ABSTRACT

Title of Document: STRUCTURAL AND SEMANTIC SELECTIVITY IN THE ELECTROPHYSIOLOGY OF SENTENCE COMPREHENSION

Clare Margaret Anne Stroud
Doctor of Philosophy, 2008

Directed By: Professor Colin Phillips
Department of Linguistics

This dissertation is concerned with whether the sentence processor can compute plausible relations among a cluster of neighboring open class words without taking into account the relationships between these words as dictated by the structure of the sentence. It has been widely assumed that compositional semantics is built on top of syntactic structures (Heim & Kratzer, 1998; Pollard & Sag, 1994). This view has been challenged by recent electrophysiological findings (Kim and Osterhout, 2005; Kuperberg, 2007; van Herten et al., 2005, 2006) that appear to show that semantic composition can proceed independently of syntactic structure. This dissertation investigates whether the evidence for independent semantic composition is as strong and widespread as has been previously claimed.

Recent studies have shown that sentences containing a semantically anomalous interpretation but an unambiguous, grammatical structure (e.g., *The meal was devouring…*) elicit a P600 response, the component classically elicited by syntactic anomalies, rather than an N400, the component typically elicited by semantic anomalies (Kim and Osterhout, 2005). This has been interpreted as evidence that the processor analyzed *meal* as a good theme for *devour*, even though this interpretation is not supported by the sentential structure. This led to the claim that semantic composition can proceed independently of syntactic structure.

Two event-related potentials (ERP) studies investigated whether the processor exploits prior structural biases and commitments to restrict semantic interpretations to those that are compatible with that expected structure. A further ERP study and a review of relevant studies reveal that in the majority of studies the P600 is not modulated by manipulations of thematic fit or semantic association between the open class words. We argue that a large number of studies that have been taken as evidence for an independent semantic processing stream can be explained as violations of the verb's requirement that its subject be agentive. A small number of studies in verb-final languages cannot be explained in this way, and may be evidence of independent semantic composition, although further experimental work is needed. We conclude that the evidence for independent semantic composition is not as extensive as was previously thought.

STRUCTURAL AND SEMANTIC SELECTIVITY IN THE ELECTROPHYSIOLOGY OF SENTENCE COMPREHENSION

By

Clare Margaret Anne Stroud

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2008

Advisory Committee:
Professor Colin Phillips, Chair
Professor Norbert Hornstein
Associate Professor Gina Kuperberg
Professor David Poeppel
Associate Professor Nan Jiang, Dean's Representative

Dedication

I dedicate this dissertation to my father, John Denman Stroud.

Acknowledgements

First and foremost, I would like to thank Colin Phillips. Over the past five years, Colin has been an inspiration to me because of his passion for his work and his dedication to the advancement of the program, the field, and the people surrounding him. Without his considerable support, patience, and guidance, this project would not have been completed.

I would like to thank David Poeppel for his support, and for the many pep talks he has given me, often in airport lounges while waiting for delayed flights. I would like to thank Norbert Hornstein for his enthusiasm for linguistics, the department, and life in general. I would also like to thank the other members of my committee, Gina Kuperberg and Nan Jiang, for their time, patience, and helpful comments.

In particular I am grateful to Ellen Lau. Ellen has been my office mate, collaborator, co-campaigner, and good friend. As we now disperse to different parts of the country, I am thankful for the friendships of several other people who also arrived in Maryland at around the same time as me, including Matt Wagers, Jon Sprouse, Diogo Almeida, Phil Monahan and Eri Takahashi. These last five years would not have been the same without the community of graduate students in the department and in the lab.

I would like to acknowledge the many people who have contributed to my experimental work over the last several years. I have benefited immensely from Brian Dillon's technical expertise and his willingness to share it with me. I would also like to thank the following people for their help with designing materials and running experiments, including Dave Kush, Shannon Hoerner, Annie Gagliardi, Pedro Alcocer, Adina Rubinoff, Christina Kim, Allison Austin, Leticia Pablos, Iván Ortega Santos, Laura Fuentes, and Antonia Carrasco.

I would like to thank the Social Sciences and Humanities Research Council of Canada and the Alberta Government for their generous support.

Finally, I am grateful for the people who have been my greatest source of strength during the doctoral program as well as in life in general: my parents, John and Martha Stroud, my sister, Julia Stroud, and, of course, Spencer Boyer.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction and background

1.1 Introduction

It has been widely assumed in psycholinguistics that there is a tight coupling of semantic and syntactic composition. Furthermore, semantic composition is generally thought to be parasitic on the computation of syntactic structure. In other words, when an incoming word is encountered, syntactic information is used first to fit the word into the current structure, and then the semantic contribution of that word is added to the representation based on the syntactic role it has been assigned. This view has been challenged by recent electrophysiological findings from a number of labs (starting with: Kuperberg et al. 2003; Kolk et al., 2003; Hoeks et al., 2004; Kim & Osterhout, 2005) that have been taken to show that semantic composition can proceed independently of syntactic structure.

These studies have shown that certain classes of sentences with semantically anomalous interpretations but unambiguously grammatical structures elicit a P600 response, the component classically elicited by syntactic anomalies, rather than an N400, the component typically elicited by semantic anomalies. For example, Kim & Osterhout (2005) recorded a P600 at the verb in sentences such as *The hearty meal was devouring….* In this sentence, *hearty meal* is unambiguously the subject of an active sentence, and because *hearty meals* do not devour things, we might have

expected the processor to consider this sentence to be semantically anomalous. Therefore, we might have expected an N400, the response typically associated with the detection of a semantic anomaly. The fact that these sentences elicit a P600 instead of an N400 has been taken as evidence that the processor recognizes that *hearty meal* makes a good theme but a poor agent for *devour*, despite the fact that the structure of the sentence does not license this interpretation. Although current accounts of this phenomenon (Kim & Osterhout, 2005; Kuperberg, 2007; van Herten et al., 2005, 2006; Bornkessel-Schlesewsky & Schlesewsky, 2008) disagree about what exactly the P600 reflects, they fundamentally argue that it arises when there is an inconsistency between the relations dictated by the structure (*hearty meal* is in the subject position of an active sentence) and the most plausible relations between the open class words based only on the word meanings (*hearty meal* should be the theme of *devour*). These accounts argue that the only way that the processor can be aware that this inconsistency exists is if it can ignore the structure of the sentence, at least temporarily, to evaluate the most plausible relations between neighboring open class words.

This line of reasoning has important potential consequences for psycholinguistic processing models. Evidence that the processor can ignore structural information would require the revision of models for the comprehension of unambiguous sentences which claim that the semantic combination of words can only take place in the manner dictated by the structure (e.g. Ferreira & Clifton, 1986; Frazier & Clifton, 1996). Even proponents of constraint-based models (e.g.,

MacDonald et al., 1994; Trueswell et al., 1994), in which semantic information plays a larger role in processing, typically assume that semantic information only affects the choice of analysis when the syntax is ambiguous. More generally, the existence of an independent semantic composition mechanism that works in parallel to a syntactic mechanism implies that multiple analyses are being considered for a single perceptual input. This would be a fundamental change relative to current psycholinguistic theories. Because the stakes are so high, it is important to carefully examine whether the evidence for a "semantic processing stream" is as strong and widespread as has been assumed.

The debate about the independence of semantic composition in processing models sounds similar to a current debate in theoretical models of the grammar. Traditional models of semantic composition have typically assumed a tight link between semantic and syntactic composition (e.g., Heim & Kratzer, 1998; Pollard & Sag, 1994). A recent proposal by Jackendoff (2002) argues for the replacement of a "syntactocentric" model with a "tripartite parallel architecture" in which combinatorial processing systems for syntax, semantics and phonology work in parallel. However, the ERP experiments that are being used to inform the processing debate about independent semantic composition involve testing whether the processor recognizes plausible relations between nearby open class words. "Plausibility" is not a concept in theoretical semantics, and in the experimental work plausibility manipulations are used primarily as a means of detecting whether the processor considers multiple analyses for a single sentence. Therefore, it is unclear the extent to

which these experimental results speak to the debate about independent semantic composition in theoretical models of grammar.

In this introductory chapter, I first briefly review the traditional interpretations of the N400 and P600 effects, and then the initial four studies that appeared to challenge the familiar N400/P600 split and have been taken as evidence for independent semantic composition. Following that, I identify a line of argumentation that underlies the four current accounts of the set of thematic P600 results (Kim & Osterhout, 2005; Kuperberg, 2007; van Herten et al., 2005, 2006; Bornkessel-Schlesewsky & Schlesewsky, 2008). The authors of these accounts have noted that although some of the thematic P600 studies may be explained by appealing to traditional notions of syntactic violation, this kind of explanation does not cover the results of every thematic P600 study. The authors of these accounts have therefore argued in favor of a sentence processing model that incorporates a semantic composition mechanism that operates across all processing situations, and plays a role in the generation of all thematic P600 responses, including those that might have otherwise been accounted for as a traditional syntactic violation. In Sections 2.1-2.5 I briefly describe each of the current accounts of the thematic P600 in turn, and then describe the common points of agreement as well as the characteristics that distinguish the accounts. Finally, I present the approach to accounting for the thematic P600 results that I take in this dissertation. I argue that although it is of course generally preferable to provide a single account for the largest possible set of results, there are downsides to taking this approach with the thematic P600 studies.

Firstly, the situations that elicit a thematic P600 appear to show a high level of variability, and the set of results can be quite confusing. A detail-oriented approach to describing this set of results, such as Kuperberg (2007), reveals six different factors that appear to impact the elicitation of a thematic P600, but the account lacks the ability to predict the result for a given sentence. In contrast, a more general approach such as the one taken by van Herten, Kolk and colleagues is able to account for a large number of results, but at the expense of detailed specification of the representations that the processor functions over (van Herten et al., 2005, 2006). I argue that an underlying factor behind the apparent variability and the difficulty in stating eliciting factors in categorical rather than probabilistic terms has arisen because the accounts have considered as homogeneous a large number of studies that in fact comprise a heterogeneous set of processing situations. The approach I take in this dissertation is to attempt to identify consistent patterns in the set of results by moving in the opposite direction of the other accounts. I claim that by examining different subsets of the studies separately, it is possible to identify areas of consistency across the results. This approach allows for clear identification of the studies that can be accounted for under the traditional umbrella of syntactic violation, and highlights those studies that are difficult to explain without either a significant alteration of the sentence processing model or of our theory of the linguistic process(es) reflected by the P600. In the final sections of this chapter, I outline the rest of the dissertation and discuss my assumptions regarding the interpretation of the N400 and its implications for interpreting the thematic P600 results.

1.1.1 Standard interpretations of the N400 and P600 effects

Prior to the discovery of the thematic P600 results, the N400 and the P600 appeared to correlate exactly with the distinction between semantic and syntactic processing. The N400 was seen as the response to a semantic anomaly or to a word that was harder to integrate semantically into its context, and the P600 was seen as the response to a syntactic violation or to increased processing required to parse a complex sentence.

Kutas and Hillyard (1980) were the first to report an ERP component that is sensitive to manipulations of semantic information. They compared incongruous sentence-final words with congruous controls (*He spread the warm bread with socks/butter*) and found a negative-going component with a higher amplitude for the incongruous word relative to the congruous word. This negative-going wave peaked at about 400 ms after the critical word, and the effect became known as the N400. In subsequent studies, it became clear that the N400 effect was not confined to sentence-final position but has also been elicited to sentence-medial anomalies (Kutas & Hillyard, 1983). Furthermore, it was determined that the N400 was not just found to anomalous words but rather is a natural response to every open-class word (Kutas, Van Petten & Besson, 1988; Van Petten & Kutas 1990). It has since become clear that the N400 is not just sensitive to semantic anomaly, but rather to a variety of manipulations of semantic information within a sentential or discourse context. The N400 effect is found when the word is congruous but unpredictable (Kutas & Hillyard, 1984), when the word is congruous but not consistent with expectations

based on world knowledge (Hagoort et al., 2004), and when the word is locally congruous but incongruent with the larger discourse (van Berkum et al., 1999). Furthermore, the N400 is also sensitive to the organization of words within semantic memory (for a review, see Kutas & Federmeier, 2000).

The P600, a large positive waveform peaking at about 600ms after the presentation of the critical word, was first reported by Osterhout and Holcomb (1992) in response to critical words that were incongruous with the expected syntactic structure in garden-path sentences such as *The broker persuaded **to** sell the stock was sent to jail*. Hagoort, Brown and Groothusen (2003) also reported this response to syntactic agreement violations and word order violations, and named the component the 'Syntactic Positive Shift', which is sometimes used as an alternate name for this component. Since then, this component has been elicited by a wide range of syntactic anomalies, including category and agreement violations (Friederici et al., 1993; Hagoort, Brown & Groothusen, 1993; Hahne & Friederici, 1999; Kaan, 2002), syntactic garden-paths (Friederici et al., 1996; Kaan & Swaab, 2003; Osterhout, Holcomb, & Swinney, 1994), and subcategorization violations (Friederici & Frisch, 2000; Osterhout & Holcomb, 1992). In recent years the P600 has also been elicited in well-formed sentences that require more processing than simple, canonical sentences. For example, the P600 has been elicited due to the presence of ambiguity (Frisch, Schlesewsky, Saddy, & Alpermann, 2002), as well as during the construction of long-distance dependencies (Fiebach, Schlesewsky, & Friederici, 2002; Kaan, Harris, Gibson, & Holcomb, 2000; Phillips, Kazanina, & Abada, 2005).

1.1.2 Initial findings

Within the space of a few years, four different labs showed P600s to what appeared to be semantic anomalies in simple grammatical sentences. These results appeared to directly contrast the traditional N400/P600 split as responses to semantic and syntactic anomalies. In English, the first study was Kuperberg, Sitnikova, Caplan and Holcomb (2003), who recorded a P600 at the verb in sentences such as (1)a., relative to the acceptable control condition, (1)b.

(1) a. For breakfast the eggs would only *eat* toast and jam. [P600]

b. For breakfast the boys would only *eat* toast and jam. [Control]

Similarly, Kim and Osterhout's (2005) first experiment also yielded a P600 to the verb in sentences such as (2)a., compared to either of the control conditions, (2)b. and c.

(2) a. The hearty meal was *devouring* the kids. [P600]

b. The hearty meal was *devoured* by the kids. [Passive control]

c. The hungry boy was *devouring* the cookies. [Active control]

The initial studies that unexpectedly showed a P600 all involved sentences in which the noun was a poor fit for the thematic role assignment dictated by the structure, but a good fit to fill another of the verb's thematic roles. For example, in Kuperberg et al., (2003), *eggs* is a poor agent for *eat*, but would make a good theme. Likewise, in Kim and Osterhout (Expt 1), *meal* is a poor agent for *devour*, but would be a good theme.

At around the same time, two groups found similar effects in Dutch. Kolk, Chwilla, van Herten and Oor (Kolk et al., 2003, Expt 1) recorded a P600 at the

relative clause verb in (3)a., relative to the control condition, (3)b. As in the English studies, this violation involved nouns that could plausibly fulfill the verb's thematic roles, but not in the way dictated by the structure. In this particular example, although both the *fox* and the *poachers* could plausibly be the agent of *hunt*, it is implausible for *foxes* to hunt *poachers* ((3)a.) but plausible for *poachers* to hunt *foxes* ((3)b.).

(3) a. De vos die op de stopers *joeg* sloop door het bos. [P600]
the fox that at the poachers *hunted*$_{sg}$ stalked through the woods
'The fox who *hunted*$_{sg}$ the poachers stalked through the woods.'
b. De stropers die op de vos *joegen* slopen door het bos. [Control]
the poachers who at the fox *hunted*$_{pl}$ stalked through the woods
'The poachers who *hunted*$_{pl}$ the fox stalked through the woods.'

In a similar experiment, Hoeks, Stowe and Doedens (2004) recorded a P600 at the verb in (4)a., relative to the control, (4)b. In this example, it is plausible for *athletes* to throw *javelins* ((4)b.), but not for *javelins* to throw *athletes* ((4)a.).

(z). a. De speer heft de atleten *geworpen*. [P600]
the javelin has the athletes *thrown*
'The athletes were *thrown* by the javelin.'
b. De speer werd door de atleten *geworpen*. [Control]
the javelin was by the athletes *thrown*
'The javelin was *thrown* by the athletes.'

The common feature across all of the initial studies that yielded a thematic P600 appeared to be the existence of a plausible way to combine the open class words, if the structure was ignored.

Kim and Osterhout's (2005) second experiment was designed to explicitly test whether the semantic relationship between the noun and the verb is necessary to elicit the P600 in this kind of sentence. They compared sentences in which the initial noun would be a plausible theme of the verb ((5)a.) with sentences in which the initial noun was not a plausible theme ((5)b.): it is plausible to *devour a meal*, but not to *devour a tabletop*. The sentences in which the noun was a plausible theme elicited a P600, whereas the sentences in which the noun was not a plausible theme elicited an N400.

(5) a. The hearty meal was *devouring* the kids. [P600]

b. The dusty tabletop was *devouring* the kids. [N400]

c. The hearty meal was *devoured* by the kids. [Control]

The results seemed to confirm the prior observation that the thematic P600 effect is only attested in situations in which the most plausible way to relate neighboring open class words is incompatible with the structure of the sentence. This led to the claim that semantic composition can proceed independently of syntactic structure. This conclusion may be too strong – in English, *was* can be followed by either the passive or the progressive, so until the reader processes the verbal suffix, the most plausible analysis is that of a passive sentence. Thus, although these results are consistent with independent semantic composition, it is also possible that semantic interpretation does conform to syntactic structure, but that the semantic combinatory process is initiated before the processing of the verbal suffix.

There are alternative explanations that do not involve an independent semantic processing stream for several of the P600 studies, such as the explanation just given

for the results of Kim and Osterhout's second experiment. Nevertheless, the various accounts of this phenomenon (Kim & Osterhout, 2005; Kuperberg, 2007; van Herten et al., 2005, 2006; Bornkessel-Schlesewsky & Schlesewsky, 2008) all point to the fact that the thematic P600 has been elicited in a number of different languages and in a number of different structural configurations, and argue that the set of results can best be accounted for by positing an independent semantic composition mechanism. This argument is considered in further detail in Section 2.

1.1.3 A parenthetical note about terminology

Kim and Osterhout (2005) introduced the term "semantic attraction" to refer to the situation in which the meanings of neighboring open class words suggest particular plausible relationships, regardless of their structural relationship. For example, in (5)a. there is "semantic attraction" between *meal* and *devour* because there is a plausible relationship between them. In contrast, in (5)b. there is no attraction between *dusty tabletop* and *devour* because the word meanings do not suggest a particular plausible relationship. The term "semantic attraction" refers specifically to plausible thematic relationships between the noun(s) and the verbs, and has also been referred to as "semantic-thematic fit" (Kuperberg, 2007). This is to be distinguished from the more general notion of semantic association between words, which often correlates with semantic attraction, but not always. For example, the words *trumpets* and *curtsey* may be semantically associated with one another, but there is no semantic attraction between them because *trumpets* is not a good fit for any of the verb's thematic roles. I use the term "semantic attraction" rather than

"semantic-thematic fit" to describe the situation in which a noun could plausibly fill one of the verb's thematic roles because much of the experimental work presented here was designed to address questions raised by the Kim and Osterhout (2005) studies, and that is the term they used. However, I do not intend this to signal commitment to the idea that the existence of a plausible thematic relationship between a noun and a verb causes the words to be combined in a magnetic fashion, regardless of their structural positions. Rather, I use it simply to describe a situation in which there is a plausible thematic fit between a noun and a verb, which may or may not be exploited to guide processing.

In a similar vein, I use the term "thematic P600" as a convenient descriptive term to refer to the P600s that have been elicited to sentences that appear to contain semantic anomalies. These P600s have been referred to in a number of different ways, including "unexpected P600s" and "semantic P600s". I have chosen to use "thematic P600" because it highlights the fact the studies in which it has been evoked involve the relationship between a verb and one or more of its arguments, but I do not intend it to signal a commitment to any particular interpretation of these effects. Similarly, by using the term as a convenient way to identify this set of results, I do not intend to indicate that the P600s in these studies are different than the familiar P600s that have been elicited to syntactic violations.

1.2 Current accounts

When the first thematic P600 results emerged, there initially appeared to be two types of explanations that would maintain these P600s under the umbrella of standard syntactic violations. The first kind of explanation stated that the P600 was elicited because there was a problem with the verbal suffix: either the processor expected one suffix and encountered another, or the processor was able to "fix" the sentence by switching one suffix for another. This kind of explanation involved a fairly narrow attempt to describe the results (e.g., in terms of specific inflection expected, not as an expectation for a general kind of structure) and carefully controlled experiments have shown that these explanations are not sufficient to cover a significant portion of thematic P600 results. Another kind of explanation that appeared initially stated that the P600 is elicited because the noun in subject position, by virtue of being inanimate, violates the verb's requirements for an agentive subject. I argue in Chapter 4 that this explanation covers the majority of the thematic P600 results. However, because none of these explanations can account for every result in the thematic P600 literature, the accounts that have been proposed for the thematic P600 (Kim & Osterhout, 2005; van Herten et al., 2005, 2006; Kuperberg, 2007; Bornkessel-Schlesewsky & Schlesewsky, 2008) have all argued for independent semantic composition.

One early proposal that was quickly discarded was that the P600 is elicited because the processor expected a particular verbal suffix but encounter a different one. For example, this could account for the P600 in Kim and Osterhout's (2005,

Expt 1) *The hearty meal was devouring…* in which one could argue that the processor was anticipating an *–ed* but encountered an *–ing*. Kolk et al. (2003) wondered whether the P600 in *The fox that at the poachers hunted*$_{sg}$*…* yielded a P600 because the processor was expecting the verb to agree with *poachers* and thus was surprised by the singular verbal suffix. Van Herten et al. (2005) tested this possibility by comparing sentences in which the number of the agent and goal was different (as in Kolk et al., 2003) and sentences in which the agent and goal had the same number (e.g., *The fox that at the poacher hunted*$_{sg}$*…*). In this example, both nouns are singular, so if the processor was expecting the verb to agree with the *poacher*, it would be satisfied when the verb carried singular inflection, and no P600 would be elicited. However, the results showed that a P600 was elicited whether the verbal inflection matched the goal noun in number or not. Therefore, the narrow interpretation of the thematic P600 as reflecting a mismatch between the expected and actual verbal inflection does not appear to be correct.

Likewise, there was an early notion that the P600 might be indexing the processor's attempt to "repair" the sentence by changing something small in the syntactic structure. For example, one might have argued that *The hearty meal was devouring…* elicited the P600 because the processor "repaired" the sentence by switching the *–ing* for an *–ed*. However, it quickly became apparent that the thematic P600 was also elicited in many situations in which no such quick fix was available. For example, Kim and Osterhout (2005b) presented a follow up study in a conference paper that tested sentences such as *The hearty meal will devour….* These sentences

also elicited a P600, even though these sentences could not easily be repaired by switching one verbal suffix for another.

A number of the studies involved an inanimate noun in the subject position of what turned out to be an active sentence. Therefore the P600s in these studies could have been elicited because the noun violated the verb's requirement that its subject be agentive (inanimate nouns are not good agents). For example, Kuperberg et al. (2003) recorded a P600 in sentences such as *For breakfast the eggs would eat….* Likewise, Kim and Osterhout (2005) recorded a P600 in sentences such as *The hearty meal was devouring….* There are two reasons why this explanation has not been given more weight in accounting for the thematic P600 results. Firstly, it initially appeared from Kim and Osterhout's study that the animacy of the subject noun was insufficient to account for the situations that elicit the P600 in English. Specifically, although a P600 was elicited in *The hearty meal was devouring…*, there was no P600 to *The dusty tabletop was devouring….* From this study, it looked as if a violation of the verb's requirement to have an agentive subject does not always elicit a P600. However, since then many studies in English (e.g., Kuperberg et al., 2006, 2007; the experimental work presented in Chapters 2-4) have yielded a P600 in all conditions that had an inanimate noun in the subject position of an active sentence, regardless of the semantic relationship between the noun and the verb. In Chapter 4, I argue that the violation of the verb's agentivity requirements can account for a large portion of the thematic P600 studies. However, for the purposes here, the point is that this

explanation of the results was given less weight than it merits partially because of the results of Kim and Osterhout's study.

A further reason that the "violation of agentivity" explanation was not considered seriously as an explanation for many of the studies is that it does not cover all of the thematic P600 results. Some studies in Dutch (Kolk et al., 2003; van Herten et al., 2005) and German (Friederici & Frisch, 2000), illustrated in (6) and (7) respectively, recorded a P600 in sentences in which the subject noun did not violate the agentivity requirements of the verb.

(6) De vos die op de stopers *joeg* sloop door het bos. [P600]
the fox that at the poachers *hunted*$_{sg}$ stalked through the woods
'The fox who *hunted*$_{sg}$ the poachers stalked through the woods.'

(7) Anna weiß, dass der Kommissar (NOM) den Banker (ACC) *abbeizte*... [P600]
Anna knows that the inspector (NOM) the banker (ACC) *stained*...
'Anna knows that the inspector *stained* the banker…'

These results show that not all thematic P600s results reflect a violation of the verb's agentivity requirements. This led to proposals that argue for a larger role for independent semantic composition in the processing of all of the thematic P600 studies, and indeed in sentence processing in general, not just for those specific situations that cannot be accounted for by appealing to an agentivity violation.

All four of the accounts that have been given for the thematic P600 results have argued for parallel processing streams. In all of these accounts, one stream functions primarily over structural information, and another stream functions primarily over semantic information. The accounts differ in their precise definition of each of those streams, and in their view of the specific process(es) that elicit the P600. A summary of these accounts can be seen in Table 1. In this section I will first briefly describe each of the accounts that have been given for the thematic P600s, and then provide more details about what the accounts broadly agree on, as well as the important features that distinguish the models.

Table 1

Summary of the current accounts of the thematic P600

	Processing Streams	**The P600 reflects…**
Kim & Osterhout (2005)	Syntactic & semantic	Detection of a syntactic violation
van Herten, Kolk et al. (2005, 2006)	Algorithmic & heuristic	Executive control indicating detection of an inconsistency and the need to review the representation
Kuperberg (2007)	Combinatorial (thematic and morphosyntactic) & semantic-association	Continued processing following detection of a conflict within the combinatorial stream(s) or between any of the streams
Bornkessel-Schlesewsky & Schlesewsky (2008)	Linking & plausibility	Problem with linguistic mapping of the two streams

1.2.1 Kim & Osterhout (2005)

Kim and Osterhout argue for parallel and independent mechanisms for semantic and syntactic composition. According to this account, the semantic composition mechanism can detect plausible relations between neighboring open

class words, unmediated by syntactic structure. If the structure of the sentence is incompatible with the interpretation formed by the semantic composition mechanism, the processor may perceive a syntactic error, even though the structure of the sentence is unambiguously grammatical.

Kim and Osterhout based their account on the results from their second experiment, in which a P600 was elicited when the initial noun was a good theme for the verb ((8)a.) and an N400 when the initial noun was a poor theme for the verb ((8)b.).

(8) a. The hearty meal was *devouring* the kids. [P600]

b. The dusty tabletop was *devouring* the kids. [N400]

c. The hearty meal was *devoured* by the kids. [Control]

Kim and Osterhout argued that in (8)a., the semantic composition mechanism detects that *meal* makes a poor agent but a great theme for *devour*. Based on this semantic analysis, the processor pursues a passive analysis, and subsequently determines that the syntax is wrong for that analysis, i.e., the verb should carry the passive morphology *–ed* rather than the active suffix *–ing*. In contrast, in (8)b., the semantic composition mechanism does not arrive at a plausible analysis of the open class words, and the processing is dominated by the outcome of the syntactic composition mechanism. Because the sentence is grammatical, the syntactic composition mechanism proceeds without a problem, and the processor recognizes the sentence as having an anomalous interpretation.

For the purposes of comparing this account to the other accounts of the thematic P600, there are two key features. Firstly, the semantic combinatorial stream specifically looks for plausible thematic relations between nearby open class words, rather than general semantic associations or other semantic relations that do not have direct implications for the structure of the sentence. Furthermore, the processor is able to use the outcome of the semantic combinatorial mechanism to infer the structural analysis of the sentence that would license that interpretation. In other words, the semantic combinatorial mechanism detects that *meal* is a good theme for *devour*, and the processor uses that information to pursue a passive analysis of the sentence, despite the fact that the syntax of the sentence may not support that analysis. Secondly, under the Kim and Osterhout account, the P600 reflects the perception of a syntactic error based on the semantic representation that is being maintained. This account does not require any alteration of the traditional interpretation of the P600, i.e., it is consistent with the idea that the P600 indicates the detection of a syntactic violation.

1.2.2 Van Herten, Kolk et al. (2005, 2006)

Van Herten, Kolk and colleagues also propose a sentence processing model in which one stream calculates plausible relations between open class words without consideration of the structural relations between those words. In their account, the heuristics stream computes plausible relations between the arguments and the verb in the sentence, and an algorithmic stream computes an interpretation of the sentence as specified by the structural relations between them. In other words, both the heuristic

stream and the algorithmic stream arrive at a semantic representation of the sentence. According to this account, an executive control system monitors whether the outputs of the two streams are compatible with one another, and a P600 is elicited when the executive control system detects a mismatch between the outputs of the streams.

Van Herten, Kolk and colleagues have primarily focused on Dutch sentences in which two nouns appear prior to the verb. For example, they recorded a P600 at the verb in two studies of sentences such as (9) (Kolk et al., 2003; van Herten et al., 2005).

(9) De vos die op de stopers *joeg* sloop door het bos. [P600]
the fox that at the poachers *hunted*$_{sg}$ stalked through the woods
'The fox who *hunted*$_{sg}$ the poachers stalked through the woods.'

According to this account, the heuristic stream computes the most plausible relations between the words, and arrives at the interpretation *the poachers hunted the fox*. In contrast, the algorithmic stream combines the words according to their structural positions, and arrives at the interpretation *the fox hunted the poachers*. An important feature of this study is that the anomaly arises from the combination of both nouns and the verb: it is plausible for foxes to hunt, it is plausible for poachers to hunt, but it is implausible for foxes to hunt poachers.

The account proposed by van Herten, Kolk, and colleagues is the only one of the four accounts to argue that the P600 is not a response to the detection of a specific linguistic violation (e.g., a syntactic violation), but rather reflects an executive control

system that monitors the quality of the representation that the processor arrives at, and mandates reprocessing of the sentence if the representation is close to acceptable and therefore suggests that the processor may have misperceived something in the sentence. If the outcome of processing is completely unacceptable, the executive system does not require the processor to recheck its work since this situation is unlikely to arise from a misperception (van de Meerendonk et al., submitted).

One advantage of this account is that it is broad enough to also cover a set of situations in which the P600 has been elicited in sentences in which the anomaly cannot be viewed as either syntactic or semantic. For example, Vissers, Chwilla and Kolk (2006) showed that orthographic errors elicited a P600 in high-cloze situations such as (10)a. but not in low-cloze situations such as (10)b.

