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Parsing Complex Noun Phrases: Effects of Hierarchical Structure and Sentence Position on Memory Load

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Abstract. In this paper, we report two experiments in Spanish designed to find out what kind of processes underlie the online parsing of complex noun phrases (NPs). To that end, we used a 'click detection' paradigm coupled with an oral comprehension task with sentences made up of complex NPs comprising embedded prepositional phrases PPs or coordinate NPs. The critical NPs consisted of words or pseudowords, and were inserted either at subject position (Experiment 1) or at object position (Experiment 2) in the sentence. Results show an opposite pattern of RTs to clicks when the complex NP is located at subject (vs. object) position, with the former case showing heavier processing demands as the parser delves deeper into the complex NP, regardless of the internal constituency of the target NP and its lexical content, and the latter yielding the opposite pattern. These results suggest that structural complexity by itself does not determine an increase in processing costs during sentence parsing, which is only apparent in cases involving deferred operations like subject-verb agreement.

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The study of parsing in natural language gravitates between two kinds of issues that have long preoccupied scholars and researchers in the field: one is the discovery of the principles that guide parsing processes and the kind of properties they exhibit (Frazier & Clifton, 1995; Hawkins, 1994; MacDonald, Pearlmutter, & Seidenberg, 1994); the other is concerned with the types of information and the cognitive resources that support parsing operations, and the way they are used under time constraints, given the limited focus of attention and storage capacity of the human language processor (Gibson, 1998; Levy, 2008; Lewis, Vasishth, & Van Dyke, 2006). The first issue includes questions like the architecture of the language processor, the relationship between the grammar and the parser, –i.e., to what extent grammatical knowledge is directly reflected in parsing processes–, and the purported universality of parsing strategies. The second issue is concerned with matters such as the automatic or controlled nature of various processing components, their degree of encapsulation, or the strategic allocation of attention and memory resources in online language processing.

Our aim in the current study is to bring together both issues by means of an experimental inquiry of the processing of two distinct but related complex structures in Spanish, namely, two types of complex noun phrases (NPs) with embedded right-branching constituents (i.e., a series of prepositional phrases attached to a head NP, or a sequence of conjoined noun phrases) located at two different critical sites in the sentence structure. In so doing, we will look for possible differences between the structures put to test in terms of processing demands, that is, as a function of the storage costs required at different critical points during the parsing of complex structures with hierarchical dependencies. The complex NPs chosen for our experiments were of two types: NPs with embedded PPs, and NPs formed with a series of coordinate NPs. As we shall see below, although both types of complex NPs share a similar hierarchical configuration, they also exhibit differences that might influence the processing costs they endure.

An important feature of the materials tested in our study is the position of the (complex) NP in the sentence. In this regard, we will contrast complex NPs at subject versus object position (Gibson, Desmet, Grodner, Watson, & Ko, 2005), with the aim of elucidating whether, and how, processing costs during parsing complex NPs change as a function of processing site. The crucial difference in this case is that processing NPs at subject position in canonical SVO sentences requires keeping track of the head NP, so

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as to establish grammatical concord between the subject and the verb, and this carries greater demands on working memory than parsing object-NPs at post-verbal position. In the latter case, the relevant syntactic dependencies among the main constituents of the sentence –i.e., between the predicate and its arguments– have already been established.

In addition, we will compare meaningful sentences with sentences with the critical NPs made up of pseudowords. This comparison is intended to find out whether the processing load effects that we may observe in full-fledged sentences turn up as well in structurally identical materials devoid of meaning. If such were the case, we would be entitled to conclude that the processing effects found in our study when parsing meaningful sentences are not sensitive to lexical or semantic variables in our materials.

Most experimental research on parsing has been devoted to studying the processing of self-embedded structures (see classical studies such as Holmes, 1973; Yngve, 1960; or Hakes, Evans, & Brannon, 1976; and more recent works, such as Gibson, 1998; Hudson, 1996; and Karlsson, 2010, among others). These studies emphasize the role of memory load in processing complex structures with open, and often long-distance, dependencies between constituents as a key issue in the implementation of parsing operations. The rationale is that parsing self-embedded structures involves establishing dependencies between non-adjacent constituents, and hence performing *deferred* operations, whose completion must be delayed until the current operations are performed in a piecemeal fashion. Such delayed operations entail a greater load in working memory, since all previously analyzed constituents have to be kept or retrieved from memory in order to integrate them with later constituents of the sentence.

The relevance of working memory limitations in online processing is beyond doubt (Chomsky & Miller, 1963; MacDonald, Just, & Carpenter, 1992; Miller & Isard, 1964). There is plentiful evidence showing that when the distance between an argument and its head increases, processing becomes progressively difficult (Gibson, 1998; 2000; Lewis & Vasishth, 2005). This is the so-called 'locality effect' in parsing. This effect comes about as a joint consequence of the need to satisfy predictions raised by the head or by the dependent constituent (e.g., expectation of an upcoming verb after a subject-NP in declarative sentences, or by a WH-phrase and its VP-head in questions, respectively), and the number of constituents (e.g., embedded phrases within the subject-NP, in the former case, or modifiers of the VP, in the latter case) that must be encoded before the prediction is fulfilled and the expected constituent is integrated in the syntactic structure. In such cases, the parser has to keep track of the head, or the dependent phrase, until both are finally integrated, thus increasing processing load.

However, there is also evidence to the contrary, that is, cases where increasing the distance between related constituents produces a speedup at the site of constituent integration (Lewis, Vasishth, & Van Dyke, 2006; Vasishth & Lewis, 2006). This facilitatory effect, also known as 'anti-locality effect', has been observed when intervening material between the head and the dependent constituent reinforces, rather than interferes with, the expected element by increasing its predictability. Anti-locality effects have been reported especially in research with head-final languages.

Given this state of affairs, current parsing models make different claims as to the prevailing factor that is deemed to be responsible for the outcomes of processing, depending on whether they are facilitatory or inhibitory. Memory-based explanations, like the Dependency Locality Theory (DLT) (Gibson, 1998; 2000), underscore the processing difficulties engendered by intervening material in long-distance dependencies, and explain these effects as a result of the introduction of new discourse referents that increase memory load. These are labeled 'storage load effects', and result in more costly retrieval of the constituent to be integrated in the syntactic structure.

Activation-based models (Lewis & Vasishth, 2005; Lewis et al., 2006; Nicenboim, Vasishth, Gattei, Sigman, & Kliegl, 2015), in turn, stress the role of memory decay and interference in explaining locality effects. In canonical SVO sentences, retrieval of non-local arguments is driven by cues that are activated at the moment of integration of the target constituent. If items sharing similar cues with the target intervene in the sentence (e.g., NPs when retrieving a prior subject-NP, or complement clauses when retrieving an earlier complement clause), the process becomes more effortful due to similarity-based interference (Lewis & Vasishth, 2005; Van Dyke & Lewis, 2003). In addition, activation-based models have tried to accommodate 'anti-locality' effects by arguing that in some cases, the processor takes advantage of certain cues provided by the intervening material to facilitate the retrieval of non-local arguments (e.g., through modification of an NP by means of relative clauses attached to it in advance of the main verb) (Konieczny, 2000; Vasishth & Lewis, 2006).

The current study capitalizes on the parsing difficulties brought about by structural complexity, as reflected in the hierarchical layout of sentences and the long-distance dependencies among its constituents, and the attendant constraints set on working memory during online processing. However, instead of focusing on complexity effects as recorded at the point of integration, that is, at the moment of retrieving

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the non-local target constituent, we will look at complexity effects *during* the storage phase, that is, while processing the intervening constituents between a complex subject-NP and the sentence predicate, compared with the same effects *after* the long-distance dependency between subject and predicate has been closed. We will do this by shifting the complex NP from subject to object position in the sentence, after the subject and the verb have been integrated.

The assessment of the effects of hierarchical structure during the storage phase in processing long-distance dependencies has usually been carried out by means of a global measure and using written materials, such as recording reading times of interposed constituents in the self-paced reading paradigm. Our study, in contrast, will use a divided attention task, namely 'click detection', and spoken materials. In so doing, our aim is to provide an online measure of processing load at precise points of the sentence, on the assumption that reaction times to extraneous stimuli (i.e., clicks or tones) interspersed in spoken sentences are a direct reflection of the attentional and working memory resources available at specific points during online processing. In support of this assumption, response times to distractor stimuli in click-detection task have been shown to be sensitive to variations in the processing difficulty of structural and semantic information in language (Cohen & Mehler, 1996) and other domains, such as music (Berent & Perfetti, 1993). Widely known are the results of early psycholinguistic studies showing that response times to clicks are slowed down near or at major syntactic boundaries (Holmes & Forster, 1970), or tend to be higher at the beginning than at end of clauses (Cutler & Norris, 1979). More recent research has revealed that clicks tend to be responded to faster when located at spoken word boundaries (which are regularly non-physical breaks) than when placed within a word (Gómez, Bion, & Mehler, 2011). Thus, our reasoning goes, we could take advantage of this measure in order to make an estimation of the cognitive load during processing of complex, hierarchically-structured phrases at various points (see Lobina, Demestre, & García-Albea, in press, for a critical assessment of the use of the click detection technique in psycholinguistic experiments).

