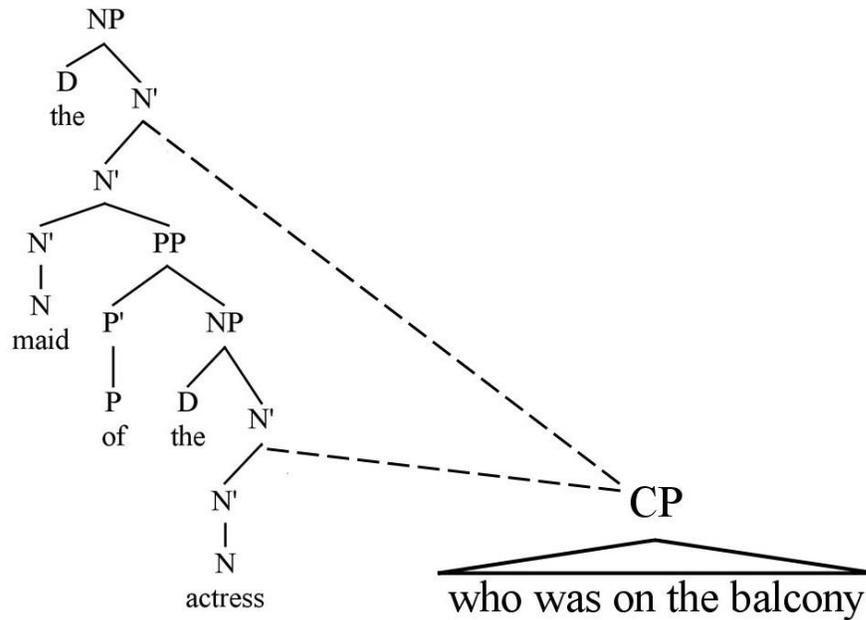
Figure 3.17. Tree Diagram Showing the Simultaneous Attachment of RCs.

These simultaneous attachments are, however, not permanent. One of the

attachments must be chosen over the other at a post-syntactic stage, when the context and

other external factors (i.e. such as intonation) are taken into consideration.

Chapter 4

STUDY 2: PREPOSITIONAL PHRASE ATTACHMENT

The current study will examine structural ambiguity triggered by prepositional phrases. As observed in Chapter 1, attachment height ambiguity can also be observed in complex NPs with prepositional phrases that can attach to either a high or a low node. This study will help confirm the findings discussed in the previous chapter.

Study 2 aims to analyze the responses of a group of native speakers of English and a group of native speakers of Spanish to semantic implausibility triggered by the attachment of ambiguous prepositional phrases. As in the previous study, both behavioral responses and EEGs will be collected simultaneously as previous studies have done it before (e.g. Van der Meij, Cuetos, Carreiras & Barber (2010)). The collection of behavioral responses does not have an impact on EEG data as observed by (Dimigen, Sommer, Hohlfeld, Jacobs, & Kliegl, 2011).

In this experiment, a group of native speakers of English will be exposed to sentences similar to those created by Thornton, McDonald, and Gil (1999), which hold ambiguous prepositional phrases, as shown in (53) and (54) below.

(53) *The dress of the singer with a great voice was made by Armani.*

(54) *The dress of the singer with white stripes was made by Armani.*

In (53), only the low attachment of the PP is plausible (i.e. *'the singer with a great voice…'*), as the high attachment yields a semantically implausible meaning (i.e. *'the dress with a great voice...'*). In (54), the opposite is true; while the high attachment is

plausible (i.e. *'the dress with white stripes…'*), the low attachment is not (i.e. *'the singer with white stripes…'*).

The models of attachment parsing described in chapter 2 can be used to predict the possible outcomes of the experiments in the present study. As with relative clauses, the Single Analysis, Late Reanalysis and Early Reanalysis models predict that English speakers will detect anomalies in low attachments. Therefore, it is expected that an N400, which is usually associated with semantic incongruity, and an RT delay will be observed when this group is exposed to LAI sentences. On the contrary, HAI sentences should not display an effect because English speakers do not perform the high attachments needed to trigger the humorous response in HAI sentences. On the other hand, the Parallel Parsing model predicts that English speakers will detect semantic anomalies in both HAI and LAI sentences. Therefore, an N400 is expected by this model in both conditions. Note that if speakers are sensitive to the semantic implausibility generated by a particular type of attachment an N400 response is expected because this response is associated with semantic incongruity (Osterhout, 1994). The predictions for English speakers' responses appear in the table below.

Table 4.1. Predicted ERP Responses of Native English Speakers to each Type of Prepositional Phase Attachment as a Function of Model of Attachment Processing.[8]

Condition	English Speaker Response	
	Single Analysis, Late Reanalysis, Early Reanalysis	Parallel Parsing
HAI	No N400	N400 / RT Delay
LAI	N400 / RT Delay	N400 / RT Delay

The Single Analysis model, based on Cuetos and Mitchell's findings, predicts that Spanish speakers will be sensitive to high attachment anomalies, as characterized by an N400 and an RT delay in this case. The Late Reanalysis model, based on Fernandez's (2002), leans towards Spanish speakers only reacting to low attachments. The Early Reanalysis model, based on reanalysis theory, predicts that Spanish speakers will be sensitive to low attachments initially exhibiting an N400 response, but they will reanalyze the sentences, triggering a P600 as a reflex of reanalysis. In HAI sentences, Spanish speakers would not have an N400 because they initially attach low; however, P600 should be observed due to reanalysis. Finally, the Parallel Parsing model, based on construal and McRoy and Hirst (1990), predicts that Spanish speakers will attach both high and low, so an N400 should be expected in both HAI and LAI conditions.

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[8] Note that neither Cuetos & Mitchell (1988) nor Fernandez (2002) makes any explicit predictions about ERPs in any of their papers. These predictions are an interpretation of what they would find in ERPs considering the conclusions of their studies.

Table 4.2. Predicted ERP Responses to each Type of Prepositional Phase

Attachment as Function of Model of Attachment Processing.[9]

Condition	Spanish Speaker Response			
	Single Analysis	Late Renalysis	Early Reanalysis	Parallel Parsing
HAI	N400 / RT Delay	No N400	P600 only	N400/RT Delay
LAI	No N400	N400 / RT Delay	N400-P600/RT Delay	N400/RT Delay

In the following sections, the experiments regarding prepositional phrase attachment will be introduced in order to test the predictions of the models above. A comparison of the results across languages will be provided afterwards.

4.1. Experiment 2A: English Prepositional Phrases

4.1.1. Method

Subjects

20 native speakers of English from 18 to 22 years of age (mean: 19.30, ±0.95), 18 female and 2 male, participated in this experiment. All subjects were right handed. They had normal vision, and no history of neurological conditions or language impairment. They participated in the study voluntarily, and were offered course credit for their participation. The recruitment process and exclusion criteria used for this experiment were similar to the ones shown in experiment 1. Out of the total 20 subjects, 1 of them was excluded due to having too many bad trials (20% of bad trials or more).

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[9] Note that neither Cuetos & Mitchell (1988) nor Fernandez (2002) makes any explicit predictions about ERPs in any of their papers. These predictions are an interpretation of what they would find in ERPs considering the conclusions of their studies.

Apparatus and Procedure

This experiment was programmed using E-Prime professional 2.0.8.90, running on a Dell desktop PC. RT data was recorded by a PST serial response box. EEG data was acquired by a 128-channel HydroCel Geodesic Sensor Net, with Ag/AgCl electrodes covered by sponges soaked in an electrolyte solution. EEG data was recorded by EGI NetStation software v.4.5. Electrode impedance were lowered below 50Ω prior to data collection. Data were digitized with a 24-bit resolution at 250Hz.

Subjects sat in front of an LCD screen in an electrically shielded, sound treated booth. They had to complete a self-paced reading task, in which they read each sentence divided by phrases, which we will call "regions". Each sentence had 5 regions as in the following example:

1. Region 1 - First NP : The dress

2. Region 2 - Second NP: of the singer

3. Region 3 - Critical PP: with a great voice

4. Region 4 - VP: was made

5. Region 5 - Final PP: by Armani.

Subjects had to press a button in order to see the next region. They were instructed to use the index finger of their dominant hand to press the button. A comprehension question was presented after each sentence was finished. An example of each kind of stimulus will appear on the next section.

Subjects were instructed to read at a normal pace (i.e. not to fast or too slow). The experiment was divided into two blocks, with a small break in between. Subjects were reminded about keeping a normal pace during the break.

Design and Stimuli

This design uses a single variable with 3 levels, in which two conditions show semantic implausibility triggered by a particular kind of attachment (1- High Attachment Implausible- HAI / 2- Low Attachment Implausible - LAI) are compared to a fully grammatical control condition (3- Control). An example of experimental and control sentences appears below.

(55) HAI*: The artist in the studio <u>with brick walls</u> was surprised by the earthquake.*

(56) LAI: *The studio of the artist <u>with brick walls</u> was destroyed by the earthquake.*

(57) Control: *The house by the building <u>with brick walls</u> was destroyed by the earthquake.*

(58) Comprehension question for sentence (56): *What destroyed the house?*

As observed in (55), the PP *'with brick walls'* generates an implausible high attachment (i.e. *'the artist with brick walls'*). In (56), the opposite is true; the low attachment is implausible (i.e. *'the artist with brick walls'*). Finally, in (57), either attachment is plausible (i.e. '*the house with brick walls' / 'the building with brick walls'*).

The sentences used in this experiment were adapted from Thornton, McDonald and Gil (1999), who used sentences in which the critical prepositional phrase (i.e. Region 3) was variable while the first two noun phrases were constant (i.e. Regions 1 and 2). We decided to alter the sentences in order to have the exact same prepositional phrase in the critical region (Region 3) across conditions in order to have less variability in the ERPs (i.e. the critical prepositional phrase in all the examples above is *'with brick walls'*).

Having the same prepositional phrase across conditions means that factors like word length and word frequency will not affect subjects' reaction times; therefore, they will not interfere with the attachment height effect that is being studied in the current research. The altered sentences were reviewed by 3 native speakers of English, who verified the plausibility of the sentences as a whole. Since the same prepositional phrase was shown across conditions, no variability regarding word length or word frequency was observed in EEGs or RTs.

Sentences in this experiment were controlled for animacy. The nouns in the two possible attachment sites were distributed in the following manner in all conditions: 14 sentences contained inanimate nouns in both high and low attachment sites (e.g. "the computer down the hall…"); 7 sentences had an animate noun in the high attachment site and an inanimate noun in the low attachment site (e.g. "the artist in the studio…"); and 7 sentences had an inanimate noun in high attachment site and an animate noun in the low attachment site (e.g. "the lab of the biologist…"). This distribution was created in order to prevent animacy from having an impact on subjects' attachment height preferences. The complete list of sentences used in this experiment appears as 'APPENDIX C'.

Although EEG data will be recorded throughout the experiment, ERPs will be locked to the critical prepositional phrase (Region 3 - underlined in the examples above). Such prepositional phrase is supposed to trigger a semantically implausible reading when a specific type of attachment is made. Each subject saw 28 experimental sentences of each kind (HAI and LAI), for a total of 56 experimental trials, 28 control sentences will be used, and 56 sentences will be added as fillers, for a total of 140 sentences in the whole experiment.

After the subject provided a response to the comprehension question, feedback was immediately provided. Comprehension questions, such as (58), never asked the subject to attach the critical PP to a particular attachment site in order to respond (i.e. the questions used for sentences (42) to (44) never asked *'what had brick walls?'*). This was done in order not to bias the subject by proving feedback about what the correct response should be. It was necessary to provide feedback in order to make sure that the subject was aware that accuracy was being recorded, and that understanding the sentences was important for the task.

4.1.2. Results

4.1.2.1. Behavioral Results

In this section we will analyze the reaction times in milliseconds to the critical region. As in experiment 1, outlier RTs faster than 310msec were removed from the data (i.e. this is an approximate projection of the fastest behavioral reaction possible according to Hawk, Coutout, Holden & Chen (2011)). Outlier RTs slower than 2 standard deviations above the mean for each subject were also removed (less than 1% of the data were removed). The table below shows the average RT values that were observed in each condition.

Table 4.3. Mean Reaction Times (SD) in msec to the Critical Region as a

Function of Condition in Experiment 2A.

	Condition		
	Control (SD)	HAI (SD)	LAI (SD)
Mean RT	957(296)	953(300)	932(294)
Example Sentence	*The house by the building* **with brick walls…**	*The artist in the studio* **with brick walls…**	*The studio of the artist* **with brick walls…**

The data above show that the Control condition is slower than the two experimental conditions. It is 4msec slower than HAU and 25msec slower than LAU. These differences were not significant; Control vs HAI: $t(18)=0.243, p=0.406;$ Control vs LAI: $t(18)=1.551, p=0.099.$

The figure below shows a comparison of the mean reaction times across conditions to each of the words in the stimulus sentences from the beginning to the end of the sentence. Region #3 corresponds to the critical prepositional phrase.
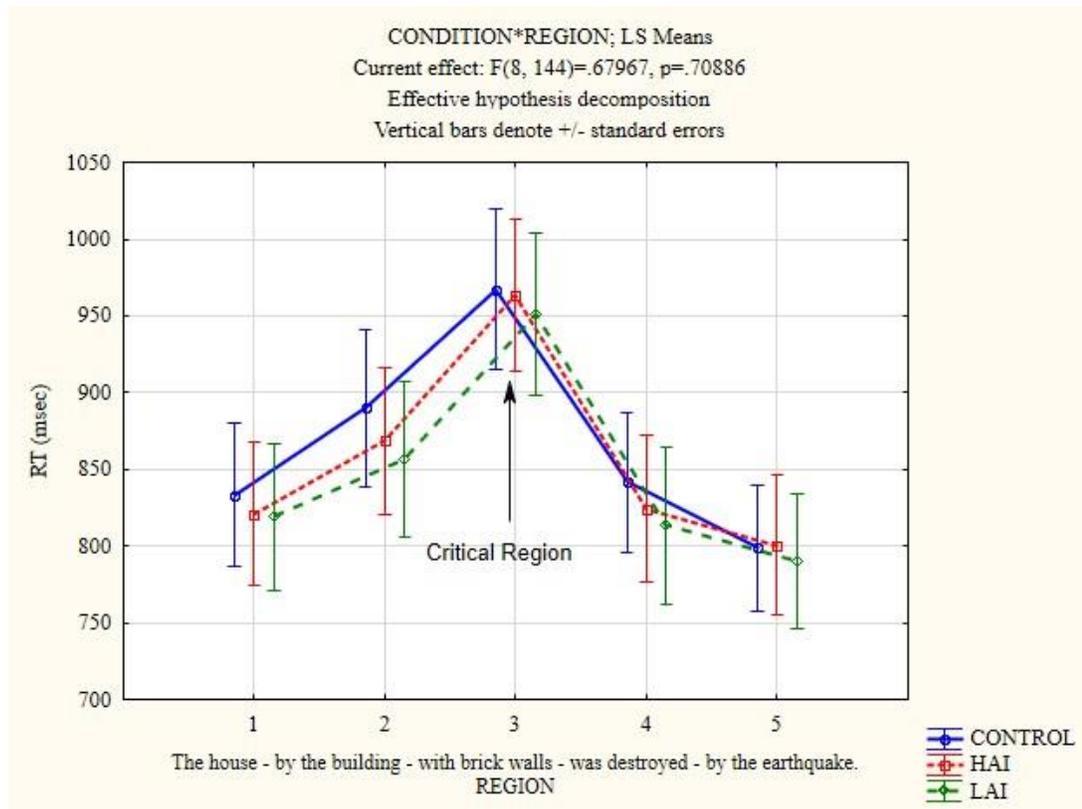
Figure 4.1. Mean Reaction Times (msec) as a Function of Region in the Sentence in Experiment 2A.

A repeated measures ANOVA was conducted on the RT data. Two within subject factors were considered: Condition (3 Levels: Control, HAI vs. LAI), and Region (5 Levels: the 5 regions observed in the graph above). Results indicate that there was a significant effect for Region; $F(4,72)=36.619, p<0.001$. As observed in the graph, reaction times increase in regions 2 and 3; this effect is explained by the fact that as PPs are added to the main NP processing effort increases, which increases reaction times regardless of the condition. This effect on complex NPs was observed by Thornton, McDonald and Gil (1999). No significant effects were found for Condition;

F(2,36)=2.679, p=0.102; and for the Condition × Region interaction; *F(8,144)=0.679, p=0.708*.