(10) a. In die bibliotheek lenen de leerlingen *boekun*... [P600]
in the library borrow the pupils *bouks*…
'In the library the pupils borrow *bouks*…'
b. De kussens zijn volgestopt met *boekun*... [N400]
the pillows are stuffed with *bouks*...
'The pillows are stuffed with *bouks*…'

The 'monitoring hypothesis' of the P600 can account for these results by claiming that the monitor detected an error, but because the orthographically-anomalous word was very close to an expected word, the processor went back over the sentence to see if it had misperceived the input. A similar explanation was given for a recent study by Vissers and colleagues (Vissers et al., 2008) in which participants were shown

pictures depicting locative relations (e.g., of a circle in front of a square) followed by a sentence that correctly or incorrectly described the picture. (e.g., correct: 'The circle is in front of the square.' or incorrect: 'The square is in front of the circle.') A P600 was elicited when the meaning of the sentence did not match the picture. According to the 'monitoring hypothesis', the executive control system detected a conflict between the concept described by the picture and the concept described by the sentence.

1.2.3 Kuperberg (2007)

Kuperberg proposes a model of sentence processing in which the processing streams interact continuously as they integrate each incoming word into the representation of the sentence. Kuperberg distinguishes between "semantic memory-based" processing and combinatorial processing. Combinatorial processing builds up a representation of the sentence based on morphosyntactic cues as well as a limited set of features (such as animacy) that are relevant for the assignment of thematic relations between the verb and its arguments. According to Kuperberg, there is not yet enough evidence to determine whether there is a single combinatorial processing stream or two streams, one of which operates over morphosyntactic information and another that computes thematic relations between a verb and its arguments.

The "semantic memory-based" stream processes the incoming words without regard to their structural positions in the sentence. Kuperberg describes two possibilities for how this stream might operate. Firstly, the semantic memory-based

stream might compare the semantic relationships between incoming open class words with semantic relationships stored in semantic memory to detect a match or mismatch. Alternatively, the semantic memory-based stream might use a plausibility-based heuristic to generate a proposition that is then compared against real-world knowledge stored in semantic memory. A processing problem within this stream generally results in an N400 effect.

In this model, the P600 reflects either a problem within the combinatorial stream(s) or between any of the three possible streams. The results from a recent study by Kuperberg and colleagues shown in (11) will be used to illustrate a selection of results that can be handled by this account (Kuperberg et al., 2007).

(11) a, Every morning at breakfast the boys would *plant*… [N400]

b. Every morning at breakfast the eggs would *eat*… [P600]

c. Every morning at breakfast the eggs would *plant*… [P600]

According to this account, there is no problem in the combinatorial stream in sentence (11)a. – the sentence is grammatical and there is no problem with assigning *boys* as the agent of *plant*. However, because *the boys would plant* is implausibly related to *every morning at breakfast* in semantic memory, an N400 is elicited at the verb. In (11)b., there is no N400 effect because all of the open class words are related in semantic memory. The P600 arises because the morphosyntactic stream assigns *eggs* as the agent of *eat*, but the thematic stream assigns *eggs* as the theme. In (11)c., the P600 is elicited at the verb for the same reason as it was in (11)b.: the morphosyntactic stream assigns *eggs* as the agent of *plant*, but the thematic stream

uses animacy features to assign *eggs* as the theme of the verb. In this model, the streams are highly interactive throughout the time that the incoming word is being processed, and the problem stemming from the inanimate subject noun is detected so quickly that the semantic memory-based stream does not complete its processing. This is the reason given for why sentence (11)c. does not elicit an N400, despite the fact that the relations between the open class words would not match a representation in memory.

1.2.4 Bornkessel-Schlesewsky & Schlesewsky (2008)

The extended Argument Dependency Model (eADM, Bornkessel & Schlesewsky, 2006) is a model of the processing of 'core' relations in simple sentences (i.e., verb-argument and inter-argument relations in single clauses) that attempts to account for processing both in head-final languages with relatively free word order such as German and in fixed-order head-initial languages such as English. A recent review article (Borkessel-Schlesewsky & Schlesewsky, in press) extends the eADM to attempt to account for all the thematic P600 results. The eADM will be discussed in further detail in Chapter 4, Section 4.3.2, so here I just present a brief description of the aspects of the model that are relevant to the thematic P600 results.

In order to extend the model to account for the series of thematic P600 results, the version of the eADM in the Bornkessel-Schlesewsky and Schlesewsky review paper (2008) includes an additional processing route that did not appear in the original model (Bornkessel & Schlesewsky, 2006). This route is called "plausibility"

processing, and uses heuristics to compute the most plausible way to combine the nouns and the verb together. It functions in parallel to a step that links verbs to their arguments. According to this model, when the processor encounters a verb, it links the verb to the nouns and assigns thematic roles according to features such as case marking, and simultaneously uses a plausibility heuristic based on lexical-semantic information to arrive at with the most plausible way to assign thematic roles. In the following step, "generalized mapping", the results from the two streams of processing are compared and integrated. Lastly, in a step that occurs only optionally depending on the particular task in the experiment, comprehenders may pass through the "well-formedness" stage which, as the name suggests, evaluates the general acceptability of the sentence. A P600 is elicited when there is a problem with either the generalized mapping or the well-formedness stages.

1.2.5 Points of agreement among the accounts

The common point of agreement across all four accounts (Kim & Osterhout, 2005; van Herten et al., 2005, 2006; Kuperberg, 2007; Bornkessel-Schlesewsky & Schlesewsky, 2008) is that the thematic P600 results can only be explained by positing multiple processing streams. A semantic stream operates over open class words, and processes them without regard to the structural relations among them. A syntactic stream provides an analysis of the sentence that is compatible with the morphosyntactic features of the sentence. All four accounts include these two streams, and Kuperberg (2007) allows for the additional possibility that a separate

processing stream calculates likely thematic relations based on a limited set of features such as animacy.

These accounts do not describe in detail how an independent semantic composition mechanism would work and instead generally suggest that the mechanism uses heuristics to arrive at an interpretation. Heuristics are used to create a "quick and dirty" guess about the interpretation of the sentence. In the most common model to rely heavily on heuristics (Townsend and Bever, 2001), there are two kinds of heuristics. In the first kind of heuristic, the "NVN strategy," the comprehender assumes that the subject of the sentence is the agent and the object of the sentence is the theme or patient, based on the fact that this is the most common pattern in English sentences (Bever, 1970). In the second kind of heuristic, the comprehender uses plausibility information to generate a likely interpretation of the sentence. This is clearly the notion of heuristics that the accounts of the thematic P600 appeal to (Kim & Osterhout, 2005; van Herten et al., 2005, 2006; Bornkessel-Schlesewsky & Schlesewsky, 2008; and Kuperberg discusses it as one possible mechanism). The Dutch version of an NVN strategy would be an NNV strategy in which the first noun is assumed to be the agent and the second noun a theme or patient. This strategy would yield the same interpretation as the syntactic analysis in a sentence such as *The fox that at the poachers hunted*…. It is only the plausibility heuristic that would yield an interpretation in which *the poachers* was the agent. The dominance of the plausibility heuristic over the NVN/NNV strategy contrasts with the results of a behavioral study that pitted the two heuristics against one another. Ferreira looked at

sentences such as *The cheese was eaten by the mouse*, in which the plausibility heuristic would yield the *mouse* as the agent, but the NVN strategy would yield the *cheese* as the agent (Ferreira, 2003). In this study, participants were equally likely to consider the *cheese* as the "do-er" relative to sentences such as *The man was bitten by the dog* in which the plausibility heuristic would not help the participant to arrive at a passive analysis. Ferreira took the results of this study to indicate that the NVN strategy is more dominant than the plausibility heuristic.

Note that, although the accounts of the thematic P600, including the account proposed here, refer to the use of a plausibility heuristic as "independent semantic composition", it is worth emphasizing again that plausibility is not a notion from the field of theoretical semantics. Rather, in these studies the plausibility manipulation is used as a test of whether the processor considers interpretations based on the meanings of the open class words, independently of the syntactic analysis it pursues for the sentence.

1.2.6 Points of disagreement among the accounts

Although the accounts differ in the way they are described due to the different theoretical backgrounds of the authors, here I draw attention to two important points where the accounts substantially differ. First, the accounts differ on whether the processing streams interact during the processing of the incoming word, or whether the processor just checks at the end whether the outputs of the streams are compatible. Second, the accounts differ on their interpretation of what the P600

directly reflects. In order to simplify the discussion that follows, I refer to a semantic and a syntactic stream rather than the specific names given to the streams by the different accounts, except where such a simplification would significantly misrepresent one of the accounts or obscure the issue at hand.

1.2.6.1. Interaction between the streams

The four accounts differ in the extent to which the processing streams interact as they process the incoming word. Van Herten, Kolk and colleagues do not appear to provide for interaction during processing; they focus instead on what occurs after the two streams have each completed processing (van Herten et al., 2005, 2006). Bornkessel-Schlesewsky and Schlesewsky (2008) and Kim and Osterhout (2005) argue that under some circumstances processing in one stream can block further processing in another stream. Kuperberg (2007) argues for significant interaction among all three processing streams throughout the processing of the incoming word.

In the account of van Herten, Kolk and colleagues, the processor arrives at a semantic representation of the sentence via two streams, a heuristics stream that recognizes plausible relations between open class words, and an algorithmic stream that combines the words in the manner dictated by the structure. Once both streams have completed processing, the executive control system checks whether the two streams have arrived at the same interpretation. There is no interaction between the streams prior to that moment.

The other three accounts all provide for a certain degree of interaction so that if one stream reaches an interpretation quickly or quickly recognizes an error, it can block continued processing in the other stream. The details differ across the three accounts. A crucial claim in Kim and Osterhout (2005) is that for a sentence such as *The hearty meal was devouring…* the semantic stream quickly recognizes that *meal* is a good theme for *devour* and this causes the processor to perceive a syntactic error. An implication of this explanation is that the processor must have recognized that the semantic stream reached a successful interpretation quickly, and ceased processing in the syntactic stream, instead determining that the syntax was wrong relative to the output of the semantic stream.

Whereas Kim and Osterhout's account included the possibility that fast successful processing in one stream would cause the other stream to discontinue processing, Kuperberg argues that, under some circumstances, if processing fails in one stream, it can cause the other stream to discontinue processing. Kuperberg argues that this is the case for sentences such as (12).

(12) Every morning at breakfast the eggs would plant… [P600]

In order to explain the lack of N400 in this sentence despite the incongruency of the word *plant* relative to the other words in the sentence, Kuperberg argues that the thematic stream quickly recognizes that *eggs* is not a suitable agent for *plant* due to its animacy, and therefore switches off processing in the semantic memory-based stream. Similarly, in the model presented in Bornkessel-Schlesewsky & Schlesewsky

(2008) a problem in the syntactic stream can block further processing in the semantic stream.

Kuperberg argues most strongly for a high level of interaction between the streams during processing, beyond whether success or failure in one stream causes the other stream to discontinue processing. A key component of her account is that the processor engages in "continued processing" if it detects any mismatches or inconsistencies among the streams. This implies that the streams are continuously checked against one another and the processor continues to attempt to find an acceptable representation for the sentence even after a problem is detected within or among the streams. This is different than the other accounts in which the outputs are only checked at the end or in which processing stops once an inconsistency is detected. In fact, we know very little about the interpretations people reach in these kinds of sentences, so it is unclear whether people do attempt to reach an acceptable representation even after detecting an error.

1.2.6.2 Process directly reflected by the P600

The accounts differ significantly on what they claim the P600 directly reflects. According to the account described by Kim and Osterhout (2005), the interpretation of the P600 does not need to be expanded beyond its traditional interpretation as the response to a syntactic violation. Bornkessel-Schlesewsky and Schlesewsky view the P600 as the response that is generated when the outputs of the syntactic and semantic streams cannot be mapped onto one another to get a coherent representation.

Kuperberg (2007) claims that the P600 reflects "continued combinatory analysis". The processor attempts further analysis of the sentence if the outputs of any two of the three streams provide conflicting analyses of the input. For example, in the sentence *…the eggs would eat…*, the syntactic stream would analyze *eggs* as the agent and the thematic stream would analyze *eggs* as the theme. The processor would then undertake further analysis in an attempt to reach an acceptable analysis of the sentence, a process which would not be successful in this particular sentence.

Van Herten, Kolk and colleagues claim that the P600 does not reflect the detection of a particular kind of linguistic anomaly or incompatibility, but rather the P600 results whenever the monitoring system detects any kind of conflict between the heuristic and algorithmic streams, or even situations in which there is a conflict between an expected word and the word that is actually encountered.

1.3 Current Approach

The accounts described in the previous section all took the approach of attempting to provide a general account that could cover the entire set of results. Although this is of course the most generally desirable approach, there are at least two drawbacks to this approach.

First, looking across the entire set of studies, there appears to be a high degree of variability in the experimental situations in which a thematic P600 is elicited. In her detailed review, Kuperberg (2007) lists six factors which all appear to make it

more likely that a P600 will be elicited, but none of which can be stated categorically. For example, sentences in which there is semantic attraction between the noun(s) and the verb generally evoke a P600. However, the absence of semantic attraction does not necessarily result in the absence of the P600. This is illustrated by a comparison of Kim and Osterhout (2005), which did not record a P600 to sentences in which the subject noun was a poor theme for the verb (13), and Kuperberg et al. (2007) which did recorded a P600 under similar conditions (14).

(13) The dusty tabletop was *devouring*... [N400]

(14) Every morning at breakfast the eggs would *plant*... [P600]

Furthermore, some of the comparisons that have commonly been drawn to illustrate the effect of a certain feature involve comparing sentences that differ in more than just the feature under focus. For example, it has been noted many times that although the thematic P600 is often elicited when the noun in subject position is inanimate (e.g., (14)), other studies have recorded a P600 in the absence of an animacy violation in sentences such as (15) (Kolk et al., 2003; van Herten et al., 2005).

(15) De vos die op de stopers *joeg* sloop door het bos. [P600]

the fox that at the poachers *hunted*$_{sg}$ stalked through the woods

'The fox who *hunted*$_{sg}$ the poachers stalked through the woods.'

The accounts of the thematic P600 have generally operated under the assumption that the processing constraints and actions in the English and Dutch cases are the same. This implies that if a particular result such as a P600 in the absence of an animacy violation is attested in the Dutch sentences, such a result would also be seen in the English sentences. However, it is not at all clear that the processing actions involved

in comprehending a structure involving one pre-verbal noun and a verb in a verb-medial language are the same as the processing actions involved in detecting an anomaly involving the combination of two pre-verbal nouns and a verb in a verb-final structure. It is possible that some of the apparent variability and confusion in the set of thematic P600 results stems from treating studies as comparable when really they involve different processing actions and constraints.

Second, the accounts that have been proposed to explain the entire set of thematic P600 results have tended to be either very detailed but lacking in predictive power, or very general but lacking detail about the specific representations that are involved in processing the sentences. On one hand, an account like that of Kuperberg (2007) is extremely detailed in its consideration of all the processing factors that influence the elicitation of the thematic P600. The review outlines six factors that all appear to play a role in the elicitation of a thematic P600. This state of affairs is consistent with Kuperberg's view of the processor as continuously interactive and dynamic, which implies that many factors will simultaneously influence the representation(s) under consideration and thus be reflected in the electrophysiological responses. However, for any given study the account cannot definitively predict whether, for example, the lack of semantic attraction between a noun and a verb will result in a P600 or not. At the other extreme, the conflict monitoring hypothesis of van Herten, Kolk and colleagues is able to cover an extremely broad set of results but lacks specificity with regard to the linguistic representations that are under consideration as the sentence unfolds incrementally,

The approach I take here is to consider subsets of the thematic P600 results separately. I argue that there is a high level of consistency within a large portion of the thematic P600 results, which is obscured when the entire set of results is considered at once. In Chapters 2 and 3 I focus on the processing situations that yield a thematic P600 in verb-medial languages such as English and Spanish. In Chapter 4 I continue that discussion, and expand the focus to also include results from verb-final languages such as Dutch and German.

1.4 Outline of dissertation

Chapter 2 presents an event-related potentials (ERP) study in Spanish that investigated whether the processor exploits prior structural biases to restrict semantic interpretations to those that are compatible with that expected structure. Chapter 3 presents an ERP study in English with a similar aim, but which involves prior structural commitments that should restrict semantic interpretations, rather than structural biases. Both of these studies were designed under the assumption that the semantic attraction effect found in Kim and Osterhout (2005) – a P600 with semantic attraction between noun and verb, and an N400 in the absence of attraction – would hold. However, the ERP studies presented in both Chapter 2 and Chapter 3 yielded a different pattern: a P600 in both the semantic attraction and no-attraction conditions. Chapter 4 presents an overview of all the studies that have manipulated semantic attraction, and claims that the original Kim and Osterhout results are the only results in which the verb in a no-attraction condition failed to elicit a P600. A replication study using the materials from the original Kim and Osterhout study corroborates this

assessment, by showing a P600 in both semantic attraction and no-attraction conditions, in addition to an N400 in the no-attraction conditions. This pattern of results suggests that a large number of studies that have been taken as evidence for an independent semantic processing stream can be explained as violations of the verb's requirement that its subject be agentive. In fact, a number of the Dutch studies can also be accounted for in this way. A small number of studies from verb-final languages cannot be accounted for by appealing to a violation of the verb's agentivity requirements. I discuss whether this is a result of coincidental gaps in the studies that have been carried out, or whether there are particular features of the verb-final processing environment that may allow for a more extensive role for the influence of independent semantic composition than in the English and Spanish studies. I conclude that the evidence for independent semantic composition is much less extensive than was previously thought.

1.5 The interpretation of the N400 and implications for the interpretation of the thematic P600 results

In this dissertation I focus primarily on accounting for the behavior of the P600, and touch on the N400 only peripherally. Before embarking on the investigation of the P600, I discuss possible interpretations of the N400 and the implications of each for the interpretation of the thematic P600 results.

It is clear that the N400 varies with the processing of semantic information and is highly sensitive to the context in which the word appears, whether that is

another word, a sentence, or a short discourse. However, it remains unclear exactly what the N400 reflects. Does the amplitude of the N400 reflect the ease or difficulty with which the current word is integrated into the prior context, or does it simply reflect the ease or difficulty of accessing the lexical item? This debate is relevant to the discussion of the thematic P600s because the presence or absence of an N400 has been used in some accounts (e.g., Kim & Osterhout, 2005; Kuperberg, 2007) in conjunction with the presence or absence of the P600 to draw conclusions about the nature of semantic combinatorial mechanisms.

The longest-held interpretation of the N400 is that it reflects the ease of integrating the current word into the prior context (Kutas & Hillyard, 1980; Osterhout & Holcomb, 1992; Brown & Hagoort, 1993; Hagoort, 2008). Specifically, a better semantic fit between the word and its context will make integration easier and result in a lower N400 amplitude. The idea is that it requires more effort to integrate (or attempt to integrate) a word into the representation if it does not fit well with the prior context or if it does not fit well with the comprehender's world knowledge. Similarly, it requires more effort to integrate an unexpected word than to integrate a word which was predicted, even when both are congruent with the context. Many N400 results are compatible with both the semantic integration and lexical access accounts, but perhaps the strongest evidence in favor of the semantic integration account are the studies that show an N400 effect to words that are incongruous within the discourse context even if congruous within the sentence (St. George, Mannes & Hoffman, 1994; van Berkum, Hagoort, & Brown, 1999; van Berkum, Zwitserlood, Hagoort, &

Brown, 2003; Swaab, Camblin & Gordon, 2004; Camblin, Gordon, & Swaab, 2007). For example:

> *As agreed upon, Jane was to wake her sister and her brother at five o'clock in the morning. But the sister had already washed herself, and the brother had even got dressed. Jane told the brother that he was exceptionally* ***slow****.* (Van Berkum, Hagoort & Brown, 1999)

Crucially, under this view the N400 reflects semantic combinatorial processes, whether independent or mediated by syntactic structure.

An alternative interpretation is that the N400 is modulated by ease or difficulty of accessing a lexical item (for a review of the electrophysiological evidence, see Kutas & Federmeier, 2000, and for an argument that this interpretation is supported by functional imaging data, see Lau et al., to appear). Semantically-related prime words or highly restricted sentential contexts can facilitate lexical access by allowing the comprehender to predict upcoming lexical items and preemptively activate the relevant features. One piece of evidence that is frequently given is that the N400 is affected by many of the same variables known to affect lexical access, such as word frequency (Smith & Halgren, 1987; Van Petten & Kutas, 1990; Allen, Badecker & Osterhout, 2003) and semantic priming (Bentin, McCarthy, & Wood, 1985; Holcomb, 1988, 1993; Rugg, 1987, 1990). These studies, however, are not particularly good evidence one way or the other, because factors that make lexical access easier could also be argued to facilitate semantic integration. For example, a semantically-related prime word could facilitate lexical access, but it

could also be argued that it is easier to integrate a word into its context (a word pair) when the two words are semantically related.

A stronger argument in favor of viewing the N400 as reflecting lexical access is the finding that words that are incongruous but share features with the expected item show a reduced N400 relative to an incongruous word that does not share features with the expected item (Federmeier & Kutas, 1999): *They wanted to make the hotel look more like a tropical resort. So along the driveway they planted rows of {palms/pines/tulips}*. They found that the expected ending, *palms*, had the lowest amplitude, *pines*, which shares some semantic features with *palms*, had an intermediate amplitude, and *tulips* had the highest amplitude. This is strong evidence for the lexical access view, as *pines* and *tulips* are equally incongruous in the context and therefore should be equally as difficult to integrate. However, if the highly restrictive context is used to predict the upcoming word, then the features of that word would already be active and therefore a word that shared some of those features would be accessed more easily. This view is further supported by the fact that the boost to an incongruous word that shares features with the expected word is largest when the context is most constraining (Federmeier & Kutas, 1999), precisely the situation under which the most precise predictions can be made and used to pre-activate words and their features.

Another piece of data that seems to point to the lexical access theory of the N400 is the fact that the N400 often seems modulated by semantic associations within

the sentence independently of how they are structurally related. For example, there was no difference in N400 amplitude to *A robin is a bird* and *A robin is not a bird* (Fischler, Bloom, Childers, Roucos & Perry, 1983). In this sentence, the word *bird* fits well within the semantic context of robins, and *robin* and *bird* are associated within semantic memory. However, the overall meaning of the sentence, once the negation is computed, is anomalous. By contrast, an increased amplitude was found for both *A robin is not a carrot* and *A robin is a carrot*, which did not differ from each other. Similar results have been found in experiments involving a variety of quantifiers (Kounios & Holcomb, 1992; Kounios, 1996; Noveck & Posada 2003; Drenhaus, Graben & Frisch 2006; Beltrán, Carreiras, Alvarez & Santamaría 2006), suggesting that the effect is not an artifact of sentences with negation. The lack of N400 effect in these cases suggests that the N400 does not reflect semantic integration that is read off the syntactic structure, although it could conceivably reflect independent semantic composition.

Although it is challenging to tease apart the two accounts because the processes of lexical access and semantic integration into the context co-occur and are tightly interdependent, it is of course important to keep in mind the two possible interpretations when using electrophysiology to investigate semantic compositional processes and the relationship between semantic and syntactic compositional mechanisms. If the N400 reflects semantic integration, the absence of an N400 effect is highly informative because it is taken to indicate that the reader has not detected a semantic anomaly. This could be either due to detecting the semantic anomaly after

the N400 time window (sometimes referred to as a temporary neural semantic illusion), or it could be because the comprehender considers the anomaly to be of a syntactic nature. Under this view, the presence or absence of the N400 effect is highly informative of how the semantic and syntactic processing mechanisms might be working together.

On the other hand, if the N400 reflects ease of lexical access, its presence or absence is less informative about the relationship between semantic and syntactic processing. Instead of assuming that the absence of the N400 effect indicates that the readers had not detected a semantic anomaly, the absence of the N400 might simply indicate that the words of the sentences were highly semantically associated. This is certainly the case for Kim & Osterhout's (2005) stimuli, in which the comparison of *The hearty meal was devouring* and *The hearty meal was devoured* did not elicit an N400 effect. Since the lexical items are identical, if we assume the N400 reflects ease of lexical access, it is clear why there is no N400 effect. Similarly, in the no-semantic-attraction condition, *The dusty tabletop was devouring*, there is a weaker association between the lexical items and therefore under the lexical access view of the N400, it is unsurprising that the N400 amplitude is higher than in the control sentence in which the lexical items are more highly associated. In this account, the modulation of the N400 is not informative about the semantic integration of the words into the sentence, although of course this must occur at some point in order for comprehension to take place. This means that the interpretation of the P600 effect

should be completely independent of the N400 modulation, abstracting away from practical considerations about component overlap.

In this dissertation, I largely assume the lexical access account of the N400, and I assume that the generation of the N400 and the P600 are independent events. This is corroborated by experimental results in Chapter 3. Nevertheless, the debate about the interpretation of the N400 is ongoing and should be kept in mind.

Chapter 2: The effects of prior syntactic biases on thematic role processing

2.1 Introduction

The results of Kim and Osterhout (2005) were taken to indicate that a passive analysis was considered despite incompatibility with the active verbal suffix. In the chapter, I will assume that this is true, but will critically evaluate the reasons why the passive analysis might have been considered, and the theoretical implications of that choice.

Kim and Osterhout (2005) recorded a P600 at the verb in (16)a., in which the NP would make a good theme for the verb, but not in (16)b., in which the NP would make a poor theme for the verb.

(16) a. The hearty meal was *devouring*... [P600]

b. The dusty tabletop was *devouring*... [N400]

c. The hearty meal was *devoured*... [Control]

Kim and Osterhout (2005) took this result to indicate that the processor analyzed *meal* as a good theme for *devour*, which would imply a passive analysis for the sentence, and subsequently determined that the syntax is wrong for that analysis (*–ing* instead of *–ed*). This led to the claim that semantic composition can proceed

independently of syntactic structure. An alternative explanation for these results is that the processor only considers interpretations that are consistent with the structural information that is currently available. In English, *was* is compatible with both passive and progressive structures, so until the reader processes the verbal suffix, the most plausible analysis is likely to be a passive analysis. Therefore, the Kim and Osterhout (2005) are compatible with two interpretations. A semantic composition mechanism may ignore syntactic cues in general. Alternatively, these particular sentences may allow the processor to integrate *devour* without taking full account of the *–ing*. This situation could arise if all of the cues prior to the verbal suffix suggest a passive analysis, and the syntactic cue that disconfirms this analysis is available to the processor later than the other cues.

In general, the sentence's representation and interpretation immediately prior to the critical verb has not been given a great deal of attention and may be a way to gain insight into what is behind the apparent variability in the body of thematic P600 results. In this chapter, I present a study designed to address a specific question suggested by the Kim and Osterhout (2005) results, namely whether knowledge about upcoming syntactic structures restricts semantic representations to those that are compatible with that expected structure. The study was designed to distinguish between two classes of models: models in which semantic composition is highly independent of syntax and ignores even structural information that has already been processed, and models in which the processor only considers interpretations that are compatible with already-processed structural information.

2.1.1 Word-by-word processing

Kim and Osterhout (2005) argued that in the "semantic attraction" condition (e.g., *The hearty meal was devouring…*), the processor considered a passive analysis based on the thematic fit between the initial NP and the verb, and in doing so, ignored the syntactic information supplied by the verbal suffix. However, there is reason to believe that the processor may have been considering a passive analysis even before it encountered the verb, and therefore before it had the information about thematic fit between the verb and the initial NP. Furthermore, it is also possible that the processor evaluated the thematic fit between the verb and the initial NP prior to encountering the syntactic cue provided by the verbal suffix. Both of these scenarios would provide an account for why the processor pursued a passive analysis for the sentence, without claiming that it did so by ignoring the syntactic cue provided by the verbal suffix. I argue that, although the Kim and Osterhout results are consistent with an independent semantic composition mechanism, there are other possible reasons for why the processor could pursue a passive analysis early in the sentence, and therefore be surprised by the active verbal suffix.

Kim and Osterhout (2005) focus on two cues: the thematic fit between the NP and the verb, and the syntactic cue provided by the verbal suffix. However, there are at least three other cues that could also provide the processor with information about whether to pursue an active or a passive analysis. Table 2 shows the relevant structural and semantic cues in the order in which they are encountered as the sentence unfolds.

Table 2

The structural and semantic cues in the sentences in Kim and Osterhout (2005)

	The hearty meal	*was*	*Devour-*	*-ing ...*
Probabilistic cues that may favor a passive analysis or are neutral between passive and active	Inherent theme-ness of the NP	Structural bias of the auxiliary	1. Thematic fit between NP and verb 2. Structural bias of the verb	
The cue that unambiguously specifies an active analysis				Active verbal suffix

At the initial NP, the processor encounters information about whether the NP is inherently a good agent or a good theme: animate NPs are typically agents whereas inanimate NPs are typically themes. The processor may use the fact that inanimate NPs are typically themes to pursue a passive analysis. At the auxiliary, the processor encounters information about whether the auxiliary is typically used in active or passive sentences. In Kim and Osterhout's materials, *was* and *had been* are compatible with both active and passive continuations, so in this case the cue may be neutral between an active and a passive analysis. At the verbal stem, the processor can evaluate whether the particular NP fits well as the theme for the verb. In the case of the "semantic attraction" condition, this cue could lead the processor to pursue a passive analysis. At the verbal stem, the processor might also access information about whether the verb occurs more frequently in passive or active form. This was not controlled in the original study, but its effect was studied in a follow up study (Kim and Osterhout, 2005b). Finally, the verbal suffix *–ing* provides definitive evidence that the sentence has an active structure.

The cues that the processor encounters prior to the verbal suffix all provide probabilistic information about whether the sentence is likely to be active or passive. Two of these cues (the "inherent theme-ness" of the NP and the thematic fit between the NP and the verb) may induce the processor to consider a passive analysis, whereas in this study the other two cues (the structural biases of the auxiliary and of the verb) are relatively neutral with respect to active versus passive analyses. After a series of four neutral or passive-biased probabilistic cues, the verbal suffix definitively indicates that the sentence has an active structure.

Here I assume that the information carried by the verbal suffix is available to the processor later than the information carried by the verbal stem; I discuss the evidence for this in Section 1.1.5. However, the argument does not fully rest on this point. The processor may pursue a passive analysis based on the fact that the sentence-initial noun is inanimate. If this is the case, the processor will be surprised when the verbal suffix violates the processor's structural expectation, whether or not the processor had already processed the information about thematic fit between the noun and the verb.

In the rest of this section, I discuss the evidence that suggests that each of these cues may influence whether the processor pursues an active or a passive structure, and how the cues and the order in which they are encountered may account for the previous results. The experiment presented in this chapter, however, attempts

to circumvent the debates surrounding which cues are used when, so it is possible to proceed directly to Section 2 without detriment to the main line of argumentation.

2.1.1.1 Inherent theme-ness of the NP

The first cue that is available for the processor to use in deciding whether to pursue an active or a passive analysis is the inherent theme-ness of the NP. Inanimate nouns tend to make better themes than agents, therefore an inanimate sentence-initial noun could tilt the processor toward considering a passive analysis. In fact, it is often simply assumed (e.g. Bornkessel-Schlesewsky & Schlesewsky, 2008) that sentences beginning with inanimate nouns lead to a preference for non-active structures in languages such as English. In the next paragraphs, I discuss whether evidence from ERP and eye-tracking studies supports the view that a sentence-initial inanimate noun causes the processor to pursue a passive analysis.