To recap, the purpose of this study is to test the influence of three variables, two structural and one lexico-semantic, on the processing of hierarchically complex structures. Our major aim was to assess the processing load accrued at two critical points of a complex NP. Target NPs had modifiers with a hierarchical, right-branching structure comprising four constituents. The critical points at which processing load was measured were either by the end of the first noun (i.e., the head and topmost constituent of the complex NP), or by the end of the third noun, located at a hierarchically lower (and later) position. To that end, we first chose two different kinds of complex NPs, either with a series of embedded PPs within the NP, or with a sequence of coordinated NPs. The interest of this comparison lies in the supposedly different processing demands of embedded PPs and coordinate NPs. Although both are thought to share the same kind of hierarchical right-branching structure[1], and have the same number of referents (four nouns, in our materials), coordinate NPs are likely to impose different requirements on feature-checking operations for subject-verb agreement. In addition, we varied the position of the complex NPs in the sentence, by comparing NPs at subject and object positions. Our concern here was to examine the role of deferred operations in parsing these complex structures. As we argued previously, in sentences with an SVO canonical structure, the head noun of the subject NP must be kept (or reactivated) in working memory in order to match the number features of the noun and the verb (in the case of non-finite verbs in Spanish). This might cause an increase in memory load when parsing subject NPs, as compared to object NPs. Finally, the complex NPs examined in this study were composed of nouns or pseudonouns. This contrast was introduced with the aim of cancelling out the possible influence of lexical meanings on the parsing process. Should the same effects occur in both cases, they could not be attributed to lexico-semantic influences.

Two experiments were run in the present study. Both experiments used spoken sentences with two alternative structures: (1) sentences with a complex NP containing three embedded PPs (henceforward the 'embedded-PP' condition); and (2) sentences with a coordinate NP containing four NPs (henceforward the 'coordinate-NP' condition). The only difference between both experiments was the location of the critical complex NP in the sentence structure: in Experiment 1, it was the subject of a subordinate complement clause, hence, before the predicate of the embedded clause (this location will be henceforward named 'subject position'), whilst in Experiment 2, it was the object of a simple transitive clause, thus after the sentence predicate (henceforward, 'object position'). As mentioned earlier, this different location entails that as the complex NP is being parsed, in Experiment 1 the parser should be expecting a verb to come (the predicate of the embedded clause), so the computation of subject-verb agreement by feature matching is yet to be performed. In contrast, in Experiment 2,

[1]Insofar as coordinate NPs exhibit a binary branching structure headed by the coordinator (i.e., conjunction), with the first member of the conjunct as its Specifier, and the second member of the conjunct as its Complement, they have the same configuration as NPs with embedded PPs (Camacho, 2003; Johannessen, 1998; Zhang, 2010).

there are no further expectations beyond the completion of the clause with the obligatory complement (that is currently being processed) of the transitive verb. Lastly, two versions of each experiment were devised to implement the contrast between complex NPs with words and with pseudowords.

In both experiments, participants were engaged in a dual task: they had to listen to the sentences for comprehension while monitoring an auditory stimulus (a tone) inserted somewhere in the audio file and executing a manual response as soon as they heard the tone.

Materials in Experiment 1 were spoken sentences consisting of a short main clause plus a subordinate complement clause with a complex NP in subject position. Head nouns in this subject-NP were words in Subexperiment 1A, and pseudowords in Subexperiment 1B. Both sentences with words (1A) and pseudowords (1B) were parseable strings, and contained interpretable propositions, though devoid of lexical meaning in Subexperiment 1B. Materials in Experiment 2 were spoken simple transitive sentences with a complex object-NP. The same contrast between words and pseudowords was used in this experiment, which yielded two corresponding subexperiments (2A: words; 2B: pseudowords).

As mentioned in the Introduction, the word-pseudoword contrast was introduced in order to test a situation in which parsing decisions (in Experiments 1 and 2), would not be biased by lexical meanings. Accordingly, we might expect to find more neutral, syntactically-driven operations in the case of sentences with pseudowords at the relevant positions. Table 1 below shows examples of materials from all experimental conditions of the two experiments.

EXPERIMENT 1

The main purpose of Experiment 1 was to compare the processing of 'embedded-PP' and 'coordinate-NP' structures, two kinds of complex phrases with supposedly different processing demands, when they are placed within a subject-NP. The difference between both structures can be stated as follows. Complex NPs with embedded PPs require parsing hierarchically nested structures in a stepwise fashion, while keeping track of the φ-features (gender and number, in the case of Spanish nouns) of the head noun of the complex NP for subsequent agreement with the sentence predicate (i.e., long-distance checking of number features, in this particular case[2]). This might involve complex, deferred operations every time an embedded noun is encountered.

In contrast, parsing coordinate NPs requires adding a new NP constituent to the NP under construction at every step of the process. This might also involve deferred operations, though of a different kind, since the number feature of the complex NP is given by the plurality of the set denoted by the coordinated NP, and thus feature-checking for agreement is not performed by retrieving or activating a single head noun of the subject-NP as in the former case. So, at first glance, processing embedded PPs in a complex NP entail different parsing requirements than processing coordinate NPs.[3] However, as far as processing load is concerned, that is, as regards the expression of these two processes in reaction time measures (as the one we are using in this study), we might expect a similar outcome, since in both cases constituents that have been previously parsed must be kept active in working memory for agreement purposes. Thus, the current study might provide comparative evidence, by way of a measure of memory load, of the processing demands that these two structures impose on sentence parsing operations.

Subexperiment 1A

Participants

Twenty undergraduate and graduate students from the Universidad Autónoma de Madrid (aged 21 to 35) volunteered to participate in this experiment. All of them were native speakers of Spanish, and none had hearing impairments.

Materials

Thirty-two experimental sentences were constructed as described above (see Table 1), 16 with a complex NP with three embedded PPs, and the other 16 with a complex NP with four coordinate NPs. Twenty-four filler sentences with the same structure were added, 12 of each kind. The nouns selected for the complex NPs of the critical sentences were matched for mean frequency

[2]In Spanish, subject-verb agreement regularly requires checking of number-features, except for copular or passive sentences (not employed in this study), where the predicate (either a predicate nominative or a verb with a passive participle) also carries gender-features.

[3]Another possible source of cognitive load in the 'embedded-PP' condition comes from the fact that the head-NP (the first in the sequence of nouns) and its NP-complements embedded in PPs might differ in number, thereby inducing an 'attraction effect', which has been shown to produce agreement errors (i.e., selection or identification of the wrong number feature in the verb) in both comprehension and production tasks, especially when the 'attractor noun' is plural and the head-noun is singular (Eberhard, Cutting, & Bock, 2005; Lago, Shalom, Sigman, Lau, & Phillips, 2015; Vigliocco Butterworth, & Semenza, 1995; Wagers, Lau, & Phillips, 2009). This risk was minimized in our study by having our materials match in number in the relevant nouns of the sequence: the first (head-NP) and third nouns in all but one of the sentences (see Appendix 1).