4.1.2.2. ERP Results

After continuous EEG data were collected, 1000msec epochs were extracted. Each epoch started 200msec before the critical region (to allow for baseline correction), and ended 800msec after. An automated procedure to identify bad channels was performed. Any channel with a difference between minimum and maximum voltage of more than 200μ in a moving average of 80 msec was marked as bad. Channels marked bad in 20% of the data or more were mark as bad in all trials. Bad channels were replaced by using spherical spline interpolation. Finally, automatic eyeblink subtraction was performed; single trials were averaged across conditions (Control, HAI, LAI), and all data were referenced to average voltage by using the ERP PCA toolkit (Dien, 2010). Note that some previous ERP experiments observing structural ambiguity, such as Carreiras, Salillas & Barber (2005). have used average mastoid reference; in the current study, it was observed that there was no noticeable difference in the effects observed on the data if voltages used average reference or mastoid reference; therefore, the current analysis is comparable to studies using voltage averaged to linked mastoids.

Three types of statistical analyses were performed on the EEG data: 1) Global Analysis, 2) Posterior Region Analysis, and 3) Visual Inspection. No between-subject factors will be used in this analysis. These analyses are explained below.

Global Analysis: A repeated measures ANOVA was conducted on the EEG data from the entire scalp. In order to perform this analysis, the scalp was divided into 4 regions of interest, which were proposed by Dien and Santuzzi (2005). Electrodes were

grouped using 2 spatial factors: anteriority (anterior vs. posterior), and laterality (left vs.

right). The areas covered by these regions are shown in the figure below.

Figure 4.2. Electrode map depicting the distribution of the 8 regions of interest.

For this global analysis, voltage values were collapsed across 3 time windows:

200-400msec, 400-600msec vs. 600-800msec. This distribution will help observe if

effects are present at different stages of the parsing process as opposed to the whole

epoch.

Conditions were compared with separate ERP analyses. In other words, only two

conditions were compared in each analysis. The factor Condition had 2 level in each of 2

analyses performed: 1) Control vs. HAI and 2) Control vs. LAI.

In summary, the repeated measures ANOVA performed on the data for the global analysis had 4 within-subject factors: 1) Anteriority (anterior vs. posterior), 2) Laterality (left vs. right), 3) Time (200-400msec, 400-600msec vs. 600-800msec), and 4) Condition (depending on the specific comparison: Control vs. HAI or Control vs. LAI). In this analysis, the main effect for Condition will be reported along with any statistically significant interactions between Condition and the other factors.

Posterior Region Analysis: Since the effects observed in the experiments were found in the posterior region, a specific analysis targeting this region will be conducted. It will have the same time windows and condition factors as the global analysis, but only the posterior region of the scalp will be considered, which means that the variable "anteriority" will not be used. To summarize, this analysis will have 3 variables: 1) Laterality (left vs. right), 2) Time (200-400msec, 400-600msec vs. 600-800msec), and 3) Condition (depending on the specific comparison: Control vs. HAI or Control vs. LAI). As in the global analysis, the main effect for condition will be reported along with any statistically significant interactions between Condition and the other factors.

Visual Inspection: A set of electrodes located in the particular area of the scalp that appears to have the most prominent effect will be selected as a critical region for an in depth analysis. A waveform plot will be provided in order to show a visual representation of the voltage values in the scalp of such region, and a small map of its distribution. This analysis will not include topographical factors. Voltage values will be grouped in 5 time windows (200-300msec, 300-400msec, 400-500msec, 500-600msec, and 600-700msec); this distribution was created in order capture effects that only reached significant in a small time window. Finally, the variable condition will have the same

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factors explained above. To summarize, this analysis will have 2 factors: 1) Time (200-300msec, 300-400msec, 400-500msec, 500-600msec vs. 600-700msec) and 2) Condition (depending on the specific comparison: Control vs. HAI or Control vs. LAI).

Control vs. HAI

Global Analysis: The figure below displays the difference topo plots HAI vs. Control.
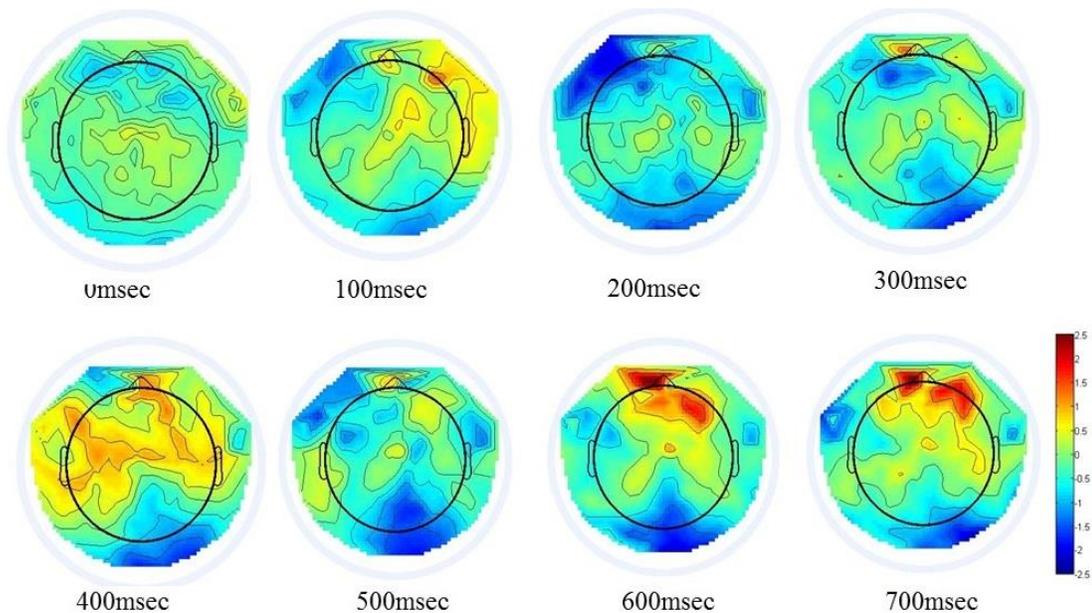
Figure 4.3. English ERP HAI data: Difference Topo Plots: HAI vs. Control.

The repeated measures ANOVA carried out for the Global Analysis shows that no main effect for Condition was observed; $F(1,18) = 0.375$, $p=0.549$. No relevant interactions reached significance in this analysis.

Posterior Region Analysis: No main effect for Condition was observed in this analysis; $F(1,18) = 1.951$, $p=0.179$. No relevant interactions reached significance. The

absence of significant effects for the Condition × Laterality interaction was probably due to the fact that the effect was localized in a small central region on the scalp.

Visual Inspection: A specific area of the scalp selected by visual inspection was identified in order to carry out a more in depth analysis. The figure below displays the map of the selected electrodes, and the waveforms that demonstrate the differences between the two conditions.

WAVES HAI VS. CONTROL – POSTERIOR REGION

HAI – The artist in the studio **with brick walls** was surprised by the earthquake.
Control – The house by the building **with brick walls** was destroyed by the earthquake
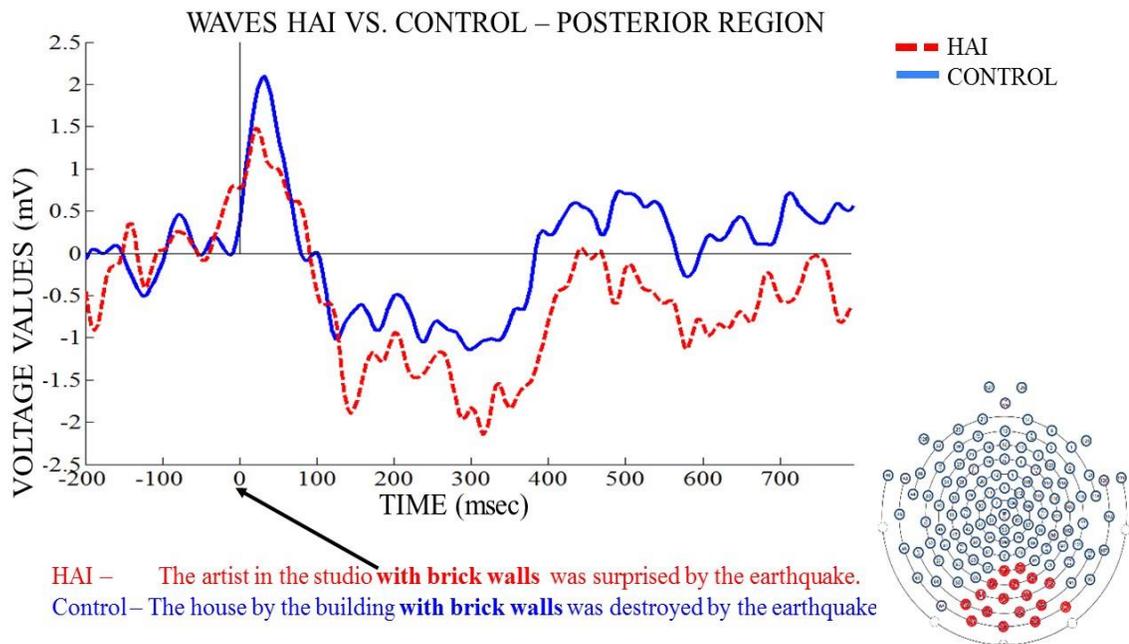
Figure 4.4. English ERP HAI data. HAI vs. Control comparison in a selected area of the scalp. Waveforms of the Posterior Negativity effect (left) and spatial distribution (right).

HAI stimuli sentences triggered Posterior Negativity. ANOVA results from the selected region indicate that the main effect for the variable Condition (i.e. HAI vs. Control) was significant across the 5 time windows; *$F(1,18)=8.511, p=0.009$*. Orthogonal

contrasts were performed at each time window, and the average voltage values in microvolts (mV) were calculated. The effect for Condition was significant at the following time windows: 200-300msec: *0.83mV, t(18)=1.850, p=0.041;* 300-400msec: *1.33mV, t(18)=2.703, p=0.008;* 400-500msec: *1.27mV, t(18)=2.712, p=0.007;* 500-600msec: *1.59mV, t(18)=2.763, p=0.008;* 600-700msec: *1.27mV, t(18)=2.126, p=0.024.*

LAI vs. Control

Global Analysis: The figure below displays the difference topo plots LAI vs. Control.
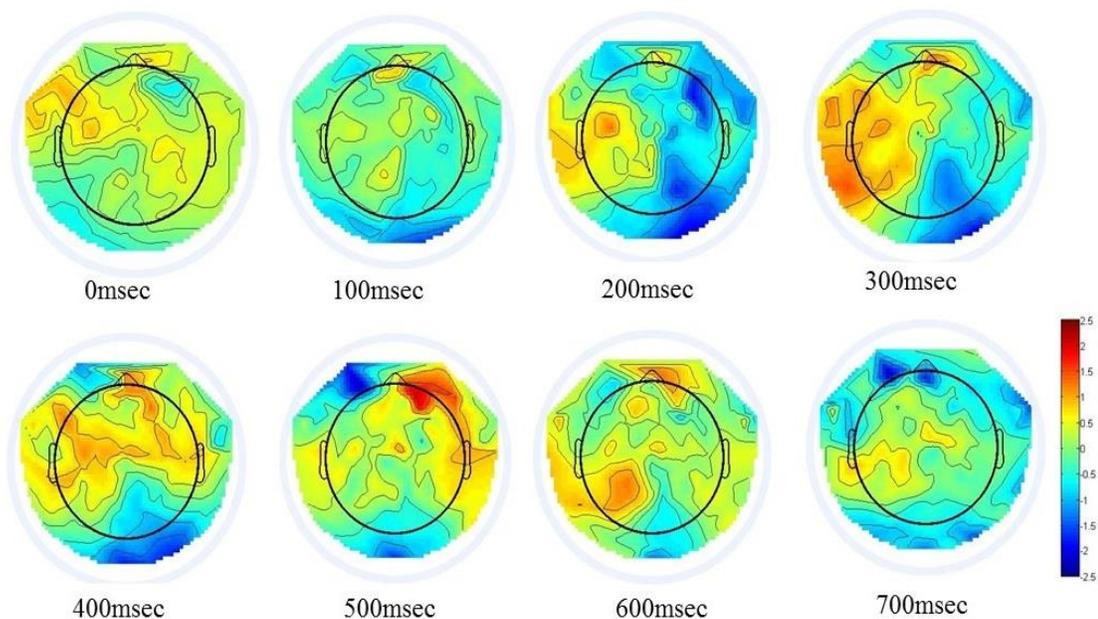
Figure 4.5. English LAI ERP data. Difference Topo Plots: LAI vs Control.

The repeated measures ANOVA conducted for the Global Analysis shows no main effect for Condition; *F(1,18) = 0.031, p=0.861.* No relevant interactions reached significance.

Posterior Region Analysis: No significant main effect for condition was observed in this analysis; $F(1,18) = 0.532$, $p=0.474$. The interaction Condition × Laterality approached significance; $F(1,18) = 3.814$, $p=0.066$, stemming from a negativity effect that appears on the right hemisphere only.

Visual Inspection: A specific area of the scalp selected by visual inspection was identified in order to carry out a more in depth analysis. The figure below displays the map of the selected electrodes, and the waveforms that demonstrate the differences between the two conditions.
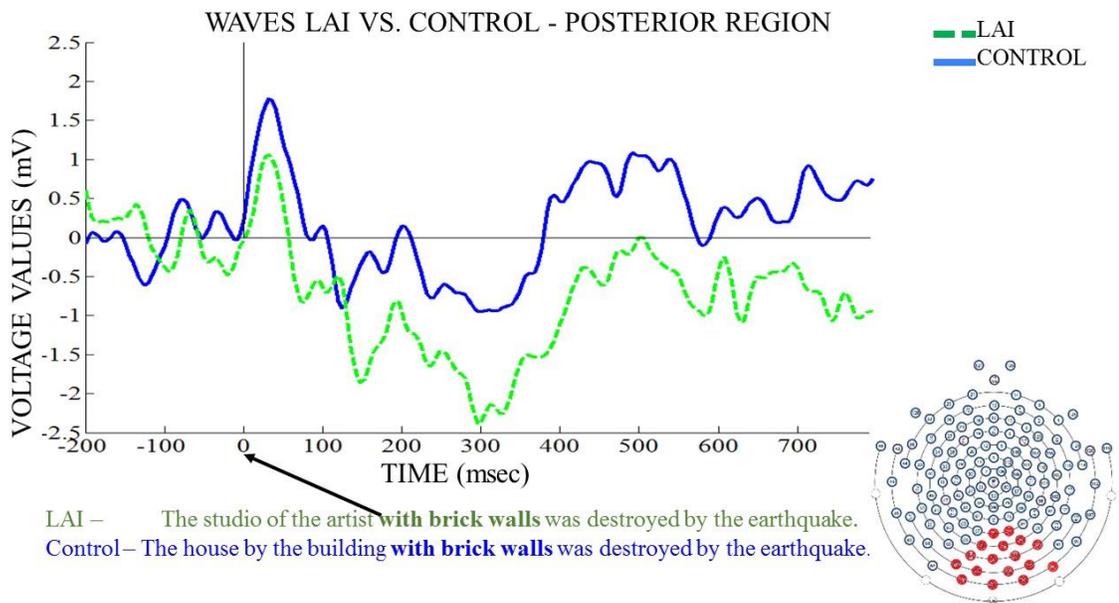
Figure 4.6. English ERP LAI data. LAI vs. Control Comparison in a Selected Area of the Scalp. Waveforms of the Posterior Negativity effect (left) and spatial distribution (right).

LAI stimuli sentences triggered Posterior Negativity. A repeated measures

ANOVA shows that the main effect of Condition (i.e. LAI vs. Control) was significant

across the 5 time windows examined: *F(1,18)=4.885, p=0.040.* Orthogonal contrasts

were performed at each time window, and the average voltage values in microvolts (mV)

were calculated. The effect for Condition was significant at the following time windows:

200-300msec: *1.02mV, t(18)=1.766, p=0.047;* 300-400msec: *1.26mV, t(18)=2.145,*

p=0.023; 400-500msec: *1.22mV, t(18)=2.180, p=0.022;* 500-600msec: *1.09mV,*

t(18)=1.970, p=0.032. Significance was not reached at the 600-700msec time window;

0.84mV, t(18)=1.413, p=0.088.