An ERP study by Weckerly and Kutas (1999) suggests that a sentence-initial inanimate noun is harder to process than a sentence-initial animate noun in English. The study showed that sentence-initial inanimate nouns (e.g., *the movie*) elicited a more negative-going ERP waveform in the 200-500 ms interval, compared to animate nouns (e.g., *the novelist*). This was interpreted as indicating difficulty in processing a sentence-initial inanimate noun. However, this result does not reveal anything about the nature of the difficulty and the steps that the processor might take to deal with it. Note that sentence-initial inanimate nouns do not appear to cause processing

difficulty in flexible word-order languages (Turkish: Demiral et al., 2008; Mandarin Chinese: Philipp et al., 2008; German: Bornkessel & Schlesewsky, 2006).

There are at least three paths that the processor could take upon encountering an inanimate noun in sentence-initial position. These accounts all assume that the processor begins with a bias toward an active sentence in which an animate noun in subject position is assigned the role of agent. (1) The processor could do extra work to process the inanimate noun as an agent in an active sentence. (2) The processor could assign the role of theme to the inanimate noun, but not use this information to make any predictions about what structure to expect. (3) The processor could assign the role of theme to the inanimate noun and use this information to pursue a passive analysis.

The results of various studies on relative clauses can be taken as evidence that the processor does not take a sentence-initial inanimate noun to be an agent. However, a study by Ferreira (2003) suggests that the processor may not use this evidence to pursue a passive analysis.

Several studies from the literature on relative clauses have shown that it is easier to process sentences in which the initial NP has to be analyzed as the theme of a relative clause verb if that initial noun is inanimate. Trueswell et al. (1994, Expt 2) examined the effect of the animacy of the initial noun in sentences that were initially ambiguous between a main clause and a reduced relative. The conditions included

inanimate ((17)a.) and animate ((17).b) nouns in either reduced or unreduced relative clauses.

(17) a. The evidence (that was) examined by the lawyer turned out…

b. The defendant (that was) examined by the lawyer turned out…

The results showed that for the sentences with animate nouns there was a significant disruption in first pass reading times in the *by*-phrase region for the reduced relative compared to the sentences with unambiguous unreduced relative clauses. In contrast, for the sentences with inanimate nouns, there was no reading time disruption for the reduced relative compared to the sentences with unambiguous unreduced relative clauses. This was taken as evidence that the syntactic disambiguation process is easier with an inanimate noun because the processor can immediately use the fact that the noun is a more typical theme than agent to attain a relative clause analysis (in which the NP is the theme of the relative clause verb). Similarly, Traxler, Morris and Seely (2002) presented evidence from eye-tracking that showed that the difficulty of object-relative clauses is greatly reduced when the initial noun is inanimate.

(18) a. The movie that the director watched received a prize at the film festival.

b. The director that the movie pleased received a prize at the film festival.

Reading times were reduced when the initial noun was inanimate ((18)a.) compared to a sentences with an initial animate noun ((18)b.). The authors interpreted this result as evidence that (18)b. is harder to process because the main clause subject noun is a typical agent, and was initially assumed to be an agent, but instead has to be analyzed

as the theme of the relative clause verb. These studies looked at sentences in which the initial noun has to be assigned as the theme of the relative clause verb, and showed that processing is facilitated if the initial noun makes a good theme and a poor agent by virtue of being inanimate. However, although this shows that the animacy of the initial NP may be used at later points in the sentence when it helps the processor to attain a less-frequent or more difficult analysis, it does not provide evidence about whether the processor actively assigns the role of theme to the initial NP when it first encounters that NP.

The results of Ferreira (2003) suggest that sentence-initial inanimate nouns confer no benefit in processing passive structures. In this study, participants were given sentences such as *The dog was bitten by the man* and *The cheese was bitten by the mouse*, in active or passive form. At the end of each sentence, participants were asked, "Who was the do-er?" Overall, participants were slower and less accurate in the passive sentences compared to the active sentences. Surprisingly, they were equally slow and inaccurate in the animate-initial (reversible) and in the inanimate-initial (non-reversible) sentences. In other words, having an initial inanimate noun did not seem to help the participants correctly achieve a passive structure for the sentences. However, it is hard to use participants' post-sentence explicit statements to make detailed inferences about on-line processing as the sentences unfold.

In summary, although the sentence-initial inanimate noun provides possible evidence that the processor could use to pursue a passive analysis, it is unclear

whether the processor uses this evidence to pursue a passive analysis immediately after encountering it. In the discussion that follows, I assume that the inanimate noun does make the processor more disposed to a passive analysis, but this is not crucial since the other cues also point toward a passive analysis.

2.1.1.2 Structural bias of the auxiliary

The second cue that might point the processor in the direction of either an active or a passive analysis is the structural bias of the auxiliary. In English, the auxiliary *was* is approximately equally compatible with a passive or a progressive. Because *was* is compatible with both active and passive analyses, it is possible that it does not cause the processor to alter its expectations for the upcoming structure. However, if the processor had pursued a passive analysis based on the initial inanimate noun, it might have a strong expectation for a form of *be*, whereas there would be no such expectation if the processor had pursued an active analysis. The expectation for a form of *be* would be confirmed when the processor encountered *was*, further strengthening the evidence for a passive analysis. Therefore, it is possible that the combination of the auxiliary and the initial noun yields a stronger expectation for the passive than would occur based on the auxiliary alone.

A second experiment in English by Kim & Osterhout (2005b) yielded similar results for sentences that started with *The hearty meal will…*, which could be followed by either the passive *be devoured…* or the active *devour…*. Unlike in English, in languages such as Spanish, different auxiliaries are typically used with the

passive and progressive verbal forms. This can provide a stronger cue for whether the sentence is likely to have an active or a passive structure. This is the topic of the experimental work presented in this chapter, and will be discussed in more detail starting in Section 2.

2.1.1.3 Goodness-of-thematic-fit between the NP and the verb

The verb stem *devour-* carries two cues about whether the sentence is likely to have an active or a passive structure. One cue is the goodness-of-fit between the verb and the NP, which may be a good agent or theme for the verb, or neither, or both. For the purpose of the studies described in the dissertation, it does not matter whether this is based on a limited set of semantic features or on a more sophisticated analysis. In the case of *meal*, which is a good theme but a bad agent for *devour*, this cue would make the processor more likely to pursue the passive analysis. In contrast, a noun like *tabletop* is a poor theme for devour, and therefore would not make the passive any more likely than it was before. Trueswell et al. (1994) provided evidence that processing is facilitated when the noun is a good fit for the thematic role it is assigned. In relative clauses of the kind *The evidence (that was) examined by the lawyer…*, in which *evidence* has to be analyzed as the theme of *examined*, the results of Experiment 1 showed that there was no processing cost for the ambiguous reduced relative when the first noun was inanimate (i.e., a poor agent but a good theme). This was interpreted as showing that the processor was already predisposed to treat the initial noun as a theme and so the disambiguating syntactic cue (*…that was…*) was redundant. Crucially, for the topic of this section, when the nouns were rated as good

patients for the particular verb (i.e., semantic fit, not just inanimacy), this was associated with an even further reduction in the cost of processing a reduced relative. Trueswell et al. (1994) interpreted this finding to indicate that the parser is immediately able to use semantic information to guide the syntactic disambiguation process. In a more recent proposal, McKoon and Ratcliff (2007) argue that the sentences in which the initial noun is a good theme for the verb are not easier because the disambiguation process is easier, but rather because the concept expressed by the sentence is easier to understand and integrate with world knowledge. For the current purpose, the main point is that comprehenders do appear to use the thematic fit between the initial noun and the verb to guide processing.

Although it is clear that the thematic fit between *meal* and *devour* could lead the processor to consider a passive analysis, it is less clear what should happen when there is a lack of thematic fit between the noun and the verb. *Tabletop* is a poor theme for *devour*, but it is also a poor agent for that verb. On the one hand, the processor may decide to do nothing and assume the general bias of English sentences for an active structure. On the other hand, the processor may decide to pursue a passive anyway, because an inanimate noun is typically a better theme than agent, even though it is not a good theme for this particular verb. Kim & Osterhout (2005) argue for the first option, which assumes that the processor pursues an active analysis unless it encounters strong evidence that the noun make a good theme for the verb. However, the experimental results presented here, as well as in other recent studies (e.g., Kuperberg, 2007), have shown that the electrophysiological response to

sentences like *The dusty tabletop was devouring…* is much more variable than it initially appeared from the Kim and Osterhout (2005) study. The extent to which the thematic fit between the initial noun and the verb modulates the P600 is discussed in detail in Chapter 4.

2.1.1.4 Structural bias of the verb

The second cue that arrives with the verb stem is information about the frequency with which the verb appears in different structures. This has the potential to be an important factor in determining whether a sentence elicits a P600 or an N400. If a verb appears frequently in passive form, we might expect the processor to commit more fully to a passive interpretation and be even more surprised when it encounters definitive evidence (i.e.,*–ing*) that disconfirms this analysis. On the other hand, a verb that appears more frequently in active sentences may make the processor less inclined to consider a passive interpretation and therefore not surprised by the active morphology, leading to an N400. Of course, as I stated in the introduction to this chapter, the discussion here assumes that the thematic P600 is caused by a mismatch between an expectation for a passive and the actual verbal suffix, as Kim and Osterhout (2005) argued. I challenge this assumption in Chapter 4, but in this discussion I assume that is true, and argue that it is possible that the processor reached a passive analysis without the need to argue that it did so by ignoring the active verbal suffix.

There is by now general agreement that comprehenders are able to use information about the frequency with which a verb appears in different kinds of structures in order to guide processing. Many studies have shown that the frequency with which a verb takes different kinds of syntactic complements (e.g., NP, sentential complement) can assist the processor to reach the correct analysis (e.g., Trueswell et al., 1993; Ferreira & Henderson, 1990; Garnsey et al., 1997; Pickering et al., 2000; Kennison, 2001; Staub, 2007). For example, Trueswell, Tanenhaus and Kello (1993) showed that readers are able to use the fact that *hope* takes a sentential complement to avoid trouble at the complement verb in *The student hoped the solution was…,* relative to *The student forgot the solution was…* in which the verb was biased toward an NP-complement. Similarly, the processor also appears to be able to use information about the frequency with which the verb appears in different forms. Spivey and Tanenhaus (1998) showed that it is easier to process reduced relatives (e.g., *The actress selected by the director*) with verbs that frequently appear as a past participle compared to verbs that more frequently appear in past tense.

Despite the evidence that the structural bias of a verb can be used to guide processing, it does not appear to affect whether or not a P600 is generated, at least in the kinds of sentences we are concerned with here. Kim and Osterhout (2005b) divided the experimental materials from Kim and Osterhout (2005, Expt 2) according to the voice bias of the verb: one group of verbs showed an active bias and another showed a passive bias, although all were transitive verbs that were acceptable in either active or passive structures. Both groups of verbs elicited a P600, with the

active-bias verbs eliciting a larger-amplitude P600 than the passive-bias verbs. Kim and Osterhout argue that the active bias serves to strengthen the "lexico-syntactic" cues, and therefore makes it harder to reconcile the interpretations based on structural cues with those based on semantic cues (i.e., goodness-of-thematic-fit). However, this interpretation is complicated by the findings of Kuperberg et al. (2006), who divided experimental materials according to the sub-categorization frames that the verbs allowed: one group was preferentially or strictly transitive (e.g., *The food was ordering…)* and another was preferentially or strictly intransitive (e.g., *The trumpets were curtseying…)*. Kuperberg et al. (2006) recorded a P600 to both, but the P600 showed a higher amplitude to those sentences containing intransitive verbs, which cannot appear in passive form. The argument made in Kim & Osterhout (2005b) cannot account for these results because the semantic cues do not suggest a passive interpretation (*trumpets* cannot be *curtseyed*), and likewise, the structural cues obtained from verb bias would also not push a passive interpretation (*curtsey* is intransitive). Therefore, the results cannot be explained by appealing to the conflicting outputs from structural and semantic processing streams. These results will be considered again in Chapter 4 in light of the experimental results presented in this dissertation, but for now the crucial idea is that the structural preferences or requirements of the verb may impact the interpretation the processor has under consideration after processing the verb stem.

2.1.1.5 Verbal suffix

The final cue that is available to the processor in deciding whether to pursue an active or a passive interpretation is the verbal suffix. As has been argued in this section so far, in the case of *The meal was devouring…*, all of the other semantic and syntactic cues are either neutral or point the processor in the direction of a passive interpretation. Therefore, if the verbal suffix is processed after these cues, it seems likely that the processor would be pursuing a passive interpretation when the verbal suffix arrives. Therefore, the P600 may be elicited because the suffix is inconsistent with the currently favored structure of the sentence.

Here I consider evidence from the lexical retrieval literature that suggests that the verbal suffix is processed later than the verbal stem. There is a long-standing and ongoing debate about whether morphologically complex words are stored as whole word forms in the lexicon (e.g., Fowler, Napps & Feldman, 1985; Bybee, 1995; Seidenberg & Gonnerman, 2000), or whether the root form and affixes of morphologically complex words are stored separately (e.g., Taft & Forster, 1976). In fact, many current approaches have now adopted a hybrid model that allows for direct access to whole forms as well as decomposition into morphemic constituents (e.g., Taft, 1994; Schreuder & Baayen, 1995; Caramazza, Laudanna & Romani, 1988; Niemi, Laine & Tuominen, 1994; Giraudo & Grainger, 2000). The complex and detailed evidence for these different models is beyond the scope of this dissertation, but I will present some evidence on the question of whether the stem is retrieved first, and therefore probably processed before the suffix. Clearly this question is more

pertinent to models that posit decomposition into morphemic constituents, but since so many models posit both decomposition and whole-word recognition as parallel components, the question of whether the stem is retrieved prior to the suffix is relevant for at least one component of most models. Note that knowing the order in which the stem and suffix are retrieved does not tell us definitely whether that is the order in which they are used at the sentence processing level. It only suggests the order in which they might be available.

Various studies have looked at this issue using compound words, manipulating the frequencies of the first and second constituents to see which one (or both) affects either lexical decision time or eye-movements. The eye movement studies (e.g., Andrews, Miller & Rayner, 2004; Hyönä & Pollatsek, 1998; Pollatsek, Hyönä & Bertam, 2000) are the most relevant here as they embed the words in a sentence context. These studies have shown that the frequencies of the first and second constituents and of the whole word all showed significant effects on gaze duration and total fixation times. Most relevantly, the effect of the frequency of the first constituent tended to show up on the earliest eye-movement measure, first fixation, while the effects of the frequencies of the second constituent and of the entire compound word generally appeared on later measures such as the second and third fixations. This suggests that the first constituent is processed first, although we should be careful about drawing too strong conclusions for our purposes because the studies involved compound words not inflected words. Additionally, in the two Finnish studies (Hyönä & Pollatsek, 1998; Pollatsek, Hyönä & Bertam, 2000), the

words were very long (typically 12 letters), and since readers tend to fixate on the 3rd or 4th letter from the left (Rayner, 1979), the second constituents in those studies may not even be perceived during the first fixation. Therefore, this result may not transfer into studies using shorter words. Niswander, Pollatsek and Rayner (2000) looked at the effect on eye-movements of root and whole word frequencies of derived and inflected words. Of particular interest here are the results on inflected words, including verbs ending in *–ed* and *–ing*. The frequency of the whole word showed significant effects beginning on first fixation times. The effects regarding the frequency of the root stem were complicated, but for verbs with stems that were used predominantly as verbs (e.g. *walked* but not *handed*), the effect of the frequency of the root stem (controlling for whole word frequency) was also seen on first fixation times. This suggests that the meaning of the root stem was accessed during the first stages of processing. It is unclear to what extent this indicates that the stem is processed prior to the suffix in the decompositional stream of lexical retrieval as of course this study does not tell us whether the suffix is processed later than the stem or simultaneously with it. This at least leaves room for a story in which the verbal stem impacts sentence processing prior to the verbal suffix.

If indeed the verbal suffix is processed last and provides the definitive proof that the representation that the processor had been pursuing up to that point is wrong, the results from Kim and Osterhout (2005) are consistent with their claim that the P600 arises because *–ing* is grammatically unacceptable relative to the passive interpretation under consideration. However, I claim that this situation is not due to

an independent semantic combinatorial mechanism that overrides the syntactic information provided by *–ing*. Rather, once all the cues, semantic and syntactic, are taken into consideration in the order in which they arrive, it is possible to explain the results without positing a parallel and independent semantic combinatorial mechanism.

In this section I presented a way of accounting for previous results in which the processor uses semantic cues to guide processing but does not consider analyses that ignore the syntactic cues. I also sought to emphasize the importance of considering the timing of arrival of all the different cues. In the next section I present an experiment that tests whether semantic composition can ignore syntactic cues, without relying on resolving whether the goodness-of-thematic-fit and structural biases of the verb are processed earlier than the verbal suffix.

2.1.2 The independence of semantic composition

As just discussed, previous ERP results are compatible with a model in which both semantic and syntactic cues are used to arrive at a representation of the sentence, with time of arrival dictating which cues appear most influential. The results are also compatible with a model in which a semantic composition mechanism functions independently of the structural information. The accounts that have been proposed for the unexpected P600 (Kim & Osterhout, 2005; Kuperberg, 2007; van Herten et al., 2005, 2006; Bornkessel-Schlesewsky & Schlesewsky, 2008) all propose parallel streams of processing that function, to differing degrees, independently from one

another. Much of the debate has centered on the extent to which the streams are independent or interactive at the current word. What has been discussed far less is the extent to which these parallel streams may be independent or interactive over segments of the sentence that span more than one word.

Most of the accounts of the thematic P600 have focused on the processing that occurs at a critical verb. The accounts vary in the extent to which the streams interact during the processing of the critical verb, or rather operate independently and then later check whether the results are compatible. In the models of Kim and Osterhout (2005) and van Herten et al. (2005, 2006), the streams are substantially independent. Although this is not discussed explicitly, the account described in Kim & Osterhout (2005) appears to assume that the semantic and syntactic combinatorial streams are completely independent and only interact after each has completed processing, to check whether the outputs are consistent with one other. Similarly, in the account of Kolk, van Herten and colleagues the 'heuristic' and 'algorithmic' streams work independently until the executive system compares them to see if they have arrived at compatible representations. In contrast, the accounts provided by Kuperberg (2007) and Bornkessel-Schlesewsky and Schlesewsky (2008) allow for more interaction as the streams each process the incoming word. Kuperberg (2007) proposes that processing in the 'combinatory' stream may begin during the N400 window and can modulate the amplitude of the N400, which itself reflects the 'semantic memory-based' stream, and vice versa, that the processing result of the semantic stream can influence whether or not processing in the combinatory stream goes ahead. Similarly,

Bornkessel-Schlesewsky and Schlesewsky (2008) argue that if the processor detects a problem in the early syntactic analysis, this can block plausibility processing (although in their model the reverse does not hold: a problem in the plausibility step does not block the processing of syntactic relations). This model, therefore, also implies a reasonable degree of interaction at the verb.

An issue that has received less attention is whether these parallel streams may be independent or interactive over larger segments of the sentence that span more than one word. More specifically, the question is whether the streams work in parallel without reconciling and integrating their outputs after every single word. For example, does Kim and Osterhout's independent semantic composition mechanism ignore just the structural information that may be provided by the current word, or does it ignore all previous structural information too? A semantic composition mechanism could be highly independent such that, at each new content word, it retrieves all of the previous content words and combines them in the most plausible way, ignoring previous commitments made regarding those content words. Although it seems highly implausible that the processor goes an entire sentence without considering whether the semantic and syntactic compositional representations are compatible with one another, it might be the case that such a mechanism operates over a span of several words. In contrast, a more restricted independent semantic composition mechanism would take the representation that had been built over the previous words and integrate the current content word into that representation in the most plausible way.

The highly independent semantic composition mechanism could allow the processor to carry forward two incompatible representations of a sentence over multiple words, so it might seem as if this is a straw man position. However, although they do not fully articulate it, this position is implied in the way Kolk, van Herten and colleagues discuss their results (Kolk et al., 2003; van Herten et al., 2005, 2006). Before the processor encounters the verb in sentences such as the *The fox that at the poachers hunted*, the processor already has sufficient information to commit to assigning the *fox* as the agent and the *poacher* as the goal. The authors argue, however, that the heuristic stream takes the meaning of the three words *fox, poachers* and *hunted* and combines them in the most plausible way – i.e., ignoring previous information that may have been previously calculated regarding their structural positions. Although the authors discuss this result as though the heuristic ignored the previous syntactic information all along, another possible reading is that at a point of difficulty speakers can reevaluate everything from scratch. The full discussion of this issue relies on an on-going debate about just how much semantic composition takes place prior to the verb in head-final languages. This debate and its implications for the thematic P600 results will be examined in much more detail in Chapter 4.

In this chapter, the focus is on narrowing down for SVO languages an issue left open by the account proposed in Kim and Osterhout (2005), namely, whether the processor can pursue interpretations that, although suggested by the most plausible relations between a cluster of neighboring words, are not compatible with structural commitments that the processor might have already made based on earlier syntactic

cues. Although there is plenty of evidence that semantic and structural information sources are used in conjunction and reconciled at the critical word in previous studies (e.g., Kim & Osterhout; Kuperberg et al., 2003; van Herten et al., 2005, 2006), in most of these studies, the critical word is a verb. Because the verb carries so much lexical-semantic and structural information that is relevant to determining the core properties of the sentence, even a theory in which semantic composition could occur over multiple words without consulting the syntactic stream would need to posit that the verb is a position where structural and semantic representations must be reconciled.

The experiment presented here tests whether the processor only considers interpretations are compatible with previous structural commitments. This is designed to distinguish between models in which the processor respects previous structural commitments and models in which a semantic processing system can ignore previous structural information.

2.2 The current experiment

As argued in the previous section, in all of the experiments conducted so far in English the results reflect interpretations that are compatible with the surface syntax of the sentence prior to the critical word. For example, the Kim and Osterhout (2005) study used an auxiliary form, *was*, that is compatible with both passive and progressive continuations. Therefore, in that experimental design, the critical structural information differentiating these two constructions is presented at exactly

the same time as the information about thematic fit between the noun and the verb. This means that the discussion of whether a semantic stream can ignore syntactic cues rests on whether the syntactic cue is processed simultaneously with or later than the verbal stem. As was discussed in the previous section, it is possible that the verbal stem is perceived first, or that the stem and suffix are perceived simultaneously but the processor uses the information in the stem first. If that is the case, the English results can be explained by a model in which there is no independent composition based upon semantic information; it just happens that in this study the particular timing of the different cues made the effect of the semantic cues appear to carry more weight.

The current study aims to reverse this timing effect, by ensuring that the structural information appears prior to the semantic information carried by the verb. In Spanish, the choice of auxiliary can be manipulated to indicate that the sentence is unlikely to have a passive structure. This design ensures that the processor will have information about structural biases at the auxiliary, prior to the information about thematic fit between the noun and the verb, which is only available once the verb has been encountered. The question addressed here is whether information about structural bias can be used to modulate the effect of semantic attraction at the verb. If the processor already has information available that suggests that the sentence is unlikely to have a passive structure, will it still try to process the subject NP as theme of the verb in cases of semantic attraction? In the case of a semantic composition mechanism that operates independently of the syntactic stream over a span of several

words, the representations proposed by the semantic processor should not be influenced by structural information carried by an earlier function word. On the other hand, if the processor respects all currently available information, structural information provided by the previous word should restrict downstream interpretations to those that are consistent with that information. If this is the case, the processor should not attempt to analyze the subject NP as the theme of the verb even if it is a good fit for that role.

In Spanish, different auxiliaries typically precede verbs in passive and progressive forms: *ser* and *estar*, respectively. Therefore, the choice of auxiliary can be used to manipulate the upcoming syntactic expectation prior to the semantic information conveyed by the main verb. Specifically, *ser* provides evidence that a verb in progressive form is unlikely to follow, and *estar* provides evidence that a passive verb form is unlikely to follow. It is crucial for the current design that these are probabilistic biases: it is not ungrammatical for *ser* to be followed by a verb in progressive form, and vice versa for *estar*. It should be noted that both auxiliaries can also be followed by an adjective. In a design similar to Kim & Osterhout's (2005) Experiment 2, grammatical controls were compared with semantic-attraction and no-attraction anomalous sentences. In the semantic-attraction anomalous sentence, the initial NP was a plausible theme for the verb, whereas in the no-attraction condition the NP was not a plausible theme for the verb. These three conditions (grammatical control, semantic-attraction and no-attraction) were tested with each of the two auxiliaries. The form of the *ser* auxiliary used in the experiment was *fue* which is the

third person singular past tense of *ser*. The form of the *estar* auxiliary used in the experiment was *estaba* which is the first and third person singular progressive tense of *estar*. *Fue* is typically used in a passive syntactic structure, and *estaba* typically is used in a progressive syntactic structure.

The passive construction is less frequent in Spanish than in English and has more specific discourse requirements. Specifically, the passive is felicitous in a situation where the theme NP has already been mentioned. Therefore, each of the target sentences in the study was preceded by a context sentence that that introduced all three NPs that began the different versions of target sentences. An example set of materials can be seen in Table 3.

Table 3

Sample materials set from the primary conditions of the Spanish ERP study

Semantic Attraction Conditions		
Context sentence		Después del fuego, el bombero formuló un aviso para prohibir la entrada al piso quemado. ... *After the fire, the fireman prepared a warning to forbid entrance into the burnt apartment.*
fue - passive prediction	Grammatical control	El aviso fue declarado por el bombero ante todos los vecinos. *The warning was declared by the fireman in front of all the neighbors.*
	Semantic Attraction	El aviso fue declarando con un megáfono para que todo el mundo lo oyera. *The warning was declaring with a megaphone so everyone would Hear it.*
	No Attraction	El piso fue declarando con un megáfono para que todo el mundo lo oyera. *The apartment was declaring with a megaphone so everyone would hear it.*
estaba - progressive prediction	Grammatical control	El bombero estaba declarando el aviso cuando el fuego se formó otra vez. *The fireman was declaring the warning when the fire rose up again.*
	Semantic Attraction	El aviso estaba declarando con un megáfono para que todo el mundo lo oyera. *The warning was declaring with a megaphone so everyone would hear it.*
	No Attraction	El piso estaba declarando con un megáfono para que todo el mundo lo oyera. *The apartment was declaring with a megaphone so everyone would hear it.*

2.2.1 Predictions

If the processor uses prior information about structural biases to guide processing, then we should expect the auxiliary manipulation in Spanish to restrict the thematic role assignments to those that are compatible with prior information about the upcoming structure. In the *fue* conditions, the processor should entertain analyses that are consistent with a passive structure. In contrast, in the *estaba* conditions, the processor should not consider analyses that imply a passive structure. If, however, the processing does not take prior structural information into account when considering

how to combine open class words, then the choice of auxiliary should not matter and the same pattern of results should be seen in both the *fue* and *estaba* conditions.

The prediction is that if the processor respects prior structural biases, the auxiliary manipulation will show an effect, whereas if a semantic stream ignores prior structural biases, the electrophysiological responses will not be affected by the auxiliary manipulation. However, there are various possible predictions for the exact pattern of electrophysiological responses.

On the one hand, if Kim and Osterhout's specific pattern is replicated, then we can make the following predictions. If the processor does use structural biases to guide processing, then when the bias suggests a passive interpretation (i.e., with *fue*), the semantic-attraction condition will yield a P600 and the no-attraction condition will yield an N400. When the bias suggests that a passive interpretation is unlikely (with *estaba*), the processor will not attempt to analyze the initial NP as a theme even when the noun would fit the role. Therefore, in the *estaba* conditions, both semantic-attraction and no-attraction conditions will yield an N400. In contrast, if the processor ignores prior information about structural biases, the responses will pattern exclusively with the attraction status of the initial NP. Therefore, with both auxiliaries, the semantic-attraction conditions will yield a P600 and the no-attraction conditions will yield an N400.

On the other hand, it is possible that the specific pattern seen in Kim and Osterhout does not replicate. In a recent study by Kuperberg et al. (2007), both the semantic-attraction and the no-attraction conditions elicited a P600 (e.g. *the eggs would only eat…* and *the eggs would only plant…*). Assuming for now that a P600 response indicates that the processor attempted a passive analysis and was surprised by the active verbal suffix, we can make the following predictions. If the processor uses previously-presented structural biases to guide processing, then the processor should only attempt a passive analysis in the *fue* conditions. This would result in a P600 in both *fue* conditions, and an N400 in both *estaba* conditions, regardless of semantic attraction. On the other hand, if a semantic stream ignores previously-presented structural biases, then it should only pursue a passive interpretation if this is suggested by semantic attraction between the initial NP and the verb. Specifically, both semantic-attraction conditions should yield a P600, independent of the auxiliary manipulation, and likewise, both no-attraction conditions should yield an N400.

Although the predictions are relatively complex, the important test is whether the auxiliary manipulation impacts the results. If the processor respects prior structural information, the auxiliary manipulation will impact the electrophysiological responses. If the processor ignores prior structural information, the responses will be the same regardless of the auxiliary. The issue of whether the semantic attraction P600/N400 split (as seen in Kim and Osterhout) will be replicated complicates the predictions about which specific components will be seen, but does not change the

basic question about whether or not the auxiliary will impact the electrophysiological responses.

2.2.2 Control sub-experiments

Because relatively few ERP studies have been conducted in Spanish, we included control conditions to confirm that syntactic and semantic anomalies elicit canonical N400 and P600 effects. This allows us to compare the ERP components generated in the novel conditions with clear results from experimental comparisons that are better understood. The semantic sub-experiment contained a pair of conditions that manipulated the semantic felicity between a noun and a following adjective. The syntactic sub-experiment contained a pair of conditions that manipulated the correctness of number agreement between a determiner and a noun. Half of the violation items involved a singular determiner/plural noun mismatch and the other half involved a plural determiner/singular noun mismatch. The control sub-experiments were run together with the attraction study. A sample set of experimental conditions is presented below in Table 4.

Table 4

Sample materials for the two control sub-experiments of the Spanish ERP study

Semantic agreement control experiment		
Context sentence		Cuando Juan se hizo millonario, contrató a un chófer y compró un carro costoso. ... *When Juan became a millionaire, he hired a chauffeur and bought an expensive car. ...*
Sem. Feli-city	+felicitous	El chófer estaba limpiando el carro lujoso, cuando Juan chocó con una moto contra la puerta del garaje. *The chauffeur was cleaning the luxurious car, when Juan crashed his motorcycle into the garage door.*
	-felicitous	El chófer estaba limpiando el carro enfadado, cuando Juan chocó con una moto contra la puerta del garaje. *The chauffeur was cleaning the angry car, when Juan crashed his motorcycle into the garage door.*
Syntactic agreement control experiment		
Context sentence		Cuando el ladrón entró por la ventana de la casa, la alarma antirrobo empezó a sonar muy alto. ... *When the thief entered the house through the window, the burglar alarm began ringing loudly. ...*
Syn. agree-ment	+agree	El ladrón estaba desconectando los hilos del alarma antirrobo cuando llegó la policía. *The thief was disconnecting the(pl.) wires of the burglar alarm when the police arrived.*
	-agree	El ladrón estaba desconectando el hilos del alarma antirrobo cuando llegó la policía. *The thief was disconnecting the(sg.) wires of the burglar alarm when the police arrived.*

The semantic felicity between a noun and its adjective has been previously tested in Spanish ERP studies. Martín-Loeches et al (2006) compared sentences containing felicitous noun-adjective combinations such as *el sentimiento profundo* ('the profound sentiment') with infelicitous noun-adjective combinations such as *el sentimiento peludo* ('the furry sentiment') and found a clear N400 (and also, unexpectedly, a small P600). In a series of both auditorily- and visually-presented mini-stories, Wicha and colleagues (2003a, 2003b) compared sentences in Spanish that translate to: *Little Red Riding Hood was carrying food to her grandmother in a*

very pretty {basket/crown}. In this case they also see a clear N400 to the infelicitous word. These experiments suggest, as would be expected, that the N400 behaves similarly in Spanish as in other languages.