Table 1. *Examples of sentences with words and pseudowords used in Experiments 1 and 2. Complex NPs appear in brackets. Pseudowords are in boldface. English pseudowords in the translated examples have been adapted for illustrative purposes*

Subexperiment	Condition	Sentences with words and pseudowords
Experiment 1		
Subexperiment 1A	Embedded-PP	*El conductor vio que [la rueda del remolque del camión de las mudanzas]estaba pinchada*
Sentences with		Lit. The driver saw that [the tire of the trailer of the truck of the moves] was punctured
words		*(The driver saw that the trailer of the moving truck had a punctured tire)*
	Coordinate-NP	*Los niños creen que [las motos, los camiones, los trenes y los aviones] son muy grandes.*
		The kids think that [the scooters, the trucks, the trains, and the planes] are very big.
Subexperiment 1B	Embedded-PP	*El conductor vio que [la **mita** del **frolador** del **fustio** de las **gabrinas**] estaba pinchada.*
Sentences with		The driver saw that [the **mipe** of the **fronker** of the **fustee** of the **gabrins**] was pricked.
pseudowords	Coordinate-NP	*Ayer vimos que [las **logas,** el **nordal**, la **namira** y el **nofón**] eran muy grandes.*
		Yesterday we saw that [the **loggles**, the **nordle**, the **narmer** and the **noffen**] were very big.
Experiment 2		
Subexperiment 2A	Embedded-PP	*El conductor cambió [la rueda del remolque del camión de las mudanzas].*
Sentences with		Lit. The driver changed [the tire of the trailer of the truck of the moves].
words		*(The driver changed the tire of the trailer of the moving truck)*
	Coordinate-NP	*Los niños dibujaron [las motos, los camiones, los trenes y los aviones].*
		The children drew [the motorcycles, the trucks, the trains and the planes].
Subexperiment 2B	Embedded-PP	*Hay que arreglar [las **logas** del **nordal** de la **namira** del **nofón**].*
Sentences with		Lit. (We) have to fix [the **loggles of** the **nordle** of the **narmer** of the **noffen**]
pseudowords		*The loggles of the nordle of the narmer of the noffen must be fixed.*
	Coordinate-NP	*El mecánico ha arreglado [la **mita**, el **frolador**, el **fustio** y las **gabrinas**.*
		The mechanic fixed [the **mipe**, the **fronker,** the **fustee, and** the **gabrins**].

and length across conditions [for the embedded-PP condition: mean frequency = 128.31 per million; mean length = 6.16 phonemes; for in the coordinate-NP condition: mean frequency = 116.46 per million; mean length = 6.28 phonemes][4]. Twelve of the 56 items comprising the experiment (21.42%) were followed by a comprehension (yes-no) question to make sure participants remained attentive to the task and to filter out participants with too many errors[5].

All sentences were digitally-recorded by a male speaker and transformed into wav files for auditory presentation. A 100 millisecond tone with a mean frequency of 330.77 Hz and a mean amplitude of 77.96 dB was inserted for the 'click detection' task at two critical positions in the experimental materials: (1) the onset of the last syllable of the first noun in the complex NP (i.e., position N1), and (2) the onset of the last syllable of the third noun in the complex NP (i.e., position N3) (see arrows in 1).

N1 ↓ N3 ↓

(1) *El conductor vio que [la rueda del remolque del camión de las mudanzas] estaba pinchada*

[4]Source of frequency count: NIM database (Universitat Rovira i Virgili, Tarragona, Spain): Guasch, Boada, Ferré, and Sánchez-Casas (2013). http://psico.fcep.urv.cat/utilitats/nim/index.php

[5]A full list of the materials of Experiment 1 (including sentences and comprehension questions of Subexperiments 1A and 1B) is shown in Appendix 1.

Position of the tone was varied in the filler sentences (i.e., placed on the last syllable of the second and fourth nouns of the complex NPs) in order to avoid regularity in tone placement. Each sentence had only one tone, so two versions (lists) of each of the experimental sentences were created.

Design and procedure

A 2×2 factorial design was used, with two within-subject independent variables with two levels each: (1) type of structure (embedded-PP vs. coordinate-NP), and (2) tone position (N1 vs. N3).

Each subject listened to 56 sentences along the experiment (32 experimental and 24 filler items). Tone position was counterbalanced across sentences, yielding two lists/versions of the experiment. Every sentence appeared only once in each list, with the tone placed at location N1 or N3 in the experimental sentences. Thus, every participant listened to the same sentences, but with different tone locations across the two versions of the experiment. In other words, each participant only listened to every sentence once, with the tone either at N1 or at N3 position. All items within each list were grouped in blocks and randomized across and within blocks. Stimuli were administered through headphones by means of the DMDX program (Forster & Forster, 2003) in a dimly lit and quiet room. Participants were instructed to listen carefully to the sentences and

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press the 'AltGr' key with their right forefinger as soon as they heard a tone, while keeping track of the sentence meaning. They were told that in some trials they would have to answer a written question presented on the screen by pushing a 'Yes' or 'No' key[6]. The experiment began with six practice trials to familiarize participants with task and materials. RTs to tones and errors in the comprehension questions were recorded by the DMDX software.

Both Subexperiments 1A and 1B were run in the same experimental session, with a short break between them. Participants were randomly administered the two subexperiments in two different orders either 1A first, then 1B, or the other way around, with half of the participants following each order. The whole experimental session lasted altogether about 45 minutes.

Results

The pattern of RTs to tones are shown in Figure 1. Reaction time data were trimmed by replacing data points below or above two standard deviations over the mean for each participant by the cutoff points (mean ± 2SD). Only 3.28 percent of data were so replaced. Mean percentage of correct responses to comprehension questions was 88.7, ranging from 75 to 100 percent across participants.

A repeated measures ANOVA with participants and items as random variables was applied on the RT data, yielding the following results: (1) a main effect of tone position which was significant in both participants and items analyses $F_1(1, 19) = 12.826$, $p = .002$; $F_2(1, 15) = 61.933$, $p = .001$; as shown in Figure 1, RTs were significantly faster for tones at N1 position. Pairwise comparisons between RTs at positions N1 and N3 revealed that the advantage for RTs at N1 over RTs at N3 was significant in both embedded PPs ($t(19) = 2.978$, $p = .008$), and coordinate NPs ($t(19) = 3.494$, $p = .002$). (2) On the other hand, no main effects of the type of structure $F_1(1, 19) = 0.546$, $p = .47$; $F_2(1, 15) = 0.083$, $p = .78$ or of the interaction between tone position and type of structure ($F_1(1, 19) = 0.183$, $p = .67$; $F_2(1, 15) = 0.189$, $p = .67$).

Thus, there appears to be a processing cost associated to the presence of a distractor stimulus when it is located in a constituent that is more deeply embedded or located later in the structure it belongs to. Interestingly, almost exactly the same processing cost accrues for structures with embedded-PPs and with coordinate-NPs. At first glance, these results are compatible with an account based on the view that

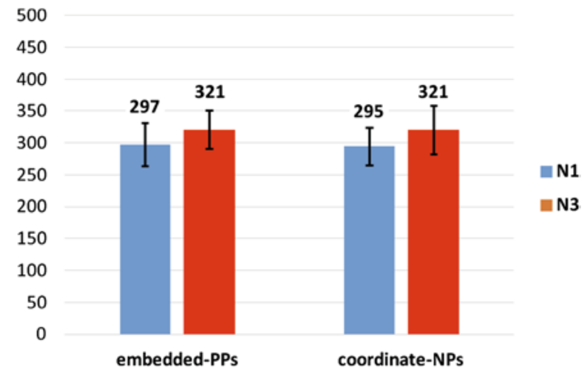

Figure 1. Mean reaction times (with error bars) to tones in sentences with embedded PPs and coordinate NPs within complex NPs in subject position, as a function of tone position.

at N3 position, processing load becomes increased due to deferred operations needed to keep track of the NP under process. However, the lack of differences between the two structures examined calls for an explanation, given the fact that on some accounts, the coordinate-NP structure is thought to be simpler in processing terms. We will come back to these results in the Discussion section.

Subexperiment 1B

Participants

The same twenty participants of Subexperiment 1A took part in this subexperiment.

Materials

The set of experimental and filler sentences used in Subexperiment 1A were modified by replacing the nouns in the complex NPs by phonotactically legal pseudo-nouns in Spanish with the same number of syllables and stress pattern as the original nouns. The number and proportion of experimental and filler sentences with pseudowords, as well as the length of the items, were identical to those in Subexperiment 1A.

The sentences were digitally-recorded by the same male speaker as in the previous experiment, and tones were inserted in the same positions (N1 and N3, for experimental sentences, and N2 and N4 for the fillers). Two lists were composed for administration of this subexperiment.

Design and procedure

The design and procedure were the same as those of Subexperiment 1A. Comprehension questions were constructed by using the appropriate pseudowords in such a way as to be answerable with a 'Yes' or 'No' response.

[6]As can be seen in Appendix 1, comprehension questions asked about the predicate-argument relation between one of the four nouns in the complex NP and the subordinate verb.

Results

Mean RTs to tones in the sentences of this subexperiment are depicted in Figure 2. Data points corrected to cutoff values amounted to 4.37 percent of all responses. Overall percentage of correct responses to comprehension questions amounted to 75 percent, ranging from 50% to 83.3%.

A repeated measures ANOVA run on the RT data, with participants and items as random variables, yielded virtually identical results to those found in the previous subexperiment. There was a significant effect of tone position in both participants and items analyses $F_1(1, 19) = 19.537$, $p = .001$; $F_2(1, 15) = 62.550$, $p = .001$, with faster RTs for tones located at N1 than at those located at N3, but no effects of type of structure $F_1(1, 19) = 0.039$, $p = .84$; $F_2(1, 15) = 0.014$, $p = .91$ or of the interaction between both factors $F_1(1, 19) = 0.709$, $p = .41$; $F_2(1, 15) = 0.9$, $p = .36$. Pairwise comparisons between RTs at positions N1 and N3 confirmed the significant advantage of RTs at N1 position in both embedded-PPs ($t(19) = 3.429$, $p = .003$), and coordinate NPs ($t(19) = 4.25$, $p = .001$).