4.1.3. Discussion

Behavioral results did not reach statistical significance across conditions.

Therefore, the RT data did not provide evidence to identify the attachment height

preferences of English speakers.

ERP results in both conditions show Posterior Negativity, which is particularly

prominent from 400 to 600msec. This effect is similar in polarity, and distribution to an

N400, which has traditionally been associated with semantic anomalies (Nigam, Hoffman

& Simons, 1992). This finding suggests that the parser prepositional phrases (PPs) to

both a high and a low node simultaneously. These findings are congruent with Construal

(Frazier & Clifton, 1996) which states that adjuncts, such as PPs, initially receive an

"underspecified" analysis, so they can associate to several different nodes. It is also

convergent with the parsing principles proposed in the "Race-based Parallel Parsing

Model" created by McRoy and Hirst (1990), which proposes that the parser attaches

adjuncts to all possible nodes during an early stage of parsing, which generate competing meanings.

The ERP results of the current experiment serve as evidence to demonstrate that at an early stage of the parsing process (immediately after perceiving the word), the parser performs both high and low attachments in prepositional phrases.

4.2. Experiment 2B: Spanish Prepositional Phrases

4.2.1. Method

Subjects

21 native speakers of Spanish from 20 to 37 years of age (mean: 26.95, ±4.42) participated in this experiment. 18 subjects were right-handed and 3 of them were left-handed. They were born in the following countries: Argentina (1), Chile (1), Colombia (12), Panama (3) and Spain (4). They were present in the USA at the moment of the study; 20 of them had been in the country for less than a year (average length of stay 4.75 months, ±1.92), and 1 for 4 and a half years. They had normal vision, and no history of neurological conditions or language impairment. They participated in the study voluntarily, and were offered $10 dollars as compensation for their participation. The recruitment process and exclusion criteria used for this experiment were similar to the ones shown in experiment 2A. All subjects of this experiment also participated in 1B.

Apparatus and Procedure

This experiment used the same apparatus and procedure described in experiment 2A.

Design and Stimuli

This design uses a single variable with 3 levels, in which two conditions show

semantic implausibility triggered by a particular kind of attachment (1- High Attachment

Implausible- HAI / 2- Low Attachment Implausible - LAI) are compared to a fully

grammatical control condition (3- Control). An example of experimental and control

sentences appears below.

(46) HAI: *El artista en el estudio <u>con paredes de ladrillo</u> fue sorprendido por el*

terremoto. (The artist in the building <u>with brick walls</u> was surprised by the

earthquake.)

(47) LAI: *El estudio del artista <u>con paredes de ladrillo</u> fue sorprendido por el*

terremoto.

(The studio of the artist <u>with brick walls</u> was surprised by the earthquake).

(48) Control: *La casa junto al edificio <u>con paredes de ladrillo</u> fue destruida por el*

terremoto. (The house by the building <u>with brick walls</u> was destroyed by the

earthquake.)

(49) Comprehension question for sentence (48): *¿Qué destruyó la casa? (What*

destroyed

the house?)

The stimuli used in this experiment are direct translations of those used in

experiment

2A. An entire list of these stimuli sentences appears in 'APPENDIX D'.

The sentences used in this experiment were adapted from the Spanish experiment

created by Thornton, McDonald and Gil (1999), who used sentences in which the critical

prepositional phrase (i.e. Region 3) was variable while the first two noun phrases were constant (i.e. Regions 1 and 2). We decided to alter the sentences in order to have the exact same prepositional phrase in the critical region (Region 3) across conditions in order to have less variability in the ERPs (i.e. the critical prepositional phrase in all the examples above is *'con paredes de ladrillo' – 'with brick walls'*). Having the same prepositional phrase across conditions means that factors like word length and word frequency will not affect subjects' reaction times; therefore, they will not interfere with the attachment height effect that is being studied in the current research. The altered sentences were reviewed by 3 native speakers of Spanish, who verified the plausibility of the sentences as a whole. Since the same prepositional phrase was shown across conditions, no variability regarding word length or word frequency was observed in EEGs or RTs.

Although EEG data will be recorded throughout the experiment, ERPs will be locked to the critical prepositional phrase (Region 3 - underlined in the examples above). Such prepositional phrase is supposed to trigger a semantically implausible reading when a specific type of attachment is made. Each subject saw 28 experimental sentences of each kind (HAI and LAI), for a total of 56 experimental trials, 28 control sentences will be used, and 56 sentences will be added as fillers, for a total of 140 sentences in the whole experiment.

As in experiment 1A, subjects were given feedback immediately after they responded each comprehension question. These questions did not assess attachment height preferences (i.e. the questions used for sentences (46) to (48) did not ask *'what*

had brick walls?'). This was done in order not to bias the subject by providing a correct response about which type of attachment was correct.

4.2.2 Results

4.2.2.1. Behavioral Results

In this section we will analyze the reaction times in milliseconds to the critical region. Outlier RTs that were faster than 310msec will removed from the data (i.e. this is the fastest behavioral reaction possible according to Hawk, Coutout, Holden & Chen (2011)). Similarly, outlier RTs that were slower than 2 standard deviations above the mean for each subject were removed from the data (less than 1% of the data were removed). Table 1 below shows the average RT values that were observed in each condition.

Table 4.4. Mean Reaction Times (SD) in msec to the Critical Region as a Function of Condition in Experiment 2B.

	Condition		
	Control (SD)	HAI (SD)	LAI (SD)
Mean RT	970(324)	972(321)	964(327)
Example Sentence	*La casa junto al edificio con paredes de ladrillo fue destruida por el terremoto. (The house by the building with brick walls was destroyed by the earthquake.)*	*El artista en el estudio con paredes de ladrillo fue sorprendido por el terremoto. (The artist in the building with brick walls was surprised by the earthquake.)*	*El estudio del artista con paredes de ladrillo fue sorprendido por el terremoto. (The studio of the artist with brick walls was surprised by the earthquake).*

The data above shows that RTs were 2msec slower in HAI condition when compared to controls. This delay was not significant; *t(20)=0.697, p=0.247*. RTs in the LAI condition were 6msec faster than controls. Statistical significance was not reached, *t(20)=0.031, p=0.488.* These RT results were expected since significance was not reached in experiments 2A and 2B.

The figure below shows a comparison of the mean reaction times across conditions to each of the words in the stimulus sentences from the beginning to the end of the sentence. Region #3 corresponds to the critical prepositional phrase.
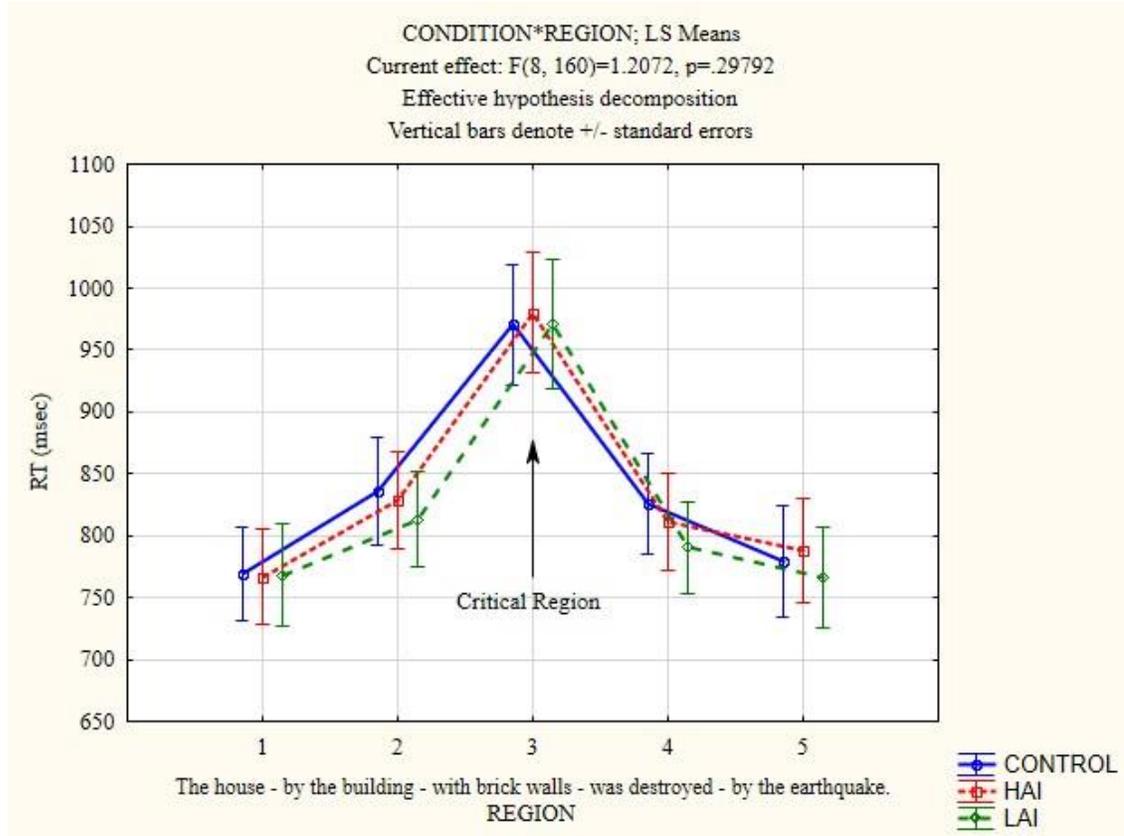
Figure 4.7. Mean Reaction Times (msec) as a Function of Region in the Sentence in Experiment 2B.

A repeated measures ANOVA was conducted on the RT data. Two within subject factors were considered: Condition (3 Levels: Control, HAI vs. LAI), and Region (5 Levels: the 5 regions observed in the graph above). Results indicate that there was a significant effect for Region; $F_{(4,80)}=23.280, p<0.001$. As in experiment 2A, reaction times increase in regions 2 and 3, which is explained by the fact that as PPs are added to the main NP, processing effort increases, which increases reaction times regardless of the

condition. This was observed by Thornton, McDonald and Gil (1999). No significant effects were found for Condition; *F(2,40)=2.502, p=0.094*; and for the Condition × Region interaction; *F(8,160)=1.207, p=0.297*.

4.2.2.2. ERP Results

After continuous EEG data were collected, 1000msec epochs were extracted. Each epoch started 200msec before the critical region (to allow for baseline correction), and ended 800msec after. An automated procedure to identify bad channels was performed. Any channel with a difference between minimum and maximum voltage of more than 200μ in a moving average of 80 msec was marked as bad. Channels marked bad in 20% of the data or more were mark as bad in all trials. Bad channels were replaced by using spherical spline interpolation. Finally, automatic eyeblink subtraction was performed; single trials were averaged across conditions (Control, HAI, LAI), and all data were referenced to average voltage by using the ERP PCA toolkit (Dien, 2010).

The same three types of statistical analysis carried out in experiment 2A were conducted on the data of the current experiment. The global analysis had 4 within-subject factors 1) Anteriority (anterior vs. posterior), 2) Laterality (left vs. right), 3) Time (200-400msec, 400-600msec vs. 600-800msec), and 4) Condition (depending on the specific comparison: Control vs. HAI or Control vs. LAI). No between-subject factors were used in this analysis. The Posterior Region analysis had the same factors except for anteriority. Finally, the Visual Inspection analysis had 5 time windows (200-300msec, 300-400msec, 400-500msec, 500-600msec vs. 600-700msec) and two conditions (Control vs HAI, Control vs LAI or HAU vs. LAI, depending on the comparison).

Control vs. HAI

Global Analysis: The figure below displays the difference topo plots HAI vs.
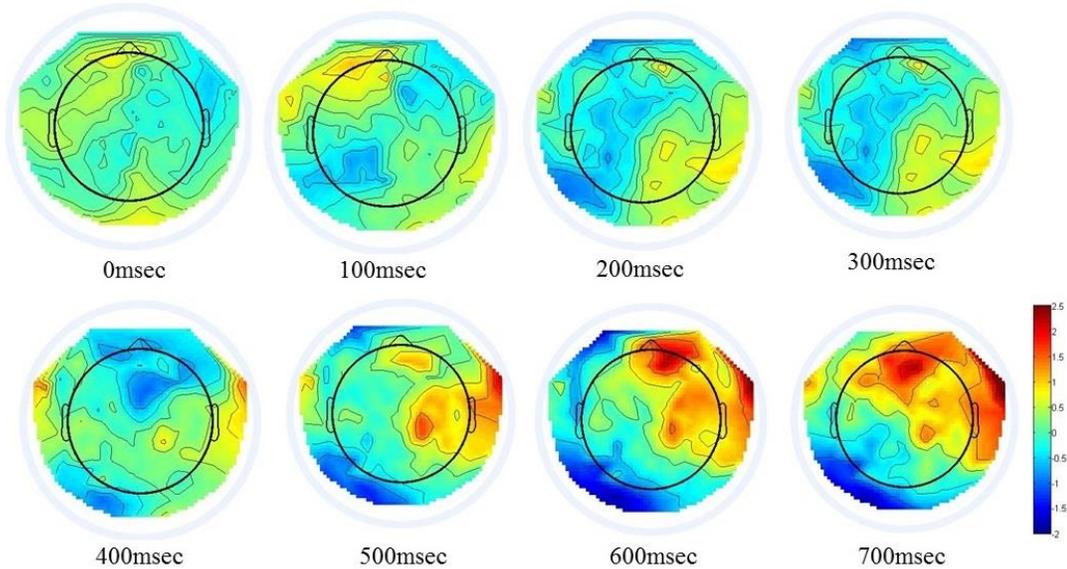
Control

Figure 4.8. Spanish HAI ERP Data. Difference Topo Plots: HAI vs. Control.

The repeated measures ANOVA carried out for the Global Analysis shows that no

main effect for Condition was observed; $F(1,20) = 0.120, p=0.731$. No relevant

interactions were significant.

Posterior Region Analysis: No significant effect for Condition was observed;

$F(1,20) = 1.030, p=0.322$. No relevant interactions reached significance. This analysis

probably did not capture the effect due to the fact that it was located in a peripheral area

of the right posterior region.

Visual Inspection: A specific area of the scalp selected by visual inspection was

identified in order to carry out a more in depth analysis. The figure below displays the

map of the selected electrodes, and the waveforms that demonstrate the differences between the two conditions.
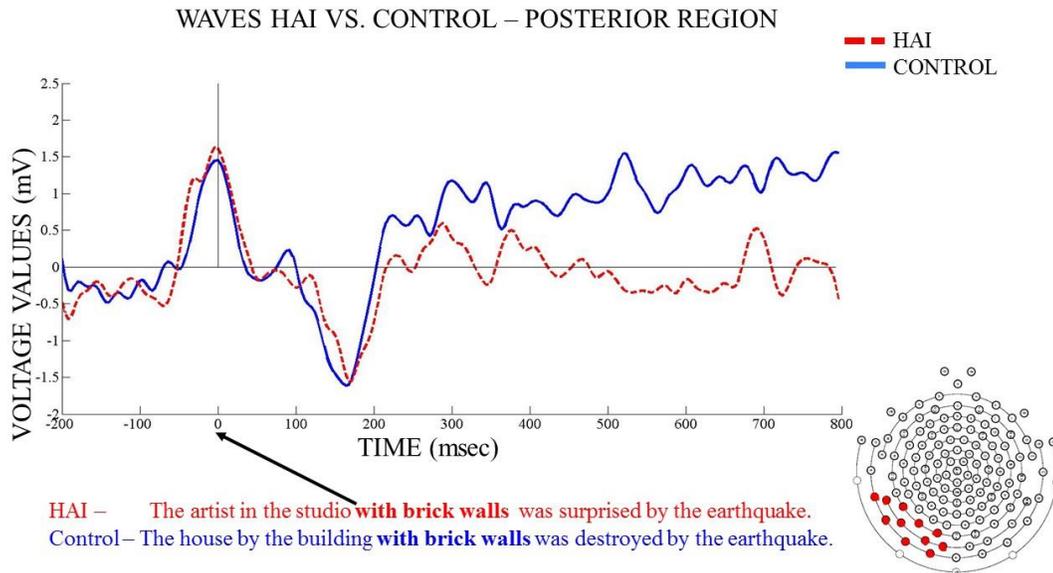
Figure 4.9. Spanish ERP HAI data. HAI vs. Control comparison in a selected area of the scalp. Waveforms of the Posterior Negativity effect (left) and spatial distribution (right).