The syntactic control sub-experiment looked at number (dis)agreement between an article and a noun. This was previously tested by Barber and Carreiras (2005), and resulted in a LAN plus a P600. Various similar studies of grammatical agreement have also been conducted in Spanish and yielded similar results: Barber and Carreiras (2005, experiment 2) and Martín-Loeches et al. (2006) also tested number agreement between a noun and its following adjective (LAN and P600 in both cases); Martín-Loeches et al. (2006) tested grammatical gender agreement between a noun and its following adjective (also LAN and P600); finally, Wicha et al. (2004) tested grammatical gender agreement between an article and a noun and found just a P600. Barber & Carreiras (2003; 2005 experiment 1) presented word pairs (article plus noun or noun plus adjective) that disagreed in number, and elicited an N400, which was surprising when compared to previous number agreement mismatches in English and Spanish. Nevertheless, this result is probably related to the difference between presenting isolated word pairs and embedding the mismatch in a sentential context.

2.3 Methods

2.3.1 Participants

31 people participated in the ERP study. Data from 1 participant were excluded due to technical problems, data from 5 participants were excluded due to low rates of correct response (<75%), and data from 1 participant were excluded due to high levels of artifacts in the EEG recordings. All 24 remaining participants (14 female; mean age 27; range 18-41 years) were healthy, native speakers of Latin-American Spanish (Perú (5), Argentina (4), Chile (4), Colombia (4), Puerto Rico (2), Guatemala (2), Venezuela (1), Ecuador (1), Costa Rica (1)). All had been in the United States for three years or less (mean: 1.5 years; range: 1 month to 3 years) except for one participant who had been in the country for five years but spoke Spanish almost exclusively in everyday life. All were right-handed and had normal or corrected-to-normal vision. All participants gave informed consent and were paid $15/hour for their participation, which lasted approximately 4 hours, including set-up time.

2.3.2 Materials

The materials for the study consisted of sets of six sentences organized in a 2 x 3 factorial design, illustrated in Table 3. The full set of materials can be seen in Appendix A. There were two levels of the auxiliary factor (*fue* and *estaba*) and three levels of the relatedness factor (control, semantic-attraction and no-attraction). The semantic control sub-experiment contained pairs of sentences corresponding to

felicitous and infelicitous noun-adjective combinations and the syntactic control sub-experiment contained pairs of sentences corresponding to grammatical and ungrammatical article-noun agreement combinations. Examples of the semantic and syntactic sub-experiments are shown in Table 4.

In all six target conditions, the sentences consisted of an NP (always determiner plus noun), followed by an auxiliary (either *fue* or *estaba*), followed by a verb with either passive or progressive verbal morphology. For the anomalous sentences, the two factors varied were the goodness-of-fit of the inanimate NP as a theme for the verb, and the auxiliary: *fue*, which is used with passives, and *estaba* which is used with progressives.

In all conditions, the target sentence was preceded by a context sentence. In Spanish, the passive construction is not felicitous if it introduces a new referent, but can be used if the NP is referring back to an NP that is already within the discourse. The context sentences were identical within each set of items, and mentioned all three possible subjects of the target sentence. The three subjects of the target sentences were an inanimate NP that was a good theme for the verb (used in the grammatical control sentence with *fue*, as well as in the semantic-attraction anomalous sentences with both *fue* and *estaba*), an inanimate NP that was a poor theme for the verb (used in the no-attraction anomalous sentences with both *fue* and *estaba*), and an animate NP (used in the grammatical control sentence for *estaba*). Although most of the target

sentences turned out to be active, the context sentences were designed to be compatible with both passive and progressive continuations.

It is important for this design that the auxiliaries have biases in one direction, but both also allow the other voice. *Ser* (and its form *fue*) is biased toward the passive, but can also be followed by the progressive (e.g., *fue buscando* which roughly translates as 'went around looking'). Likewise, *estar* (and its form *estaba*) are biased toward the progressive but can also be followed by a passive form (e.g., *estaba cerrado por* 'was in the state of being closed by'). If these continuations were impossible rather than unlikely, we would have a straight syntactic violation, which would not allow us to investigate the factors that modulate the thematic P600.

The grammatical control sentences using *fue* and *estaba* had different syntactic structures. The grammatical control for the two anomalous sentences with *fue* had a passive structure (the analog of *the hearty meal was devoured*), and the grammatical control for the two anomalous sentences with *estaba* had an active progressive sentence (the analog of *the hungry boy was devouring*). Different grammatical controls were chosen for the *fue* and *estaba* sentences to increase naturalness. As just described, although the combinations of *fue*+progressive and *estaba*+passive are possible, they are dispreferred. Therefore, sentences with the combinations of *fue*+passive and *estaba*+progressive were a better choice for the grammatical control sentences with which the anomalous sentences would be compared. It was not anticipated that this would be a problem because Kim &

Osterhout (2005, experiment 1) compared the anomalous *the hearty meal was devouring* to both an active control (*the hungry boy was devouring…*) and a passive control *(the hearty meal was devoured…*). In that study, the choice of control did not impact the results.

For each set of six sentences, a verb and three NPs were chosen. The verb was chosen to be felicitous in both passive and progressive constructions, as judged by native Spanish speakers who helped with the development of the materials. The verbs chosen for this experiment tend to impose less rigid selectional restrictions than those used in many of the experiments under study here (e.g., Kim & Osterhout, 2005; Kuperberg et al. 2003, 2006, 2007; Kolk et al., 2003; van Herten et al., 2005, 2006) because it is harder in Spanish to find concrete verbs that are felicitous in passive voice. The verbs that are most felicitous tend to be verbs from business or newspaper language, such as *investigar* 'investigate', *firmar* 'sign', *entregar* 'deliver'. Different verbs were used for each item set, with the exception of twelve verbs which were repeated once each in order to increase the felicity of certain items. Following the selection of the verb, three NPs were chosen: one animate noun that could be a good agent for the verb, one inanimate noun that could be a good theme for the verb, and another inanimate noun that was a poor theme for the verb. In order to prevent the initial determiner in the target sentence from providing a clue about which of the three previously-mentioned nouns was going to be the subject of the sentence, all three nouns in an item shared the same grammatical gender. In order to guard against possible confounds due to non-pertinent differences (e.g., in word length or

frequency), almost all (96%) of the nouns appeared in one item as the attractive noun and in another item as the non-attractive noun. This was not the case for 4% of the items in which the nouns were changed to increase the felicity of those items.

In order to avoid biasing participants to consistently attribute a certain interpretation to the violations, the material following the critical verb in the anomalous versions of each item were varied. This was important because one account for the results states that a P600 is evidence that the processor pursued a passive analysis, which led to the perception of a syntactic error (*-ing* not *–ed*), whereas an N400 is evidence that the processor considered an active analysis, which led to the perception of a semantic error (inanimate NPs do not perform this action). The material after the verb might change the way the participants perceived the violation, and therefore change the component that was evoked. For example, if participants always saw a *by*-phrase after the anomalous inanimate NP+progressive form, it might lead them to adopt a passive analysis for the overall sentence, and therefore classify the violation as a syntactic error (*-ing* not *–ed*). Therefore, the completions were distributed equally among three options: a by-phrase ('by the fireman'), an inanimate NP ('the apartment'), or a preposition or other adverb ('with a megaphone' or 'many times'). The majority of words following the critical verb were short: mainly prepositions and definite articles, with some slightly longer adverbs.

Materials for the two control sub-experiments began in a very similar form to the target experimental items: context sentence, determiner, noun, auxiliary, verb, post-verbal continuation. These items were designed so that certain features were quite consistent, making it difficult for participants to anticipate specific features of the target conditions. Across the entire set of experimental materials, the second, target sentences contained equal numbers of the following beginnings: inanimate+*fue*, inanimate+*estaba*, animate+*fue* and animate+*estaba*.

180 sets of items for the target conditions were distributed across six presentation lists in a Latin Square design such that each list contained 30 items per condition. 60 pairs of grammatical agreement items were distributed across two presentation lists. 60 pairs of items manipulating semantic felicity were also distributed across two separate presentation lists. These two control sub-experiments were then crossed such that there were four presentation lists for the control sub-experiment items. The six lists of target items were crossed with the four lists of control sub-experiment items, and 60 filler items to create 24 lists with 360 items each. Each list was seen by one of the 24 participants included in the analysis. The filler items were similar to the experimental items in maintaining a two-sentence format, and were all grammatically correct but had a variety of different syntactic structures. Thus, items from the six target conditions made up half of the items, and the ratio of acceptable to unacceptable sentences was 1:1. Furthermore, since the violations occurred either earlier in the sentence (target conditions) or later in the

sentence (control sub-experiment conditions), participants needed to pay attention to the entire sentence in order to accurately judge the well-formedness of the sentence.

2.3.3 Procedure

Participants were comfortably seated in a dimly lit testing room about 100 cm in front of a computer monitor. Each two-sentence pair (context sentence plus target sentence) was preceded by a fixation cross. All items appeared in black font on a white screen. Participants pressed a button to initiate presentation of the trial. The context sentence was presented in two self-paced sections in 25 pt font: after reading the first half of the sentence, participants pressed a button to see the second half, which began 180 ms after the button press. After reading the second half of the sentence, participants pressed a button and the target sentence began 180 ms later. Target sentences were presented one word at a time in 30 pt font. Each word appeared in the center of the screen for 300 ms, followed by 200 ms of blank screen. The last word of each sentence was marked with a period, and 1000 ms later a question mark prompt appeared on the screen. Participants were instructed to read the sentences carefully without blinking and to indicate with a button press whether the sentence was an acceptable sentence of Spanish. Feedback was provided for incorrect responses. Each experimental session was preceded by a 3-trial practice session that included both acceptable and unacceptable sentences. Participants received feedback and were able to ask clarification questions about the task at this time. The experimental session was divided into 7-8 blocks lasting 15 minutes each, and participants could request additional breaks at their discretion.

2.3.4 EEG recording

EEG was recorded from 28 Ag/AgCl electrodes, mounted in an electrode cap (Electrocap International): midline: Fz, FCz, Cz, CPz, Pz, Oz; lateral: F3/4, F7/8, FC3/4, FT7/8, C3/4, T7/8, CP3/4, TP7/8, P4/5, P7/8, O1/2. Recordings were referenced to the left mastoid. Additional electrodes were placed on the left and right outer canthus, and above and below the left eye to monitor eye movements. The EEG and EOG recordings were amplified by a SynAmpsTM Model 5083 EEG amplifier, and sampled at 1 kHz using an analog bandpass filter of 0.1-70 Hz. Impedances were kept below 5 kΩ.

2.3.5 EEG analysis

All comparisons were based upon single word epochs, consisting of the 100 ms preceding and the 1000 ms following the start of the presentation of the critical words. Prior to any further analyses, epochs with ocular and other large artifacts were rejected from analysis based on visual screening. In addition, epochs from trials to which the participant responded inaccurately were excluded. Five participants' data were excluded because of accuracy below 75%. Epochs showing a divergence from 0 of more than 75μV were excluded automatically. Data from one participant were excluded because only 22% of critical epochs remained after all these measures were taken. For the remaining 24 participants, after all the exclusion criteria were applied, 65% of the trials were included in the final analysis. This rate is relatively low compared to a typical inclusion rate of about 80%. There are two likely reasons for this. Firstly, most ERP studies do not exclude trials to which the participants respond

inaccurately. Secondly, the fact that subjects read long context sentences prior to the target sentences probably resulted in a higher rate of ocular artifacts during the target sentences.

The waveforms were normalized using a 100 ms prestimulus baseline. Averaged waveforms were filtered offline using a 10 Hz low-pass filter for presentation purposes, but all statistics are based on unfiltered data. The following latency intervals were chosen for analysis, based on the intervals used in the literature and on visual inspection: 300-500 ms (N400), 600-1000 ms (P600). The interval 0-200 ms was also analyzed to test for any possible early differences.

For statistical analyses, six regions of interest (ROIs) were used in the ANOVAs, consisting of groups of three electrodes at each ROI: left anterior (F3, FC3, C3), anterior midline (FZ, FCZ, CZ), right anterior (F4, FC4, C4), left posterior (CP3, P3, O1), posterior midline (CPZ, PZ, OZ), right posterior (CP4, P4, O2). These ROIs were organized into the two topographic factors *laterality* (left, midline, right), and *posteriority* (anterior, posterior).

ANOVAs were performed separately for the conditions with *fue* and for those with *estaba* because the difference in length of the auxiliary could introduce irrelevant differences in the waveforms. In any case, the hypotheses were that the auxiliary would cause the *semantic-attraction* and *no-attraction* anomalous conditions to perform differently relative to the controls; there is no hypothesis about

comparing, for example, the *semantic-attraction* condition with *fue* and the *semantic-attraction* condition with *estaba*.

ANOVAs were performed hierarchically, using the within-subjects factor *condition* (*control, semantic-attraction, no-attraction*). All *p*-values reported below reflect the application of the Greenhouse-Geisser correction where appropriate, to control for violations of the sphericity assumption (Greenhouse & Geisser, 1959), together with the original degrees of freedom. Due to the large number of possible interactions in this design, I discuss only those interactions for which follow-up analyses yielded significant contrasts within the levels of the interacting factors.

2.4 Results

2.4.1 Accuracy

Overall accuracy on the behavioral acceptability judgment task for the main six conditions was 84%. The accuracy on the two grammatical control conditions was higher (*fue*: 92%; *estaba:* 90%) than for the four anomalous conditions (*fue*+semantic-attraction: 75%; *fue*+no-attraction: 84%; *estaba*+semantic-attraction: 82%, *estaba*+no-attraction: 84%). This is likely because the anomaly resulted from the addition of a single letter at the end of the verb (e.g., passive *-ado* became progressive *-ando*) and therefore may easily have been missed, especially if the verb is long and the suffix far from the fixation point. As noted above, only trials with correct responses were included in the analysis.

The semantic control sub-experiment showed an overall accuracy that was somewhat lower, 77%. Average accuracy for the felicitous condition was 84%, and for the infelicitous condition it was only 70%, suggesting that perhaps some noun-adjective combinations were not as infelicitous as had been intended, or perhaps that these anomalies were not perceived as being as bad as other anomalies in the experiment. The syntactic control experiment showed an overall accuracy of 87% (grammatical 89%, ungrammatical 85%).

2.4.2 Control sub-experiments

The results for the semantic and syntactic control experiments were as expected: an N400 effect at the adjective in the infelicitous noun-adjective combinations, and a P600 at the nouns that were preceded by a determiner that mismatched in number.

2.4.2.1 Semantic violation

In the 0-200 ms interval, there were no differences between the conditions. In the N400 interval (300-500 ms), the semantic violation condition was more negative than the control condition over the whole scalp. There was a main effect of condition in the overall ANOVA, in addition to significant effects in all six regions of interest except for the right anterior region which was only marginally significant. Figure 1 shows an electrode array, and the *F*-values can be seen in Table 5 below.

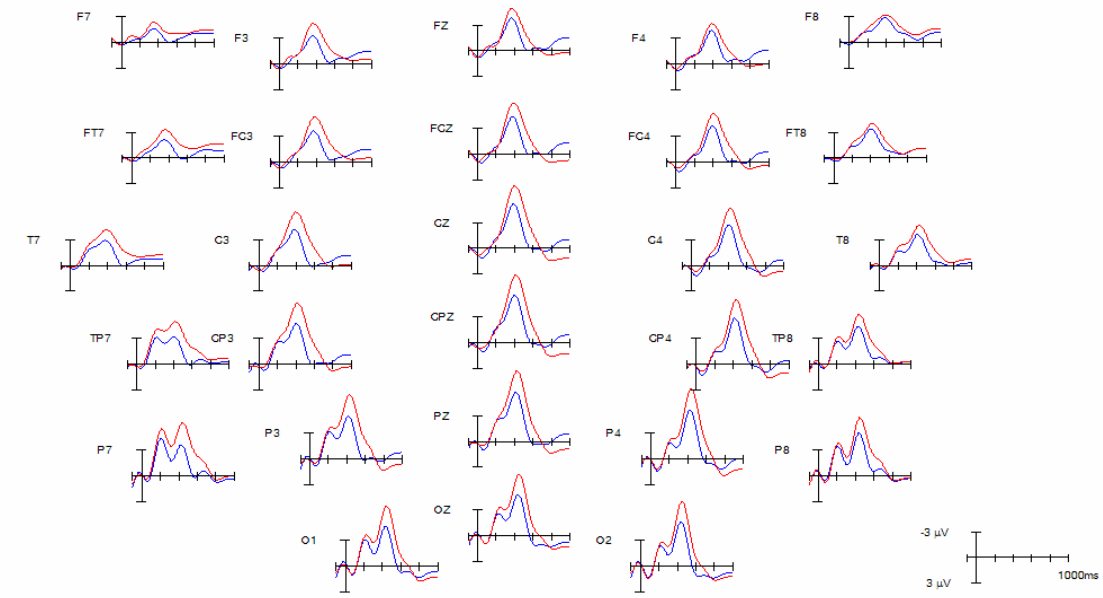

Figure 1. Grand average responses at the critical adjective in the semantic sub-experiment conditions in the Spanish ERP experiment, showing the felicitous condition (blue) and the infelicitous condition (red)

Table 5

ANOVA *F*-values for comparisons of the semantic sub-experiment conditions at the critical adjective in the Spanish ERP study

Semantic Felicity	0-200 ms	300-500 ms
cond (1,23)	-	8.00 *
cond × lat (2,46)	-	-
cond × post (1,23)	-	-
cond × lat × post (2,46)	-	-
Effect of condition at individual ROIs:		
Anterior – left (1,23)	-	9.35 **
Anterior – midline (1,23)	-	7.26 *
Anterior – right (1,23)	-	3.59 †
Posterior – left (1,23)	-	9.26 **
Posterior – midline (1,23)	-	8.26 **
Posterior – right (1,23)	-	6.25 *

** = <0.01, * = <0.05, † = <0.1

2.4.2.2 Syntactic violation

Visual inspection suggested that the two waveforms might already differ significantly in the 0-200 ms interval, particularly at the central and posterior electrodes. This was confirmed by the ANOVA, which indicated a significant effect of condition ($F(1,23) = 5.24$, $p < .05$) and a marginally significant interaction of condition and posteriority ($F(1,23) = 3.52$, $p < .1$). This difference was marginally significant in the anterior midline and right ROIs (anterior midline: $F(1,23) = 3.26$, $p < .1$; anterior right: $F(1,23) = 3.98$, $p < .1$) and was significant in all posterior ROIs (posterior left: $F(1,23) = 6.46$, $p < .05$; posterior midline: $F(1,23) = 6.43$, $p < .05$; posterior right: ($F(1,23) = 5.99$, $p < .05$). However, this early difference disappeared and there were no significant differences in the 300-500ms interval in any of the ROIs.

In the P600 interval (600-1000 ms), the violation condition was more positive than the control condition. The effect was seen over the entire scalp, but was largest at posterior and midline electrode sites, resulting in interactions between condition and posteriority and between condition and laterality, and a marginally significant three-way interaction between condition, posteriority and laterality. The effect was significant in all regions of interest.

Although the difference in the early interval is unexpected, it should not impact our interpretation of the P600 effect. Firstly because there was no significant difference in the interval directly prior to the P600 interval, and secondly because the

magnitude of the baseline difference is much smaller than the magnitude of the P600 effect (approximately 1 μV in the 0-200ms interval, approximately 5 μV in the 600-1000ms interval, averaged across the head). It therefore seems unlikely that the difference in the P600 interval could be the result of pre-existing differences.

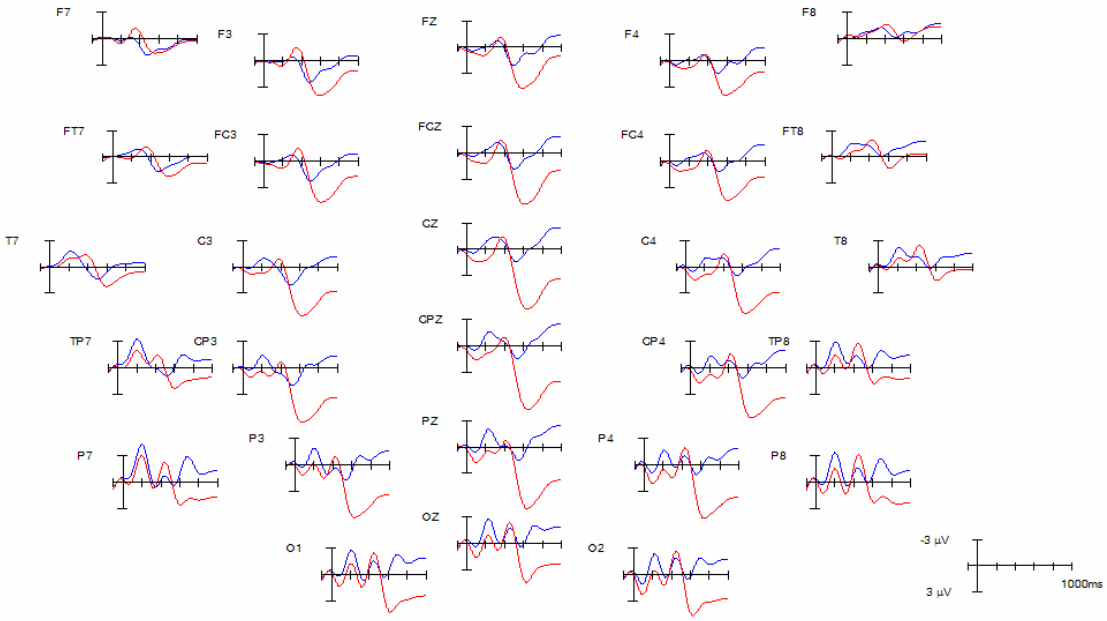

Figure 2. Grand average responses at the critical noun in the syntactic sub-experiment conditions in the Spanish ERP experiment, showing the grammatical agreement condition (blue) and the mismatch agreement condition (red)

Table 6

ANOVA *F*-values for comparisons of the syntactic sub-experiment conditions at the critical noun in the Spanish ERP study

Syntactic Agreement	0-200 ms	300-500 ms	600-1000 ms
cond (1,23)	5.24 *	-	46.19 **
cond × lat (2,46)	-	8.77 **	9.58 *
cond × post (1,23)	3.52 †	-	12.22 *
cond × lat × post (2,46)	-	3.72 *	3.43 †
Effect of condition at individual ROIs:			
Anterior – left (1,23)	-	-	31.90 **
Anterior – midline (1,23)	3.28 †	-	39.03 **
Anterior – right (1,23)	3.98 †	-	34.48 **
Posterior – left (1,23)	6.46 *	-	42.38 **
Posterior – midline (1,23)	6.43 *	-	47.07 **
Posterior – right (1,23)	5.99 *	-	43.63 **

** = <0.01, * = <0.05, † = <0.1

2.4.3 Semantic-Attraction Conditions: Pre-critical words

Because visual inspection suggested that there may be differences among the *estaba* conditions prior to the critical verb, ANOVAs were performed on the following intervals: 0-200 ms and 300-500 ms after presentation of the noun in the sentence-initial NP, and 0-200 ms and 300-500 ms after presentation of the auxiliary. The 300-500 ms interval following presentation of the auxiliary corresponds to the time interval immediately preceding the presentation of the critical verb.

2.4.3.1 Pre-critical Noun

Analyses at subsequent words treat the *fue* and the *estaba* conditions separately due to possible differences introduced because the two auxiliaries are of different lengths. However, at the noun there should be no such differences, and

therefore all six conditions were entered in to an ANOVA with six levels of condition. There were no significant effects of condition, or interactions with condition, in either the 0-200 ms or 300-500 ms intervals following presentation of the noun.

2.4.3.2 Pre-critical Auxiliary

As discussed above, all analyses at the auxiliary and at subsequent words treated the *fue* and the *estaba* conditions separately because the two auxiliaries were of different lengths and therefore could have introduced differences that were unrelated to the primary manipulation of the study.

Fue: In the analysis of the three *fue* conditions (grammatical control, semantic-attraction and no-semantic-attraction), there were no significant effects of condition and no interactions with condition in either the 0-200 ms or the 300-500 ms intervals after the presentation of the auxiliary.

Estaba: In the analysis of the three *estaba* conditions (grammatical control, semantic-attraction and no-attraction), there were significant effects of condition at the auxiliary. The grand-average waveforms are shown in Figure 3. In the 0-200 ms interval, there was a marginally significant effect of condition and a significant interaction between condition and posteriority (Table 7 shows the *F*-values). Follow-up pairwise comparisons show that these effects arose because the no-attraction

condition was more positive than the other two conditions in the posterior ROIs. The control and semantic-attraction conditions did not differ from each other.

In the 300-500 ms interval, there was a three-way difference between the conditions, with the no-attraction condition being more positive than the semantic-attraction condition, which in turn was more positive than the control condition, leading to a significant effect of condition. This effect was somewhat stronger across the back half of the head, reflected in a significant interaction between condition and posteriority. Table 7 shows the *F*-values for the pairwise comparisons of the three conditions.

This pattern of responses is somewhat unexpected. The two anomalous conditions differ throughout the epoch, specifically at the posterior electrodes. There is no principled reason for the semantic-attraction and the no-attraction conditions to differ from one another, since the nouns were counterbalanced across items such that 96% of the nouns appeared in one item at the semantically-attractive noun and in another item as the non-attractive noun. Therefore, the two conditions should not differ until the verb position.

However, there is a possible principled explanation for why the control condition was different than the two anomalous conditions in the 300-500 ms interval. The control condition, up to this point, consists of an animate noun plus *estaba*, while the semantic-attraction and no-attraction conditions consist of an

inanimate noun plus *estaba*. It is therefore conceivable that the animacy of the noun in combination with an auxiliary that has its own semantic and aspectual contributions would result in processing differences. The details of this are considered in the discussion section. Responses in the semantic-attraction condition begin to positively diverge from the control condition around 300 ms (the no-attraction condition was positive relative to the control condition throughout the epoch). This waveform difference may be of the type that is seen to superficial variations in experimental materials. On the other hand, it is also possible that this is a P600 with an early-onset, indicating that the participants had, at least temporarily, perceived an error the inanimate+*estaba* sequence. Unfortunately these differences severely impact our ability to interpret the results at the critical verb in the *estaba* conditions.

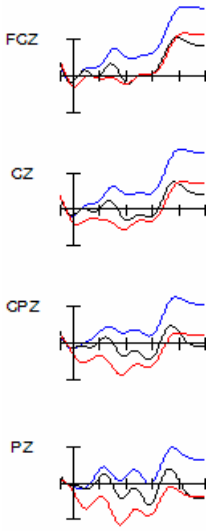

Figure 3. Grand average responses at the auxiliary in the *estaba* conditions in the Spanish ERP experiment, showing the grammatical control (blue), the semantic-attraction (black) and the no-attraction (red) conditions

Table 7

ANOVA *F*-values for comparisons of the *estaba* conditions at the auxiliary in the Spanish ERP study

Estaba	0-200 ms	300-500 ms
cond (2,46)	3.25†	6.32**
cond × lat (4,92)	-	-
cond × post (2,46)	4.18*	6.05**
cond × lat × post (4,92)	-	-
Control vs. Semantic-attraction		
cond (1,23)	-	6.29*
cond × lat (2,46)	-	-
cond × post (1,23)	-	-
cond × lat × post (2,46)	-	-
Effect of condition at individual ROIs:		
Anterior – left (1,23)	-	5.20*
Anterior – midline (1,23)	-	9.44**
Anterior – right (1,23)	-	7.97*
Posterior – left (1,23)	-	3.52†
Posterior – midline (1,23)	-	4.74*
Posterior – right (1,23)	-	3.97†
Control vs. No-attraction		
cond (1,23)	6.97*	14.25**
cond × lat (2,46)	-	3.13†
cond × post (1,23)	7.67*	5.20*
cond × lat × post (2,46)	-	-
Effect of condition at individual ROIs:		
Anterior – left (1,23)	-	4.79*
Anterior – midline (1,23)	-	7.98*
Anterior – right (1,23)	-	7.57*
Posterior – left (1,23)	11.71**	18.28**
Posterior – midline (1,23)	14.92**	23.79**
Posterior – right (1,23)	13.98**	21.06**
Semantic-attraction vs. No-attraction		
cond (1,23)	-	-
cond × lat (2,46)	-	-
cond × post (1,23)	5.71*	12.23**
cond × lat × post (2,46)	-	-
Effect of condition at individual ROIs:		
Anterior – left (1,23)	-	-
Anterior – midline (1,23)	-	-
Anterior – right (1,23)	-	-
Posterior – left (1,23)	4.82*	-
Posterior – midline (1,23)	5.55*	3.97†
Posterior – right (1,23)	5.98*	4.55*

** = <0.01, * = <0.05, † = <0.1

2.4.4 Semantic-attraction Conditions: Critical word

2.4.4.1 Fue

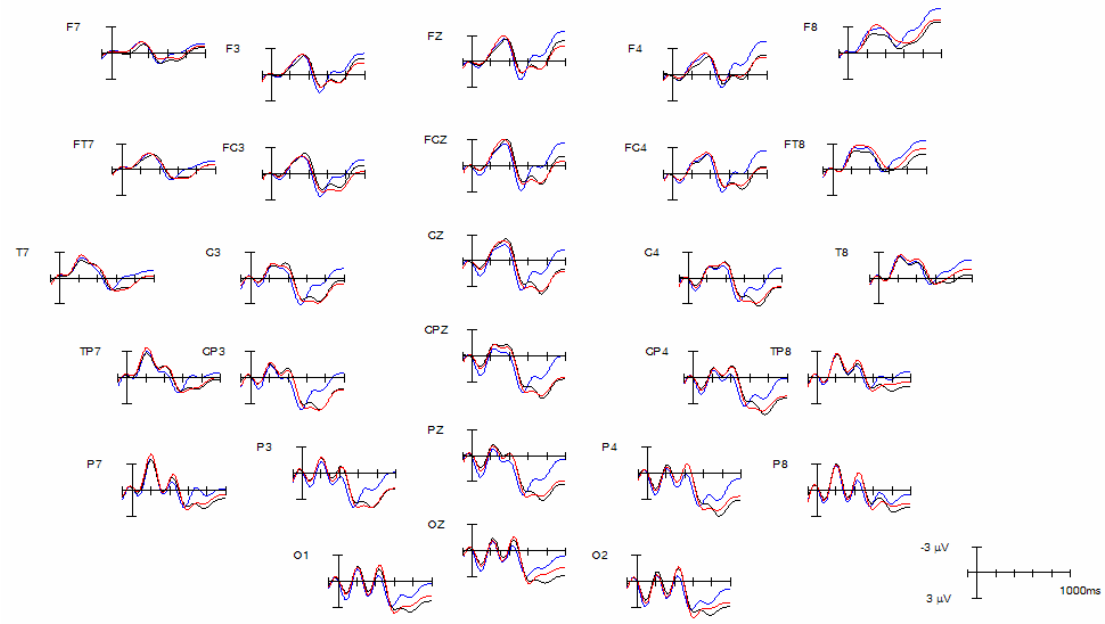

Figure 4. Grand average responses at the critical verb in the *fue* conditions in the Spanish ERP experiment, showing the grammatical control (blue), the semantic-attraction (black) and the no-attraction (red) conditions

In the ANOVAs comparing all three conditions, there were no differences in the 0-200 ms interval or in the 300-500 ms interval. In the 600-1000 ms interval, there was a main effect of condition ($F(2,46) = 3.84$, $p < .05$). To determine the source of this effect, planned pairwise comparisons were made between all possible pairs of conditions (Table 8). Both violation conditions (semantic-attraction and no-attraction) showed a positivity relative to the control condition. The effect was distributed across the whole scalp, and largest in midline and posterior regions.