Exactly the same pattern of results obtained with meaningful sentences (Experiment 1A) was replicated with sentences with no lexical-semantic content, though interpretable in terms of thematic role assignment. This provides support to the view that the effects found in these experiments are syntactic in nature. The results of this experiment will be discussed later in conjunction with those of Experiment 1A.

EXPERIMENT 2

The purpose of Experiment 2 was to compare the processing of embedded-PPs or coordinate-NPs within a complex NP that is placed at object position. The materials, design and procedure of this experiment were exactly the same as in Experiment 1, except for the fact that the complex NPs chosen as processing targets had a different location and grammatical role in the sentence. Capitalizing on this difference, we wanted to find out whether the absence of deferred operations during the processing of these two complex structures in object-NPs would yield a different pattern of response times to distractor tones located at the same critical points as in Experiment 1, (i.e., at the end of the first or the third noun of the complex NP). As in the previous experiment, we also set out to test sentences with and without lexical content in the complex NP.

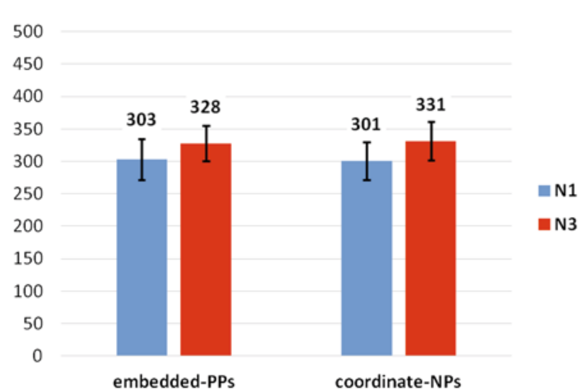

Figure 2. Mean reaction times (with error bars) to tones in sentences with embedded PPs and coordinate NPs with pseudowords, within complex NPs in subject position, as a function of tone position.

Subexperiment 2A

Participants

Twenty volunteers from the Universidad Autónoma de Madrid community (aged 18 to 45) took part in this experiment. All of them were native speakers of Spanish, and none had hearing impairments. None of them had participated in the previous experiment.

Materials

Thirty-two experimental sentences were constructed based on the materials of Subexperiment 1A. All the sentences from that experiment were modified by extracting the subordinate clause, changing the embedded verb for a transitive verb, and adding a (simple NP or null) subject, on occasion preceded by an adverbial phrase. Care was taken to select verbs that preferentially took an NP (instead of a clausal) complement, and to match the (Adv)-(subject-NP)-verb sequences for length, in order to have homogeneous materials across experimental items before the object-NP. Another twenty-four filler sentences taken from the set of fillers in Subexperiment 1A were modified following the same guidelines. Thus, we had altogether 56 items with the same target NPs of Subexperiment 1A. Likewise, comprehension questions were added at the end of 12 sentences of the experiment, with the same distribution as in the previous experiment.[7]

All sentences were digitally-recorded by the same male speaker as in Experiment 1, and the 100 ms tone introduced at the same positions of the target NPs. An example of an experimental sentence with the location of distractor tones is shown in (2).

N1 ↓ N3 ↓

(2) *El conductor vio [la rueda del remolque del camión de las mudanzas]*

[7]A full list of the materials of Experiment 2 (including sentences and comprehension questions of Subexperiments 2A and 2B) is provided in Appendix 2.

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Design and procedure

The same design and procedure of Subexperiment 1A were used in this subexperiment.

Both Subexperiments 2A and 2B were run in the same experimental session, with a short break between them. Participants were randomly assigned to one of the two subexperiments, and then performed the other one, with half of the participants following each order. The whole experimental session lasted about 45 minutes.

Results

Mean RTs to tones across the four experimental conditions are shown in Figure 3. Data points corrected by means of the procedure described in Experiment 1 amounted to only 2.18 percent. In addition, data from one participant and one item were removed from the analyses due to high number of errors or missing responses. Mean percentage of correct responses to comprehension questions of the remaining participants was 88.7, ranging from 75 to 100 percent across subjects.

RT data were subjected to a repeated measures ANOVA with subjects and items as random variables. There was a main effect of tone position, which was nonsignificant in the participants analysis $F_1(1, 18) = 2.878$, $p = .10$ and significant in the items analysis $F_2(1, 14) = 9.086$, $p = .009$. Reaction times to tones in N1 position were slower than to tones at N3 position, as shown in Figure 3. On the other hand, there was no effect of the type of structure $F_1(1, 18) = 0.942$, $p = .34$; $F_2(1, 14) = 1.446$, $p = .25$ nor of the interaction between type of structure and tone position $F_1(1, 18) = 0.938$, $p = .35$; $F_2(1, 14) = 2.574$, $p = .13$. Pairwise comparisons between RTs to tones at positions N1 and N3 yielded a non-significant difference in the embedded-PP condition ($t(14) = 1.778$, $p = .10$), and a significant difference in the coordinate-NP condition $t(14) = 2.974$, $p = .01$).

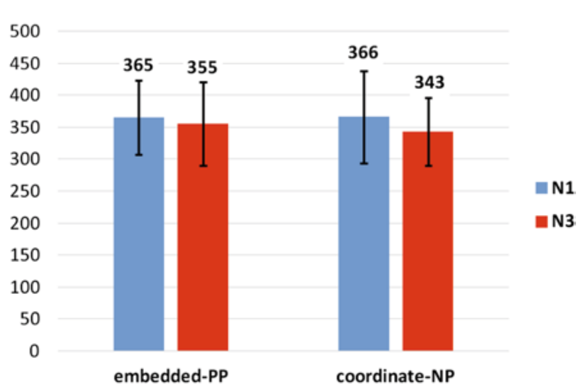

Figure 3. Mean reaction times (with error bars) to tones in sentences with embedded PPs and coordinate NPs within complex NPs in object position as a function of tone position.

Opposite to the results found in Subexperiment 1 with complex-NPs at subject position, when the NPs are located at object position distractor tones are harder to detect when placed in a hierarchically higher (or earlier) constituent. This effect, however, is weak in the case of NPs with embedded-PPs, when compared to NPs with coordinate-NPs. Recall that a crucial difference between parsing subject and object NPs is that the latter does not require to keep track of the head noun of the NP for agreement checking.

This pattern of results suggests that when listeners are faced with a post-verbal NP that can be assigned the object function in a simple transitive sentence, they need to allocate more attentional resources to recover the head of this NP, in order to build an adequate representation of the syntactic and thematic relations between subject, verb and object, and grasp the main idea conveyed by the sentence. Once this is accomplished, the constituents embedded within this object-NP (and branching to the right of its head) do not cause any additional strain on the listener's memory. In fact, as the current results show, processing load appears to diminish as the listener proceeds through deeper layers of the NP. Thus, it seems that when the listener is relieved of the task of retrieving a prior constituent during parsing –as it was the case in the subject-NP condition (Experiment 1)–, storage load effects are significantly reduced. To put it briefly, storage demands seem to be dependent on integration requirements.

Subexperiment 2B

Participants

The same twenty participants of Subexperiment 2A took part in this subexperiment.

Materials

The set of experimental and filler sentences used in Subexperiment 2A were modified by replacing the nouns in the complex NPs by the same phonotactically legal pseudo-nouns in Spanish used in Subexperiment 1B. The number and proportion of experimental and filler sentences, as well as the length of the items, were identical to those in Subexperiment 1A.

Sentences were digitally-recorded by the same male speaker as in the previous experiments, and tones were inserted in the same positions (N1 and N3, for experimental sentences, and N2 and N4 for the fillers). Two lists were composed for administration of this subexperiment.

Design and procedure

The design and procedure were identical to those of Subexperiment 2A. Comprehension questions were constructed in such a way as to be answerable with a 'Yes' or 'No' response.

Results

Mean reaction times to distractor tones in positions N1 and N3 are presented in Figure 4. A repeated measures ANOVA with participants and items as random variables produced the following results: (1) a main effect of tone position, that was significant in both participants and items analyses $F_1(1, 19) = 24.247$, $p = .001$; $F_2(1, 15) = 8.249$, $p = .012$, with longer RTs to tones located at N1 position; (2) no effect of the type of structure in either analysis $F_1(1, 19) = 0.016$, $p = .9$; $F_2(1, 15) = 0.022$, $p = .88$; and (3) a nonsignificant interaction of structure × tone position in both subjects analysis $F_1(1, 19) = 3.080$, $p = .09$, and items analysis $F_2(1, 15) = 1.618$, $p = .22$. Pairwise contrasts between RTs at N1 and N3 positions revealed a significant advantage of N1 over N3 tones in both conditions (for embedded PPs: $t(19) = 5.445$, $p = .001$; for coordinate NPs: $t(19) = 2.427$, $p = .025$). However, although the structure × tone position interaction was not significant, the N1-N3 difference was somewhat larger numerically in embedded-PPs than in coordinate NPs.