HAI stimuli sentences triggered Posterior Negativity, which was localized in the left posterior area of the scalp. ANOVA results revealed that the main effect for the variable Condition (i.e. HAU vs. Control) was significant across the 5 time windows; $F(1,20)=6.003, p=0.023$. The interaction Time $\times$ Condition was also significant; $F(4,80)=3.939, p=0.005$. Orthogonal contrasts were performed at each time window, and the average voltage values in microvolts (mV) were calculated. The effect for CONDITION was significant at the following time windows: 200-300msec: *0.48mV,*

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t(20)=1.817, p<0.042; 300-400msec: *0.72mV, t(20)=1.995, p=0.030;* 400-500msec:

0.85mV, t(20)=2.234, p=0.019; 500-600msec: *1.38mV, t(20)=2.401, p=0.013;* 600-

700msec: *1.31mV, t(20)=2.757, p=0.006.*

LAI vs. Control

Global Analysis: The figure below displays the difference topo plots LAI vs.
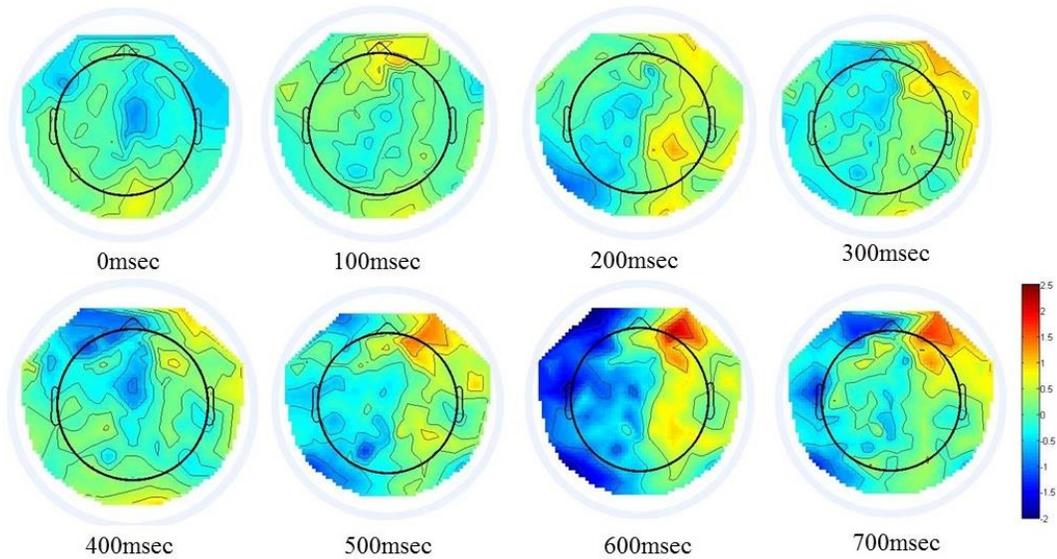
Control.

Figure 4.10. Spanish LAI ERP Data. Difference Topo Plots: LAI vs Control.

The repeated measures ANOVA carried out for the Global Analysis shows that no

main effect for Condition was observed; *F(1,20) = 0.914, p=0.350.* No relevant

interactions reached significance.

Posterior Region Analysis: No main effect for Condition was observed; *F(1,20) =*

1.408, p=0.249. No relevant interactions were significant. As in the HAI vs. Control

comparison, this analysis probably could not capture the effect due to the fact that it was located in a peripheral area of the right posterior region.

Visual Inspection: A specific area of the scalp selected by visual inspection was identified in order to carry out a more in depth analysis. The figure below displays the map of the selected electrodes, and the waveforms that demonstrate the differences between the two conditions.
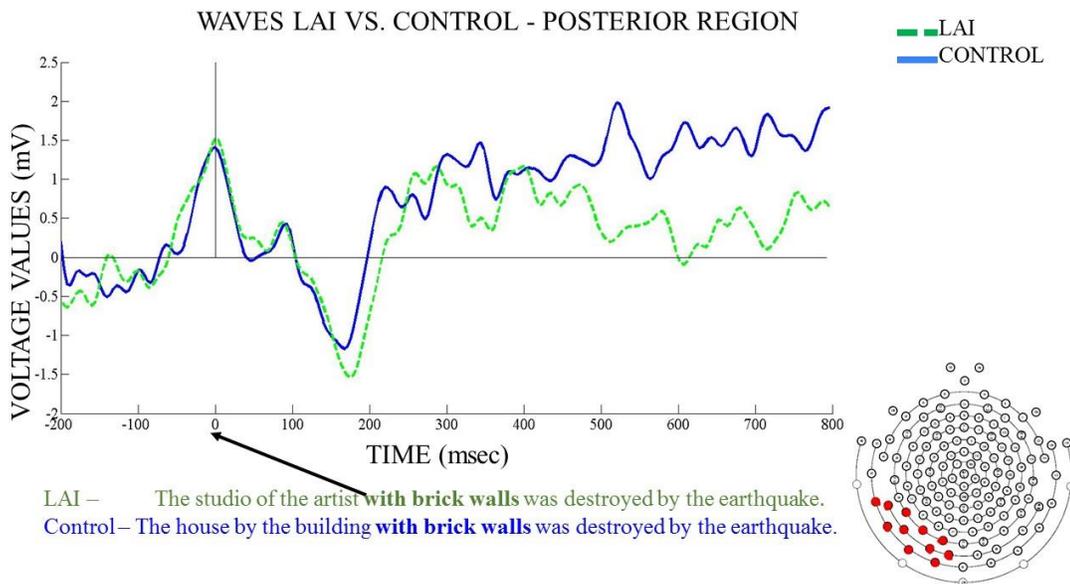
Figure 4.11. Spanish ERP LAI data. LAI vs. Control comparison in a selected area of the scalp. Waveforms of the Posterior Negativity effect (left) and spatial distribution (right).

LAI stimuli sentences triggered Posterior Negativity, which was localized in the right posterior area of the scalp. A repeated measures ANOVA shows that the main effect of Condition (i.e. LAI vs. Control) did not reach significance across the 5 time windows

from 200 to 700msec after the onset of the critical verb: *F(1,20)=2.587, p=0.123.* However, orthogonal contrasts performed at individual time windows demonstrate that the effect reached significance: 500-600msec: *1.06mV, t(20)=1.996, p=0.030;* 600-700msec: *1.22mV, t(20)=2.315, p=0.016.* Significance was not reached at the following time windows: 200-300msec: *0.20mV, t(20)=0.601, p=0.277;* 300-400msec: *0.41mV, t(20)=1.066, p=0.114;* 400-500msec: *0.36mV, t(20)=0.989, p=0.167.* The Time × Condition interaction reached significance; *F(4,80)=6.093, p<0.001.*

4.2.3. Discussion

ERP results in both conditions show Posterior Negativity, which appears at 200msec but is particularly prominent at between 500 to 700msec after the critical verb. This finding suggests that the parser attaches Spanish prepositional phrases (PPs) to both a high and a low node simultaneously. These findings are congruent with Construal (Frazier & Clifton, 1996) which states that adjuncts, such as PPs, initially receive an "underspecified" analysis, so they can associate to several different nodes. It is also convergent with the parsing principles proposed in the "Race-based Parallel Parsing Model" created by McRoy and Hirst (1990), which proposes that the parser attaches adjuncts to all possible nodes during an early stage of parsing, which generate competing meanings. These results are similar to those of the English PP experiment, previously described.

Behavioral results show no statistical significance across conditions. This is due to the fact that RTs are not as sensitive as ERPs to capture subjects' reaction to anomalous responses. This matches the findings of Thornton, McDonald and Gil (1999) who did not find an effect in Spanish prepositional phrases, using eye-tracking as their measurement.

The ERP results demonstrate that at an early stage of the parsing process (immediately after perceiving the word), the parser performs both high and low attachments in prepositional phrases in Spanish. The effect that occurs at this early stage seems to only be observed in ERPs, which means that the effect is not strong enough to be captured in behavioral measurements such as RTs and eye-tracking. This reinforces the relevance of ERPs in order to capture early stages of parsing.

4.3. Comparison of Prepositional Phrase Attachment across Languages

In this section, we will compare the data obtained in English and Spanish in the prepositional phrase attachment experiments. The data from both languages will be pooled in order to provide a grand average and calculate the statistical differences between languages.

4.3.1. RT Results

The table below displays the average RTs to the critical region in the pooled data.

Table 4.5. Mean Reaction Times (SD) in msec to the Critical Region as a Function of Condition in Experiment 2A.

	Condition		
	Control (SD)	HAI (SD)	LAI (SD)
Mean RT	969(220)	972(214)	961(228)
Example Sentence	*The house by the building* **with brick walls…**	*The artist in the studio* **with brick walls…**	*The studio of the artist* **with brick walls…**

The data above shows that RTs to the critical region were 3msec slower when compared against controls. This difference was not significant; *t(39)=0.309, p=0.759.* RTs in the LAU condition were 8msec faster than controls. Significance was not reached; *t(39)=0.908, p=0.369.*

The figure below displays the pool RT data of both English and Spanish speakers collapsed. The graph shows the average RTs across 5 regions in the sentence in 3 conditions. Region 3 corresponds to the critical prepositional phrase.
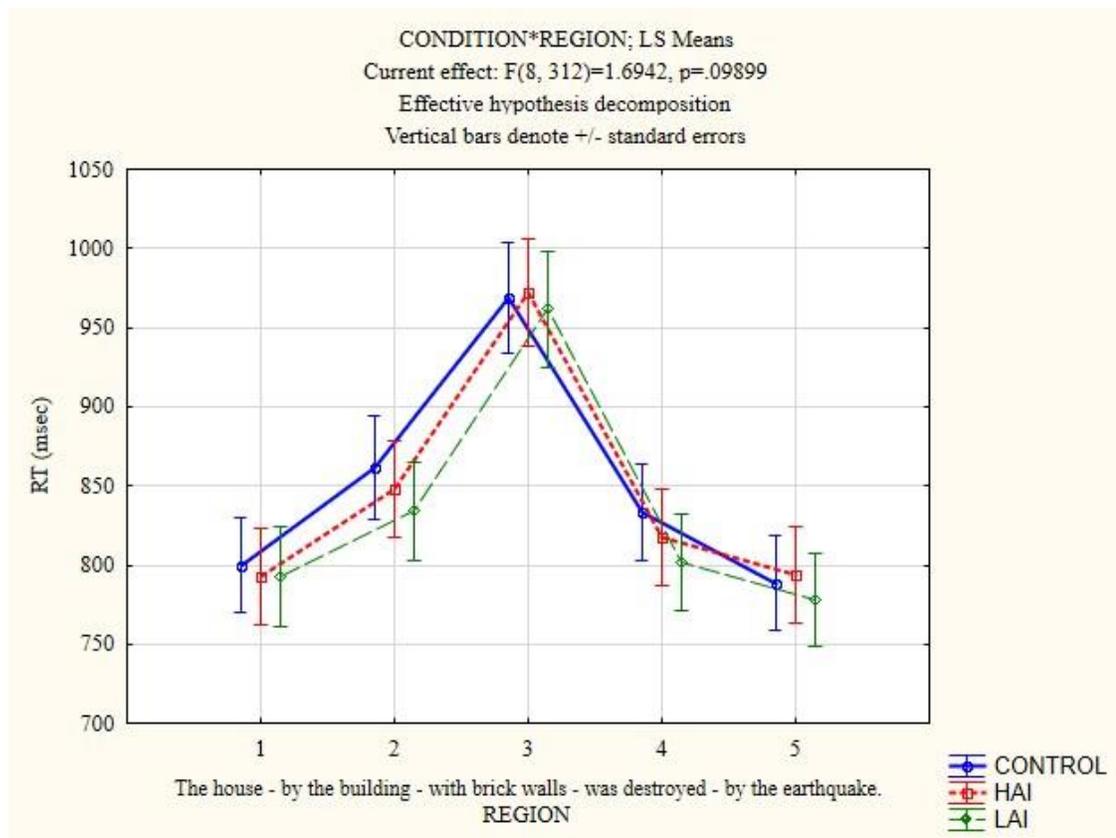
Figure 4.12. Pooled Data from English and Spanish: Mean Reaction Times (msec) as a Function of Region in the Sentence.

A repeated measures ANOVA showed no significant main effect for Language; *F(1,38)=0.034, p=0.853.* The interaction Language × Condition was also not significant. *F(2,76)=0.406, p=0.667.* A significant effect for Region was observed; *F(4,152)=49.595, p<0.001.* As in experiment 2A and 2B, reaction times increase in regions 2 and 3. This is explained by the fact that as PPs are added to the main NP, processing effort increases, which generates a delay in reaction times regardless of the condition. This was observed by Thornton, McDonald and Gil (1999). No significant effects were found for the Language × Region; *F(4,152)=1.708, p=0.150.*

4.3.2. ERP Results

The EEG data from both English and Spanish PP experiments was aggregated in order to compute a general average. The same three types of statistical analysis carried out in experiment 2A were conducted on general average. The between-subject factor language (English vs. Spanish) as added to the three analysis. The global analysis had 4 within-subject factors 1) anteriority (anterior vs. posterior), 2) laterality (left vs. right), 3) time (200-400msec, 400-600msec vs. 600-800msec), and 4) condition (depending on the specific comparison: Control vs. HAI or Control vs. LAI). No between-subject factors were used in this analysis. The Posterior Region analysis had the same factors except for anteriority. Finally, the Visual Inspection analysis had 5 time windows (200-300msec, 300-400msec, 400-500msec, 500-600msec vs. 600-700msec) and two conditions (Control vs HAI or Control vs LAI depending on the comparison).

The repeated measures ANOVA performed on the data had the same 5 within-subject factors used in the analysis of experiments 2A and 2B: 1) Anteriority (anterior vs. posterior), 2) Laterality (left vs. right), 3) Time (200-300msec, 300-400msec, 400-

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500msec, 500-600msec vs. 600-700msec), and 4) Condition (depending on the specific comparison: Control vs. HAI or Control vs. LAI). The factor Language (English vs. Spanish) was added as a between subject factor.

Control vs. HAI

<u>Global Analysis:</u> The following figure displays the difference topo plots HAI vs. Control from the pooled data (English and Spanish combined).
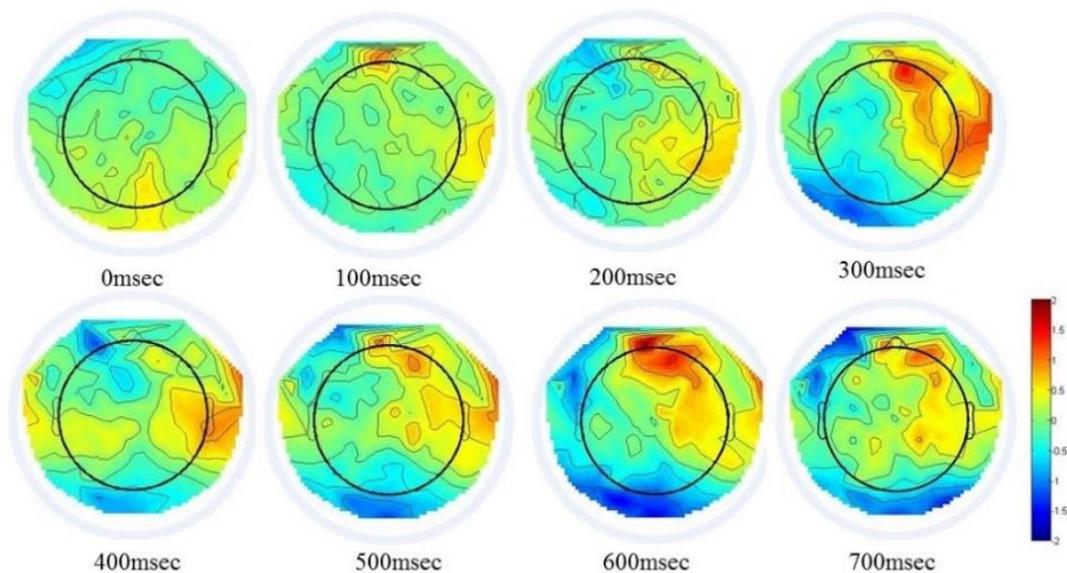
Figure 4.13. Pooled HAI ERP Data from both languages. Difference topo plots – HAI vs Control.