Table 8

ANOVA *F*-values for comparisons of the *fue* conditions at the critical verb in the Spanish ERP study

Fue	0-200 ms	300-500 ms	600-1000 ms
Control vs. Semantic-attraction			
cond (1,23)	-	-	4.41 *
cond × lat (2,46)	-	-	-
cond × post (1,23)	-	-	-
cond × lat × post (2,46)	-	-	2.85 †
Effect of condition at individual ROIs:			
Anterior – left (1,23)	-	-	-
Anterior – midline (1,23)	-	-	4.87 *
Anterior – right (1,23)	-	-	3.88 †
Posterior – left (1,23)	-	-	4.13 *
Posterior – midline (1,23)	-	-	5.15 *
Posterior – right (1,23)	-	-	3.36 †
Control vs. No-attraction			
cond (1,23)	-	-	7.61 *
cond × lat (2,46)	2.71 †	-	-
cond × post (1,23)	-	-	-
cond × lat × post (2,46)	-	-	-
Effect of condition at individual ROIs:			
Anterior – left (1,23)	-	-	8.26 **
Anterior – midline (1,23)	-	-	8.10 **
Anterior – right (1,23)	-	-	6.12 *
Posterior – left (1,23)	-	-	7.29 *
Posterior – midline (1,23)	-	-	6.12 *
Posterior – right (1,23)	-	-	4.93 *
Semantic-attraction vs. No-attraction			
cond (1,23)	-	-	-
cond × lat (2,46)	-	-	-
cond × post (1,23)	-	-	-
cond × lat × post (2,46)	-	-	-
Effect of condition at individual ROIs:			
Anterior – left (1,23)	-	-	-
Anterior – midline (1,23)	-	-	-
Anterior – right (1,23)	-	-	-
Posterior – left (1,23)	-	-	-
Posterior – midline (1,23)	-	-	-
Posterior – right (1,23)	-	-	-

** = <0.01, * = <0.05, † = <0.1

2.4.4.2 Estaba

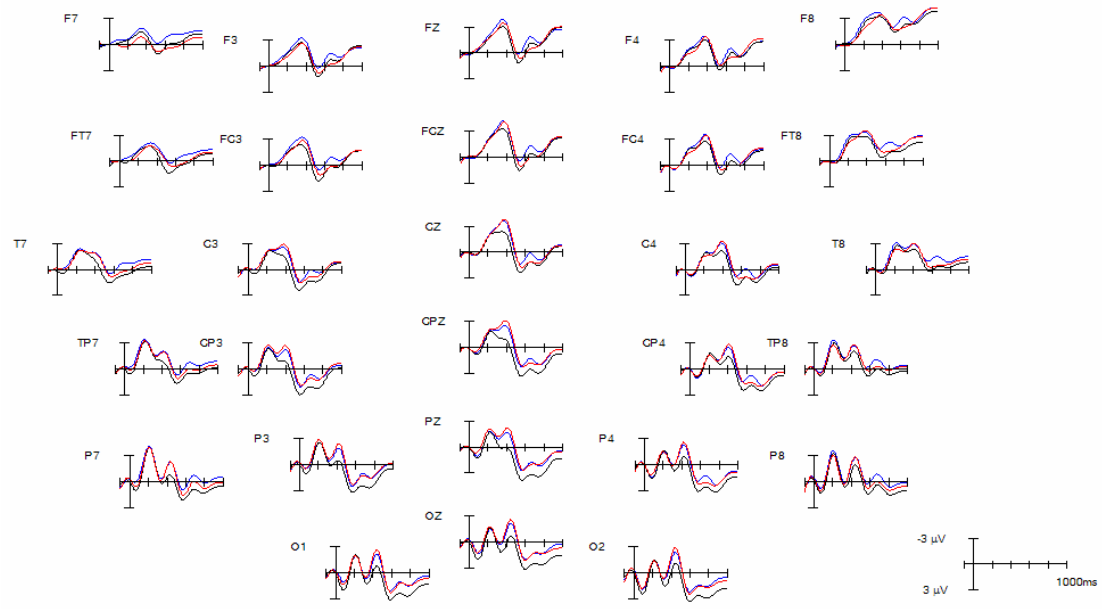

Figure 5. Grand average responses at the critical verb in the *estaba* conditions in the Spanish ERP experiment, showing the grammatical control (blue), the semantic-attraction (black) and the no-attraction (red) conditions

Although visual inspection suggests that the semantic-attraction condition may be positive-going relative to the other two conditions beginning at about 300 ms, in the ANOVAs comparing all three conditions (control, semantic-attraction, no-attraction), there were no significant differences in any of the intervals (0-200 ms, 300-500 ms, 600-1000 ms). Because these errors are relatively egregious (akin to *The dusty tabletop was devouring…*), it seems unlikely that the participants would have failed to perceive the error. Therefore, it seems likely that an error response at the verb was obscured by differences in the response to the previous auxiliary.

2.5 Discussion

The aim of this study was to test whether the processor only considers interpretations that are consistent with the expected structure of the sentence. Previous research (e.g., Kim & Osterhout, 2005) had suggested that the processor might be able to propose interpretations based on word meanings that were incompatible with the relationships between those words as determined by the morphological form of the verb. An alternative interpretation of the previous results is that the relevant syntactic information arrived later than the relevant semantic information, so that the semantic interpretation under consideration did not contradict the currently-available structural information. In order to test these two theories, we conducted an experiment in which we provided the syntactic information about what structures could be expected prior to the semantic information that would allow the processor to determine the likeliest way of combining those word meanings. If a semantic combinatorial mechanism functions independently of all structural information, it should ignore prior information about structural biases. On the other hand, if the semantic combinatorial mechanism respects information about prior structural biases, the processor will only consider interpretations consistent with those biases.

In a comparison of the responses to sentences with *fue*, which was likely to be followed by a passive, we found that both violation conditions (with semantic attraction between the noun and the verb, and without) showed a P600 relative to the control condition, and there was no N400 effect in either condition. The violation

conditions did not differ from each other. The responses to sentences with *estaba*, which was unlikely to be followed by a passive, were more complicated to interpret because there were no significant differences at the verb. In addition, the conditions were found to already differ at the auxiliary, meaning that there was an unanticipated difference between the combinations of animate+*estaba* (control condition) and inanimate+*estaba* (violation conditions). The manipulation of the auxiliary did impact the processing at the verb, but of course significant discussion will be needed in order to determine what we can and cannot conclude from these results.

The results from the *fue* conditions are clear and have straightforward implications. The P600 (and lack of N400) in the semantic-attraction condition nicely replicates in Spanish the result of the semantic-attraction condition in Kim and Osterhout (2005). Unlike the English auxiliary *was*, the auxiliary *fue* strongly favors a passive structure. Therefore it is perhaps even less surprising that the processor should appear to have pursued a passive interpretation until the moment when it encountered the active verbal suffix *-ando*. The no-attraction condition also elicited a P600, but no N400, which is not consistent with the Kim & Osterhout (2005) results. This finding is surprising under any account that predicts that the thematic P600 is only modulated by semantic attraction between the noun and the verb. There are at least two possible accounts that might explain this discrepancy. The first possibility involves using the framework presented in this chapter to suggest a reason that the Spanish and English results might differ. It is possible that because the Spanish *fue* provided a much stronger cue for a passive interpretation than *was* did in English, this

was enough to make up for the fact that the goodness-of-thematic-fit between the verb and the noun did not suggest a passive interpretation. Therefore, in the case of the Spanish no-attraction condition, the processor may already have been considering a passive interpretation which resulted in a P600, whereas in the English no-attraction case the cues were not strongly enough in favor of a passive interpretation, resulting in an N400. The second possible account for the P600 in the no-attraction condition in the Spanish study is that the lack of P600 in the no-attraction condition in Kim and Osterhout's study does not consistently replicate. Although the result in the no-attraction condition initially appeared to be an anomaly, two further studies presented here as well as two studies by Kuperberg and colleagues (Chapters 3 & 4; Kuperberg et al., 2006, 2007) also elicited P600s in no-attraction conditions. This pattern of results, discussed further in Chapter 4, casts doubt on the notion that semantic attraction is necessary to elicit the P600.

The lack of N400 in the no-attraction condition in this experiment, relative to the N400 in the no-attraction condition in Kim and Osterhout (2005), can be explained if the amplitude of the N400 reflects the level of semantic association between the NP and the verb, as was argued in Chapter 1, Section 5. In Kim and Osterhout, the no-attraction conditions were formed by combining the semantically-attractive sentence-initial NP from one item with the verb and post-verbal continuation from another item. Therefore, the level of association between the NP and the verb in the no-attraction condition was low, resulting in an N400 with increased amplitude. On the other hand, in the current experiment, there was a higher

level of semantic association between the NP and the verb in the no-attraction condition. Because all three NPs (attractive, non-attractive, animate) had to be mentioned in a felicitous context sentence, they generally came from the same semantic field or could be used to describe a single situation. Therefore, although the non-attractive NP made a poor theme for the verb, the two were often semantically associated, resulting in no amplitude change in the N400.

Turning to the conditions with *estaba*, we first have to explain why the electrophysiological responses are already different at the auxiliary *estaba*. As laid out in the results section, it looks as if there are two different things going on. First, given the counterbalancing of nouns in the semantic-attraction and no-attraction conditions, there appears to be noise in one or both of the anomalous conditions,. Secondly, it also looks as if both semantic-attraction and no-attraction conditions are positive relative to the control condition, beginning at about 300 ms. I will restrict the discussion to the latter effect, since it is the one for which there may be a linguistically-motivated explanation.

We did not anticipate the difference at *estaba* in Spanish, because such a difference was not found in the nearest English counterparts. In Kim & Osterhout's first experiment, they included two control conditions: a passive *The hearty meal was devoured* and an active *The hungry boy was devouring*…. They found that the choice of control did not matter, and in subsequent studies only included the passive control condition. The large number of conditions in our study made it impossible to include

both active and passive control conditions, and we chose to use an active control for the *estaba* conditions because it was easier to make these sentences felicitous following a context sentence that also needed to be compatible with the other five versions of each item. It turns out that the active versus passive control condition may matter in Spanish, and in a manner that impacts the ERP responses. This difference could come from either the auxiliary *estar* itself, or from the imperfect morphology which it appeared with. *Estar* is used with stage-level predicates (from the work of Carlson, 1977), which indicate temporary states – e.g. *I am happy right now*, or *I am sick*, whereas its counterpart *ser* is used with individual-level predicates that indicate more permanent states, as in *I am a happy person in general*, or *I am tall*. It could be that *estar* is used more easily with animate nouns (that might change states more often) than with inanimate nouns which might have more permanent characteristics, although this is not impossible – for example, both auxiliaries could be used with an adjective such as *expensive*, with *ser*+*expensive* indicating that an object is always expensive, and *estar*+*expensive* indicating that the price of an object is high right now. The imperfect verbal suffix *–aba*, as in *estaba*, which the form of the auxiliary used with the progressive tense, may itself go less well with inanimate nouns than animate nouns, since inanimate nouns may occur infrequently with the progressive morphology because they are not general good agents.

Although there is clearly a difference between animate+*estaba* (control) and inanimate+*estaba* (violation conditions), it is unclear exactly what the difference reflects. On one hand, it could be a non-interpretable difference in waveforms such as

might be found by using materials that are not controlled for length, etc. On the other hand, it could be a meaningful difference associated with a response to a linguistic anomaly. Although the semantic-attraction condition is more positive than the control condition, it is not clear whether this can be considered a P600 because it begins relatively early (around 300ms) and because the scalp distribution is similar across the whole head rather than being concentrated toward the back of the head. In any case, the shape of the effect looks very different than the P600 found at the verb in the *fue* conditions and the P600 found to the determiner-noun number mismatches in the syntactic control sub-experiment.

Given this pre-existing difference, can we say anything about the responses at the verb? Based on the results from the Kim & Osterhout study, we predicted that if the processor is able to use previous syntactic information to restrict the interpretations it considers, we would see N400s to both violation conditions with *estaba*. If the processor ignores the syntactic information provided by the auxiliary, the violation conditions with *estaba* should pattern exactly with the *fue* conditions. The observed results suggest that neither of these two possibilities describe the results. Visual inspection of the waveforms suggests that perhaps the semantic-attraction condition shows evidence of a P600, beginning at about 300ms. If true, this would mean that the semantic-attraction conditions with both *fue* and *estaba* would show P600s, which would be evidence against our hypothesis that the thematic P600 should not be elicited if the syntactic information is provided earlier. However, it would be wrong to interpret the waveform as showing a P600 for a variety of reasons.

First, it is not a significant difference and does not approach significance (in the window 600-1000ms for a comparison of the control and semantic-attraction conditions, for the effect of condition $F(1,23) = .99$, $p = .33$, and the interaction of condition and posteriority $F(1,23) = 1.33$, $p = .26$). Second, the semantic-attraction condition was more positive than the control condition already at the previous word, so that difference may be carried over from the previous word but briefly hidden because of re-baselining and therefore only appears to emerge at a latency of 300ms. Third, the no-attraction condition does not show any error response at all, which should make us question the response to the attraction condition as well.

2.6 Summary

Notwithstanding the caveats and limitations presented in the previous section, what we can say is that the thematic P600 is also elicited in Spanish. This adds evidence that the effect is robust and can be found in a variety of languages, as well as under different circumstances such as following a long context sentence. We also conclude that the semantic attraction effect does not seem to be the sole determining factor of this effect, as was suggested by Kim & Osterhout (2005). Either a stronger passive cue provided by the auxiliary can make up for a lack of semantic attraction, or, as becomes clearer through the series of experiments presented in this dissertation as well as studies by Kuperberg et al (e.g. 2006), the attraction effect is not as robust as it appeared in Kim & Osterhout (2005). Kim and Osterhout's argument for an independent semantic composition mechanism crucially relied on the fact that the P600 is not elicited when the meanings of the individual words do not support a

passive interpretation (i.e., in the no-attraction condition). If the attraction effect does turn out to be more complicated and variable than was initially thought, it will be harder to argue for an independent semantic composition mechanism. Although the precise interpretation of the *estaba* results is complicated, we can definitely say that they do not pattern with the *fue* results. This is not compatible with a model in which the unexpected P600 simply depends on the existence of attraction between the noun and the verb.

Chapter 3: The structural selectivity of thematic P600 effects

3.1 Introduction

In Chapter 2 I argued that it is possible to account for the results of Kim and Osterhout (2005) without appealing to an independent semantic processing stream, instead using a processor that conforms to all currently available structural and semantic cues. A review of the structural and semantic cues available to the processor prior to the verb suggested that the processor was likely to be pursuing a passive analysis before encountering the verbal suffix because a sentence-initial inanimate noun is more compatible with a passive analysis. Under this account, the P600 may reflect the fact that the processor encountered a structural cue, the verbal suffix, that disconfirmed the analysis that it had been pursuing. I presented an experiment that was designed to address a question raised by the two possible interpretations of the Kim and Osterhout results, namely, whether the processor respects or ignores prior structural cues. Although the auxiliary manipulation impacted the ERP responses, the results did not conclusively show that the structural information provided by the auxiliary limited the interpretations considered by the processor. In addition, the P600 to both attractive and non-attractive conditions suggested that the role of semantic attraction in the elicitation of the thematic P600 may not be as dependable as it initially appeared.

The experiment presented in this chapter was designed to provide a stronger test for whether the processor respects prior structural commitments by using an earlier, unambiguous and salient structural cue that should restrict the interpretations that are considered downstream, rather than a cue that introduces a probabilistic bias, as in the previous experiment. This experiment also provides an additional opportunity to examine the effect of semantic attraction on the thematic P600.

In previous studies in English and Spanish, there are questions that one could raise about the effectiveness of the structural cues that were manipulated to test whether the processor respects or ignores structural information. In the case of Kim and Osterhout (2005), a key question for the interpretation of the results is whether the verbal suffix is processed simultaneously with or later than the verbal stem. If the verbal suffix is processed later than the verbal stem, then the results do not provide support for an independent semantic processing stream. On the other hand, if the verbal suffix is already available by the time that the processor analyzes the goodness-of-fit between the noun and the verb, then it is possible to argue that the processor considers interpretations that do not respect currently available structural cues. However, it is also possible that the P600 is elicited because the verbal suffix disconfirms the passive analysis that had been pursued based on the sentence-initial inanimate noun, and or the P600 could reflect a general problem with thematic processing independently of the semantic content of the verbal stem. The latter two views are supported by the studies in which semantic attraction does not modulate the P600 (e.g., Chapter 2; Kuperberg et al., 2007).

In the Spanish ERP study presented in Chapter 2, there is no doubt that the structural cue is encountered earlier than the goodness-of-fit information, but it is possible to question whether participants use the cue at all. The auxiliary provides probabilistic rather than unambiguous information about the likelihood of upcoming structures. It is possible to argue that the processor does not avail itself of the probabilistic information to constrain the analyses it pursues. If this were the case, then any results that appeared to show that the processor ignores prior structural biases would in fact be revealing that the processor is not sensitive to this particular indicator of structural bias.

The experiment presented in this chapter pursues a similar issue to the experiment presented in the previous chapter, but in this experiment the structural cue provides conclusive evidence about the sentence structure, rather than information about probabilistic biases. In addition, the structural cue is presented multiple words prior to the critical verb, so there is no doubt that the cue should already have been processed when the verb is encountered. This experiment provides a strong test of whether or not the processor respects prior commitments by making sure the structural cue on which the commitments are based is salient and unambiguous, so we can be confident that the processor has made those commitments.

3.1.1 Previous studies

A defining feature of many of the studies conducted in English and Spanish is that the nouns that may enter into "attraction" relationships are found in argument

positions of the verb. In the majority of the English and Spanish studies on this topic the P600 has been elicited at the verb in a simple SV(O) sentence, as in (19) and (20).

(19) a. The hearty meal was *devouring*… (Kim & Osterhout, 2005)

b. The hearty meal will *devour*… (Kim & Osterhout, 2005b)

(20) a. For breakfast the eggs would only *eat*… (Kuperberg et al., 2003, 2007)

b. For breakfast the eggs would only *plant*… (Kuperberg et al., 2007)

c.i. … the food would *order*…

c.ii. … the trumpets would *curtsey*… (Kuperberg et al., 2006)

In examples (19) and (20), the processor can already determine at the auxiliaries *was* or *would* that the initial NP is in an argument position. In those examples, the processor can immediately tag the first NP as an argument, but prior to encountering the critical verb, it does not yet know whether the NP will be an agent in an active sentence or a theme in a passive sentence. If, as Kim and Osterhout claim, the processor attempts to analyze the NP as the theme of that verb, it would be acting consistently with the prior structural information indicating that the NP is in an argument position.

The debate, as framed by Kim and Osterhout (2005), is about whether an independent semantic processor can compute the most plausible relations among a cluster of neighboring open class words, not taking into account the relationships between these words as dictated by the structure of the sentence. A strong test of this account is to see whether a noun that is in the vicinity of the verb, although clearly

structurally marked as not an argument of that verb, is interpreted as the theme of the verb if such an interpretation is suggested by the meanings of the words. If there is a semantic processing stream that functions independently from structural constraints, it should be possible to interpret a nearby noun as the theme, no matter what structural position it appears in. On the other hand, if the processor only proposes semantic interpretations that are fully consistent with the structure of the sentence, then non-arguments should never be interpreted as arguments of the verb, no matter how plausible the combination might be.

The current experiment was designed under the assumption that the semantic attraction effect between a noun in an argument position and a verb was reliable, and was intended as a test of whether it is possible to cancel the semantic attraction effect between a noun and a verb by clearly indicating that the noun is not in an argument position. If the thematic P600 in the semantic-attraction condition in Kim and Osterhout (2005) indicates, as they argue, that the processor attempted to interpret the noun as the theme in a passive sentence, and if the processor respects prior structural commitments, then we should not see a thematic P600 in a case where the noun is attractive but in a non-argument position. In light of the set of experiments presented here, and other recent experiments (e.g. Kuperberg et al., 2007), it has become clear that semantic attraction does not consistently modulate the P600 even when the noun is in an argument position. The implications of this for the interpretation of the results will be considered in the discussion section of this chapter and in Chapter 4.

Results from Dutch studies seem to speak to this issue already by providing an apparent counterexample to the hypothesis that the processor only considers interpretations that are consistent with prior structural information. For example, Kolk et al. (2003) and van Herten et al. (2005) elicited a P600 at the verb in *The fox that at the poachers hunted*…. In this example, there is enough pre-verbal structural information for the processor to commit to the *fox* as agent and the *poachers* as goal because the *poachers* appears in a prepositional phrase, which clearly indicates that *poachers* are not the agent. In this case, the P600 has been interpreted as indicating that the processor detected that the sentence structure is not compatible with the most plausible semantic analysis, which was constructed without taking into account the pre-verbal structural information. While this could be taken as evidence that the processor does not respect prior structural commitments in general, there are good reasons to think that the English and Dutch results may be reflecting different things. The Dutch studies differ in multiple dimensions from the English studies in the focus of this chapter, including the number of nouns that must be taken into account, the structural ambiguities that arise incrementally through the sentence, and processing differences in verb-medial and verb-final clauses. These differences make it difficult to determine whether variations in the results arise because of differences in the prior structural commitments or because of other differences in the processing steps and representations. I will discuss the results from the Dutch studies in Chapter 4.

3.1.2 The current experiment

The aim of the current study was to investigate whether the processor respects prior structural commitments by testing whether nouns that are not potential arguments of the verb show the same semantic attraction effect as those that are in the verb's argument positions. To test this, we manipulated the attractiveness of a noun inside a prepositional phrase modifying the subject noun. This noun is linearly closest to the verb, but by the time the verb is encountered, it is unambiguously clear that the noun cannot be an argument of that verb. We also manipulated the semantic attractiveness of the head noun. A sample set of experimental conditions is presented in Table 9. As discussed above, the structural cue that indicates that the noun inside the PP is not an argument of the verb is unambiguous, it is encountered a number of words before the verb, and because argument-hood is a key property of a sentence, this is likely to be a highly salient cue.

Table 9

Sample set of materials from primary conditions of the Interference ERP study (SA=semantically-attractive; NA=not-attractive)

Intervening noun	**Head noun**			
No intervener	Control	The large lawn		was mowed…
	SA-head	The large lawn		was mowing…
	NA-head	The rural house		was mowing…
SA-intervener	Control	The tall grass	on the large lawn	was mowed…
	SA-head	The tall grass	on the large lawn	was mowing…
	NA-head	The front porch	beside the large lawn	was mowing…
NA-intervener	Control	The tall grass	around the rural house	was mowed…
	SA-head	The tall grass	around the rural house	was mowing…
	NA-head	The front porch	of the rural house	was mowing…

In the no-intervener conditions, we expected to find the basic semantic-attraction effect, as seen in Kim & Osterhout (2005): a P600 when the noun is semantically-attractive, and an N400 when the noun is not attractive. The novel question in the experiment is about the conditions with intervening nouns: will the semantic-attraction effect at the verb pattern with the attractiveness of the head noun or with the attractiveness of the intervening noun? Because the intervening noun is linearly closer to the verb, if the processor does not respect prior structural commitments, the attractiveness of the intervening noun should have the largest influence on the attraction effect at the verb. This should result in a P600 when the intervening noun is semantically-attractive, and an N400 when it is not. By contrast, if the processor only considers interpretations that are consistent with prior structural information, the semantic attraction effect at the verb should pattern with the attractiveness of the head noun. This view predicts a P600 whenever the head noun is

semantically-attractive and an N400 when it is not, regardless of the attractiveness of the intervener.

The clearest pattern of results would be if the attraction effect patterns with either the head or the intervener. However, if the processor does not respect prior structural commitments, the attraction effect might instead pattern with any noun in the vicinity: the head or the intervener. This could occur if, at the verb, the processor attempts to make any nearby attractive noun the theme of the verb. In this scenario, we expect a P600 if either the head or intervening noun is an attractive theme. The P600 should only be absent in the condition in which neither the head nor the intervener is an attractive theme. This outcome still contrasts with the predictions of a model in which the processor respects prior structural commitments, which predicts that the semantic attraction effect should pattern only with the attractiveness of the head noun.

The experiment also included a pair of conditions that manipulated the felicity of noun-adjective combinations and a pair of conditions that manipulated the correctness of determiner-noun number agreement, with the aim of providing canonical N400 and P600 effects. This allows us to compare the ERP components generated in the main experimental conditions with clear results from experimental comparisons that are better understood. Sample materials can be seen in Table 10.

Table 10

Sample materials from the two control sub-experiments of the Interference ERP study

Semantic felicity control conditions	
+ felicitous	Sarah carefully examined the sticker after the **friendly child** gave it to her.
− felicitous	Sarah carefully examined the sticker after the **friendly cheese** gave it to her.
Syntactic agreement control conditions	
+ agree	The patient is glad that **this** talented **surgeon** will operate on her arm.
− agree	The patient is glad that **this** talented **surgeons** will operate on her arm.

3.2 Experimental Materials and Methods

3.2.1 Participants

26 people participated in the ERP study. Data from 2 participants were excluded due to technical problems with the recording. Data from 2 additional participants were not collected for the syntactic control sub-experiment due to a programming error, but these participants were still included in the analysis of the main experimental conditions and the semantic control sub-experiment. The 24 participants (17 female; mean age 20; range 18-28 years) were healthy, native speakers of English. All were strongly right-handed based on the Edinburgh Handedness Inventory (Oldfield, 1971) and had normal or corrected-to-normal vision. Participants gave informed consent and were paid $10/hour for their participation, which lasted approximately 3.5 hours, including set-up time.

3.2.2 Materials

The materials for this study consisted of sets of nine sentences, organized in a 3 × 3 factorial design, illustrated in Table 9. There were three levels of the head noun

factor (control, SA-head, NA-head) and three levels of the intervening noun factor (no-intervener, SA-intervener, NA-intervener). The semantic control sub-experiment contained pairs of sentences with felicitous and infelicitous adjective-noun combinations, and the syntactic control sub-experiment contained pairs of sentences with grammatical and ungrammatical article-noun number agreement.

In the nine main experimental conditions, the sentences always began with an NP consisting of a determiner, an adjective and a noun. For the six conditions with an intervener, the head noun was then modified using a PP consisting of a preposition, a determiner, an adjective and a noun. All nine conditions were followed by *was* and then a verb with either passive (control sentences) or progressive (violation sentences) morphology.

To create the nine versions of each item, a verb and four NPs were chosen. All the verbs were felicitous in both passive and progressive constructions. Verbs that seemed to have stronger selectional restrictions were preferred, so that the good-theme and poor-theme NPs would be strongly contrastive. Verbs were used in an average of 1.7 items sets in the entire material set, with no more than 4 repetitions per verb. Of the four inanimate NPs, two were good themes for the verb, and two were poor themes for the verb. The NPs were chosen so that all four head plus intervener combinations (SA-head and NA-head with SA-intervener and NA-intervener) yielded felicitous combinations. The preposition joining the head and the intervening nouns was allowed to vary across conditions in order to achieve the most felicitous

combinations. For the conditions with intervening NPs, one of the semantically-attractive NPs was assigned to be the SA-head and the other was assigned to be the SA-intervener, and similarly for the non-attractive NPs. For the three conditions without intervening nouns, the head NPs were matched to those used as interveners in the other conditions. Given that our hypothesis was that the head nouns would all pattern the same (regardless of the attractiveness of the intervener and the presence/absence of the intervener) and that the intervening nouns would pattern differently, choosing the same NPs for the head nouns across the board while using different ones for the intervening NPs might be seen as favoring our own hypothesis. Therefore, the head nouns in the no-intervener conditions matched the intervening nouns in the intervener conditions. This is illustrated by the sample set of materials in Table 9. In order to guard against possible confounds, the items were created in pairs, such that in the second pair of items, a verb was selected so that all the semantically-attractive nouns from the first item became the unattractive nouns in the second item, and vice versa. Thus, across the entire set of items, the NPs in each condition were matched.

The material following the critical verb in the grammatical control sentences followed one of two patterns: half the items ended with a *by*-phrase (e.g., "by the teenage"), and half ended with a prepositional phrase or short adverbial phrase (e.g., "with a lawn mower" or "every week"). For the anomalous sentences, the material following the verb was distributed equally among three options: a *by*-phrase, a prepositional phrase or short adverb, and an inanimate NP which was generally a

good theme for the verb that it followed. Across items the majority of words directly following the critical verb were short. The variation in endings was chosen to avoid biasing participants to consistently attribute a certain interpretation to the violations – for example, if they always saw a *by*-phrase after the anomalous inanimate NP + progressive form, it might lead them to consistently classify this as a syntactic error (the verb should have been in passive form), which could be seen as creating a bias for a P600 response, rather than as a semantic error (inanimate NPs do not perform this action), which might be seen as biasing participants towards an N400.

Materials for the semantic control sub-experiment all followed the pattern shown in Table 10, in which the felicity of an adjective-noun combination was manipulated in an adverbial clause modifying a main clause. In order to guard against possible confounds, each critical noun was used in one pair as the felicitous noun and in another pair as the infelicitous noun. Materials for the syntactic control sub-experiment also followed the pattern shown in Table 10. Half of the syntactic control items used a plural determiner with a plural noun (match) or a singular noun (mismatch), and the other half used a singular determiner with a singular noun (match) or a plural noun (mismatch).

3.2.3 Design

Due to the large number of conditions in the experiment, the lists were not formed in a purely Latin Square Design. 180 sets of items for the target conditions were distributed across six presentation lists such that each list contained 30 items per

condition. Instead of including one version per item, three versions were chosen from each pair of items (the pairs contained the same NPs but different verbs, such that the SA-head from one was the NA-head in the other, etc.). Because the pairs of items contained combinations of four different NPs in two different structural positions as well as two different verbs, the similarity among the versions in each list was minimal. For example, a list could contain the following three versions from a pair of items: *The large lawn was mowed…, The front porch beside the large lawn was mowing,* and *The tall grass around the rural house was repainting*. Note that this list only included one NP twice (*the large lawn*) and this appeared once in head position and once as an intervener. The list also included one verb twice, but once as *mowed* and once as *mowing*. Given that participants each read a total of 540 sentences, this level of repetition is unlikely to be problematic. The full set of NP + verb combinations can be seen in Appendix B.