A similar pattern of results to that of the previous subexperiment emerged in this one, so the same conclusions may be drawn as regards the factors underlying the sensitivity of the parser to a distractor stimulus that stands in the way when processing an object NP. In the case of complex NPs (be they with embedded-PPs or coordinate-NPs) with no lexical content and located at the object position of a simple transitive sentence, processing demands are found to rise when encoding the first, hierarchically highest noun of the phrase. This purportedly shows that storage costs in parsing are substantially cut down when main syntactic relations have been established among the sentence constituents.

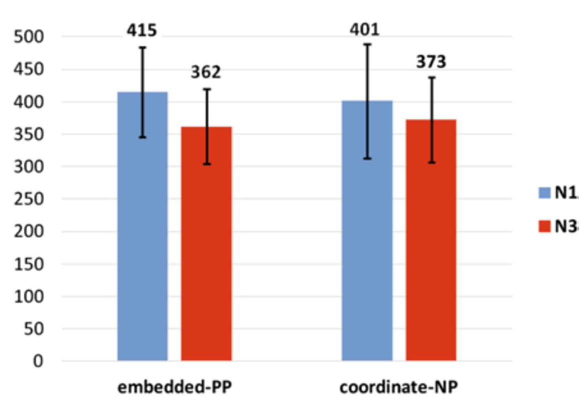

Figure 4. Mean reaction times (with error bars) to tones in sentences with embedded PPs and coordinate NPs with pseudowords, within complex NPs in object position, as a function of tone position.

As the current results indicate, this effect is enhanced when the object NP is made of pseudowords instead of meaningful words.

General Results

Taken together, the results of the two subexperiments comprising Experiment 2 provide an entirely different landscape of the parsing process underlying subject and object NPs to that shown by the results of Experiment 1. Whilst subject NPs with hierarchically embedded NPs show increased memory load as the parser delves deeper into the structure, with higher RTs to a distractor tone at N1 when compared to the same stimulus located at N3, object NPs exhibit the opposite pattern, with a reduction in processing complexity beyond the first constituent of the structure under analysis.

In order to substantiate this contrastive pattern of results, we carried out a joint statistical comparison of RTs of both experiments. We plotted response times to N1 vs. N3 tones as a function of the position of the complex NP (subject, in Experiment 1, vs. object, in Experiment 2), and performed two repeated measures ANOVA's with the data of both experiments, with participants and items as random factors: the first analysis was carried out with NPs comprising words, and the second with NPs made up of pseudowords. The results of these analyses are shown in Figures 5 (for NPs with words) and 6 (for NPs with pseudowords).

The two ANOVAs performed yielded the following significant effects: a main effect of the position of the target NP (subject vs. object), and an interaction between NP position and tone location (N1 vs. N3). As for the first effect, RTs were substantially faster in both analyses to tones in subject-NPs than to tones in object-NPs (51 ms in NPs with words –Experiment 1: $F_1(1, 37) = 12.081$, $p = .001$; $F_2(1, 29) = 161.029$, $p = .001$;

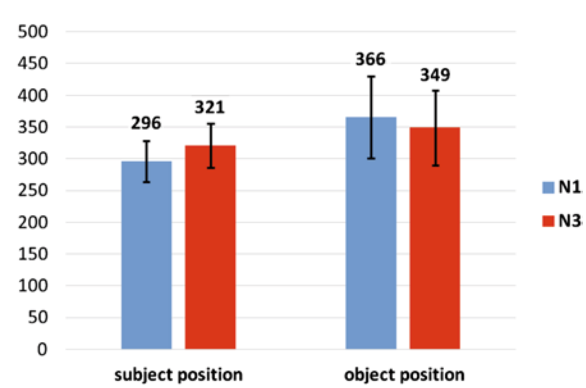

Figure 5. Mean reaction times (with error bars) to tones in sentences with complex NPs with words, as a function of NP position and tone position (N1 vs. N3).

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72 ms in NPs with pseudowords –Experiment 2: $F_1(1, 38) = 19.863$, $p = .001$; $F_2(1, 30) = 155.294$, $p = .001$).

If anything, we would have expected to find faster RTs with the object-NP materials (Experiment 2), given that the syntactic structure of the sentences in that experiment was simpler. However, our results square with previous data from a self-paced reading study by Gibson and colleagues (Gibson et al., 2005) with slightly different materials from ours –i.e., relative clauses modifying either the subject- or the object-NP of a sentence. Their results showed that reading times were slower for object-modifying than subject-modifying RCs, but only when the RC was restrictive. According to the authors, this surprising result follows from a combination of two facts: on the one hand, the fact that restrictive RCs convey background information, and on the other hand, the fact that background information is usually provided –and thus more easily understood– early in a sentence, as in subject-modifying RCs when compared to object-modifying RCs. Nevertheless, we should bear in mind that though the target materials (complex NPs) were identical in our two experiments, sentential contexts were different in each experiment, and each one was done by a different sample of participants.

As regards the interaction between NP-position and tone location, it was also significant in both participants and items analyses in NPs with words and with pseudowords (for NPs with words –Experiment 1: $F_1(1, 37) = 12.167$, $p = .001$; $F_2(1, 29) = 41.469$, $p = .0001$; for NPs with pseudowords –Experiment 2: $F_1(1, 38) = 43.519$, $p = .001$; $F_2(1, 30) = 22.113$, $p = .001$).

Another result that is worth noting is the disparity between the results of both experiments in terms of the variability of RTs to tones in NPs, that is, when comparing NPs at subject and object position, as shown by the error bars displayed in Figures 5 and 6. It is apparent that RTs to tones in NPs at object position (Experiment 2) are much more variable than to tones

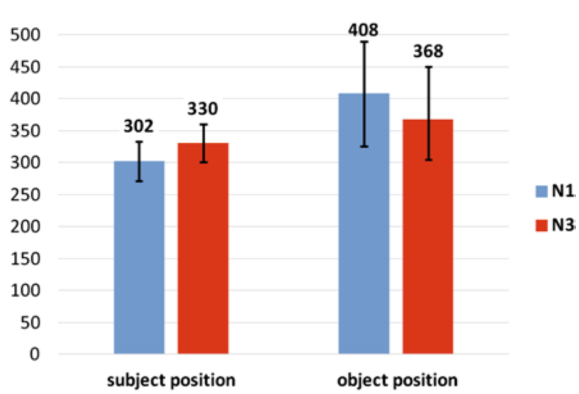

Figure 6. Mean reaction times (with error bars) to tones in sentences with complex NPs with pseudowords, as a function of NP position and tone position (N1 vs. N3).

in NPs at subject position (Experiment 1), irrespective of the location of the distractor tone in the NP (N1 or N3) and the lexical status of the items in NPs (words or pseudowords) (see error bars in Figures 1 through 4). This is presumably related to the consistently slower RTs found to tones in object NPs.

As shown in Figures 5 and 6, both for NPs with words and with pseudowords, RTs to N1 tones are faster than to N3 tones when the NP is in subject position, and slower when the NP is in object position. These analyses provide a statistical confirmation of the contrastive pattern of results across both experiments, and allow us to conclude that processing complex NPs in subject position impose greater demands on working memory as the parser proceeds down the hierarchy of constituents. In contrast, when the NPs are in object position, the parser seems not to be influenced by the increasing complexity of the NP under analysis. Thus, given that the structural configuration of the target structures examined in these two experiments was the same, the difference between them cannot be based on the hierarchical layout of the materials, but rather on the processing demands triggered by these structures in terms of deferred operations (or lack thereof).

Recent work using the 'click-detection' paradigm (Lobina et al., in press) has shown that in simple sentences of the form NP-V-NP, RTs in the detection of a tone tend to decrease along the sentence. According to the authors, these results can be explained by a combination of syntactic and perceptual effects. As the parser proceeds along the sentence, there is less material to process due to incrementality, and thus, fewer structural expectations to verify. Therefore, more resources can be devoted to performing the secondary task of click detection. In addition, processing costs are enhanced at earlier sentence positions due to perceptual uncertainty. Lobina et al. found converging evidence in an ERP experiment that yielded a sequential pattern of two components (N1 and P3), respectively associated with perceptual uncertainty and processing effort. At first blush, these results seem to contradict our current findings. However, it could be argued that the structural complexity of the materials in both studies goes in the opposite direction: in Lobina et al's study, complexity declines along the sentence, whilst in ours it increases within the critical complex NPs.