The ANOVA conducted for the Global Analysis shows no main effect for Language; $F(1,38) < 0.001, p=0.991$. Condition was not significant either; $F(1,38) = 0.012, p=0.910$. No relevant interaction reached significance.

Posterior Region Analysis: No significant main effect for Condition was observed; $F(1,38) = 1.163, p=0.287$. The interaction Condition × Language × Laterality reached significance; $F(1,38) = 3.853, p=0.056$, stemming from the presence of a posterior negativity effect that is more prominent on the right side of the scalp in Spanish and to the left side in English.

Visual Inspection: A specific area of the scalp selected by visual inspection was identified in order to carry out a more in depth analysis. The figure below displays the map of the selected electrodes, and the waveforms that demonstrate the differences between the two conditions.
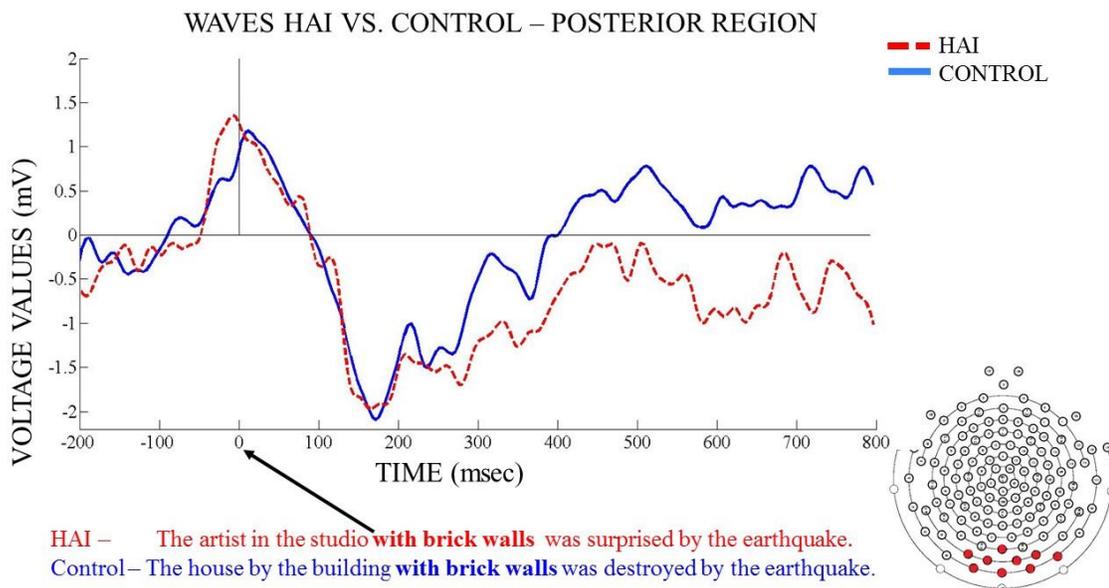
Figure 4.14. Pooled HAI ERP Data from both languages. HAI vs. Control comparison in a selected area of the scalp. Waveforms of the Posterior Negativity effect (left) and spatial distribution (right).

HAI stimuli sentences triggered Posterior Negativity, which was localized in a peripheral region of the posterior area of the scalp. The ANOVA revealed that the main effect for the variable Condition (i.e. HAI vs. Control) was significant across the 5 time windows; *F(1,38)=7.485, p=0.009*. There was no significant main effect for the variable Language (i.e. English vs. Spanish): *F(1,38)=0.016, p=0.899*. The interaction Condition × Language*: F(1,38)=0.26, p=0.609.* Orthogonal contrasts were performed at each time window, and the average voltage values in microvolts (mV) were calculated. The effect for Condition was significant at the following time windows: 200-300msec: *0.30mV, t(39)=1.305, p=0.100;* 300-400msec: *0.71mV, t(39)=2.327, p=0.013;* 400-500msec: *0.72mV, t(39)=2.543, p=0.008;* 500-600msec: *0.95mV, t(39)=2.529, p=0.008;* 600-700msec: *1.06mV, t(39)=2.750, p=0.005.*

LAI vs. Control

<u>Global Analysis:</u> The following figure displays the difference topo plots LAI vs. Control from the pooled data (English and Spanish combined).
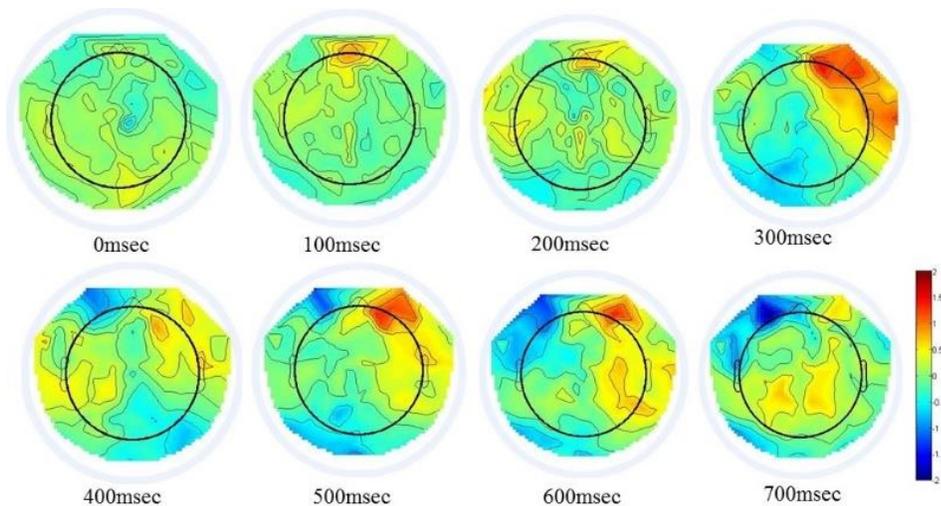

Figure 4.15. Pooled LAI ERP Data from both languages. Difference topo plots – LAI vs Control.

The repeated measures ANOVA conducted shows no effect for Condition; *F(1,38) = 0.232, p=0.632.* The interaction Condition × Language × Laterality approached significance. *F(1,38) = 4.059, p=0.051,* stemming from posterior negativity effects that were found on the left side of the scalp in Spanish, and on the right side in English.

Posterior Region Analysis: The main effect for Condition did not reach significance; *F(1,38) = 0.612, p=0.438.* The interaction Condition × Language × Laterality was significant; *F(1,38) = 4.941, p=0.032.* This interaction was due to the fact that the effect is found on the left side of the scalp in Spanish and on the right side in English.

Visual Inspection: The LAI condition triggered a Posterior Negativity effect in the left side of the scalp in Spanish. This effect was observed in English on the right side of the scalp. As observed in the topo plots in the previous figure, the opposite localization of the effects across languages caused the effect to be washed out when the data was aggregated, for that reason, it was not possible to determine a specific region of the scalp in which a strong effect could be observed in both languages. The following figure shows a side by side comparison of the effects on English and Spanish.
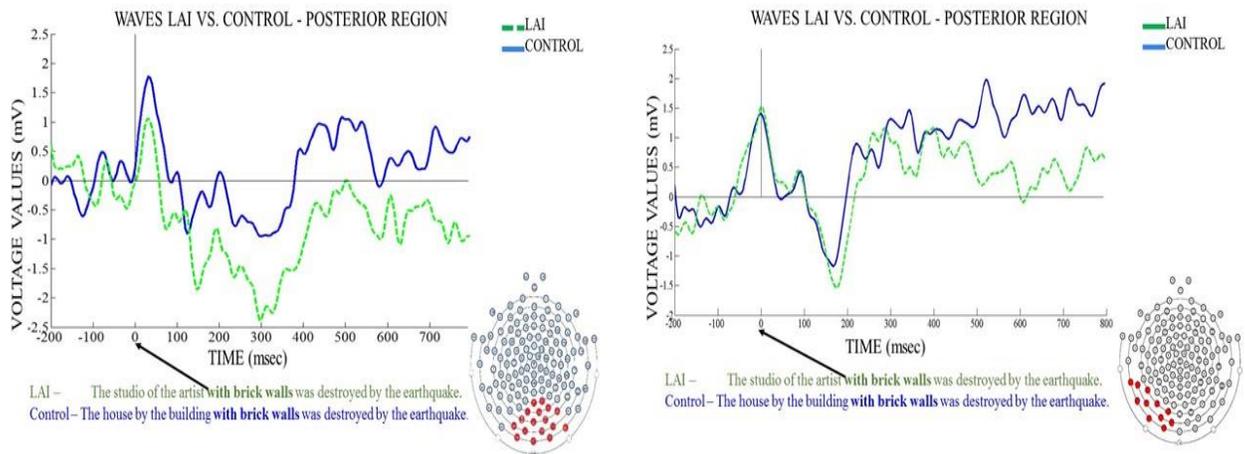
Figure 4.16. Comparison of the LAI ERP Data from both languages. English Waveforms LAI vs. Control (left); Spanish Waveforms LAI vs. Control (right).

As observed in the figure above, posterior negativity effects are observed in both languages, but in different regions. For an in depth analysis of such effects, please refer to sections 4.1.2.2. and 4.2.2.2.

4.3.3. Discussion

RT results show no significant effects across conditions, which was expected since the same was observed in both PP experiments. No significant effects for language suggest that both English and Spanish speakers are able to read phrases at the same pace.

EEG results show a Posterior Negativity effect in the comparison between HAI and Control. Both of the English and Spanish PP experiments show a Posterior Negativity effect in the comparison of LAI against Control, but these effects disappeared when the data was pooled. This was probably due to the fact that the effect was not located in the exact same region of the scalp in both languages, which is supported by the

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fact that the interaction Condition × Laterality × Language was significant. However, note that the individual experiments confirm the sensitivity of the speakers to both high and low semantic implausibility triggered by prepositional phrases; the only difference is the specific part of the scalp in which the effect is observed. Note that no clear reason exists to justify the fact that English and Spanish subjects showed significant effects in different areas of the scalp. It is possible that the differences in the topography of the effect are due to individual subject variability.

Finding significant effects in both HAI and LAI conditions and no main effects for the variable Language, or significant Condition × Language interactions, suggests that both English and Spanish perform both high and low attachments, and due to this, they are sensitive to semantic implausibility in both kinds of attachments.

These results hint at the idea that the parsing of ambiguous prepositional phrases occurs as in the figure below, in which the PP is attached to two simultaneous sites.
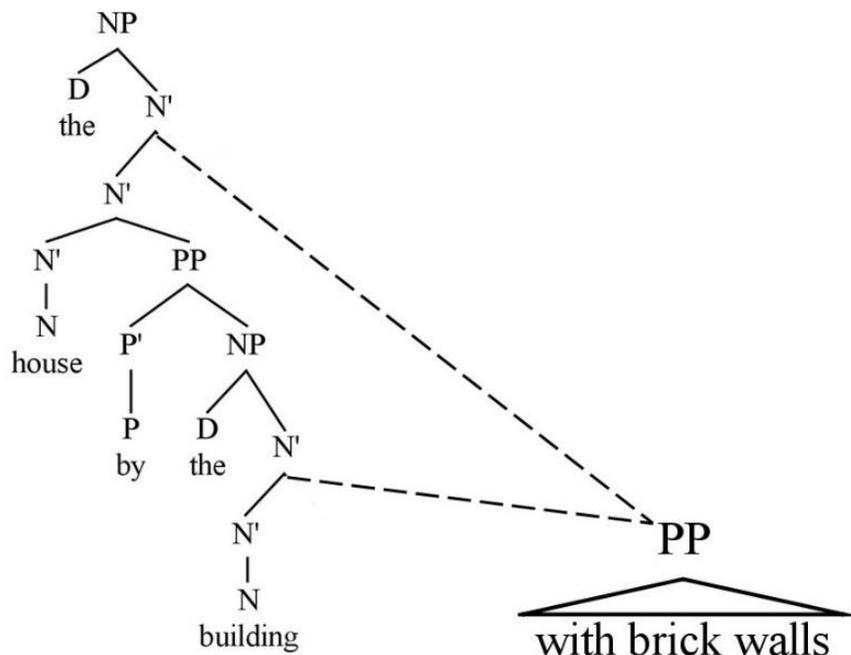
Figure 4.17. Tree Diagram Showing the Simultaneous Attachment of PPs.

To summarize, PPs attachment in both English and Spanish seems to occur in a similar way to RC attachment. This is predicted by the theory since both RCs and PPs that attach to NPs (Adjunct PPs) are both adjuncts, and, therefore, do not receive the immediately specified analysis that arguments receive according to Construal theory (Frazier & Clifton, 1996).

Chapter 5

CONCLUSIONS

This chapter will be divided into 4 sections. In the first section, the experiments from chapters 3 and 4 will be summarized. In the second section, the models described in chapter 2 and the predictions they made will be revisited. In the third section, a general model of parsing for ambiguous attachments will be presented. Lastly, the final section will discuss the limitations of this study and ideas for future research that emerged from the current study.

5.1. Summary of the Experiments

In experiment 1A, English native speakers were exposed to ungrammaticality triggered by the attachment of an RC to either a high or a low node in a sentence (e.g. *'the maid of the brides who was…'*). RT results displayed a significant delay at the critical verb in the LAU (Low Attachment Ungrammatical) condition when compared to controls, and no significant effect was found in the HAU (High Attachment Ungrammatical) condition at the critical verb compared to controls. These findings replicate Fernandez (2002). However, a significant spill-over effect i.e. an increase in reaction times to the word that immediately followed the critical verb) was found in both the high and low conditions, indicating that speakers' RTs slow down by ungrammaticality in both high and low attachment sites. This indicates that ungrammaticality is perceived in both attachment sites,

but it is not clear why RT delays are not observed at the critical verb in the high attachment condition and why it only appears in subsequent words.

The ERP results from experiment 1A revealed that both HAU and LAU conditions triggered a Posterior Negativity effect similar in distribution and polarity to an N400. These results support the idea that native speakers of English attach RCs to both high and low sites simultaneously during an initial stage, which is why they are sensitive to ungrammaticality in both sites.

In experiment 1B, which was a replication of experiment 1A with Spanish stimuli, native Spanish speakers were exposed to sentences with relative clauses that could trigger ungrammaticality if a specific kind of attachment (i.e. high or low) is performed (e.g. *'the maid of the brides who was…'*). No significant RT effects were observed in any condition. However, ERP results show a significant Posterior Negativity effect in both HAU and LAU conditions. This finding is similar to what was observed with native speakers of English in experiment 1. Since both conditions triggered a significant response, it can be concluded that native speakers of Spanish are sensitive to ungrammaticality triggered by RCs attached to both high and low nodes, which implies that both attachments are performed simultaneously at early stages of the parsing process.

Note that in both experiments, 1A and 1B, an N400-like effect (i.e. Posterior Negativity) was observed instead of a LAN, which is usually associated with morpho-syntactic violations. However, previous studies testing morpho-syntactic agreement violations related to subject-verb agreement (e.g. *"the brides was…"*) have also reported N400-like effects instead of a LAN (Tanner & Van Hell, 2014). This suggests that ERP effects in the posterior area of the scalp (i.e. N400-like) can indicate that the parser

perceived ungrammaticality, as in the specific attachments that were used in this study (e.g. LOW: *"the maid of the brides that was…"*).

In experiment 2A, native speakers of English were exposed to sentences with prepositional phrases that could trigger semantic incongruity if attached to a particular node (i.e. either high or low) (e.g. *'the dress of the singer with a great voice…'*). RT results did not show statistically significant results in any condition. This might be due to the fact that the small number of subjects that participated in this experiment might not have provided sufficient statistical power to achieve significant results. However, ERP results reveal that a Posterior Negativity effect was observed in both HAI (high attachment implausible) and LAI (low attachment implausible) conditions. This implies that speakers are sensitive to semantic implausibility in both low and high attachments, which means that both high and low attachments are performed at early stages of the process. These findings are similar to the ones observed with RCs in experiment 1.

In experiment 2B, which is the Spanish equivalent of experiment 2A, native speakers of Spanish were exposed to sentences with PPs capable of triggering semantic implausibility if attached to either a high or a low node (e.g. *'the dress of the singer with a great voice…'*). RT results showed no statistically significant effect among conditions. Nevertheless, ERP results display a significant Posterior Negativity effect in both HAI (High Attachment Implausible) and LAI (Low Attachment Implausible) conditions. This means that native speakers of Spanish attach prepositional phrases to both high and low sites, which explains their sensitivity to the implausibility triggered by both types of attachments. A similar pattern was observed in the ERP results from experiment 2, in which native speakers of English were exposed to the same types of stimuli.