60 pairs of items from the syntactic agreement sub-experiment were distributed across two presentation lists. 60 pairs of items from the semantic felicity sub-experiment were also distributed across two separate presentation lists. The lists from the two control sub-experiments were crossed such that there were four presentation lists for the control sub-experiment items. The six lists of target items were crossed with the four lists of control sub-experiment items, and combined with 150 filler items to create 24 lists with 540 items each. 120 of the filler items were grammatically correct with a variety of different syntactic structures, and 30 of the filler items contained argument structure violations (e.g., *John put the painting*

during...). In total, items from the nine target conditions made up half of the items, and the experiment-wide ratio of acceptable to unacceptable sentences was 1:1. Across the set of materials the violations occurred in a variety of positions throughout the sentence, so participants needed to pay attention to the entire sentence in order to accurately judge the well-formedness of the sentence. Each of the 24 lists was seen by one of the 24 participants included in the analysis.

3.2.4 Plausibility norming

To confirm that the nouns in the attractive and non-attractive conditions were judged as good themes and poor themes, we conducted a preliminary offline plausibility study. We also wanted to check that the two nouns chosen for each item as semantically-attractive were roughly equal in terms of their attractiveness, and similarly for the two non-semantically attractive nouns. 12 participants from the University of Maryland community were asked to rate how plausible they thought sentences such as (21) and (22). were, on a five-point scale from 1=bad to 5=good. The participants received course credit for their participation.

(21) a. SA-v1 Barry mowed the large lawn.

b. SA-v2 Barry mowed the tall grass.

(22) a. NA-v1 Barry mowed the rural house.

b. NA-v2 Barry mowed the front porch.

A subset of 40 items was chosen randomly from the full set of 180 items. The NPs were placed in a simple active frame, consisting of a proper name plus the verb

and the NP in object position. The semantically-attractive nouns are seen in (21)a. and b., and the two non-attractive nouns are shown in (22)a. and b. The four versions of each of the 40 items were distributed across four lists in a Latin Square Design so that each participant only saw one version of an item. Because the target items were all intended to be scored as very plausible or very implausible, 20 fillers were designed to fall within the middle values on the five-point scale, in order to encourage participants to use the whole scale.

The results can be seen in Figure 6. The ratings data show that the manipulation worked as intended. Paired-sample t-tests showed that there was no difference between the two semantic-attraction versions, or between the two no-semantic-attraction versions. As hoped, SA-v1 was significantly more plausible than both NA-v1 ($t(11)=14.31$, $p<.001$) and NA-v2 ($t(11)=17.48$, $p<.001$). Likewise, SA-v2 was significantly more plausible than NA-v1 ($t(11)=15.52$, $p<.001$) and NA-v2 ($t(11)=17.26$, $p<.001$).

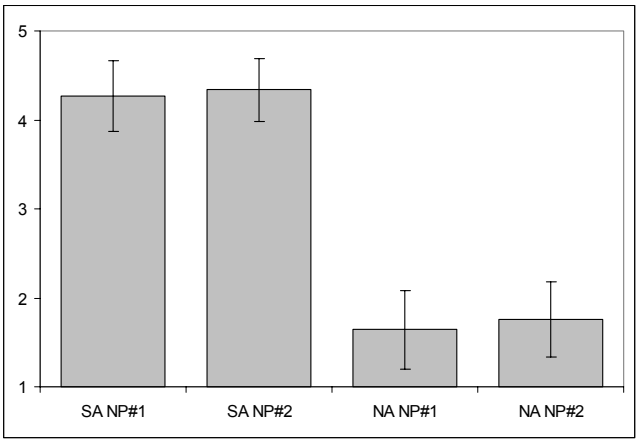

Figure 6. Plausibility norming results from the Interference ERP study, showing standard deviation

3.2.5 Procedure

Participants were comfortably seated in a dimly lit testing room about 100 cm in front of a computer monitor. Each sentence was preceded by a fixation cross. All items appeared in black font on a white screen. Participants pressed a button to initiate presentation of the trial. Sentences were presented one word at a time in 30 pt font. Each word appeared in the center of the screen for 300 ms, followed by 200 ms of blank screen. The last word of each sentence was marked with a period, and 1000 ms later a question mark prompt appeared on the screen. Participants were instructed to read the sentences carefully without blinking and to indicate with a button press whether the sentence was an acceptable sentence of English. Participants were told that there are various different ways that sentences can be unacceptable, and they were given examples of canonical semantic anomalies (e.g., *I drink my coffee with cream and socks*) and canonical syntactic anomalies (e.g., *I drinks my coffee*). They

were instructed to answer "yes" if the sentence "seemed like a fine sentence in English," and "no" if there was any kind of problem with the sentence. Feedback was provided for incorrect responses. The experimental session was divided into 7-8 blocks lasting 15 minutes each, although participants could request additional breaks at their discretion.

3.2.6 EEG recording

EEG was recorded from 28 Ag/AgCl electrodes, mounted in an electrode cap (Electrocap International): midline: Fz, FCz, Cz, CPz, Pz, Oz; lateral: F3/4, F7/8, FC3/4, FT7/8, C3/4, T7/8, CP3/4, TP7/8, P4/5, P7/8, O1/2. Recordings were referenced to the left mastoid. Additional electrodes were placed on the left and right outer canthus, and above and below the left eye to monitor eye movements. The EEG and EOG recordings were amplified by a SynAmpsTM Model 5083 EEG amplifier, and sampled at 1 kHz using an analog bandpass filter of 0.1-70 Hz. Impedances were kept below 5 kΩ.

3.2.7 EEG analysis

All comparisons were based upon single word epochs, consisting of the 100 ms preceding and the 1000 ms following the start of the presentation of the critical words. Prior to any further analyses, epochs with ocular and other large artifacts were rejected from analysis based on visual screening. Epochs showing a divergence from 0 of more than 75μV on any electrode were excluded automatically. In addition,

epochs from trials in which the participants responded inaccurately were excluded. After all these exclusions, 76% of the trials were included in the final analysis. This rate is slightly lower than the usual rate of inclusion of about 80%, for two reasons. Firstly, participants read 540 sentences so there were probably more ocular and muscular artifacts than usual. Secondly, many other ERP studies do not exclude items to which the participants responded incorrectly.

The waveforms of the individual trials were normalized using a 100 ms prestimulus baseline. Averaged waveforms were filtered offline using a 10 Hz low-pass filter for presentation purposes, but all statistics are based on unfiltered data. The following latency intervals were chosen for analysis, based on the intervals used in the literature and on visual inspection: 300-500 ms (N400), 600-800 ms (P600). The 0-200 ms interval was also analyzed to check for early differences.

For statistical analyses, six regions of interest (ROIs) were used in the ANOVAs, consisting of groups of three electrodes at each ROI: left anterior (F3, FC3, C3), anterior midline (FZ, FCZ, CZ), right anterior (F4, FC4, C4), left posterior (CP3, P3, O1), posterior midline (CPZ, PZ, OZ), right posterior (CP4, P4, O2). These ROIs were organized into the two topographic factors *laterality* (left, midline, right), and *anterior-posterior*.

ANOVAs were performed separately for the conditions without an intervening NP and for those with an intervening NP because the critical word is in a

different sentence position (fifth vs ninth word, respectively), which could introduce confounding differences. This does not impact the ability to interpret the results with regards to the main question of the experiment, which involves the effect of changing the semantic attractiveness of the head noun and intervening noun, and does not involve the impact of the presence of an intervening noun.

ANOVAs were performed hierarchically. For the no-intervener conditions, the within-subjects factor was *head* (control, semantically-attractive head, non-attractive head). For the conditions with intervening nouns, the within-subjects factors were *head* (control, semantically-attractive head, non-attractive head) and *intervener* (semantically-attractive intervener, non-attractive intervener). All *p*-values reported below reflect the application of the Greenhouse-Geisser correction where appropriate, to control for violations of the sphericity assumption (Greenhouse & Geisser, 1959), together with the original degrees of freedom. Due to the large number of possible interactions in this design, we discuss only those interactions for which follow-up analyses yielded significant contrasts within the levels of the interacting factors.

3.3 Results

3.3.1 Accuracy

Overall accuracy on the behavioral acceptability judgment task for the primary nine conditions was 94%. The accuracy was high for each condition (Control+No-intervener 95%, SA-head+No-intervener 96%, NA-head+No-intervener,

97%, Control+SA-intervener 92%, SA-head+SA-intervener 95%, NA-head+SA-intervener, 96%, Control+NA-intervener 86%, SA-head+NA-intervener 96%, NA-head+NA-intervener 97%).

The semantic control sub-experiment showed an overall accuracy of 91% (felicitous sentences 93%, infelicitous sentences 89%). The agreement conditions showed an overall accuracy of 89%. Average accuracy for the ungrammatical agreement condition was only 85%, suggesting that participants either experienced some difficulty in detecting these violations, or that they were less attentive to these violations, perhaps because they were less striking than the attraction violations.

3.3.2 No-intervener conditions

The no-attraction condition elicited an N400 effect relative to the other two conditions, and both the semantic-attraction and the no-attraction conditions elicited a P600 response relative to the control condition. Figure 7 shows the grand-averaged waveforms for the three no-intervener conditions.

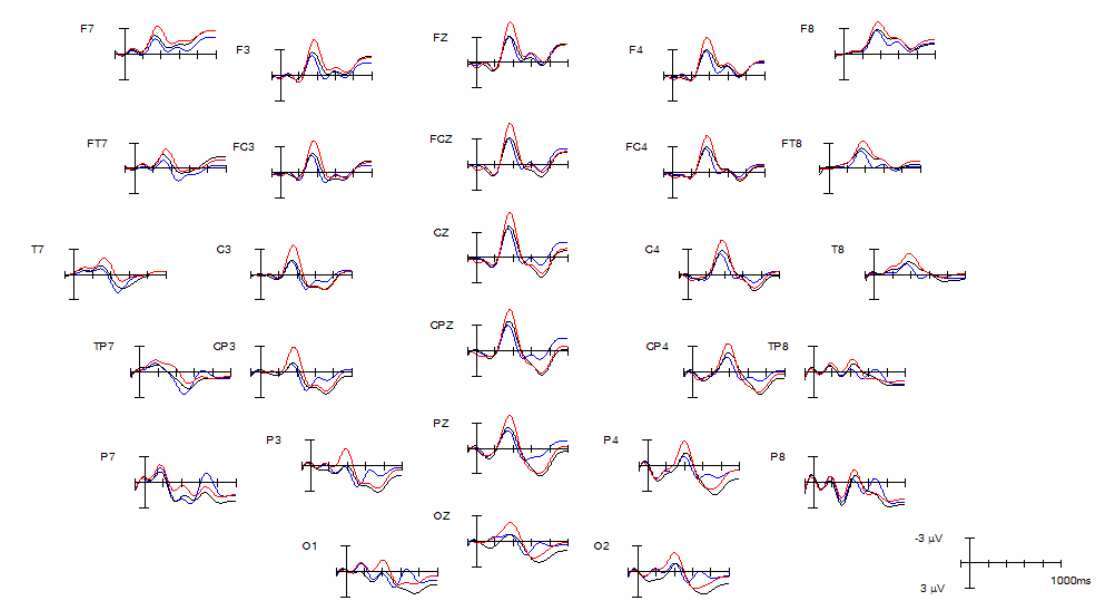

Figure 7. Grand average responses at the critical verb in the no-intervener conditions in the Interference ERP experiment, showing the grammatical control (blue), the semantic-attraction (black) and the no-attraction (red) conditions

In the ANOVAs comparing all three conditions (control, semantic-attraction, no-attraction), there were no differences in the 0-200 ms interval. In the 300-500 ms interval, there was a main effect of *head* ($F(1,23) = 5.16$, $p < .05$). To determine the source of this effect, planned pair-wise comparisons were made between the control and the semantic-attraction conditions, between the control and the no-attraction conditions, and between the semantic-attraction condition and the no-attraction conditions (Table 11). These confirm that the effect of head type was due to greater negativity in the no-attraction condition relative to the other two conditions, which did not differ from each other. In this interval, the no-attraction condition was more negative than the control condition over the entire scalp, yielding a main effect of condition and significant effects in all ROIs. The no-attraction condition was also

more negative than the semantic-attraction condition, yielding a main effect of condition. This difference was significant in the left anterior and left posterior regions, marginally significant in the anterior midline regions, and did not reach significance in the right anterior and right posterior regions.

In the 600-800 ms interval, the two violation conditions were positive relative to the control condition, particularly across the posterior half of the scalp. The ANOVAs comparing all three conditions showed an interaction of *head* and *posteriority* ($F(1,23) = 3.68$, $p < .05$). In the planned comparisons (Table 11), the semantic-attraction versus control comparisons and the no-attraction versus control comparisons both showed *head* by *posteriority* interactions. For the semantic-attraction versus control comparisons, this was significant in all posterior regions. For the no-attraction versus control comparisons, the difference was significant in the center posterior region and marginally significant in the left and right posterior regions. The semantic-attraction and no-attraction conditions did not differ from each other in this interval.

Table 11

ANOVA *F*-values for comparisons of the no-intervener conditions at the critical verb in the Interference ERP study

No intervener	0-200 ms	300-500 ms	600-800 ms
Control vs. Semantic-attraction			
head (1,23)	-	-	-
head × lat (2,46)	-	-	-
head × post (1,23)	-	-	6.78 *
head × lat × post (2,46)	-	-	-
Effect of head condition at individual ROIs:			
Anterior – left (1,23)	-	-	-
Anterior – midline (1,23)	-	-	-
Anterior – right (1,23)	-	-	-
Posterior – left (1,23)	-	-	5.06 *
Posterior – midline (1,23)	-	-	5.55 *
Posterior – right (1,23)	-	-	4.53 *
Control vs. No-attraction			
head (1,23)	-	9.32 **	-
head × lat (2,46)	-	-	-
head × post (1,23)	-	-	4.31 *
head × lat × post (2,46)	-	-	-
Effect of head condition at individual ROIs:			
Anterior – left (1,23)	-	11.99 **	-
Anterior – midline (1,23)	-	7.01 *	-
Anterior – right (1,23)	-	6.24 *	-
Posterior – left (1,23)	-	9.31 **	3.35 †
Posterior – midline (1,23)	-	5.38 *	5.10 *
Posterior – right (1,23)	-	4.83 *	3.83 †
Semantic-attraction vs. No-attraction			
head (1,23)	-	4.95 *	-
head × lat (2,46)	-	-	-
head × post (1,23)	-	-	-
head × lat × post (2,46)	-	-	-
Effect of head condition at individual ROIs:			
Anterior – left (1,23)	-	6.11 *	-
Anterior – midline (1,23)	-	3.27 †	-
Anterior – right (1,23)	-	-	-
Posterior – left (1,23)	-	8.87 **	-
Posterior – midline (1,23)	-	3.07 †	-
Posterior – right (1,23)	-	-	-

** = <0.01, * = <0.05, † = <0.1

3.3.3 Intervener conditions

For the conditions in which either the head noun or the intervening noun was not attractive, the waveform was more negative in the 300-500 ms interval, compared to the conditions in which both head and intervener nouns were semantically attractive. This effect was stronger for a non-attractive head noun than for a non-attractive intervening noun. All of the violation conditions elicited P600s relative to the control conditions, with no significant differences among the conditions. Figure 8 shows the grand-averaged waveforms for the three conditions with semantically-attractive interveners, and Figure 9 shows the three conditions with non-attractive interveners. Figure 10 illustrates the effect of the intervener within each level of head noun.

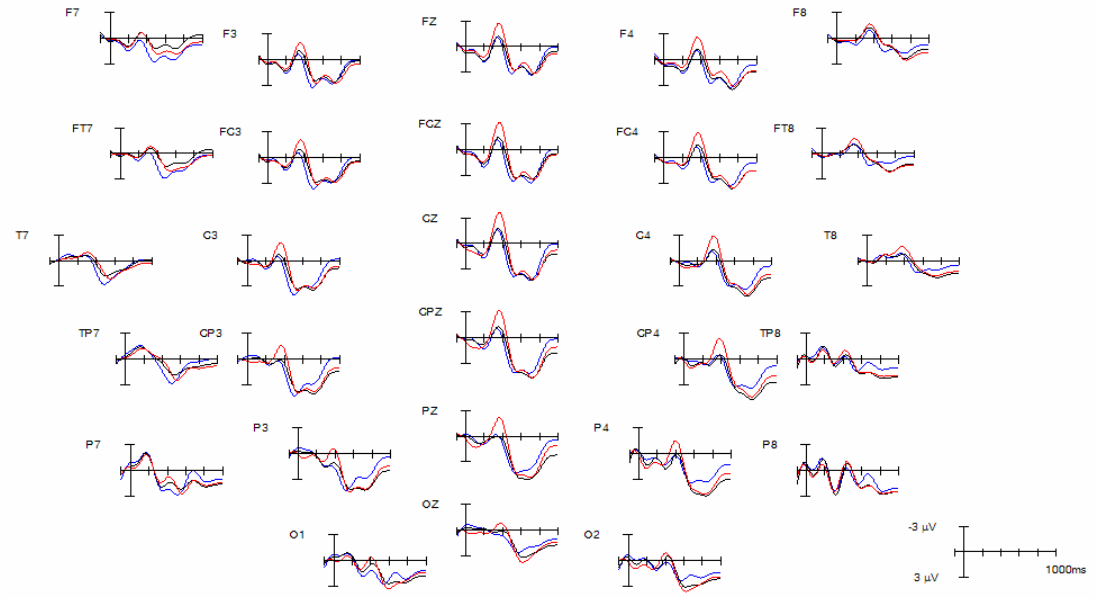

Figure 8. Grand average responses at the critical verb in the semantically-attractive intervener conditions in the Interference ERP experiment, showing the grammatical control (blue), the semantic-attraction (black) and the no-attraction (red) conditions

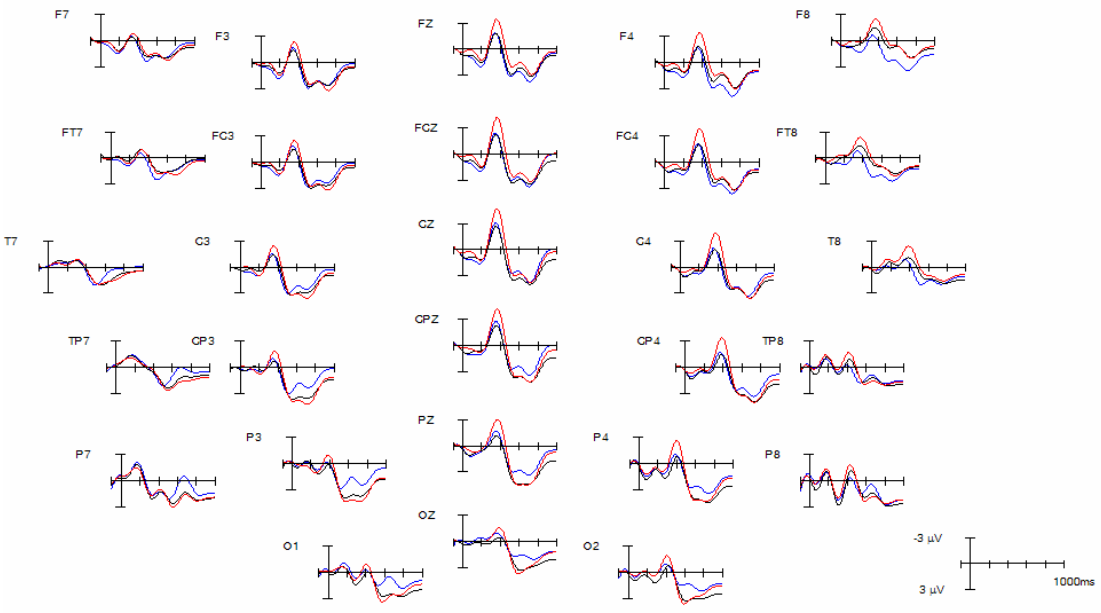

Figure 9. Grand average responses at the critical verb in the non-attractive intervener conditions in the Interference ERP experiment, showing the grammatical control (blue), the semantic-attraction (black) and the no-attraction (red) conditions

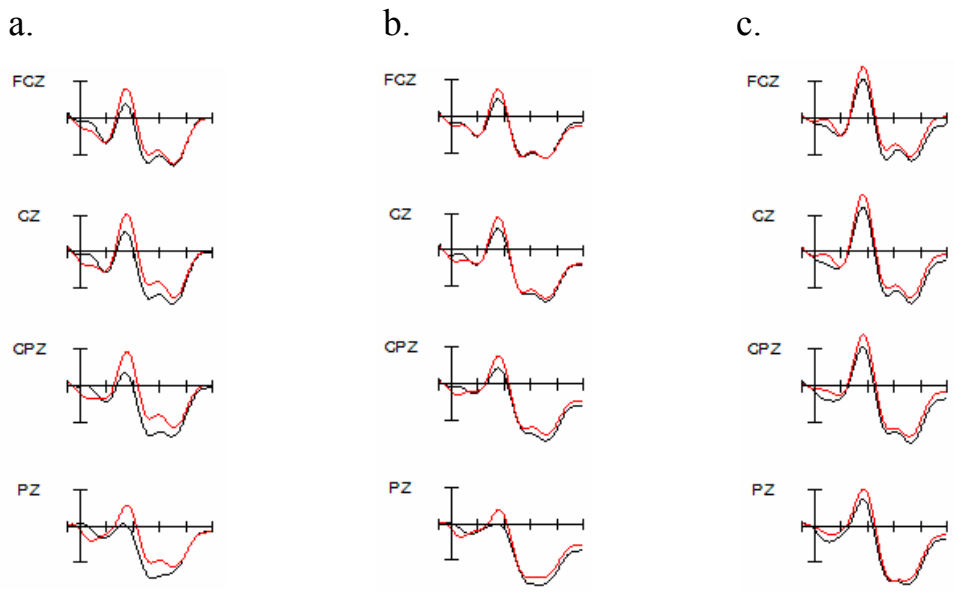

Figure 10. Grand-average responses at the critical verb in the six intervener conditions, showing semantically-attractive intervener (black) and non-attractive intervener (red) for (a) grammatical control, (b) semantically-attractive head, and (c) non-attractive head

The 3 × 2 ANOVAs for all six intervener conditions had two experimental factors, *head* (control, semantically-attractive head, non-attractive head) and *intervener* (semantically-attractive intervener, non-attractive intervener). The results are shown in Table 12.

Table 12

ANOVA *F*-values for comparisons of the intervener conditions at the critical verb in the Interference ERP study

3x2 ANOVA	0-200 ms	300-500 ms	600-800 ms
head (2,46)	-	11.80 **	-
intervener (1,23)	-	6.47 *	-
head × intervener (2,46)	-	-	-
head × lat (4,92)	-	3.14 *	4.16 **
head × post (2,46)	3.01 †	-	12.08 **
head × lat x post (4,92)	-	-	-
intervener × lat (2,46)	-	-	-
intervener × post (1,23)	-	-	-
intervener × lat x post (2,46)	-	-	-
head × intervener × lat (4,92)	-	-	2.88 †
head × intervener × post (2,46)	-	-	-
head × intervener × lat x post (4,92)	-	-	-

** = <0.01, * = <0.05, † = <0.1

0-200 ms: There was a marginally significant interaction between *head* and posteriority. However, there were no significant differences in this window in any of the pairwise comparisons in any region of interest (Tables 13 and 14) except for a marginally significant difference in the right posterior regions of the control condition (with semantically-attractive intervener) versus non-attractive head (with semantically-attractive intervener) (Table 13). It is therefore likely that the effect is spurious.

300-500 ms: In this interval, conditions with either a non-attractive head noun or a non-attractive intervening noun showed an increased negativity consistent with an N400 effect. This was reflected in significant effects of both *head* and *intervener*. Although broadly distributed, the increased negativity associated with non-attractive

head was strongest in the midline and right regions, leading to an interaction between *HNcondition* and laterality.

Effect of the head noun manipulation in the 300-500 ms interval: In the overall 3 × 2 ANOVA, there was a significant effect of *head*. In order to determine what was responsible for this effect, two separate ANOVAs were conducted, examining the effect of *head* (control, semantically-attractive head, non-attractive head) within each of the two levels of the intervener factor – the first ANOVA included the three conditions with semantically-attractive interveners, and the second ANOVA included the three conditions with non-attractive interveners.

In the analysis of the three conditions with semantically-attractive interveners, there was a main effect *of head* ($F(1,23) = 6.25$, $p < .001$). Planned pairwise comparisons (Table 13) showed that this was because the non-attractive head condition was more negative than both the control or the semantically-attractive head conditions, which did not differ from each other. The increased negativity in the non-attractive head condition relative to the control condition yielded a significant effect of *head* in the overall analysis and also at each individual topographic region. The increased negativity in the non-attractive head condition relative to the semantically-attractive head condition yielded a significant effect *of head* in the overall analysis and a significant or marginally significant effect in each individual topographic region.

In the analysis of the three conditions with non-attractive interveners, the pattern was the same. There was a main effect of *head* ($F(1,23) = 5.48$, $p < .01$) and, because the effect was larger in midline and right regions, there was also an interaction of *head* and *laterality* ($F(2,46) = 4.48$, $p < .01$). Planned pairwise comparisons (Table 14) showed that this pattern occurred because of the increased negativity of the non-attractive head noun condition relative to the control and semantically-attractive head noun conditions, which did not differ from each other. The non-attractive head noun condition was more negative than the control condition particularly towards the front and on the right, leading to effects of *head, head* by *laterality*, and *head* by *posteriority*. The effect was significant in all anterior regions and marginally significant in the midline and right posterior regions. The non-attractive head noun condition was also more negative than the semantically-attractive head noun condition toward the right, leading to effects of *head* and a *head* by *laterality* interaction. The effect was significant in each individual topographic region except for the left anterior region.

Table 13

ANOVA *F*-values for comparisons of the semantically-attractive intervener conditions at the critical verb in the Interference ERP study

Semantically-attractive intervener (1,23)	0-200 ms	300-500 ms	600-800 ms
Control vs. Semantic-attraction			
head (1,23)	-	-	-
head × lat (2,46)	-	-	-
head × post (1,23)	-	-	4.37 *
head × lat × post (2,46)	-	-	-
Effect of head condition at individual ROIs:			
Anterior – left (1,23)	-	-	-
Anterior – midline (1,23)	-	-	-
Anterior – right (1,23)	-	-	-
Posterior – left (1,23)	-	-	2.96 †
Posterior – midline (1,23)	-	-	-
Posterior – right (1,23)	-	-	3.69 †
Control vs. No-attraction			
head (1,23)	-	15.40 **	-
head × lat (2,46)	-	-	-
head × post (1,23)	-	-	5.19 *
head × lat × post (2,46)	-	-	-
Effect of head condition at individual ROIs:			
Anterior – left (1,23)	-	19.29 **	-
Anterior – midline (1,23)	-	13.23 **	-
Anterior – right (1,23)	-	9.29 *	-
Posterior – left (1,23)	-	15.83 **	5.44 *
Posterior – midline (1,23)	-	13.44 **	3.43 †
Posterior – right (1,23)	3.16 †	5.88 *	6.09 *
Semantic-attraction vs. No-attraction			
head (1,23)	-	5.89 *	-
head × lat (2,46)	-	-	-
head × post (1,23)	-	-	-
head × lat × post (2,46)	-	-	-
Effect of head condition at individual ROIs:			
Anterior – left (1,23)	-	3.66 †	-
Anterior – midline (1,23)	-	5.47 *	-
Anterior – right (1,23)	-	5.57 *	-
Posterior – left (1,23)	-	4.16 †	-
Posterior – midline (1,23)	-	4.16 †	-
Posterior – right (1,23)	-	3.75 †	-

** = <0.01, * = <0.05, † = <0.1

Table 14

ANOVA *F*-values for comparisons of the non-attractive intervener conditions at the critical verb in the Interference ERP study

Non-attractive intervener	0-200 ms	300-500 ms	600-800 ms
Control vs. Semantic-attraction			
head (1,23)	-	-	-
head × lat (2,46)	-	-	2.68 †
head × post (1,23)	-	-	15.64 **
head × lat × post (2,46)	-	-	-
Effect of head condition at individual ROIs:			
Anterior – left (1,23)	-	-	-
Anterior – midline (1,23)	-	-	-
Anterior – right (1,23)	-	-	-
Posterior – left (1,23)	-	-	13.35 **
Posterior – midline (1,23)	-	-	6.66 *
Posterior – right (1,23)	-	-	5.20 *
Control vs. No-attraction			
head (1,23)	-	6.53 *	-
head × lat (2,46)	-	7.25 *	12.89 **
head × post (1,23)	-	4.80 *	20.59 **
head × lat × post (2,46)	-	-	-
Effect of head condition at individual ROIs:			
Anterior – left (1,23)	-	5.24 *	-
Anterior – midline (1,23)	-	11.76 **	-
Anterior – right (1,23)	-	12.48 **	-
Posterior – left (1,23)	-	-	8.67 **
Posterior – midline (1,23)	-	3.56 †	-
Posterior – right (1,23)	-	4.04 †	-
Semantic-attraction vs. No-attraction			
head (1,23)	-	11.53 **	-
head × lat (2,46)	-	6.15 *	3.70 *
head × post (1,23)	-	-	-
head × lat × post (2,46)	-	-	-
Effect of head condition at individual ROIs:			
Anterior – left (1,23)	-	4.54 *	-
Anterior – midline (1,23)	-	13.82 **	-
Anterior – right (1,23)	-	13.02 **	-
Posterior – left (1,23)	-	-	-
Posterior – midline (1,23)	-	6.92 *	-
Posterior – right (1,23)	-	13.23 **	-

** = <0.01, * = <0.05, † = <0.1

Effect of the intervening noun manipulation in the 300-500 ms interval: In the overall 3x2 ANOVAs, there was a significant effect of *intervener* ($F(1,23) = 6.47$, $p < .05$). This was due to increased negativity in the non-attractive intervener conditions relative to the semantically-attractive intervener conditions, within all levels of the *head* factor, including the two grammatical control conditions. Planned comparisons (Table 15) of semantically-attractive intervener versus non-attractive intervener conditions, within each level of *head* (control, semantically-attractive head, non-attractive head), revealed that the effect of the attractiveness of the intervener was not as strong as the effect of the attractiveness of the head. In the comparison of the two control conditions, there was a marginal effect of *intervener* which was significant at left anterior, left posterior and central posterior regions. The comparison within the two semantic-attraction head conditions did not reach significance. The comparison within the two non-attractive head conditions showed a marginal interaction between *intervener* and *laterality*, which was due to marginally significant differences in the central anterior, right anterior and right posterior regions.