Discussion

The experiments reported in this paper have shown that listeners take more time to detect a distractor tone inserted within a complex NP in a sentence comprehension task, when the tone is located deeper in the structure, or at a later position within the NP, as compared to tones located at structurally higher (or earlier) positions, but *only when the complex NP is located at subject position* (Experiment 1). This effect appears to be syntactic in nature, since it also occurs in sentences made up of pseudowords (see Hahne & Jescheniak, 2001; Humphries, Binder, Medler, & Liebenthal, 2007; Hung & Hsieh, 2015; Yamada & Neville, 2007, as examples of previous studies using nonsense words with similar purposes). Furthermore, the opposite pattern of RTs was encountered when the tone was inserted in a complex NP at object position (Experiment 2). The combined pattern of results of the two experiments suggests that participants' sensitivity to distractor stimuli is bound to parsing operations in cases where the parser is processing hierarchically complex stimuli that require deferred operations, and not so much influenced by perceptual factors, such as the serial position of the distractor stimulus in the string. This is what characterizes the processing of subject NPs, as opposed to object NPs. The contrasting pattern of results found in sentences with complex subject- vs. object-NPs suggests that hierarchical structure (i.e., embeddedness) is perhaps a necessary, but not sufficient, condition to generate an increase in memory load as the parser goes about analyzing new constituents of the input string.

A possible account of these effects is that the attachment of an embedded PP (e.g., '*del camión*' in '*la rueda*$_{N1}$ *del remolque*$_{N2}$ *del camión*$_{N3}$' '*of the truck*' in '*the tire*$_{N1}$ *of the trailer*$_{N2}$ *of the truck*$_{N3}$') to the current NP –or DP,– (headed by '*la rueda*''*the tire*') at subject position entails an increase in processing costs associated to the computation of the current argument (i.e., the whole NP) by retrieving values that have been previously computed for a smaller argument, namely the complex NP/DP that has been parsed so far (i.e., '*la rueda del remolque*' '*the tire*$_{N1}$ *of the trailer*$_{N2}$'). By hypothesis, this kind of computation would ensue every time a new constituent is attached to the matrix constituent.

A similar line of reasoning may be followed to make sense of the pattern of response times to tones in the 'coordinate-NP' condition. The attachment of an incoming conjunct in complex coordinated NPs (e.g., '*(y) el freno*' in '*el cambio*$_{N1}$ *(y) el embrague*$_{N2}$ *(y) el freno*$_{N3}$' '*(and) the brakes*' in '*the gearbox*$_{N1}$ *(and) the clutch*$_{N2}$ *(and) the brakes*$_{N3}$') triggers the retrieval of the NP-conjuncts processed so far (i.e., values of the complex NP previously computed for smaller arguments).

The analysis of coordinate NPs we have just sketched rests on the assumption that these structures are similar to complex NPs with embedded PPs, both sharing an analogous hierarchical configuration. Given this structural similarity, we submit that the parser is subject to the same working memory constraints when processing both kinds of structures. Thus, the parser starts by encoding the first noun of the complex NP, and labeling it as subject of the subordinate clause, which sets off the expectation of a predicate. This expectation should remain in memory through the series of intervening constituents (PPs or NPs) that follow the first NP, until retrieval of the predicate is feasible. This brings about storage-load effects that are enhanced by the structural identity of the intervening constituents, thereby giving rise to a temporary interference that causes RTs to an extraneous tone to increase when the tone is located within one of the intervening phrases (e.g., at position N3). This account of the process is congruent with the assumptions of current parsing models that attribute a significant role to working memory in sentence processing, either as a result of storage and integration processes (Gibson, 1998; 2000), or by virtue of interference effects (Lewis & Vasishth, 2005; Lewis et al., 2006; Van Dyke & Lewis, 2003). However, in their current form, neither of these models seems capable of providing a clear account of the processing load effects obtained in our study.

Whatever difference may lie between the two structures tested in our experiments, such difference did not result in any significant variation in our reaction-time data. This could be due to a lack of sensitivity of RT measures in the tone-monitoring task to this nuanced difference, or to a bias introduced by the comprehension questions used in our experiments. These questions queried about some particular fact or feature of one of the four nouns in the sequence of NPs/PPs disclosed in the predicate (see questions in Appendices 1 and 2), which might have encouraged participants to retain all four nouns of the complex NPs in our experiments.

Accordingly, the evidence provided by our experiments shows that a series of phrases of the same kind embedded within a subject NP cause a similar strain on working memory when parsing embedded PPs within an NP and coordinate NPs, and this effect appears to be purely syntactic. In this regard, we may draw the following conclusions: (1) the pattern of reaction times to tones inserted in complex syntactic structures of the kind used in our experiments suggests that memory load increases as embedded or coordinated constituents accumulate in the course of processing; (2) this may be taken as an indication that the parser is keeping track of encoded constituents so as to perform deferred syntactic operations, like subject-verb agreement, at a later processing stage. A more fine-grained account of the underlying processes –for instance, to figure out whether processing of material in the storage interval is more liable to storage-load or to interference effects, or testing whether or not parsing a given type of structure actually involves carrying out deferred operations– would require more sensitive tasks and materials, so as to provide a more comprehensive picture of the incremental processing of complex phrases in sentence understanding.

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APPENDIX 1: LIST OF MATERIALS USED IN EXPERIMENT 1

SUBEXPERIMENT 1A

1.1. Embedded-PPs: List of experimental and filler sentences used in Subexperiment 1A, including comprehension questions and their correct answers.

EXPERIMENTAL SENTENCES

1. Alguien dijo que los bichos de las hojas de las plantas de la terraza estaban muertos.
2. María vio que las agujas del reloj de la fachada de la iglesia estaban rotas.
3. Me pareció que los dibujos del comic de la revista del domingo eran muy graciosos.
   Question: ¿La revista sale los lunes? NO
4. El maestro vio que los cajones del pupitre del alumno de la escuela estaban llenos.
5. La gente dice que las flores del jardín de la posada de la aldea son preciosas.
6. Todos dicen que las fotos de la portada de la revista del quiosco son muy buenas.
   Question: ¿Son buenas las fotos? YES
7. El conductor vio que la rueda del remolque del camión de las mudanzas estaba pinchada.
8. La gente decía que las letras del cartel de la fachada del almacén eran feas.
9. Ayer supimos que las grietas del cristal del mirador del salón eran muy grandes.
10. El cura anunció que las campanas de la torre de la parroquia del valle estaban viejas.
11. La prensa anunció que las tumbas de la cripta de la catedral de la villa sufrieron daños.
12. El mozo vio que los cojines del sofá del vestíbulo del albergue estaban sucios.
    Question: ¿Estaban limpios los cojines? NO
13. Me han dicho que las llaves del portero de la finca del duque han desaparecido.
14. Hemos visto que los dibujos del cuaderno de la sobrina del pintor eran muy bonitos.
15. La prensa opina que los discursos del líder del partido de la oposición son muy persuasivos.
16. Acabo de ver que la tapa del baúl de los vestidos de la actriz está abierta.

FILLER SENTENCES

1. El mecánico vio que la hélice del motor estaba estropeada
2. El corrector dijo que los párrafos del capítulo eran demasiado largos
   Question: ¿Eran largos los párrafos? YES
3. La modista cree que los botones del abrigo son demasiado grandes
4. La prensa opina que la insignia del equipo está anticuada
5. No nos gusta que las fotos del libro estén en blanco y negro
6. Hemos comprobado que las sillas del estudio son comodísimas
   Question: ¿Las sillas estaban en la cocina? NO
7. Los vecinos dicen que los ladridos del perro no les dejan dormir
8. Me parece que los lazos del vestido son muy vistosos
9. He comprobado que las bombillas de la lámpara están fundidas
   Question: ¿Están fundidas las bombillas? YES
10. El cajero vio que los números de la cuenta estaban equivocados
11. Mi madre ha visto que los marcos de los espejos del tocador de su cuarto están rotos
12. Nos desagrada que la luz de las farolas de las plazas de la ciudad sea amarilla

1.2. Coordinate-NPs: List of experimental and filler sentences used in Subexperiment 1A, including comprehension questions and their correct answers.