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5.1.1. General Summary

Our contribution to knowledge was twofold. On the one hand, it was demonstrated that the parser in both English and Spanish shows sensitivity to ungrammaticality and semantic implausibility triggered by both high and low attachments, which means that no attachment site is preferred over the other in early stages of the parsing process and that parallel parsing occurs in this type of structures. On the other hand, since very similar responses to stimuli were observed in both languages, we can conclude that the early stages of parsing are alike in Spanish and English.

Additionally, we observed similar responses in the experiments with relative clauses, which examined morpho-syntactic disagreement, and the experiments with prepositional phrases, which evaluated semantic implausibility. This implies that the parallel parsing process is applied to both types of structures, which indicated that parallel parsing can be measured by both morpho-syntactic and semantic processing. Observing effects in both PPs and RCs is predicted by the theory because both structures are types of adjunct phrases that, according to Frazier and Clifton (1996), would not behave as complements, which attach directly to a preferred node.

5.2. Revisiting the Models of Attachment Processing

In this section, the models of attachment processing will be evaluated by using the results obtained in the experiments to provide evidence to support them or refute them. A more specific description of the models can be found in chapter 2, and their predictions for each experiment appear in chapters 3 and 4.

The Single Analysis model, based on the findings by Cuetos and Mitchel (1988), proposed a single attachment to a predetermined node that was different according to the

language. This model predicted that English speakers would attach RCs and PPs only to a low node, and Spanish speakers will do so to a high node. These predictions did not match the outcome of the experiments in the current research. As it was observed, both English and Spanish speakers attach both high and low. Therefore, the asymmetry posited by this model was not observed.

The Late Reanalysis model was based on Fernandez (2002). This model stated that English and Spanish speakers would both initially attach adjunct phrases to low nodes only. During a later post-syntactic stage, Spanish speakers would reanalyze and change their preference to a high attachment. The results of our experiments do not support this model because we could observe that both English and Spanish speakers attach adjunct phrases to both high and low nodes. This implies that the initial preference for low nodes that was predicted by the model does not exit. Also, our results support the idea that no reanalysis takes place at any stage of the process, but instead, speakers select one of the attachments they already performed over the other without the need for reanalysis.

The Early Reanalysis proposed that speakers of both languages would attach adjunct phrases to low nodes only, but shortly after, Spanish speakers would reanalyze, and change their preference to a high node, which would be observed as a P600 effect, usually associated with reanalysis, in the ERP data. The outcomes of our experiments does not support this model. First of all, speakers of both English and Spanish were sensitive to semantic implausibility and ungrammaticality in both high and low attachment sites, which means that both attachments are performed. Secondly, no P600 effect was observed in any condition.

Finally, the Parallel Parsing model , based on Construal (Clifton & Frazier, 1996), and the Race-based Parallel Parsing Model (McRoy & Hirst, 1990), predicted that speakers would simultaneously attach to both nodes regardless of the language, and that the possible asymmetries in off-line measurements between languages was due to post-syntactic parsing strategies that apply at a very late stage of parsing. The outcomes we observed in our experiments match the predictions of this model. Our results show significant effects in both conditions in both languages, which implies that at the early stages of the parsing process, parallel parsing occurs regardless of the language.

5.3. Towards a Parallel Parsing Model of Adjunct Attachment Processing

The Parallel Parsing model turned out to be correct in its predictions of the outcomes for our experiments. Therefore, we will use it to explain how the parsing of RCs and PPs occurs. McRoy and Hirst (1990) suggested that adjuncts attach to all possible available nodes during an early stage of parsing, which generate competing meanings. This competition is resolved at a post-syntactic processing stage, which involves prosody and pragmatics. A very similar account was described by Clifton and Frazier (1996), who claimed that adjuncts received an "underspecified analysis" (i.e. adjuncts did not attach immediately to a predetermined node), but rather associated to all possible nodes available, and at a later stage one node was chosen over the other. This time course of the attachment process is summarized in the graph below.
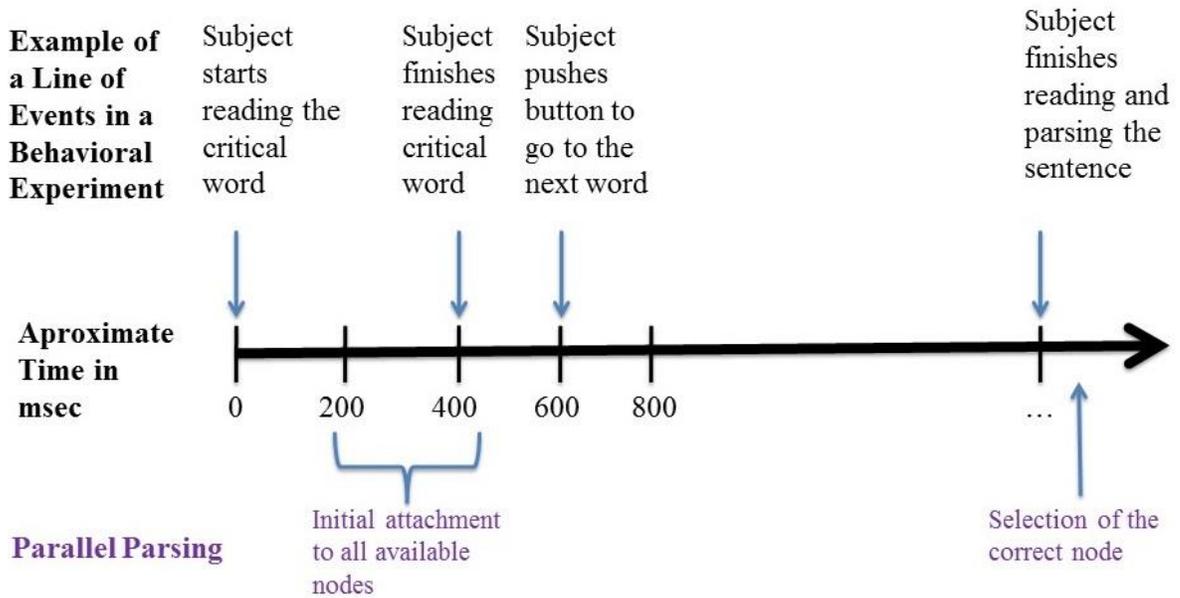
Figure 5.1. Detailed time course of the parallel parsing attachment process

This model of parsing implies that adjunct phrases undergo several simultaneous attachments when the structure is built by the parser. This can be observed in the tree diagrams below.
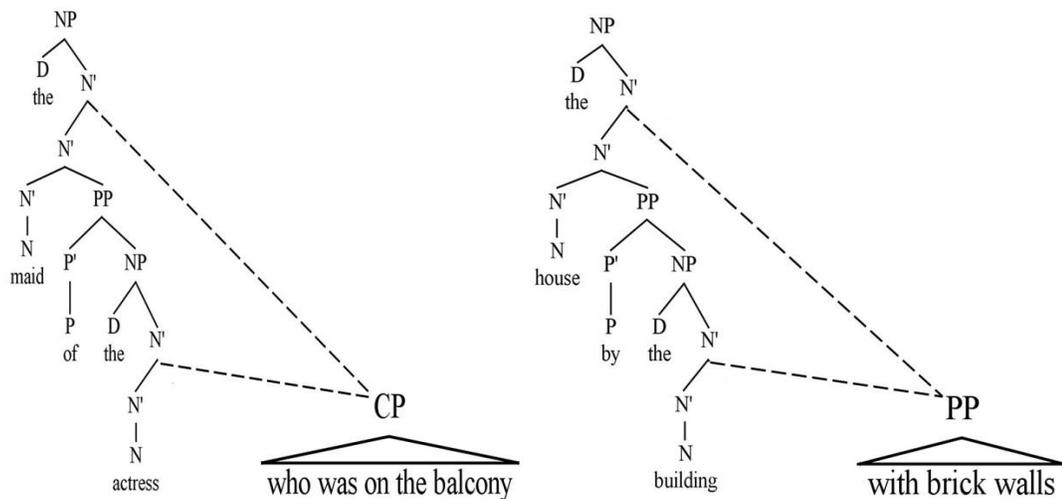
Figure 5.2. Trees depicting parallel parsing in adjuncts.

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The tree diagrams above show how adjuncts are attached to both high and low nodes. As previously stated, these attachments are not permanent, as suggested by the dotted lines. One attachment must be selected over the other. This selection process occurs at a late stage that our ERP experiments were not designed to capture. At this late stage, the parser incorporates additional language specific cues (e.g. prosody) or contextual cues (e.g. pragmatics) into the syntactic and semantic readings of the structure.

Sentences in the tree diagrams above are fully ambiguous. However, in some sentences, one of the possible attachments for an RC or a PP can trigger ungrammaticality (e.g. *'the maid of the brides who was'*) or semantic implausibility (e.g. *'the studio of an artist with brick walls'*). Since both attachments are computer at an early stage of parsing, the parser notices ungrammaticality or semantic incongruity in one of the attachments, which is why we observed ERP responses in our experiments. Then, at a late post-syntactic stage in which pragmatics and prosody are computed, the parser selects the correct attachment, and cuts the other. We will call this phenomenon "Pruning", and it is exemplified in the tree diagrams below.
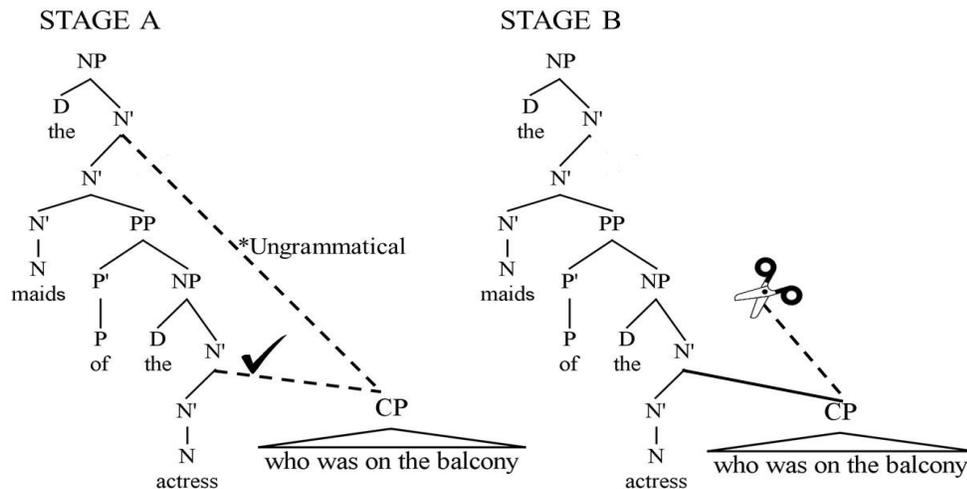
Figure 5.3. Parallel parsing stages.

The tree diagram on the left displays the initial stage in which both high and low attachments are processed. The parser notices that the ungrammaticality of the structure *'the maids who was'*. At stage B, the parser selects the low attachment which generates a grammatical structure (*'the bride who was'*) and prunes the ungrammatical attachment.

Note that Pruning is not observed in the ERP data. This is due to the fact that pruning is not an instance of reanalysis (i.e. when the parser has to destroy a previous incorrect structure, and build a new one again), which would trigger an N400. Pruning, as described here, is merely a selection process, in which the parser chooses one of the possible attachments. The evidence for Pruning lies in the responses from questionnaire studies (e.g. Cuetos & Mitchell, 1988), which indicate that speakers actually prefer one attachment over the other when they are asked to make a decision about it.

5.4. How this Study Fits in the Current Scientific Context

In this section, the findings of the current research will be analyzed in light of previous theories and experimental studies that were discussed in the introduction. Specifically, this section will present a brief discussion about parsing theories, the Pseudo-Relatives, previous ERP studies, and prosodic disambiguation.

5.4.1. Parsing Theories

As discussed in the introduction, two main types of parsing theories exist: serial models and parallel parsing models. Serial models indicate that the parser performs a series of steps in order to build the structure for a sentence. Initially, an analysis is performed based on parsing heuristics (e.g. Late Closure or Minimal Attachment); if the parser realizes that the structure that is being built is ungrammatical, the parser must reanalyze. These models suggested that speakers would prefer one type of attachment

(i.e. high or low) over the other, and they would have to reanalyze if ungrammaticality or semantic implausibility was perceived. In contrast, parallel parsing models state that the parser can perform several simultaneous attachments. These models suggest that speakers would attach to both high and low nodes.

As previously mentioned, the current study showed that native speakers of both English and Spanish are sensitive to the ungrammaticality and semantic implausibility triggered by both high and low attachments. These results support parallel parsing models. Additionally, because this study examined the parsing of adjuncts (i.e. RCs and PPs), it can be concluded that the findings matched the claims made by Frazier and Clifton (1996), who said that parallel parsing applied to adjuncts since they are not considered primary relations.

5.4.2.   Pseudo-Relatives

Grillo (2012) claimed that the asymmetries found between English and Spanish attachment height preferences as evidenced by questionnaires (i.e. low for English and high in Spanish) was due to the presence of a Pseudo-Relative structure, which is applied to all RCs in Spanish and is ungrammatical in English. According to this theory, Spanish speakers were supposed to only attach high due to the existence of such structural principle. The findings of the current research contradict this theory. Spanish speakers attached RCs to both high and low nodes, as English speakers did, regardless of the fact that Pseudo-Relatives exist in Spanish and not in English. Moreover, both English and Spanish speakers attached to both high and low nodes in PPs, which are not subject to the Pseudo-Relative construction. This fact serves to confirm that parallel parsing applies

equally to different kinds of adjuncts, and not just to RCs, which corroborates that the existence of a Pseudo-Relative structure does not affect the parsing of RCs.

5.4.3.   Previous ERP Studies

Hopf, Baden, Meng & Mayer (2003) conducted a study, in which they examined how the parser reacted to objects with ambiguous case morphology in German. They observed that objects with ambiguous case morphology were initially analyzed as if they had the incorrect case (i.e. the verb required a different case for the object), as evidenced by an N400-like response, which quickly disappeared, after the parser reanalyzed. Hopf et al. (2003) concluded that these findings matched the predictions made by the Garden Path theory, which stated that parsing was a two state process (i.e. analysis and reanalysis).

The current study did not have the same results as those observed by Hopf, Baden, Meng and Mayer (2003). Note that their research explored primary relations (i.e. the relationship between a verb and its object), as opposed to the non-primary relations (i.e. adjuncts) examined in the current study. Simultaneous attachment to multiple sites was observed in the current research, as evidenced by a posterior negativity effect in all conditions. These findings support parallel parsing in adjuncts; however, they do not contradict Hopf et al. (2003). Frazier and Clifton (1996) argued that primary and non-primary relations were treated differently by the parser; parsing heuristics are applied to primary relations while parallel parsing is applied to non-primary relations. Consequently, both studies support the Construal theory by Clifton and Frazier (1996). While primary relations (i.e. verbs and objects) undergo serial parsing as in Hopf et al. (2003), non-primary relations undergo parallel parsing as in the current study.

Carreiras, Salillas and Barber (2005) conducted an ERP experiment with ambiguous relative clauses with grammatical gender mismatch (i.e. the grammatical gender of an adjective inside an RC matched the noun in either the high or the low nodes, but not in both). They observed a P600 to the high condition when compared against the low condition. The findings of this study were not replicated by the current research. First of all, Carreiras, Salillas and Barber (2005) did not use a fully ambiguous control condition to compare the voltage values of the high and low conditions separately, and only compared high against low, which made it impossible to observe whether subjects were sensitive to the low condition in that experiment. Additionally, note that Carreiras, Salillas and Barber (2005) used gender mismatch instead of subject-verb agreement. While both violations are closely related (i.e. they are morpho-syntactic violations). Previous research demonstrates that subject-verb agreement can trigger different ERP responses from those generated by other types of morpho-syntactic violations (Tanner & Van Hell, 2014). This can account for the differences in the ERP responses observed.

5.4.4. Prosodic Disambiguation

Previous studies have observed that prosody can be used as a disambiguating mechanism during the parsing of ambiguous structures (Carlson, Clifton & Frazier, 2001, Speer & Blodgett, 2006; Briscoe & Buttery, 2007). The current study used visual stimuli in order to prevent speakers from using prosodic cues to parse the sentences used as a stimuli.