Table 15

ANOVA *F*-values for comparisons of the semantically-attractive intervener and non-attractive conditions at the critical verb in the Interference ERP study

	0-200 ms	300-500 ms	600-800 ms
Control: semantically-attractive intervener vs. non-attractive intervener			
intervener (1,23)	-	3.61 †	-
intervener × lat (2,46)	-	-	-
intervener × post (1,23)	-	-	-
intervener × lat × post (2,46)	-	-	-
Effect of intervener condition at individual ROIs:			
Anterior – left (1,23)	-	5.14 *	-
Anterior – midline (1,23)	-	-	-
Anterior – right (1,23)	-	-	-
Posterior – left (1,23)	-	5.93 *	-
Posterior – midline (1,23)	-	4.86 *	-
Posterior – right (1,23)	-	-	-
Semantically-attractive head: semantically-attractive intervener vs. non-attractive intervener			
intervener (1,23)	-	-	-
intervener × lat (2,46)	-	-	-
intervener × post (1,23)	-	-	-
intervener × lat × post (2,46)	-	-	-
Effect of intervener condition at individual ROIs:			
Anterior – left (1,23)	-	-	-
Anterior – midline (1,23)	-	-	-
Anterior – right (1,23)	-	-	-
Posterior – left (1,23)	-	-	-
Posterior – midline (1,23)	-	-	-
Posterior – right (1,23)	-	-	-
Non-attractive head: semantically-attractive intervener vs. non-attractive intervener			
intervener (1,23)	-	-	-
intervener × lat (2,46)	-	3.43 †	3.87 *
intervener × post (1,23)	-	-	-
intervener × lat × post (2,46)	-	-	-
Effect of intervener condition at individual ROIs:			
Anterior – left (1,23)	-	-	-
Anterior – midline (1,23)	-	2.93 †	-
Anterior – right (1,23)	-	2.99 †	-
Posterior – left (1,23)	-	-	-
Posterior – midline (1,23)	-	-	-
Posterior – right (1,23)	-	3.45 †	-

** = <0.01, * = <0.05, † = <0.1

600-800 ms: In this interval, all four of the violation conditions showed a positivity relative to the control conditions, and did not differ significantly from each other. This effect was strongest across the posterior portion of the scalp, resulting in an interaction between *head* and *posteriority* ($F(2,46) = 12.08$, $p < .01$). The effect was slightly stronger on the left, resulting in an interaction between *head* and *laterality* ($F(4,92) = 4.61$, $p < .01$). There were no effects of the intervening noun manipulation.

As in the 300-500 ms interval, two separate ANOVAs were conducted, examining the effect of *head* condition (control, semantically-attractive head, non-attractive head) while holding the intervener constant.

In the analysis of the three conditions with semantically-attractive interveners, there was an interaction between *head* and *posteriority* ($F(2,46) = 3.34$, $p < .05$). Planned pairwise comparisons (Table 15) confirmed that this arose because both violation conditions are more positive than the control, but they did not differ from each other. In a comparison of control versus semantically-attractive head conditions, there was an interaction between *head* and *posteriority*, and the difference was marginally significant in the left posterior and right posterior regions. In a comparison of control versus non-attractive head conditions, there was a *head* by *posteriority* interaction, and the difference was significant in the left posterior and right posterior regions, and marginally significant in the midline posterior region.

With the three conditions with non-attractive interveners, the two violation conditions were more positive in the posterior half of the scalp, and the effect was strongest on the left. This was reflected in interactions between *head* and *posteriority* ($F(2,46) = 11.12$, $p < .01$) and between *head* and *laterality* ($F(4,92) = 6.05$, $p < .01$). In the pairwise comparison of control versus semantically-attractive head conditions, there was a significant interaction between *head* and *posteriority*, and a marginal interaction between *head* and *laterality*. The difference was significant in all posterior regions. In the comparison of control and non-attractive head conditions, there were interactions between *head* and *laterality* and between *head* and *posteriority*, and the difference was significant only in the left posterior region. The semantically-attractive head and non-attractive head conditions did not significantly differ from one another in any region of interest.

There was no significant effect of *intervener* in the 600-800 ms interval, when comparing the two control conditions, the two semantically-attractive head conditions, or the two non-attractive head conditions.

3.3.4 Control sub-experiments

3.3.4.1 Semantic anomaly

There were no differences between conditions in the 0-200 ms interval. In the N400 interval (300-500 ms), the semantic anomaly condition was more negative than the control condition over the whole head, although it was strongest over the right hemisphere. There was a main effect of *condition* and an interaction between

condition and *laterality*. The effect of condition was significant in all ROIs, except for the left anterior region which was only marginally significant. Figure 11 shows the electrode map, and the *F*-values can be seen in Table 16 below.

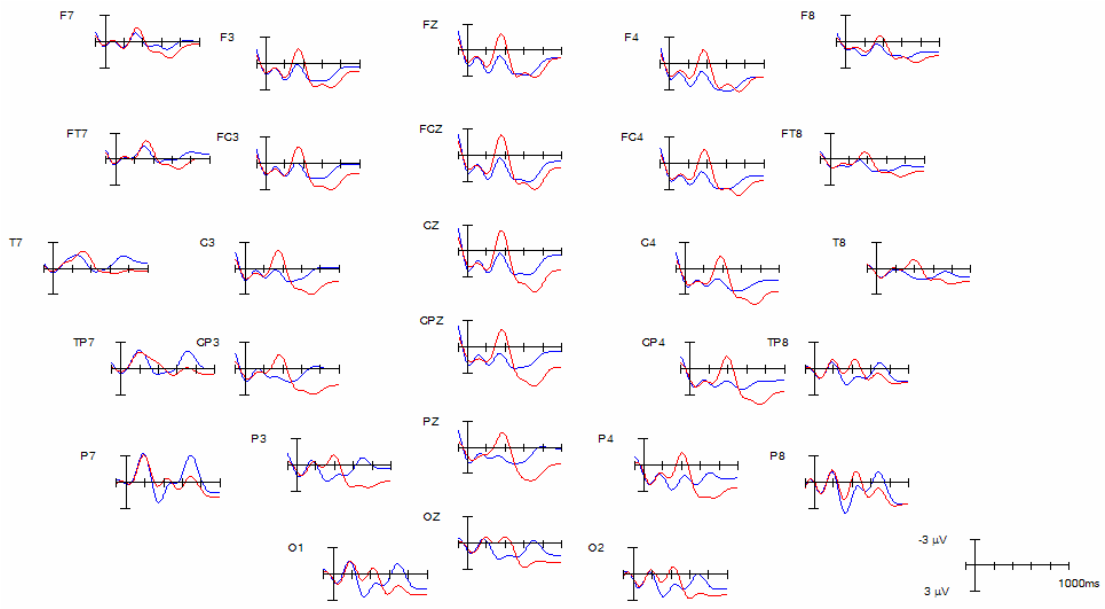

Figure 11. Grand average responses at the critical noun in the semantic sub-experiment conditions in the Interference ERP experiment, showing the felicitous (blue) and the infelicitous (red) conditions

Table 16

ANOVA *F*-values for comparisons of the semantic sub-experiment conditions at the critical noun in the Interference ERP study

Semantic Felicity	0-200 ms	300-500 ms
cond (1,23)	-	9.78 **
cond × lat (2,46)	-	5.46 *
cond × post (1,23)	-	-
cond × lat × post (2,46)	-	3.11 †
Effect of condition at individual ROIs:		
Anterior – left (1,23)	-	3.90 †
Anterior – midline (1,23)	-	8.41 **
Anterior – right (1,23)	-	11.48 **
Posterior – left (1,23)	-	7.81 *
Posterior – midline (1,23)	-	7.11 *
Posterior – right (1,23)	-	8.72 **

** = <0.01, * = <0.05, † = <0.1

3.3.4.2 Syntactic violation

In the 0-200 ms interval, there was a marginally significant interaction of *condition* and *posteriority*, due to the violation condition being slightly more negative than the control condition across the back half of the scalp, but this difference was not significant in any individual region. In the 300-500 ms interval, there were no differences between the conditions. In the P600 interval (600-800 ms), the violation condition was more positive than the control condition especially in the central-posterior region. However, this was not a significant difference. The lack of significance in the P600 window was unexpected, and follow-up analyses indicate that this was caused because the mismatch trials with a singular-plural mismatch did show a significant effect ($F(1,21) = 6.54$, $p < .05$; significant in all posterior ROIs), whereas the plural-singular mismatches showed no P600 response ($F(1,21) < 1$). The reason behind this difference in response is outside the scope of the current study.

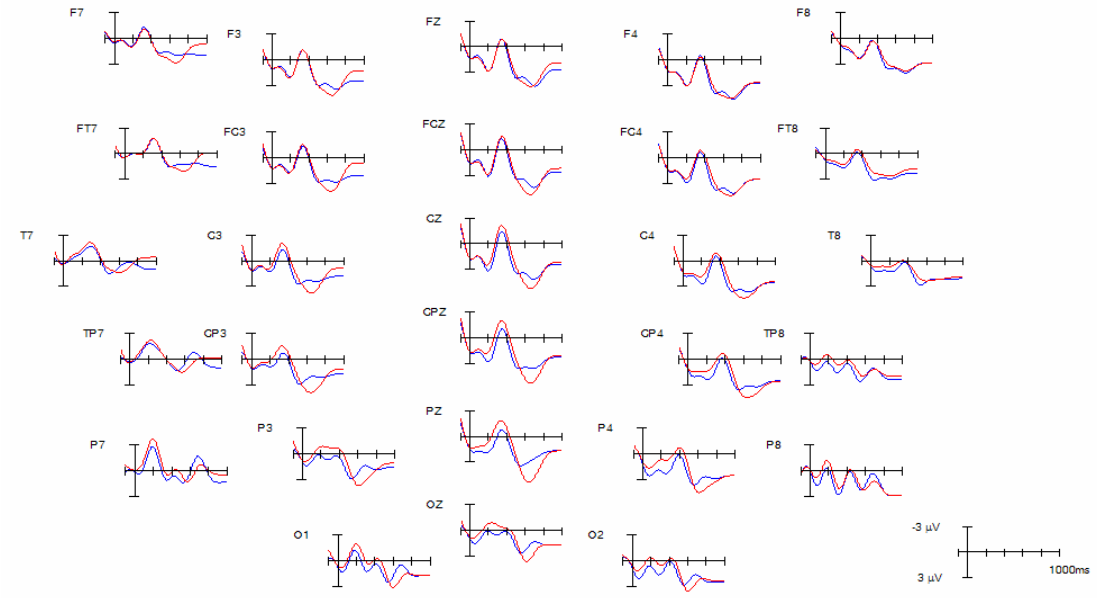

Figure 12. Grand average responses at the critical noun in the syntactic sub-experiment conditions in the Interference ERP experiment, showing the grammatical agreement (blue) and mismatch agreement (red) conditions

3.4 Discussion

The aim of this study was to test whether nouns in non-argument positions would elicit the same attraction effects as nouns in argument positions. Previous research (e.g., Kim & Osterhout, 2005) has suggested that the processor might be able to propose interpretations based on combining word meanings in ways that are incompatible with the relationships between those words as determined by their structural positions. An alternate interpretation of those results is that in those studies the relevant structural information arrived later than the relevant semantic information, so that although semantic information may play a role in determining the

interpretations under consideration, the processor respects currently available structural information. In order to test these two accounts, we manipulated the semantic attraction of nouns in an argument position as well as the attraction of nouns in a non-argument position. The structural information about which noun is a possible argument of the verb is available prior to the arrival of the verb because one noun appears as the subject of the sentence while the other appears inside a prepositional phrase that modifies the first noun. If there is a semantic processing stream that builds structures independently of a syntactic processing stream and does not respect prior structural commitments the semantic attraction effect should be seen either to the linearly closest noun, or to any noun in the vicinity. On the other hand, if the processor only considers interpretations that are consistent with prior structural information, the semantic attraction effect should be modulated only by the attractiveness of the noun in the argument position.

Results show that all violation conditions elicited a P600 relative to the grammatical control conditions, regardless of the attractiveness of either the head or the intervening noun. There was no difference between the P600s elicited to semantic-attraction and no-attraction nouns. In addition, both no-attraction heads and no-attraction interveners were associated with a higher-amplitude N400 than attractive heads and interveners, although the effect of a non-attractive head was larger than the effect of a non-attractive intervener. Perhaps the most striking aspect of these results is that in all three triplets of conditions (grammatical control,

semantically-attractive head, non-attractive head) the pattern of results is essentially the same, regardless of the presence or nature of the intervener (Figures 8, 9 and 10).

This experiment was designed with the expectation that a non-attractive head noun would not elicit a P600, as in Kim & Osterhout (2005), which would have allowed us to see whether a sentence with a non-attractive head but a semantically-attractive intervening noun would elicit a P600 or not. Because it turned out that a P600 was always elicited regardless of the attractiveness of the head noun, it is impossible to tell whether the nouns in non-argument positions also impacted the P600 component. This means that we cannot conclusively answer our original question about whether the attractiveness effect tracks with the head or the intervening noun, which was a proxy for the question of whether or not nouns in non-argument positions are ever under consideration for receiving thematic roles assigned by the verb. In rest of this section, I first elaborate how the results violate the assumptions that the experimental design rested on, and following that, I discuss how we can interpret the pattern of results and what they say about the factors that elicit the thematic P600.

The pattern of results do not support Kim and Osterhout's contention that the N400 and the P600 occur in complementary distribution in this kind of sentence, with the P600 indicating that the processor attempted a passive interpretation and the N400 indicating that the processor did not attempt a passive interpretation. Firstly, all violation conditions elicited a P600, with no evidence of modulation by the semantic

attractiveness of the nouns. Secondly, although the N400 was elicited by both non-attractive head nouns and non-attractive intervening nouns, it was always accompanied by a P600 in the violation conditions. And thirdly, the N400 modulation by the attractiveness of the intervener was also found in the comparison of the two grammatical control conditions, raising questions about the extent to which the N400 reflects the detection of semantic anomaly, at least in these sentences.

In this study, all three conditions with non-attractive head nouns elicited a P600. Since the publication of Kim and Osterhout (2005), various additional studies have shown P600s in the absence of attraction between the noun and the verb. Kuperberg et al. (2006) elicited a P600 to non-attractive combinations such as *...the trumpets would curtsey…*, and Kuperberg et al. (2007) elicited a P600 at the verb in sentences such as *For breakfast the eggs would plant*. The Spanish ERP experiment presented in Chapter 2 also did not show modulation of the P600 by the attractiveness of the noun. In the context of that experiment, a possible explanation for this finding was that because the auxiliary *fue* was strongly biased toward the passive structure, the processor pursued a passive analysis regardless of the attraction between the noun and the verb. However, in light of the growing number of studies in English that show P600s to non-attractive noun-verb combinations, it seems more likely that the Spanish results do not represent a special case. The finding that non-attractive noun-verb combinations frequently elicit P600s cannot be reconciled with Kim & Osterhout's argument that the P600 indicates that a semantic processing stream pursued a passive analysis, because it is unclear why such a stream would pursue a passive

interpretation in sentences in which the noun is not a plausible theme for the verb. Note that this does not mean that the processor was not pursuing a passive N – it could have been pursuing a passive based on the sentence-initial inanimate noun – just that the recognition of thematic attraction between the noun and the verb was not the driving factor.

The results from the current study show that the N400 was modulated by both the attractiveness of the head noun and the attractiveness of the intervener, such that a lack of attraction in either noun elicited a higher-amplitude N400 than in conditions where both nouns were good themes for the verb. Although the effect elicited by a non-attractive head noun was larger and more consistent than the effect elicited by a non-attractive intervening noun, the fact that nouns in both positions modulated the N400 could be taken as evidence the attractiveness effect does not discriminate based on structural information. In other words, since the N400 modulation by attractiveness is half of Kim & Osterhout's attractiveness effect (the other half is P600 modulation by attractiveness), should the N400 results showing modulation by both arguments and non-arguments be taken as partial support for the argument that the attractiveness effect indicates a model with an independent semantic processing stream? I argue that this interpretation of the N400 results is not correct for two reasons. Firstly, Kim and Osterhout's argument relied on the complementarity of the N400 and P600 components. Under this view, an N400 indicated that the noun-verb combination did not warrant an attempted passive interpretation, whereas a P600 was an indication that a passive interpretation had been pursued. In light of this, it is

unclear what a combination of an N400 and a P600 means, and it seems imprudent to use Kim & Osterhout's framing of what the components mean in a situation in which the complementarity of components did not hold. Secondly, the modulation by the attractiveness of the intervener was even found for the two grammatical control sentences: the grammatical control with a non-attractive intervener was more negative in the 300-500 ms interval than the grammatical control with a semantically-attractive intervener. This suggests that the modulation of the N400 here is not an indication of semantic anomaly but probably reflects a lower level of semantic association between the nouns and the verb in the non-attractive intervener case than in the attractive-intervener case. For a complete discussion of what the N400 reflects, please see Chapter 1, Section 5.

The fact that semantic attraction does not consistently modulate the thematic P600 raises fundamental questions about what does in fact elicit the thematic P600. It has been noted before (e.g., Kuperberg, 2007) that many of the stimuli that elicit a P600 involve issues with the animacy of the noun in relation to the selectional restrictions of the verb. In the studies discussed so far (Chapter 2; this Chapter; Kim & Osterhout, 2005; Kuperberg et al., 2006, 2007) the sentences all began with an inanimate noun but later structural information revealed that the sentence had an active structure. The P600 in this situation could arise in at least two different ways. First, it is possible that the P600 is elicited because the verb requires an animate subject but the noun in subject position is inanimate. Second, if the sentence-initial inanimate noun sets up an expectation for a passive structure, then the P600 could

result when the processor ascertains that the incoming sentence does not match the expectation. Under both of these views, the animacy of the noun in relation to the selectional restrictions of the verb is the relevant factor for determining when a P600 should be elicited, and both views can be accommodated within the 'canonical' view of the P600 as a response to a syntactic violation.

Many of the models that have attempted to find an overarching account for the thematic P600 have pointed to the Dutch studies of stimuli such as *The fox that at the poachers hunted…* as evidence that the thematic P600 can be elicited even in the absence of an animacy violation (e.g., Kuperberg, 2007). However, in English and other SVO languages, the P600 has rarely been elicited in the absence of an animacy violation. In a study that explicitly manipulated the animacy of the critical noun, Packynski et al. (2006) found that sentences such as (23)a elicited an N400, whereas the conditions with inanimate nouns in (23)b elicited an N400 plus P600 combination. There was no effect of semantic association.

(23) a. *…the man's pain was understood by the {hypochondriac/violinist}*

b. *…the man's pain was understood by the {medicine/pens}*

The difficulty with interpreting this study is that it is unclear whether this is a real violation rather than just an unexpected word: *hypochondriacs* and *violinists* can certainly understand pain. The absence of the P600 might indicate that the thematic P600 does not occur in English in the absence of an animacy violation, but it is also possible that there is no P600 because these sentences were not perceived as true violations.

Among studies that have manipulated semantic anomaly within the N400 literature, many do not involve an animacy violation. For example, in the original report of the N400, in *I drink my coffee with cream and {sugar/socks}* (Kutas & Hillyard, 1980) both anomalous and acceptable words were inanimate. Some studies of semantic anomalies contain a mixture of sentences that involve an animacy violation and sentences that do not. For example, the semantic anomaly condition in Osterhout and Nicol (1999), which elicited an N400 and no positivity, contained a mixture of sentences such as *The expensive ointment will loathe*, which does include an animacy violation, and sentences such as *The cat won't bake*, in which there is no animacy violation. Similarly, in an Italian study (De Vincenzi et al., 2003) the semantic anomalies which elicited an N400 but no P600 comprised a mix of anomalies involving animacy such as (24)a. and b., and sentences that do not involve animacy such as (24)c.

(24) a. Il nuovo capotreno *germoglia* alla partenza della locomotive.
the new guard sprouts at-the departure of-the locomotive.
'The new guard sprouts at the departure of the locomotive.'
b. L'olio extra vergine *tossisce* in modo molto saporito.
the oil extra virgin coughs in way very tasty
'The extra virgin olive-oil coughs in a very tasty way.'
c. Lo spettatore straniero *abbaia* mostrando un grande entusiasmo.
the spectator foreign barks showing a great enthusiasm
'The foreign spectator barks showing a great enthusiasm.'

Therefore, many of the studies from the N400 literature on semantic anomaly do not help us to decide whether an animacy violation (or structural expectations based on animacy) is the crucial factor in eliciting the thematic P600.

There is one study that elicited a P600 in a situation with an animate subject that did not involve a violation of the animacy requirements of the verb's selectional restrictions. Kuperberg et al. (2007), which showed an N400 and a small P600 to *For breakfast, the boys would plant…*. However, the P600 was much smaller in that condition compared to the sentences which did involve an animacy violation (*…the eggs would eat…* and *…the eggs would plant…*). In this case, the anomaly stems from a pragmatic problem between the preamble *For breakfast…* and the subject noun and verb *…the boys would plant…*, because that is an unlikely thing to do at breakfast time. This makes it harder to spell out exactly what processes and representations are involved, compared to sentences in which the anomaly is between the noun and the verb.

There is one study that appears to contradict the argument that has been made up to this point. Geyer et al. (2006) recorded an N400 and a P600 at the noun in object position in sentences such as (25) when participants judged the sentences for plausibility, although in a second experiment in which participants answered content questions, there was no P600.

(25) Tyler cancelled the *tongue*…

In this case, the critical noun does not violate any animacy requirements of the verb because *cancelled* takes an inanimate object (e.g., *the subscription*). Unlike in sentences such as *The hearty meal was devouring…* where I argued that the P600 might arise when the processor's expectations for a passive sentence are disconfirmed, in the *tongue* sentences there is no violation of structural expectations. Also, unlike the *hearty meal* sentences in which the structure prior to the verbal suffix was ambiguous between an active and a passive, in the *tongue* example there is no ambiguity about what structural position the critical noun will be in or what structure the sentence will have. The cases that can be described as involving an animacy violation, the violation of a structural expectation, or a case of structural ambiguity, can be essentially accounted for using the "traditional" interpretation of the P600 which states that a P600 reflects a syntactic violation, structural reanalysis, or increased syntactic effort. This does not work for the *tongue* example. This is the critical study that provides evidence for expanding the set of things that elicit the P600 to include a "thematic" violation that is independent of syntactic errors/processing/reanalysis. This is the idea expressed in Kuperberg (2007), which states that there may be a thematic stream separate from the morphosyntactic stream, or that there may be a general combinatorial stream that functions primarily over morphosyntactic information but also uses some information about thematic fit between verbs and core arguments.

3.5 Summary

The manipulation of the fit of the initial noun as a theme for the verb did not impact the elicitation of a P600. All anomalous conditions elicited a P600, regardless of whether or not either the head noun or intervener noun made a good theme for the verb. These results suggest that the P600s in this study, and others like it, actually reflect the detection of a standard syntactic violation. Specifically, the inanimate noun in subject position is not a good agent, but the verb requires an agentive subject. This notion is explored further in the next chapter.

Chapter 4: The effect of semantic attraction and semantic association on the thematic P600

4.1 Introduction

Although the thematic P600 effect in sentences such as *The hearty meal was devouring…* initially seemed to be modulated by the semantic relationship between the noun(s) and the verb, recent studies have not consistently found this pattern. A central implication of the theory of an independent semantic composition mechanism is that the P600 should only be elicited when the initial noun is a good theme (but a poor agent) for the verb. If the P600 is not modulated by semantic relationships, the argument for independent semantic composition would be significantly weakened.

The first thematic P600 study to explicitly manipulate semantic attraction between content words in a sentence (Kim and Osterhout, 2005) appeared to show that this manipulation has a clear-cut effect on the P600. In that study, a P600 was evoked if the noun was a good theme for the verb, and the P600 was not evoked when the noun made a poor theme for the verb. By now, however, a number of studies have investigated the impact on the P600 of various semantic manipulations, including semantic attraction as well as general semantic association (Hoeks et al., 2004; Kim & Osterhout, 2005; Kuperberg et al., 2006, 2007; van Herten et al., 2006; Chapters 2 and 3), and these studies have shown that the effect is more variable than it initially

appeared. A P600 is evoked consistently when the initial noun is semantically related to the verb but not a good subject. In contrast, when the noun(s) and the verb are unrelated some studies have found a P600 and others have not. Because these studies have been taken as evidence for the existence of a semantic processing stream that works in parallel to the structural processing stream, it is important to understand whether these effects are found consistently and in a widespread set of circumstances, or whether in fact there is a fairly limited set of circumstances in which semantic attraction or association play a role. In this chapter, I argue that a majority of the thematic P600 results can best be accounted for without appealing to a semantic processing stream. These studies all involved an inanimate NP in the subject position of an active sentence, so the P600s might reflect the violation of the verb's agentivity requirement for its subject. A limited number of the results cannot be explained in this way and may provide evidence for an independent semantic composition mechanism. I discuss whether there are particular features of the processing environments that appear to admit the influence of semantic information that distinguishes these environments from the ones in which there is no evidence of the influence of semantic attraction and/or association.

The two main manipulations of semantic information have been semantic attraction and semantic association. Semantic attraction refers to whether a noun fits as a specific thematic role for the verb. For example, Kim and Osterhout manipulated the suitability of the subject NP as a potential theme for the verb. On the other hand, semantic association refers to the semantic relatedness of two words and does not

impose category constraints. For example, two verbs can be semantically associated, but two verbs cannot be semantically attracted. Semantic association can be quantified in a variety of ways, including explicit ratings of "how related are these two words" as well as more general measures of how often two words tend to co-occur in the same text. Whereas semantic attraction and semantic association tend to correlate to some extent, that is not always the case. This is illustrated in an example from Kuperberg et al. (2006), *the trumpets would curtsey…*, in which the noun and the verb are associated with one another, but there is no semantic attraction between *trumpets* and *curtsey* because *trumpets* cannot serve as either the agent or the theme of *curtsey*. At the level of looking at the general pattern of results, the manipulations of semantic attraction and of semantic association have shown a similar pattern. As Kuperberg (2007) points out in her review article, whenever the noun(s) and the verb are either semantically attractive or semantically associated, a P600 is consistently elicited. In contrast, when there is no semantic attraction or when there is no semantic association, sometimes a P600 is elicited but sometimes it is not.

Questions about the role of semantic manipulations such as attraction and association are central to the discussion of whether the thematic P600 results provide evidence for independent semantic composition. Kim and Osterhout (2005) relied on their experimental contrast between the P600 in the semantic attraction condition and the N400 in the no-attraction condition to claim that a separate semantic processing stream was able to compute the most plausible way to combine an NP and a verb, and that the processor only pursued a passive interpretation when the semantic stream

suggested it. Under Kim and Osterhout's view the semantic processing stream computes specific relationships (e.g., 'this NP is a good theme for this verb'), and the output is checked against the relationships licensed by the structure. If it turns out, as I have suggested in Chapters 2 and 3, that in many cases a P600 can be elicited even when the NP makes a poor theme for the verb, then it is hard to argue that the effect is being driven by an independent semantic processing stream that computes plausible relationships.

Other accounts of the thematic P600 (van Herten et al., 2005, 2006; Kuperberg, 2007; Bornkessel-Schlesewsky & Schlesewsky, 2008) have a more expanded view of the way that semantic information is related to the thematic P600. For example, Kuperberg's (2007) model has two processing streams that run independently of the morphosyntax, including a "semantic memory-based stream" that calculates associative relationships between content words in a sentence, as well as a combinatorial stream that calculates likely thematic relationships. Semantic association is the relevant variable for the semantic memory-based stream, while semantic attraction is the relevant variable for the thematic combinatorial stream. According to this model, if either the output of the semantic memory-based stream or the thematic stream appears incompatible with the morphosyntax, the processor engages in "continued processing", which is reflected by the P600 effect. It is unclear how semantic association evidence could be deemed incompatible with the morphosyntactic analysis, because, by definition, semantic association does not involve specific relationships (e.g., 'theme of x'). Nevertheless, in this model,

manipulations of both semantic association and semantic attraction are claimed to affect whether the P600 will be elicited.

There are differences among the different accounts (Kim & Osterhout, 2005; Kuperberg, 2007; van Herten et al., 2005, 2006; Bornkessel-Schlesewsky & Schlesewsky, 2008) as to whether the relevant variable is semantic attraction or semantic association, and whether the semantic stream is seen as computing structurally-relevant relationships (e.g., 'this is a good theme for the verb') or rather just recognizing that the words are associated in some way. However, across all of the current models, the thematic P600 results are taken to indicate that semantic relationships between the content words can guide combinatorial processing. The variability surrounding the appearance of a P600 in conditions that lack semantic attraction or association is problematic for all of the accounts just mentioned.

In order to provide a more detailed understanding of the role of semantic information in influencing the analyses that the processor pursues, and to reach an account that would allow us to predict whether a P600 will be evoked for a given sentence type, we must examine the apparent variability in the P600's sensitivity to semantic manipulations more closely. In this section, I argue that the variability is systematic, and that understanding the kinds of processing situations in which the P600 does appear sensitive to semantic manipulations and those in which it does not can not only help us make sense of the variability, but also lead us to a greater understanding of when and how semantic information plays a significant role in

processing. I first examine the evidence that the P600 is sensitive to semantic attraction and then, separately, the evidence that the P600 is sensitive to semantic association between the noun(s) and the verb. I also consider results from verb-medial languages such as English and Spanish separately from the studies in which the anomaly arises in a verb-final clause, such as in Dutch or German. I argue that many of the studies in the set of thematic P600 results may in fact be a response to a syntactic violation caused by the inanimate subject NP, which makes a poor agent for the verb. Therefore, these studies do not provide support for an independent semantic composition mechanism. There are a number of studies that do not involve agentivity violations, and for each one I discuss whether the results can be seen as speaking to the issue of whether there is an independent semantic composition mechanism. I argue that there is at least one Dutch study that may provide evidence for the influence of semantic information on combinatorial processing, and I discuss the possibility that this contrast might result from differences in processing situations in verb-medial versus verb-final clauses.

This way of looking at these results represents a shift in approach compared to the accounts that have attempted to provide overall descriptions and accounts of the set of thematic P600 results. Firstly, these accounts have tended to not consider results from verb-medial and verb-final languages separately, despite potential differences in the processing actions involved. More fundamentally, however, prior accounts have taken the view that the semantic stream is constantly analyzing incoming content words (e.g., identifying plausible relationships or associations), and

constantly influencing the analysis that the processor pursues. In this chapter I consider the possibility that there may be a limited set of circumstances in which semantic information influences combinatorial processing, although there is little evidence that the effects are widespread.

4.2 Semantic attraction in English and Spanish

I have used the term "semantic attraction" to generally refer to a situation where a noun is a good fit with one of the verb's thematic roles. In previous literature this property has been referred to in a number of different ways (see Kuperberg, 2007), which although referring to roughly the same thing, provide different emphasis. The term "semantic-thematic fit" is more neutral than "semantic attraction" in terms of its implications about whether the processor actively attempts to combine the words together. The term "reversibility" has also been used, primarily in studies on Dutch verb-final clauses, to describe a situation in which a pair nouns are a good fit for the verb's thematic roles (e.g., one as agent and the other as theme/recipient), but where the structure corresponds to the opposite assignment (i.e., the noun that is a good agent is in the theme position).

In this section and the following one, I examine the studies that have manipulated semantic attraction in verb-medial languages such as English and Spanish. In these studies, the relevant computation is between a single noun and the following verb. In Section 3, I examine the Dutch study that explicitly manipulated reversibility. In this study, the relevant computation is between two nouns and the

following verb. I argue that there is little evidence that the related properties of semantic attraction and reversibility modulate the thematic P600. The question of whether semantic attraction modulates the thematic P600 is particularly relevant for Kim and Osterhout's model, which specifically states that the semantic processing stream evaluates each noun with regard to its fit as one of the verb's thematic roles. However, the question is relevant for all of the accounts that posit a semantic processing stream, because all of them rely on the notion that the thematic P600 is modulated by semantic information in some way. If it turns out that the evidence for modulation by semantic attraction or association is not as strong or widespread as is often assumed, this will significantly weaken the support for an independent semantic composition stream.

At least five studies in English and Spanish have included conditions that explicitly varied whether an inappropriate subject NP is or is not a plausible them for the verb. In all of those studies, a P600 (and no N400) was elicited in the semantic attraction condition. Although the first study to explicitly manipulate semantic attraction (Kim & Osterhout, 2005) did not elicit a significant P600 in the no-attraction condition (although this condition did show a small positivity in the P600 interval), more recent studies have not replicated that finding. A summary of the results of the no-attraction condition can be seen in Table 17.