EXPERIMENTAL SENTENCES

1. Alguien dijo que los mosquitos, las moscas, las hormigas y la araña estaban muertos.
2. María vio que la mesilla, el armario, la butaca y la estufa estaban rotos.
3. Me pareció que el título, la trama los diálogos y los chistes eran muy graciosos.
4. El maestro vio que los tubos, la vasija, el bidón y la garrafa estaban llenos.
   Question: ¿El bidón estaba lleno? YES
5. La gente dice que la blusa, el abrigo, la chaqueta y la bufanda son preciosos.
6. Todos dicen que el guión, la dirección, los actores y la música son muy buenos.
7. El mecánico vio que el cambio, el embrague, el freno y las llantas estaban estropeados.
   Question: ¿Estaba estropeado el volante? NO
8. La gente decía que las sobrinas, el yerno, la abuela y el suegro eran feos.
9. Los niños creen que las motos, los camiones, los trenes y los aviones son muy grandes.
10. El alcalde anunció que las alfombras, las cortinas los tapices y el telón estaban viejos.
11. La prensa decía que los tejados, las cornisas, las fachadas y los muros sufrieron daños.
12. La camarera vio que las botellas los vasos los platos y los cubiertos estaban sucios.
13. Me han dicho que las joyas los relojes, las tarjetas y las monedas han desaparecido.
14. Hemos visto que los cuadros los carteles, las fotos y los dibujos eran muy bonitos.
    Question: ¿Eran bonitos los carteles? YES
15. Acaban de decirme que los museos los colegios, las tiendas y los bancos están abiertos.
16. La prensa opina que la novela, el documental, el reportaje y la película son muy persuasivos.

FILLER SENTENCES

1. El mecánico vio que la palanca y el muelle estaban estropeados.
2. El corrector dijo que los párrafos y los títulos eran demasiado, largos.
3. La modista cree que los vestidos y el abrigo son demasiado grandes.
4. La prensa opina que la foto y el comentario están anticuados.
5. Mi madre ha visto que los vasos y la cafetera están rotos.
   Question: ¿Están rotos los platos? NO
6. Nos desagrada que la luz y las plantas sean amarillas.
7. Los vecinos dicen que los ruidos y las voces no les dejan dormir.
   Question: ¿Duermen bien los vecinos? YES
8. Me parece que los sombreros y el traje son muy vistosos.
9. He comprobado que la lámpara y la linterna están fundidas.
10. El bailarín notó que los adornos y los flecos se habían desprendido.
    Question: ¿Los adornos y los flecos estaban bien sujetos? NO
11. No nos gusta que los carteles, los anuncios, las fotos y la película estén en blanco y negro.
12. El sastre ha dicho que los tejidos, las telas, el forro y los hilos son muy bastos.

SUBEXPERIMENT 1B

1.3. Embedded-PPs: List of experimental and filler sentences used in Subexperiment 1B, including comprehension questions and their correct answers.

EXPERIMENTAL SENTENCES

1. Alguien dijo que los flachos de las plondas de las busas de la gramera estaban muertos.
2. María vio que las obrijas del gafor de la blesaca de la ironda estaban rotas.
3. Me pareció que las nobesas del brucio de la filoca del petiso eran muy graciosas.
   Question: ¿El petiso era muy gracioso? NO
4. El maestro vio que los gadones del palojo del chibre de la gurtana estaban llenos.
5. La gente dice que las clotas del terín de la rufa del perismo son preciosas.
6. Todos dicen que las bolnas de la garufa de la inofa del buralo son muy buenas.
   Question: ¿Son buenas las bolnas? YES
7. El conductor vio que la mita del frolador del fustio de las gabrinas estaba pinchada.
8. La gente decía que las manigas del opalio de la mátira del gurto eran feas.
9. Ayer vimos que las logas del nordal de la namira del nofón eran muy grandes.
10. El alcalde anunció que las calonas de la tusa de la onubia del plandro estaban viejas.
11. La prensa anunció que las fanelas de la crasta de la mirta de la pasila sufrieron daños.
12. El mozo vio que los algubios del ferno del trafo del lozal estaban sucios.
    Question: ¿Estaba sucio el ferno? NO
13. Me han dicho que las afintas del glador de la tustia del fano han desaparecido.
14. Hemos visto que los facucios del atiso de la rodia del bredo eran muy bonitos.
15. Acabo de ver que la chada del fanul de los fonastos del mador está abierta.
16. La prensa opina que los trafonos del greno del púndido de la farnición son muy persuasivos.

FILLER SENTENCES

1. El mecánico vio que la fímula del bosto estaba estropeada.
2. El corrector dijo que los sárulos del canístico eran demasiado largos.
   Question: ¿Eran largos los sárulos? YES
3. La modista cree que los falones del namido son demasiado grandes.
4. La prensa opina que la ustania del aropo está anticuada.
5. No nos gusta que las mufas del nucio estén en blanco y negro.
6. Hemos comprobado que las runcas del histolio son comodísimas.
   Question: ¿Las runcas eran incómodas? NO
7. Los vecinos dicen que los gulidos del crasto no les dejan dormir.
8. Me parece que los canos del banisto son muy vistosos.
9. He comprobado que las barundas de la sánida están fundidas.
   Question: ¿Están fundidas las barundas? YES
10. El cajero vio que los manecos de la turma estaban equivocados.
11. Mi madre ha visto que los murtos del brúnido del ranelor del crambo están rotos.
12. Nos desagrada que la calia de las traconas de las plaudas de las curatas sea amarilla.

1.4. Coordinate-NPs: List of experimental and filler sentences used in Subexperiment 1B, including comprehension questions and their correct answers.

EXPERIMENTAL SENTENCES

1. Alguien dijo que los flachos, las plondas, las busas y la gramera estaban muertos.
2. María vio que las obrijas, el gafor, la blesaca y la ironda estaban rotos.
3. Me pareció que las nobesas, el brucio, la filoca y el petiso eran muy graciosos.
4. El maestro vio que los gadones, el palojo, el chibre y la gurtana estaban llenos.
   Question: ¿El palojo estaba lleno? YES
5. La gente dice que las clotas, el terín, la rufa y el perismo son preciosos.
6. Todos dicen que las bolnas, la garufa, la inofa y el buralo son muy buenos.
7. El conductor vio que la mita, el frolador, el fustio y las gabrinas estaban estropeados.
   Question: ¿Estaba bien el frolador? NO
8. La gente decía que las manigas, el opalio, la mátira y el glurto eran feos.
9. Ayer vimos que las logas, el nordal, la namira y el nofón eran muy grandes.
10. El alcalde anunció que las calonas, la tusa, la onubia y el plandro estaban viejos.
11. La prensa anunció que las fanelas, la crasta, la mirta y la pasila sufrieron daños.
12. La camarera vio que las algubias, la ferna, el trafo y el lozal estaban sucios.
13. Me han dicho que las afintas, el glador, la tustia y el fano han desaparecido.
14. Hemos visto que los facucios, el atiso, la rodia y el bredo eran muy bonitos.
    Question: ¿Era bonito el atiso? YES
15. Acabo ver que la chada, el fanul, los fonastos y el mador están abiertos.
16. La prensa opina que la nucia, el trofano, el retolano y el greno son muy persuasivos.

FILLER SENTENCES

1. El mecánico vio que la fímula y el bosto estaban estropeados.
2. El corrector dijo que los sárulos y el canístico eran demasiado largos.
3. La modista cree que los falones y el namido son demasiado grandes.
4. La prensa opina que la ustania y el aropo están anticuados.
5. Mi madre ha visto que los astajos y el ranelor están rotos.
   Question: ¿Los astajos están enteros? NO
6. Nos desagrada que la calia y las traconas sean amarillas.
7. Los vecinos dicen que los gulidos y el crasto no les dejan dormir.
   Question: ¿Los gulidos les molestan? YES
8. Me parece que los canos y el banisto son muy vistosos.
9. He comprobado que las barundas y la sánida están fundidas.
10. El bailarín notó que las franas y el bosardo se habían desprendido.
    Question: ¿Las franas y el bosardo estaban bien sujetos? NO
11. No nos gusta que los foranes, los camunos, las mufas y el nulio estén en blanco y negro.
12. El sastre ha dicho que los lumidos, las palacas, el findo y los fanes son muy bastos.

APPENDIX 2: LIST OF MATERIALS USED IN EXPERIMENT 2

SUBEXPERIMENT 2A

1.1. Embedded-PPs: List of experimental and filler sentences used in Subexperiment 2A, including comprehension questions and their correct answers.

EXPERIMENTAL SENTENCES

1. Hemos eliminado los bichos de las hojas de las plantas de la terraza.
2. Por fin han arreglado las agujas del reloj de la fachada de la iglesia.
3. Alguien ha ensuciado los dibujos del comic de la revista del domingo.
   Question: ¿La revista sale los lunes? NO
4. Han estado reparando los cajones del pupitre del alumno de la escuela.
5. Unos gamberros han cortado las flores del jardín de la posada de la aldea.
6. La gente miraba las fotos de la portada de la revista del quiosco.
   Question: ¿Han visto las fotos? YES
7. El conductor cambió la rueda del remolque del camión de las mudanzas.
8. Un pintor ha diseñado las letras del cartel de la fachada del almacén.
9. Hay que arreglar las grietas del cristal del mirador del salón.
10. Van a cambiar las campanas de la torre de la parroquia del valle.
11. Hemos visitado las tumbas de la cripta de la catedral de la villa.
12. El mozo estuvo limpiando los cojines del sofá del vestíbulo del albergue.
    Question: ¿Estaban rotos los cojines? NO
13. Alguien ha robado las llaves del portero de la finca del duque.
14. Los alumnos retocaron los dibujos del cuaderno de la sobrina del pintor.
15. La prensa ensalzó los discursos del líder del partido de la oposición.
16. Un carpintero ha colocado la tapa del baúl de los vestidos de la actriz.