The results of the current research show that speakers from both English and Spanish attach ambiguous RCs and PPs to both high and low nodes during the early stages of the parsing process (i.e. as evidenced by ERPs). However, it does provide

evidence about which mechanism is used by the parser to select the final attachment. It has been stated in this chapter, and throughout the discussion of the experiments, that this selection process incorporates post-syntactic processes, which include prosody. The idea that post-syntactic elements come into play at late stages of the parsing process was mentioned by McRoy and Hirst (1990), and reprised by Fernandez (2002). The current study was not designed to observe the late stages of the parsing process, or to observe the impact of prosody in attachment height preferences. Therefore, it must be acknowledged that the findings of the current study do not provide sufficient information to generate conclusions about prosodic disambiguation.

5.4.5.   Summary

To summarize, the biggest contribution of the current study was the observation of the simultaneous attachment of RCs and PPs to two nodes (i.e. high and low) in both English and Spanish. These findings can be used as evidence to support parallel parsing in adjuncts, which was posited by McRoy and Hirst (1990) and the Construal theory by Clifton and Frazier (1996).

The current study presents evidence against the Pseudo-Relative construction theory. Since speakers attach both high and low, it can be inferred that the existence of a Pseudo-Relative construction in Spanish does not affect the parsing process.

The current research does not contradict previous ERP findings directly. Hopf, Baden, Meng and Mayer (2003) examined primary relations, and Carreiras, Salillas and Barber worked with gender mismatch, which this study did not address. Note that both Hopf et al. (2003) and the current study support Clifton and Frazier's (1996) Construal

theory; primary relations are subject to serial parsing, as in Hopf et al. (2003), and adjuncts are subject to parallel parsing, as in the current research.

5.5. Limitations and Future Directions for Future Study

The current study tested Reaction Times and ERPs simultaneously. While both of the measurements were successfully gathered, in future experiments, it would be ideal to take only one kind of measurement at a time. Having different RTs in every subject basically means that each of them saw the words at a different rate, and that the periods between the presentation of one word and the next were different across subjects (e.g. subject A saw the words at a rate of approximately 500msec per word, and subject B did so at 600msec). This could have increased the variation of the voltage values in the ERP reports (e.g. because 500msec after the starting point of the word, subject A is already seeing another word, and subject B is not). Combining behavioral and ERP measurements in the same experiment does not compromise the reliability of the data (Dimigen, Sommer, Hohlfeld, Jacobs, & Kliegl, 2011). Also, several previous studies have used this type of combination (e.g. Van der Meij, Cuetos, Carreiras & Barber, 2010). However, it would be ideal to use fixed presentation in order to ensure that the stimuli are presented at the same rate across subjects. However, note that the possible variation that the combined use of ERPs and RTs could have created in the ERP data did not interfere with the finding of significant effects across conditions.

The current research reports on the speakers' brain responses to ambiguous attachments in English and Spanish only. We selected this pair because several experiments have previously been conducted to examine asymmetries in attachment preferences between the two languages. However, English and Spanish are closely

related; both of them come from Indo-European roots and have an SVO syntactic frame.

Asymmetries in the parsing of relative clauses and/or prepositional phrases (i.e. as attested by off-line measurements) have been claimed in languages with different typological backgrounds: high attachment is preferred in Dutch (Brysbaert & Mitchell, 1996), French (Zagar, Pynte & Rativeau, 1997), Japanese (Kamide & Mitchell, 1999), and Greek (Papadopoulou & Clahsen, 2003), and low attachments are favored in Arabic (Abdelghany & Fodor, 1999), Swedish, Norwegian and Romanian (Ehrlich, Fernandez, Fodor, Stenshoel & Vinereanu, 1999). With this in mind, ERP experiments could be carried out with speakers of languages pairs with different historical and typological backgrounds. Based on the results of the current research, we predict that parallel parsing would be observed regardless of the language.

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Appendix A

STIMULI FOR EXPERIMENT 1A

The following sentences were used as stimuli for experiment 1A. They are discriminated by condition. All sentences were taken from Fernandez (2002).

HIGH ATTACHMENT UNGRAMMATICAL (HAU)

1. Andrew had dinner yesterday with the nephews of the teacher that was in the communist party.

2. The journalist interviewed the coaches of the gymnast that was signing autographs during the competition.

3. The personnel manager was observing the secretaries of the accountant that was hired temporarily.

4. Julia had spoken with the secretaries of the lawyer that was telephoning the office all morning.

5. My friend met the aides of the detective that was investigating the assassination case.

6. Charlie met the interpreters of the ambassador that was hosting the party last night.

7. Roxanne read the reviews of the poem that was unfinished.

8. The plumber adjusted the pipes of the sink that was improperly installed since last week.

9. Mary replaced the wires of the amplifier that was not working since we moved last summer.

10. My brother liked listening to the recordings of the song that was on the first side of the album.

11. The chef could not find the lids of the pan that was on the cupboard of the left.

12. The thief took the keys of the trunk that was in the closet in the hall.

13. The journalist was unable to interview the daughter of the hostages that were about to exit the airplane.

14. Patricia saw the teacher of the students that were in the library the other day.

15. Linda wrote to the manager of the assistants that were evaluating her study.

16. The hotel director didn't want to see the guide of the tourists that were waiting at the reception desk.

17. The receptionist greeted the client of the lawyers that were waiting in the conference room.

18. Nobody noticed the bodyguard of the ambassadors that were talking to the photographer at the party.

19. Ivana met the son of the delegates that were watching television in the den.

20. Lisa could not find the refill of the pens that were in the lower desk drawer.

21. The student read the revision of the manuscripts that were on the list of readings required for the class.

22. The archaeologists finally found the panel of the sarcophagi that were described in the poem.

23. Harry had inspected the printer of the computers that were on top of the desk.

24. Susan admired the hallways of the apartment that were on the upper floor of the building.

LOW ATTACHMENT UNGRAMMATICAL (LAU)

1. Andrew had dinner yesterday with the nephew of the teachers that was in the communist party.

2. The journalist interviewed the coach of the gymnasts that was signing autographs during the competition.

3. The personnel manager was observing the secretary of the accountants that was hired temporarily.

4. Julia had spoken with the secretary of the lawyers that was telephoning the office all morning.

5. My friend met the aide of the detectives that was investigating the assassination case.

6. Charlie met the interpreter of the ambassadors that was hosting the party last night.

7. Roxanne read the review of the poems that was unfinished.

8. The plumber adjusted the pipe of the sinks that was improperly installed since last week.

9. Mary replaced the wire of the amplifiers that was not working since we moved last summer.

10. My brother liked listening to the recording of the songs that was on the first side of the album.

11. The chef could not find the lid of the pans that was on the cupboard of the left.

12. The thief took the key of the trunks that was in the closet in the hall.

13. The journalist was unable to interview the daughters of the hostage that were about to exit the airplane.

14. Patricia saw the teachers of the student that were in the library the other day.

15. Linda wrote to the managers of the assistant that were evaluating her study.

16. The hotel director didn't want to see the guides of the tourist that were waiting at the reception desk.

17. The receptionist greeted the clients of the lawyer that were waiting in the conference room.

18. Nobody noticed the bodyguards of the ambassador that were talking to the photographer at the party.

19. Ivana met the sons of the delegate that were watching television in the den.

20. Lisa could not find the refills of the pen that were in the lower desk drawer.

21. The student read the revisions of the manuscript that were on the list of readings required for the class.

22. The archaeologists finally found the panels of the sarcophagus that were described in the poem.

23. Harry had inspected the printers of the computer that were on top of the desk.

24. Susan admired the hallway of the apartments that were on the upper floor of the building.

CONTROL

Note: these sentences will be used as control conditions for both HAU and LAU sentences. For instance, sentence 1 of the control list corresponds to both sentence 1 in the LAU list and sentence 1 in the HAU list.

1. Andrew had dinner yesterday with the nephew of the teacher that was in the communist party.

2. The journalist interviewed the coach of the gymnast that was signing autographs during the competition.

3. The personnel manager was observing the secretary of the accountant that was hired temporarily.

4. Julia had spoken with the secretary of the lawyer that was telephoning the office all morning.

5. My friend met the aide of the detective that was investigating the assassination case.

6. Charlie met the interpreter of the ambassador that was hosting the party last night.

7. Roxanne read the review of the poem that was unfinished.

8. The plumber adjusted the pipe of the sink that was improperly installed since last week.

9. Mary replaced the wire of the amplifier that was not working since we moved last summer.

10. My brother liked listening to the recording of the song that was on the first side of the album.

11. The chef could not find the lid of the pan that was on the cupboard of the left.

12. The thief took the key of the trunk that was in the closet in the hall.

13. The journalist was unable to interview the daughters of the hostages that were about to exit the airplane.

14. Patricia saw the teachers of the students that were in the library the other day.

15. Linda wrote to the managers of the assistants that were evaluating her study.

16. The hotel director didn't want to see the guides of the tourists that were waiting at the reception desk.

17. The receptionist greeted the clients of the lawyers that were waiting in the conference room.

18. Nobody noticed the bodyguards of the ambassadors that were talking to the photographer at the party.

19. Ivana met the sons of the delegates that were watching television in the den.

20. Lisa could not find the refills of the pens that were in the lower desk drawer.

21. The student read the revisions of the manuscripts that were on the list of readings required for the class.

22. The archaeologists finally found the panels of the sarcophagi that were described in the poem.

23. Harry had inspected the printers of the computers that were on top of the desk.

24. Susan admired the hallways of the apartments that were on the upper floor of the building.

Appendix B

STIMULI FOR EXPERIMENT 1B

The following sentences were used as stimuli for experiment 1B. They are discriminated by condition. All sentences were taken from Fernandez (2002).

HIGH ATTACHMENT UNGRAMMATICAL (HAU)

1. Andrés cenó ayer con los sobrinos del maestro que estaba en el partido comunista.

2. El periodista entrevistó a los entrenadores del gimnasta que estaba firmando autógrafos durante la competición.

3. El gerente observaba a los secretarios del contador que estaba contratado temporalmente.

4. Julia había hablado con las secretarias del abogado que estaba llamando a la oficina toda la mañana.

5. Mi amigo conoció a los ayudantes del detective que estaba investigando el caso del asesino.

6. Carlos conoció a los intérpretes del embajador que estaba organizando la fiesta de anoche.

7. Rosa leyó las críticas de la poesía que estaba impresa en las últimas páginas de la revista.

8. El plomero ajustó los tubos del fregadero que estaba instalado incorrectamente desde la semana pasada.

9. María reemplazó los cables del amplificador que estaba sin funcionar desde la mudanza del verano pasado.

10. A mi hermano le gustaba escuchar las grabaciones de la canción que estaba en la primera cara del álbum.

11. El cocinero no pudo encontrar las tapas de la cacerola que estaba en la mesa de la izquierda.

12. El ladrón se llevó las llaves del baúl que estaba en el armario del pasillo.

13. El periodista no pudo entrevistar a la hija de los rehenes que estaban a punto de salir del avión.

14. Patricia vio al profesor de los estudiantes que estaban en la biblioteca el otro día.

15. Linda escribió al jefe de los asistentes que estaban evaluando su informe.

16. El director del hotel no quiso ver al guía de los turistas que estaban esperando en recepción.

17. La recepcionista saludó al cliente de los abogados que estaban esperando en la sala de conferencias.

18. Nadie vio al guardespaldas de los embajadores que estaban hablando con el fotógrafo de la fiesta.

19. Ivana conoció al hijo de los delegados que estaban viendo la televisión en el salón.

20. Lisa no pudo encontrar la mina de los bolígrafos que estaban en el cajón del escritorio.

21. El estudiante leyó la revisión de los manuscritos que estaban en la lista de lecturas requeridas para la clase.

22. Los arqueólogos finalmente encontraron el panel de los sarcófagos que estaban descritos en el poema.

23. Enrique había inspeccionado la impresora de los computadores que estaban encima del escritorio.

24. Susana admiró el pasillo de los apartamentos que estaban en el piso de arriba del edificio.

LOW ATTACHMENT UNGRAMMATICAL (LAU)

1. Andrés cenó ayer con el sobrino de los maestros que estaba en el partido comunista.

2. El periodista entrevistó al entrenador de los gimnastas que estaba firmando autógrafos durante la competición.

3. El gerente observaba al secretario de los contadores que estaba contratado temporalmente.

4. Julia había hablado con la secretaria de los abogados que estaba llamando a la oficina toda la mañana.

5. Mi amigo conoció al ayudante de los detectives que estaba investigando el caso del asesino.

6. Carlos conoció al intérprete de los embajadores que estaba organizando la fiesta de anoche.

7. Rosa leyó la crítica de las poesías que estaba impresa en las últimas páginas de la revista.

8. El plomero ajustó el tubo de los fregaderos que estaba instalado incorrectamente desde la semana pasada.

9. María reemplazó el cable de los amplificadores que estaba sin funcionar desde la mudanza del verano pasado.

10. A mi hermano le gustaba escuchar la grabación de las canciones que estaba en la primera cara del álbum.

11. El cocinero no pudo encontrar la tapa de las cacerolas que estaba en la mesa de la izquierda.

12. El ladrón se llevó la llave de los baúles que estaba en el armario del pasillo.

13. El periodista no pudo entrevistar a las hijas del rehén que estaban a punto de salir del avión.

14. Patricia vio a los profesores del estudiante que estaban en la biblioteca el otro día.

15. Linda escribió a los jefes del asistente que estaban evaluando su informe.

16. El director del hotel no quiso ver a los guías del turista que estaban esperando en recepción.

17. La recepcionista saludó a los clientes del abogado que estaban esperando en la sala de conferencias.

18. Nadie vio a los guardaespaldas del embajador que estaban hablando con el fotógrafo de la fiesta.

19. Ivana conoció a los hijos del delegado que estaban viendo la televisión en el salón.

20. Lisa no pudo encontrar las minas del bolígrafo que estaban en el cajón del escritorio.

21. El estudiante leyó las revisiones del manuscrito que estaban en la lista de lecturas requeridas para la clase.

22. Los arqueólogos finalmente encontraron los paneles del sarcófago que estaban descritos en el poema.

23. Enrique había inspeccionado las impresoras del computador que estaban encima del escritorio.

24. Susana admiró los pasillos del apartamento que estaban en el piso de arriba del edificio.

CONTROL

Note: these sentences will be used as control conditions for both HAU and LAU sentences. For instance, sentence 1 of the control list corresponds to both sentence 1 in LAU list and sentence 1 in HAU list.

1. Andrés cenó ayer con el sobrino del maestro que estaba en el partido comunista.

2. El periodista entrevistó al entrenador del gimnasta que estaba firmando autógrafos durante la competición.

3. El gerente observaba al secretario del contador que estaba contratado temporalmente.

4. Julia había hablado con la secretaria del abogado que estaba llamando a la oficina toda la mañana.

5. Mi amigo conoció al ayudante del detective que estaba investigando el caso del asesino.

6. Carlos conoció al intérprete del embajador que estaba organizando la fiesta de anoche.

7. Rosa leyó la crítica de la poesía que estaba impresa en las últimas páginas de la revista.

8. El plomero ajustó el tubo del fregadero que estaba instalado incorrectamente desde la semana pasada.

9. María reemplazó el cable del amplificador que estaba sin funcionar desde la mudanza del verano pasado.

10. A mi hermano le gustaba escuchar la grabación de la canción que estaba en la primera cara del álbum.

11. El cocinero no pudo encontrar la tapa de la cacerola que estaba en la mesa de la izquierda.

12. El ladrón se llevó la llave del baúl que estaba en el armario del pasillo.

13. El periodista no pudo entrevistar a las hijas de los rehenes que estaban a punto de salir del avión.

14. Patricia vio a los profesores de los estudiantes que estaban en la biblioteca el otro día.

15. Linda escribió a los jefes de los asistentes que estaban evaluando su informe.

16. El director del hotel no quiso ver a los guías de los turistas que estaban esperando en recepción.

17. La recepcionista saludó a los clientes de los abogados que estaban esperando en la sala de conferencias.

18. Nadie vio a los guarda espaldas de los embajadores que estaban hablando con el fotógrafo de la fiesta.

19. Ivana conoció a los hijos de los delegados que estaban viendo la televisión en el salón.

20. Lisa no pudo encontrar las minas de los bolígrafos que estaban en el cajón del escritorio.

21. El estudiante leyó las revisiones de los manuscritos que estaban en la lista de lecturas requeridas para la clase.

22. Los arqueólogos finalmente encontraron los paneles de los sarcófagos que estaban descritos en el poema.

23. Enrique había inspeccionado las impresoras de los computadores que estaban encima del escritorio.

24. Susana admiró los pasillos de los apartamentos que estaban en el piso de arriba del edificio.

Appendix C

STIMULI FOR EXPERIMENT 2A

The following sentences will be used as stimuli for experiment 2A. They are discriminated by condition. All sentences were adapted from the stimuli created by Thornton, McDonald and Gil (1999).

HIGH ATTACHMENT IMPLAUSIBLE (HAI)

1. The hall by the computer with expanded memory was used by the programmer.

2. The library of the book with ripped pages was visited by the researcher.

3. The house of the vagrant with beer breath was found by the police.

4. The truck by the puppy with floppy ears was painted by her owner.

5. The building behind the park with baseball diamonds was owned by the mayor.

6. The stereo near the album with soulful ballads was cleaned by the singer.

7. The man on the crutches with rubber tips was hit by the train.

8. The yard near the fence with maple trees was photographed by my father.

9. The vases of the flowers with thorny stems were picked by the gardener.

10. The river by the castle with torture chambers was admired by the prince.

11. The tower by the bush with poison berries was burned by the fire.

12. The river by the city with towering sky-scrapers was painted by an artist.

13. The lion in the zoo with matted fur was trained by the circus.

14. The office at the headquarters with tennis courts was used by the broker.

15. The firm of the lawyer with fuzzy eyebrows was sued by the client.

16. The mistake on the calculator with faulty wiring was observed by the scientist.

17. The toolshed near the motorbike with engine problems was wrecked by the boy.

18. The sink by the plumber with hairy arms was bought by my wife.

19. The boxer in the sauna with wooden paneling was defeated by the challenger.

20. The driver on the bus with radial tires was hired by the principal.

21. The biologist in the lab with open windows was surprised by the result.

22. The criminal in a jail with guard towers was arrested by the detective.

23. The gym of the athlete with bulging muscles was criticized by the promoter.

24. The artist in the studio with brick walls was embarrassed by the incident.

25. The glass by the coffeepot with automatic shutoff was broken by the sleeper.

26. The professor in the class with weekly readings was criticized by the students.

27. The stable of the horse with painful blisters was cleaned by the jockey.

28. The parade for a diplomat with wool gloves was admired by the viewers.

LOW ATTACHMENT IMPLAUSIBLE (LAI)

1. The computer down the hall with expanded memory was used by the programmer.

2. The book in the library with ripped pages was read by the researcher.

3. The vagrant near the house with beer breath was found by the police.

4. The puppy by the truck with floppy ears was loved by her owner.

5. The park behind the building with baseball diamonds was admired by the mayor.

6. The album near the stereo with soulful ballads was recorded by the singer.

7. The crutches of the man with rubber tips were left at the station.

8. The fence around the yard with maple trees was built by my father.

9. The flowers in the vase with thorny stems were picked by the gardener.

10. The castle by the river with torture chambers was visited by the prince.

11. The bush by the tower with poison berries was burned by the fire.

12. The city by the river with towering sky-scrapers was destroyed by the flood.

13. The zoo of the lion with matted fur was visited by the president.

14. The headquarters near the office with tennis courts was used by the broker.

15. The lawyer in the firm with fuzzy eyebrows was sued by the client.

16. The calculator of the mistake with faulty wiring was bought by the scientist.

17. The motorbike by the toolshed with engine problems was wrecked by the boy.

18. The plumber by the sink with hairy arms was hired by my wife.

19. The sauna of the boxer with wooden paneling was cleaned by the maid.

20. The bus of the driver with radial tires was stopped by the principal.

21. The lab of the biologist with open windows was visited by the dean.

22. The jail near the criminal with guard towers was visited by the detective.

23. The athlete in the gym with bulging muscles was recruited by the promoter.

24. The studio of the artist with brick walls was photographed during the incident.

25. The coffeepot by the glass with automatic shutoff was broken by the sleeper.

26. The class of the professor with weekly readings was criticized by the students.

27. The horse in the stable with painful blisters was ridden by the jockey.

28. The diplomat in a parade with wool gloves was admired by the viewers.

CONTROL

1. The tablet near the computer with expanded memory was returned by the costumer.

2. The dictionary next to the bible with ripped pages was borrowed by the tourist.

3. The jock next to the slob with beer breath was sentenced by the judge.

4. The puppy near the bunny with floppy ears was run over by a car.

5. The stadium near the park with baseball diamonds was visited by the president.

6. The cassette near the album with soulful ballads was destroyed by the investigator.

7. The crutches next to the chair with rubber tips were left at the station.

8. The yard near the park with maple trees was cleaned by the janitor.

9. The roses near the vines with thorny stems were watered by the servant.

10. The dungeon by the castle with torture chambers was rebuilt by the historians.

11. The bush by the tree with poison berries was trimmed by the gardener.

12. The street in the city with towering sky-scrapers was crowded by the protestors.

13. The lion next to the tiger with matted fur was fed by the zoo keepers.

14. The club next to the park with tennis courts was visited by the tourist.

15. The lawyer next to the architect with fuzzy eyebrows was hired by the singer.

16. The machine inside the building with faulty wiring was lifted by the professor.

17. The motorcycle by the car with engine problems was confiscated by the police.

18. The lawyer of the doctor with hairy arms was assaulted by a criminal.

19. The house near the building with wooden paneling was condemned by the architect.

20. The bus next to the car with radial tires was burned by the fire.

21. The lab in the building with open windows was remodeled by the researcher.

22. The castle near the jail with guard towers was visited by the scientist.

23. The athlete next to the gymnast with bulging muscles was photographed by the artist.

24. The building next to the house with brick walls was destroyed by the earthquake.

25. The radio near the coffeepot with automatic shutoff was bought by the pianist.

26. The syllabus of the class with weekly readings was praised by the committee.

27. The gardener of the gymnast with painful blisters was hugged by his daughter.

28. The model next to the actress with wool gloves was photographed by the press.

Appendix D

STIMULI FOR EXPERIMENT 2B

The following sentences will be used as stimuli for experiment 2B. They are discriminated by condition. All sentences were adapted from the stimuli created by Thornton, McDonald and Gil (1999) and are direct translations of the sentences from experiment 2A, which appear in APPENDIX C.

HIGH ATTACHMENT IMPLAUSIBLE (HAI)

1. El pasillo junto al computador con memoria expandible fue recorrido por el ingeniero.

2. La biblioteca del libro con paginas gastadas fue visitada por el investigador.

3. El barrio del delincuente con mal aliento fue encontrado por la policia.

4. El camion junto al perrito de orejas puntiagudas fue pintado por el estudiante.

5. El edificio detras del parque con canchas de futbol fue comprado por el alcalde.

6. El radio junto al album de baladas tristes fue limpiado por el cantante.

7. El hombre en las muletas de puntas de goma fue golpeado por el tren.

8. El patio de la cerca con arboles de manzanas fue fotografiado por mi padre.

9. El florero junto a las rosas con espinas largas fue pintado por el jardinero.

10. El rio junto al castillo con camaras de tortura fue admirado por el principe.

11. La torre junto al arbusto con frutos venenosos fue quemada en el incendio.

12. El rio junto a la ciudad con rascacielos altos fue pintado por un artista.

13. El leon en el zoologico de gran melena fue entrenado por el circo.

14. La oficina junto al club con canchas de tenis fue visitada por el corredor de bolsa.

15. La firma del abogado con cejas prominentes fue demandada por el cliente.

16. El error en la calculadora con cables sueltos fue observado por el cientifico.

17. El garaje con la motocicleta con el motor descompuesto fue destruido por el adolescente.

18. La tuberia junto al fontanero con brazos fuertes fue revisada por mi esposa.

19. El boxeador en el sauna con pisos de baldosa fue vencido por el retador.

20. El conductor del bus con llantas grandes fue contratado por el director.

21. El biologo del laboratorio con las ventanas abiertas fue sorprendido por el resultado.

22. El criminal en la carcel con torres de guardia fue arrestado por el detective.

23. El gimnasio del atleta de fuertes musculos fue criticado por el promotor.

24. El artista del estudio con paredes de ladrillo fue interrogado por el detective.

25. La sala del televisor con apagado automatico fue limpiada por la asistente.

26. El profesor de la clase con lecturas semanales fue criticado por los estudiantes.

27. El establo del caballo con heridas en las patas fue limpiado por el corredor.

28. El desfile de la reina con corona de diamantes fue admirado por los espectadores.

LOW ATTACHMENT IMPLAUSIBLE (LAI)

1. El computador del pasillo con memoria expandible fue utilizado por el ingeniero.

2. El libro en la biblioteca con paginas gastadas fue leido por el investigador.

3. El delincuente del barrio con mal aliento fue encontrado por la policia.

4. El perrito junto al camion de orejas puntiagudas fue adoptado por el estudiante.

5. El parque detras del edificio con canchas de futbol fue admirado por el alcalde.

6. El album junto al radio de baladas tristes fue grabado por el cantante.

7. Las muletas del hombre con puntas de goma fueron dejadas en la estacion.

8. La cerca del patio con arboles de arce fue construida por mi padre.

9. Las rosas en el florero con espinas largas fueron plantadas por el jardinero.

10. El castillo junto al rio con camaras de tortura fue visitado por el principe.

11. El arbusto junto a la torre con frutos venenosos fue quemado en el incendio.

12. La ciudad junto al rio con rascacielos altos fue destruida por la inundacion.

13. El zoologico con el leon de gran melena fue visitado por el presidente.

14. El club junto a la oficina con canchas de tenis fue visitado por el corredor de bolsa.

15. El abogado de la firma con cejas prominentes fue demandado por el cliente.

16. La calculadora con el error con cables sueltos fue comprada por el cientifico.

17. La motocicleta en el garaje con el motor descompuesto fue destruida por el adolescente.

18. El fontanero junto a la tuberia con brazos fuertes fue contratado por mi esposa.

19. El sauna del boxeador con pisos de baldosa fue limpiado por la empleada.

20. El bus del conductor con llantas grandes fue detenido por el director.

21. El laboratorio del biologo con las ventanas abiertas fue visitado por el director.

22. La carcel del criminal con torres de guardia fue visitada por el detective.

23. El atleta del gimnasio de fuertes musculos fue reclutado por el promotor.

24. El estudio del artista con paredes de ladrillo fue fotografiado por el detective.

25. El televisor de la sala con apagado automatico fue limpiado por la asistente.

26. La clase del profesor con lecturas semanales fue homenajeado por los estudiantes.

27. El caballo del establo con heridas en las patas fue montado por el corredor.

28. La reina del desfile con corona de diamantes fue admirada por los espectadores.

CONTROL

1. La tableta junto al computador con memoria expandible fue utilizada por el ingeniero.

2. El diccionario junto a la Biblia con paginas gastadas fue utilizado por el turista.

3. El deportista junto al vago con mal aliento fue sentenciado por el juez.

4. El perrito junto al conejo de orejas puntiagudas fue atropellado por un carro.

5. El estadio junto al parque con canchas de futbol fue visitado por el presidente.

6. El casete junto al album de baladas tristes fue destruido por el investigador.

7. Las muletas junto a la silla con putas de goma fueron dejadas en la estacion.

8. El patio del parque con arboles de manzanas fue limpiado por mi conserje.

9. Las flores junto a las rosas con espinas largas fueron arrancadas por el sirviente.

10. La prision junto al castillo con camaras de tortura fue reconstruida por un arquitecto.

11. El arbusto junto a la planta con frutos venenosos fue cortado por el jardinero.

12. La calle en la ciudad con rascacielos altos fue cerrada por los bomberos.

13. El leon junto a la leonesa de gran melena fue alimentado por los guardianes.

14. El club junto al parque con canchas de tenis fue visitado por el turista.

15. El abogado junto al arquitecto con cejas prominentes fue contratado por el cantante.

16. La maquina en el edificio con cables sueltos fue levantada por el profesor.

17. La motocicleta junto al carro con el motor descompuesto fue confiscada por la policia.

18. El abogado junto al fontanero con brazos fuertes fue asaltado por un criminal.

19. La casa junto al edificio con pisos de baldosa fue demolida por el arquitecto.

20. El bus junto al camion con llantas grandes fue quemado por el incendio.

21. El laboratorio en el edificio con las ventanas abiertas fue remodelado por el investigador.

22. El castillo junto a la carcel con torres de guardia fue inspeccionado por el detective.

23. El entrenador del atleta de fuertes musculos fue fotografiado por el artista.

24. La terraza del edificio con paredes de ladrillo fue observada por el policia.

25. La camara del computador con apagado automatico fue reemplazada por la empleada.

26. El estudiante del profesor con problemas visuales fue felicitado por el experto.

27. La garrapata del perro con heridas en las patas fue encontrada por el veterinario.

28. La madre de la dama con corona de diamantes fue insultada por el comerciante.

SUBJECT QUESTIONNAIRE

SubjectID: ☐

SUBJECT QUESTIONNAIRE

A. Basic Information   Date: _____

- Gender: M / F
- Date of Birth: _____   Age: _____   Level of Education: _____

Family

- Mother's highest education level:_____   Father's highest education level: _____

B. Language Exposure

- What language(s) are spoken at home? _____

- What is your primary language? _____

- What other languages do you speak? _____

- What languages can you understand (although may not speak)? _____

- Father's primary language: _____ Other languages the father speaks fluently: _____

- Mother's primary language: _____ Other languages the mother speaks fluently: _____

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C. Speech, Language, & Hearing History

- Is there any history of the following in your family? (check all that apply and state relationship of family):

    Speech or language disorder_____   Hearing impairment_____   Learning Disorder_____

- Did you ever exhibit a language delay as a child?   No   Yes   (explain) _____

- If yes, when was the language delay first apparent?

    _____

- Have you ever been evaluated by or worked with any of the following? (check all that apply and please explain)

	Evaluation Only	Sessions		Evaluation Only	Sessions
Ear Nose and Throat (ENT) Doctor	_____	_____	Reading Specialist	_____	_____
Neurologist	_____	_____	Speech Language Pathologist	_____	_____
Psychologist	_____	_____	Other:		
Audiologist	_____	_____	_____	_____	_____

Explanations: _____

_____

- Have you ever worn hearing aid(s)?   No   Yes
- If yes, at what age did you begin wearing the hearing aid(s)? _____
- If you wear a hearing aid(s), at what time(s) during the day and for what activities?

    _____

D. Medical History/ Development

- Have you been diagnosed with…

  PDD?   No   Yes   Asperger's Syndome?   No   Yes

  Autism? No   Yes   ADD/ADHD?   No   Yes

- Do you take any medication?   No   Yes   (explain)_____

  _____

- Which hand do you use most?   Left   Right   Both equally

Is there any information you would like to share with us to help us understand you better?

_____

We are committed to including subjects from all backgrounds in research and therefore collect the following information. You may choose not to provide this information.

(please check one in <u>both</u> categories)

<u>Ethnic Category (please check one)</u>   **<u>Racial Category (please check one)</u>**

☐   Hispanic or Latino   ☐   American Indian/Alaska Native

☐   Not Hispanic or Latino   ☐   Asian

☐   Do not wish to respond   ☐   Native Hawaiian or Other Pacific Islander

                                                              ☐   Black or African American

                                                              ☐   White

                                                              ☐   Do not wish to respond

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Appendix F

INSTITUTIONAL REVIEW BOARD (IRB) APPROVAL LETTER

UNIVERSITY OF DELAWARE RESEARCH OFFICE

210 Hullihen Hall
University of Delaware
Newark, Delaware 19716-1551
Ph: 302/831-2136
Fax: 302/831-2828

DATE: March 3, 2016

TO: Angel Ramirez-Sarmiento, MA, PhD Student
FROM: University of Delaware IRB

STUDY TITLE: [585609-3] Parsing Heuristics Experiment

SUBMISSION TYPE: Continuing Review/Progress Report

ACTION: APPROVED
APPROVAL DATE: March 3, 2016
EXPIRATION DATE: March 24, 2017
REVIEW TYPE: Expedited Review

REVIEW CATEGORY: Expedited review category # *(7)*

Thank you for your submission of Continuing Review/Progress Report materials for this research study. The University of Delaware IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that <u>informed consent</u> is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

If you have any questions, please contact Nicole Farnese-McFarlane at (302) 831-1119 or nicolefm@udel.edu. Please include your study title and reference number in all correspondence with this office.