FILLER SENTENCES

1. El mecánico ha desmontado la hélice del motor.
2. El corrector revisó los párrafos del capítulo.
   Question: ¿Han revisado los párrafos? YES
3. La modista descosió los botones del abrigo.
4. El presidente cambió la insignia del equipo.
5. Todo el mundo ha elogiado las fotos del libro.
6. Hemos vendido las sillas del comedor.
   Question: ¿Las sillas estaban en la cocina? NO
7. Los niños grabaron los ladridos del perro.
8. La niña arrancó los lazos del vestido.
9. Hay que cambiar las bombillas de la lámpara.
   Question: ¿Necesitamos nuevas bombillas? YES
10. El cajero vio que los números de la cuenta estaban equivocados
11. Mi madre ha visto que los marcos de los espejos del tocador de su cuarto están rotos
12. Nos desagrada que la luz de las farolas de las plazas de la ciudad sea amarilla

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1.2. Coordinate-NPs: List of experimental and filler sentences used in Subexperiment 2A, including comprehension questions and their correct answers.

EXPERIMENTAL SENTENCES

1. El insecticida aniquiló los mosquitos, las moscas, las hormigas y las arañas.
2. Ya hemos comprado la mesilla, el armario, la butaca y la estufa.
3. Los críticos elogiaron el título, la trama, los diálogos y los chistes.
4. Hay que fregar los tubos, la vasija, el bidón y la garrafa.
   Question: ¿Hay que fregar el bidón? YES
5. He llevado al tinte la blusa, el abrigo, la chaqueta y la bufanda.
6. La prensa criticó el guion, la dirección, los actores y la música.
7. El mecánico ha arreglado el cambio, el embrague, el freno y las llantas.
   Question: ¿Han arreglado el volante? NO
8. Hemos visitado a las sobrinas, el yerno, la abuela y el suegro.
9. Los niños dibujaron las motos, los camiones, los trenes y los aviones.
10. Unos operarios han recogido las alfombras, las cortinas los tapices y el telón.
11. Los albañiles repararon los tejados, las cornisas, las fachadas y los muros.
12. El camarero guardó las botellas, los vasos, los platos y los cubiertos.
13. Los ladrones robaron las joyas los relojes, las tarjetas y las monedas.
14. Todo el mundo admira los cuadros los carteles, las fotos y los dibujos.
    Question: ¿Eran apreciados los carteles? YES
15. Aún no han abierto los museos, los colegios, las tiendas y los bancos.
16. La prensa elogió la novela, el documental, el reportaje y la película.

FILLER SENTENCES

1. El mecánico arregló la palanca y el muelle.
2. El corrector revisó los párrafos y los títulos.
3. La modista zurció los vestidos y el abrigo.
4. La prensa manipuló la foto y el comentario.
5. Mi madre ha fregado los vasos y la cafetera.
   Question: ¿Están sucios los vasos ahora? NO
6. Nos agradan la luz y las plantas.
7. Hemos suprimido los ruidos y las voces.
   Question: ¿Se han escuchado voces? YES
8. Tengo que renovar los sombreros y el traje.
9. El niño encendió la lámpara y la linterna.
10. El modisto cambió los adornos y los flecos.
    Question: ¿Los adornos siguen en su sitio? NO
11. Aún no hemos recibido los carteles, los anuncios, las fotos y la película.
12. El sastre conservó los tejidos, las telas, el forro y los hilos.

SUBEXPERIMENT 2B

1.3. Embedded-PPs: List of experimental and filler sentences used in Subexperiment 2B, including comprehension questions and their correct answers.

EXPERIMENTAL SENTENCES

1. Hemos eliminado los flachos de las plondas de las busas de la gramera.
2. Por fin han arreglado las obrijas del gafor de la blesaca de la ironda.
3. Alguien ha ensuciado las nobesas del brucio de la filoca del petiso.
   Question: ¿El petiso fue censurado? NO
4. Han estado reparando los gadones del palojo del chibre de la gurtana.
5. Unos gamberros han cortado las clotas del terín de la rufa del perismo.
6. La gente miraba las bolnas de la garufa de la inofa del buralo.
   Question: ¿Han visto las bolnas? YES
7. El conductor cambió la mita del frolador del fustio de las gabrinas.
8. Un pintor ha diseñado las manigas del opalio de la mátira del gurto.
9. Hay que arreglar las logas del nordal de la namira del nofón.
10. Van a cambiar las calonas de la tusa de la onubia del plandro.
11. Hemos visitado las fanelas de la crasta de la mirta de la pasila.
12. El mozo estuvo limpiando los algubios del ferno del trafo del lozal.
    Question: ¿Estaba roto el ferno? NO
13. Alguien ha robado las afintas del glador de la tustia del fano.
14. Los alumnos retocaron los facucios del atiso de la rodia del bredo.
15. La prensa ensalzó la chada del fanul de los fonastos del mador.
16. Un carpintero ha colocado los trafonos del greno del púndido de la farnición.

FILLER SENTENCES

1. El mecánico ha desmontado la fímula del bosto.
2. El corrector revisó los sárulos del canístico.
   Question: ¿Han revisado los sárulos? YES
3. La modista descosió los falones del namido.
4. El presidente cambió la ustania del aropo.
5. Todo el mundo ha elogiado las mufas del nucio.
6. Hemos vendido las runcas del histolio.
   Question: ¿Hemos comprado las runcas? NO
7. Los niños grabaron los gulidos del crasto.
8. La niña arrancó los canos del banisto.
9. Hay que cambiar las barundas de la sánida.
   Question: ¿Necesitamos nuevas barundas? YES
10. El cajero anotó los manecos de la turma.
11. Mi madre ha limpiado los murtos del brúnido del ranelor del crambo.
12. El ayuntamiento ha encendido la calia de las traconas de las plaudas de las curatas.

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1.4. Coordinate-NPs: List of experimental and filler sentences used in Subexperiment 2B, including comprehension questions and their correct answers.

EXPERIMENTAL SENTENCES

1. El insecticida aniquiló los flachos, las plondas, las busas y la gramera.
2. Ya hemos comprado las obrijas, el gafor, la blesaca y la ironda.
3. Los críticos elogiaron las nobesas, el brucio, la filoca y el petiso.
4. Hay que fregar los gadones, el palojo, el chibre y la gurtana.
   Question: ¿Hay que fregar el palojo? YES
5. He llevado al tinte las clotas, el terín, la rufa y el perismo.
6. La prensa criticó las bolnas, la garufa, la inofa y el buralo.
7. El mecánico ha arreglado la mita, el frolador, el fustio y las gabrinas.
   Question: ¿Estaba bien el frolador? NO
8. Hemos visitado las manigas, el opalio, la mátira y el glurto.
9. Los niños dibujaron las logas, el nordal, la namira y el nofón.
10. Unos operarios han recogido las calonas, la tusa, la onubia y el plandro.
11. Los albañiles repararon las fanelas, la crasta, la mirta y la pasila.
12. El camarero guardó las algubias, la ferna, el trafo y el lozal.
13. Los ladrones robaron las afintas, el glador, la tustia y el fano.
14. Todo el mundo admira los facucios, el atiso, la rodia y el bredo.
    Question: ¿Era admirado el atiso? YES
15. Aún no han abierto la chada, el fanul, los fonastos y el mador.
16. La prensa elogió la nucia, el trofano, el retolano y el greno.

FILLER SENTENCES

1. El mecánico arregló la fímula y el bosto.
2. El corrector revisó los sárulos y el canístico.
3. La modista zurció los falones y el namido.
4. La prensa manipuló la ustania y el aropo.
5. Mi madre ha fregado los astajos y el ranelor.
   Question: ¿Los astajos están sucios ahora? NO
6. Nos agradan la calia y las traconas.
7. Hemos suprimido los gulidos y el crasto.
   Question: ¿El crasto se oía? YES
8. Tengo que renovar los canos y el banisto.
9. El niño encendió las barundas y la sánida.
10. El modisto cambió las franas y el bosardo.
    Question: ¿Las franas y el bosardo quedaron en su sitio? NO
11. Aún no hemos recibido los foranes, los camunos, las mufas y el nulio.
12. El sastre conservó los lumidos, las palacas, el findo y los fanes.