Table 17

Summary of the English studies that manipulated semantic attraction

Study	**No-attraction condition - Sample sentence**	**Result**
Kim & Osterhout (2005)	*The dusty tabletop was devouring…*	N400
Kuperberg et al. (2006)	*…the trumpets would curtsey…*	P600
Kuperberg et al. (2007)	*Every morning at breakfast the eggs would plant...*	P600
Spanish Expt (Ch. 2)	*The apartment fue declaring…*	P600
Interference Expt (Ch. 3)	*The rural house* {+/- intervener} *was mowing…*	N400 P600

Four of the studies shown in Table 17 tested the effect of semantic attraction directly by manipulating whether or not the initial noun was a plausible theme for the following transitive verb. Kim and Osterhout (2005) found only an N400 in their no-attraction condition, Kuperberg et al., (2007) and the Spanish experiment presented in Chapter 2 found only a P600 in the no-attraction condition, and a fourth study (Interference Expt, Chapter 3) found both an N400 and a P600. I am assuming that the presence or absence of the N400 is related to word association effects (see Chapter 1, Section 5 for more details), and will focus in this section on the presence or absence of the P600.

Kuperberg et al. (2006) did not directly test the effect of semantic attraction, but instead focused on the effect on the P600 of the transitivity of the verb and the effect on the P600 of the plausibility of the sentence in its passive version. Although Kuperberg and colleagues did not specifically manipulate semantic attraction in this study, the results are relevant to the current discussion because both manipulations compared one group of sentences in which the open class words could suggest a passive analysis with another group of sentences in which the open class words could not have suggested a passive analysis. The original design in Kuperberg et al. (2006)

was intended to evoke animacy violations by comparing sentences such as *For breakfast the eggs would eat…* with good sentences such as *For breakfast the boys would eat…* which resulted in a P600 to the animacy violation sentences. Because the objective of the study was to test for the effect of the animacy of the subject of the sentence, the materials were heterogeneous in terms of the transitivity of the verb and whether or not the sentences could be turned into plausible passives. In order to test whether particular factors within the materials modulated the P600, Kuperberg and colleagues divided the materials in two ways. Firstly, they divided the materials according to the transitivity of the verb, comparing sentences with preferentially or strictly transitive verbs (e.g., *order*) and sentences with preferentially or strictly intransitive verbs (e.g., *curtsey*). Both sets of materials showed a P600 effect, but the amplitude of the P600 to the intransitive verbs was higher than the amplitude of the P600 to the transitive verbs. In the second comparison, Kuperberg and colleagues divided the materials according to how plausible each sentence was when passivized, separating those items that were plausible in the passive form versus those that were either implausible or impossible in the passive form. For example, for the critical items *...the food would order...* and *...the trumpets would curtsey...*, they looked at the plausibility ratings of *...the food would be ordered...* and *...the trumpets would be curtseyed...*. Both plausible-in-passive sentences such as *...the food would order...* and impossible/implausible-in-passive sentences such as *...the trumpets would curtsey...* elicited a P600. The amplitude of the P600 to the implausible-in-passive sentences was higher than the amplitude of the passive sentences that were possible in the passive. In summary, a P600 was evoked even when the content words of the

sentence could not have suggested that a passive analysis was the most plausible analysis.

In the studies presented here (Chapters 2 & 3), the P600s in the attraction and no-attraction conditions were identical. A subset of electrodes from each of those studies is reproduced here (Figures 13 and 14). The fact that the two P600s in the Interference study (Chapter 3) were identical provides particularly compelling evidence that semantic attraction does not modulate the P600, because in the no-attraction condition an N400 immediately preceded the P600, and yet there was no difference in the amplitude of the P600s.

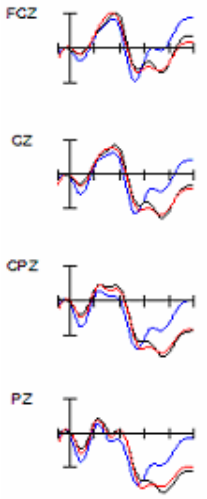

Figure 13. Grand average responses at the critical verb in the *fue* conditions in the Spanish ERP study (Chapter 2), showing the grammatical control (blue), the semantic-attraction (black) and the no-semantic-attraction (red) conditions

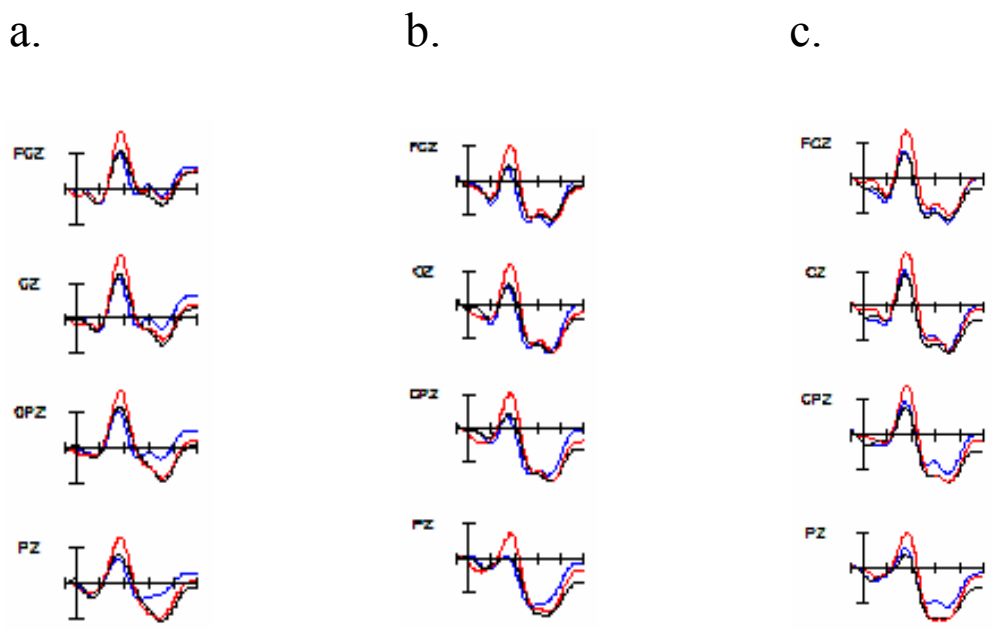

Figure 14. Grand-average responses at the critical verb in the nine conditions in the Interference ERP study (Chapter 3), showing grammatical control (blue), SA-head (black) and NA-head (red) conditions with (a) no-intervener, (b) SA-intervener, and (c) NA-intervener

In summary, looking across the set of studies that tested whether semantic attraction modulates the P600, Kim and Osterhout (2005) is the only study that did not show a P600 in the no-attraction condition. This difference may be due to unanticipated differences between the materials in the studies, despite the fact that a subset of the conditions in the two ERP experiments presented here were designed to be highly similar to the Kim and Osterhout materials. However, a careful look at the results from the Kim and Osterhout study suggests an alternative possibility. In that study, the no-attraction condition is more positive than the control condition starting around 600 ms, but this difference was not significant *(F*'s < 1, $p > 1$). It could be

that the apparent variability in the response to the no-attraction condition stems from general variability in ERP responses, unrelated to the intended manipulation. This possibility is explored in the next section.

4.3 Replication of Kim & Osterhout (2005, Expt 2)

The results of Kim & Osterhout (2005) stand out against the other studies because this was the only study in which the no-attraction condition did not elicit a P600. This is particularly striking because some of the conditions in each of the two ERP experiments presented here were designed to be highly similar to the materials in Kim & Osterhout's study. In the Spanish study (Chapter 2) the three *fue* conditions were designed to include the same manipulation of semantic attraction as in Kim and Osterhout. Furthermore, the format of the target sentences was highly similar to the format of the sentences in the Kim and Osterhout study. However there were certain differences among the materials that may have caused unintended differences. For example, unlike the Kim and Osterhout study, the nouns were less concrete in the Spanish study and the target sentences were preceded by a context sentence that included all of the nouns that began the three versions of the target sentence. Also, it is possible that *fue* sets up a stronger passive expectation than *was* does in English, therefore making it more likely for the processor to pursue a passive analysis independently of the semantic attraction (or lack thereof) between the noun and the verb. The three no-intervener conditions from the Interference study (Chapter 3) were even more closely matched to the Kim and Osterhout materials. A possible difference is that the items in the Interference study were more homogenous than the Kim &

Osterhout materials. For example, Kim & Osterhout used both *was* and *had been* as the pre-verbal auxiliaries, and the NPs had a high level of variability, whereas the Interference study used only *was* and all NPs followed the same format consisting of *The* + adjective + noun. In order to address the possibility that the materials were responsible for the variability in results, we attempted to replicate Kim & Osterhout's Experiment 2, using their materials. A sample set of materials is shown in Table X.

Table 18

Sample set of materials from the Replication ERP study

Condition	**Sample sentence**
Passive control	The hearty meal was devoured …
Semantic-attraction violation	The hearty meal was devouring …
No-semantic-attraction violation	The dusty tabletops were devouring …

The goal of the study was to find out whether a replication of Kim and Osterhout's study would confirm Kim and Osterhout's earlier result, or whether it would corroborate the alternative pattern of results found in our studies and others. If the results confirm Kim and Osterhout's results, the semantic-attraction should yield a P600 and the no-attraction condition should yield an N400 but no P600. If the results corroborate the pattern of results found in the studies presented here, the semantic-attraction condition should yield a P600 and the no-attraction condition should yield an N400 and a P600.

4.3.1 Experimental Materials and Methods

4.3.1.1 Participants

Twenty-one members of the University of Maryland community (7 female; mean age 21; range 18-28 years) participated in the ERP study. The participants were healthy, native speakers of English. All were strongly right-handed based on the Edinburgh Handedness Inventory (Oldfield, 1971) and had normal or corrected-to-normal vision. Participants gave informed consent and were paid $10/hour for their participation, which lasted between 1.5 and 2 hours, including set-up time.

4.3.1.2 Materials

The materials for this study consisted of sets of three sentences, illustrated in Table 18. There were three levels of the condition factor (passive control, semantic-attraction violation, and no-attraction violation). The materials were taken directly from Kim & Osterhout (2005) Experiment 2. The sentences all began with a subject NP, then either *was* or *had been*, and then a verb. The three versions of each item shared the same verb, and the subject NP was either a good theme for the verb (passive control and semantic-attraction violation) or a poor theme for the verb (no-attraction violation). The NPs varied in their internal structure, and included a variety of adjectives, numerals, possessives, definite and indefinite determiners, bare nouns and compound nouns. The verb appeared in either the passive form (control) or the progressive form (violation conditions). All subject NPs appeared in two item sets: once as the semantically-attractive NP and once as the non-attractive NP.

4.3.1.3 Design

96 sets of items for the target conditions were distributed across three presentation lists in a Latin Square Design such that each list contained 32 items per condition. 112 filler items were added to each list according to the numbers of different kinds of filler sentences in Kim and Osterhout (2005): 20 sentences containing a variety of semantic anomalies, 20 containing a variety of syntactic violations, and 72 acceptable sentences. The original paper did not provide further information about the fillers so a variety of different types of semantic anomalies and syntactic violations were used. The total number of sentences was 208, with a 1:1 ratio of acceptable to unacceptable sentences. The number of targets, fillers, and the general make-up of the fillers was the same as in Kim & Osterhout, although the filler sentences were different.

4.3.1.4 Procedure

Participants were comfortably seated in a dimly lit testing room about 100 cm in front of a computer monitor. Each sentence was preceded by a fixation cross. All items appeared in black font on a white screen. Participants pressed a button to initiate presentation of the trial. Sentences were presented one word at a time in 30 pt font. Each word appeared on the screen for 300 ms, followed by 200 ms of blank screen. The last word of each sentence was marked with a period, and 1000 ms later a question mark prompt appeared on the screen. Participants were instructed to read the sentences carefully without blinking and to indicate with a button press whether the sentence was an acceptable sentence of English. Feedback was provided for incorrect

responses. The experimental session was divided into 3 blocks lasting 15 minutes each, although participants could request additional breaks at their discretion.

4.3.1.5 EEG recording

EEG was recorded from 28 Ag/AgCl electrodes, mounted in an electrode cap (Electrocap International): midline: Fz, FCz, Cz, CPz, Pz, Oz; lateral: F3/4, F7/8, FC3/4, FT7/8, C3/4, T7/8, CP3/4, TP7/8, P4/5, P7/8, O1/2. Additional electrodes were placed on the left and right outer canthus, and above and below the left eye to monitor eye movements, and also on the right mastoid. Recordings were referenced to the left mastoid and re-referenced to the average of left and right mastoids. The EEG and EOG recordings were amplified by a SynAmpsTM Model 5083 EEG amplifier, and sampled at 1 kHz using an analog bandpass filter of 0.1-70 Hz. Impedances were kept below 5 kΩ.

4.3.1.6 EEG analysis

All comparisons were based upon single word epochs consisting of the 100 ms preceding and the 1000 ms following the start of the presentation of the critical words. Prior to any further analyses, epochs with ocular and other large artifacts were rejected based on visual screening. Epochs showing a divergence from 0 of more than 100μV were excluded automatically. In addition, epochs from trials in which the participant responded incorrectly were excluded. After all these exclusions, 81% of the trials were included in the final analysis.

The EEG waveforms from individual trials were normalized using a 100 ms prestimulus baseline. Averaged waveforms were filtered offline using a 10 Hz low-pass filter for presentation purposes, but all statistics are based on unfiltered data. The following latency intervals were chosen for analysis, based on the intervals used in the literature and on visual inspection: 300-500 ms (N400), 600-800 ms (P600). The 0-200 ms interval was also analyzed, in order to test for possible early differences.

For statistical analyses six regions of interest (ROIs) were used in the ANOVAs, consisting of groups of three electrodes at each ROI: left anterior (F3, FC3, C3), anterior midline (FZ, FCZ, CZ), right anterior (F4, FC4, C4), left posterior (CP3, P3, O1), posterior midline (CPZ, PZ, OZ), right posterior (CP4, P4, O2). These ROIs were organized into the two topographic factors *laterality* (left, midline, right), and *posteriority* (anterior, posterior).

ANOVAs were performed hierarchically with the within-subjects factor *condition* (*control, semantic-attraction, no-attraction*). All *p*-values reported below reflect the application of the Greenhouse-Geisser correction where appropriate, to control for violations of the sphericity assumption (Greenhouse & Geisser, 1959), together with the original degrees of freedom. Due to the large number of possible interactions in this design, we discuss only those interactions for which follow-up analyses yielded significant contrasts within the levels of the interacting factors.

4.3.2 Results

4.3.2.1 Accuracy

Overall accuracy on the behavioral acceptability judgment task for the three conditions was 95% (control: 96%, semantic-attraction: 94%, no-attraction: 95%).

4.3.2.2 ERP Results

The no-attraction condition elicited an N400 effect relative to the other two conditions, and both violation conditions elicited a P600 relative to the control condition, regardless of semantic attraction. The grand-averaged waveforms for these three conditions are shown in Figure 15.

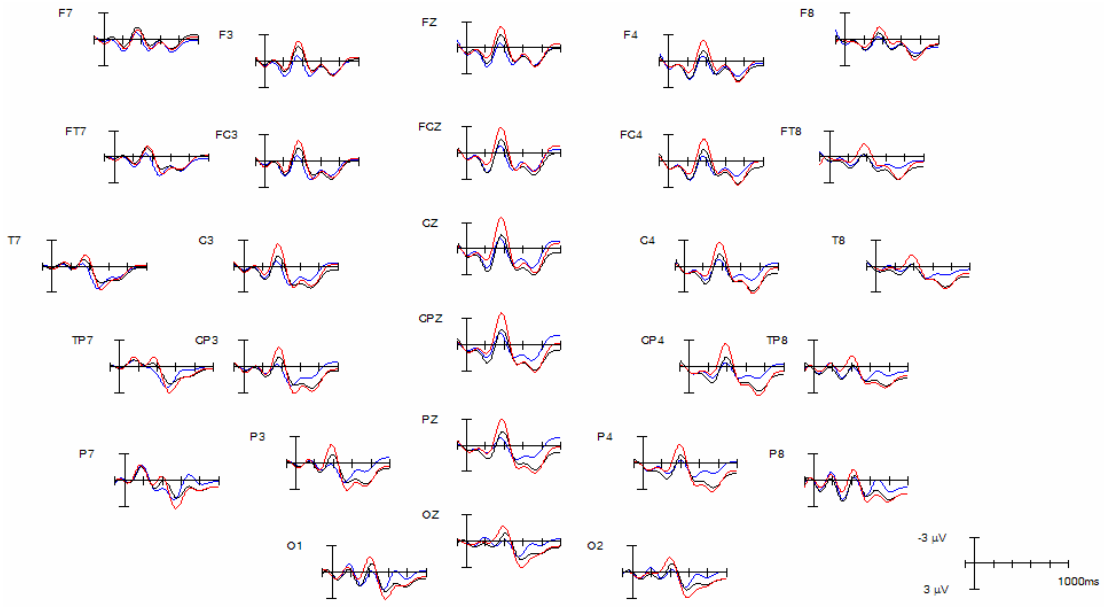

Figure 15. Grand average responses at the critical verb in the Replication ERP experiment, showing the grammatical control (blue), the semantic-attraction (black) and the no-attraction (red) conditions

In the ANOVAs comparing all three conditions (control, semantic-attraction, no-attraction), there were no differences in the early 0-200 ms interval. In the 300-500 ms interval, there was a main effect of condition ($F(2,40) = 5.75$, $p < .01$). To determine the source of this effect, planned pairwise comparisons were made between all possible pairs of conditions (Table 19). These confirm that the effect of condition arose solely because the no-attraction condition was more negative than the other two conditions, which did not differ from each other. The no-attraction condition was more negative than the control condition over the entire head, yielding a main effect of condition and significant effects in all ROIs. The no-attraction condition was also more negative than the semantic attraction condition, yielding a marginally significant main effect of condition. This difference was marginally significant in the midline and right anterior and left posterior regions, and did not reach significance in the left anterior and posterior regions.

In the 600-800 ms interval, there was an interaction between condition and posteriority ($F(2,40) = 4.97$, $p < .05$). The planned comparisons confirm that this arose because the semantic-attraction and no-attraction conditions were more positive than the control condition across the posterior regions, but did not differ from each other.

Table 19

ANOVA *F*-values for comparisons at the critical verb in the Replication ERP study

	0-200 ms	300-500 ms	600-800 ms
Control vs. Semantic-attraction			
cond (1,20)	-	-	-
cond × lat (2,40)	-	-	-
cond × post (1,20)	-	-	3.53†
cond × lat × post (2,40)	-	-	-
Effect of condition at individual ROIs:			
Anterior – left (1,20)	-	3.54†	-
Anterior – midline (1,20)	-	-	-
Anterior – right (1,20)	-	-	-
Posterior – left (1,20)	-	-	3.07†
Posterior – midline (1,20)	-	-	3.07†
Posterior – right (1,20)	-	-	4.70*
Control vs. No-attraction			
cond (1,20)	-	12.34**	3.31†
cond × lat (2,40)	-	-	2.82†
cond × post (1,20)	-	-	8.97**
cond × lat × post (2,40)	-	-	-
Effect of condition at individual ROIs:			
Anterior – left (1,20)	-	11.93**	-
Anterior – midline (1,20)	-	9.24**	-
Anterior – right (1,20)	-	6.23*	-
Posterior – left (1,20)	-	12.86**	8.71**
Posterior – midline (1,20)	-	10.57**	7.56*
Posterior – right (1,20)	-	7.90*	9.64**
Semantic-attraction vs. No-attraction			
cond (1,20)	-	3.47†	-
cond × lat (2,40)	-	-	-
cond × post (1,20)	-	-	-
cond × lat × post (2,40)	-	-	-
Effect of condition at individual ROIs:			
Anterior – left (1,20)	-	-	-
Anterior – midline (1,20)	-	3.35†	-
Anterior – right (1,20)	-	3.33†	-
Posterior – left (1,20)	-	-	-
Posterior – midline (1,20)	-	3.97†	-
Posterior – right (1,20)	-	3.67†	-

** = <0.01, * = <0.05, † = <0.1

4.3.3 Discussion

The aim of this study was to test whether the variation across studies in whether a P600 was elicited in the no-attraction condition is the result of differences among the materials of the different studies. Kim & Osterhout (2005) found that the no-attraction condition did not elicit a P600, but four other studies (Kuperberg et al., 2006; Kuperberg et al., 2007; Spanish Expt, Chapter 2; Interference Expt, Chapter 3) found that a P600 was elicited regardless of the presence of semantic attraction between the noun and the verb. In order to test whether this apparently inconsistent pattern of results was due to relatively minor changes in materials design, we attempted to replicate Kim & Osterhout's results using their original materials. If the pattern of results across the studies is due to changes in the materials, we should have found the same pattern as in the original Kim & Osterhout study, i.e., a P600 in the semantic attraction condition and an N400 (with no P600) in the no-attraction condition. On the other hand, if the lack of a P600 in the no-attraction condition of Kim & Osterhout's study was due to other factors, we should have found a P600 in both violation conditions, regardless of attraction, in addition to the N400 in the no-attraction condition.

Results show that the verbs in all violation conditions elicited a P600 relative to the grammatical control conditions, and that that there was no difference between the P600s elicited in semantic-attraction and no-attraction conditions. In addition, the no-attraction condition elicited a greater N400 relative to the other two conditions, which did not differ from each other in the 300-500 ms interval.

This pattern of results provides support for the view that the lack of a P600 to the no-attraction condition in Kim & Osterhout (2005) is an exception to the general pattern, and that a P600 is consistently elicited in this structural configuration in English, regardless of whether or not the subject noun is a good theme for the verb in addition to being a poor agent. Figure 16 illustrates this point visually: it shows grand average ERP waveforms at electrode CPZ from the three experiments presented here. In each case the black line shows a condition in which the noun is a good theme for the verb, the red line shows a condition in which the noun is a poor theme for the verb, and the blue line shows the grammatical control. Across all five comparisons, the P600 effect does not differ, even when an N400 effect causes the waveforms to diverge in an earlier interval.

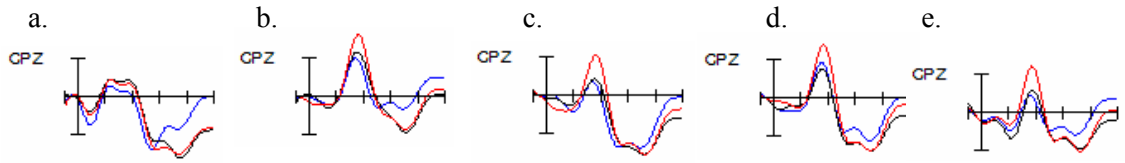

Figure 16. Grand-average waveforms at the critical verb in a. Spanish study (Chapter 2), b. Interference study (Chapter 3) – no intervener, c. Interference study – semantic-attraction intervener, d. Interference study – no-attraction intervener, e. Kim & Osterhout replication study (this chapter), showing the grammatical control (blue), semantic-attraction (black) and no-attraction (red) conditions

If the evidence for an independent semantic combinatorial stream came from selective sensitivity to noun-verb theme relations, then this set of findings directly

undermines that evidence. Several possible explanations can be given to account for the pattern of results. First, the P600 could have been elicited because the processor detected that the inanimate subject of the active sentence violates the verbs' selectional restrictions for an agentive subject. Second, the P600 could have arisen in all these conditions because the sentence-initial inanimate noun led the processor to expect a passive, and later structural information disconfirmed that analysis. Lastly, one could still propose an independent semantic composition system and argue that its effects are masked by P600s elicited by violations of agentivity or structural expectations, but there is no evidence in these studies that specifically favors that position.

4.4 Semantic attraction in Dutch

In the previous section I argued that the manipulation of semantic attraction does not modulate the P600 in the kinds of structures that have been tested in English and Spanish. In this section I review a series of Dutch studies that show a broad resemblance to the English studies, but that also have a number of differences. In Dutch SOV clauses it is possible to create sentences in which the most plausible subject and object are reversed, e.g., in the sentence *The fox that at the poachers hunted…* (Kolk et al., 2003; van Herten et al., 2005). This then creates sentences in which the subject is a plausible theme of the verb, as in the English studies just reviewed. But there is also a difference due to the presence of the second NP. The property manipulated in the Dutch studies is referred to as "reversibility", which, due

to the differences just described, is related to but not identical to the property "semantic attraction".

The first experiment in van Herten et al. (2006) compared sentences that were not plausible, but could either be rendered plausible by reversing the nouns ((26).b) or were not plausible even when the nouns were reversed ((27)b.). In the reversible example, (26)b., although the sentence contains an implausible proposition, that *ladders* climb *painters*, a plausible proposition can be formed by reversing the nouns, i.e., *painters* climb *ladders*. In contrast, the non-reversible example, (27)b., expresses an implausible proposition, *apples* climb *trees*, but reversing the nouns to form *trees* climb *apples* does not make a plausible proposition.

(26) a. De schilder die op de ladder *klom* viel plotseling. [Control]
the painter that on the ladder *climbed* fell suddenly.
'The painter that *climbed* the ladder fell suddenly.'

b. De ladder die op de shilder *klom* viel plotseling. [Reversible violation]
the ladder that on the painter *climbed* fell suddenly
'The ladder that *climbed* the painter fell suddenly.'

(27) a. De eekhoorn die in de boom *klom* er schattig uit. [Control]
the squirrel that in the tree *climbed* looked cute
'The squirrel that *climbed* in the tree looked cute.'

b. De appel die in de boom *klom* zag er sappig uit. [Non-reversible violation]

the apple that in the tree *climbed* looked juicy

'The apple that *climbed* the tree looked juicy.'

The verb in both the reversible violation condition and the non-reversible violation condition evoked a robust P600. There was also a small N400 at some right posterior sites in the non-reversible condition. These results suggest that reversibility does not play a role in modulating the P600 in Dutch. It could be that the relevant semantic manipulation that modulates the P600 is not semantic attraction/reversibility but rather semantic association. As van Herten and colleagues point out, their Experiment 1 did not control semantic association between the words – the non-reversible condition contained combinations of content words (e.g., *apple, tree, climb*) that are just as highly associated with one another as the content words in the reversible condition (*ladder, painter, climb*). Therefore, if, in contrast to the English results, the P600 is only elicited when the content words are semantically associated, this experiment should not show a difference between conditions. The second experiment in van Herten et al. (2006), which will be discussed in Section 3, addresses this issue.

Hoeks, Stowe and Doedens (2004) also contained a pair of conditions that differed in the thematic fit between the subject NP and the verb. Sentence (28)a. expresses a proposition that is impossible, but reversal of the arguments yields a highly plausible proposition. Sentence (28)b. also expresses an impossible proposition, but in contrast to (28)a., reversing the arguments does not yield a plausible proposition.

(28) a. De speer heeft de atleten geworpen. [Reversible violation]

the javelin has the athletes thrown

'The javelin has thrown the athletes.'

b. De speer heeft de atleten opgesomd. [Non-reversible violation]

the javelin has the athletes summarized

'The javelin has summarized the athletes.'

Both conditions elicited a P600, but the P600 effect was smaller in the non-reversible condition. The non-reversible condition also elicited a small N400, so it is possible that the reduced P600 in this condition was due to component overlap rather than to a difference in the processes that lead to the P600, although the results presented in Chapters 2 and 3 show that a difference in the N400 interval does not always lead to a difference in the P600 amplitude.

Like the English and Spanish studies that manipulated semantic attraction, the Dutch studies that explicitly manipulated reversibility did support the notion that a P600 is only elicited when a plausible semantic analysis of the sentence is not supported by the structural analysis of the sentence. The experimental results of van Herten et al. (2006, Expt 1) and Hoeks et al. (2004) can be explained as a response to a violation of the verb's agentivity requirements for its subject. In van Herten et al. (2006, Expt 1), the reversible condition contains *The ladder…climbed…* and the non-reversible condition contains *The apple…climbed…. Climbed* requires an agentive subject, so it is possible that the P600 arose in both conditions because the inanimate noun in subject position makes a poor agent. Likewise, in Hoeks et al. (2004), the reversible condition contained *The javelin…has thrown…* and the non-reversible

condition contains *The javelin has summarized*…. The P600 in both conditions may have been elicited because *javelin* makes a poor agent.

4.5 Summary of the effect of semantic attraction manipulations on the P600

In her review article, Kuperberg (2007) states that "semantic-thematic reparability *alone* could not explain the P600 effects evoked by these semantic-thematic violations" [my italics]. Based on an overview of the set of results from studies in English, Spanish and Dutch that manipulated semantic attraction and reversibility, I contend that a stronger statement is justified: there is no current evidence that the P600 is sensitive to the thematic fit between the noun(s) and the verb in the sentence, but is sensitive to the animacy of the nouns that fill its thematic roles. The evidence does not support the idea that the processor identifies plausible relations in ways that are not supported by the surface syntax. On the other hand, the evidence from the thematic P600 studies does support the idea that the processor identifies the suitability of the subject noun as an agent for the verb, a process which is entirely compatible with the surface syntax.

This generalization is incompatible with Kim and Osterhout's claim that the P600 reflects a standard syntactic violation, which results when an independent semantic stream proposes a passive interpretation based on semantic attraction, and the processor subsequently detects a syntactic "violation" relative to the output of the semantic stream. This interpretation of the P600 is only supported if the P600 is absent in circumstances where the putative semantic stream should not pursue a

passive interpretation. More generally, the results of the set of semantic attraction studies do not provide evidence for an independent semantic stream that tries to combine nouns and verbs in a way that is consistent with the selectional restrictions of the verb. We cannot exclude the possibility that such a stream might exist, but we do not find clear positive evidence for its existence.

All of the studies that specifically manipulated semantic attraction contained an inanimate noun in the subject position of an active sentence, which suggests that in these studies the P600 may index the violation of the verb's requirements that its subject be a good agent, and agents are normally animate. Agentivity can plausibly be considered a grammatical features, so the P600s in these studies may be viewed as a standard P600 to a syntactic violation. In Chapters 2 and 3 I argued that the P600s in the English and Spanish studies might also have been evoked because the processor expected a passive structure based on the inanimacy of the initial noun, and then had its expectation disconfirmed at the verb. This account works less well for the Dutch studies because by the time the processor reaches the verb, there is already sufficient information to clearly establish that the sentence does not have a passive structure. I return to differences in the processing constraints in English and Dutch in Section 7 of this chapter.

However, the results of the studies discussed so far are also compatible with the existence of a semantic processing stream that is not tied to calculating plausible thematic role assignments, but rather responds to more general associations between

the words, whether or not those associations can be implemented within the sentence. For example, in *the trumpets would curtsey*…, a semantic stream might detect that the words are highly associated, but be insensitive to the fact there is no plausible way to join the words in a structurally simple sentence. In the next section I discuss the evidence for a stream that is sensitive to manipulations of semantic associations between the content words.

4.6 Semantic association

Here I use the term "semantic association" to encompass measures such as explicit ratings of how associated two words are, as well as measures such as Latent Semantic Analysis (Landauer & Dumais, 1997; Landauer et al., 1998) that provide information about how often two words appear in the same context.

4.6.1 Dutch

A second experiment by van Herten and colleagues manipulated semantic association between open class words, and the results were taken as evidence that semantic association modulates the P600 (van Herten et al., 2006, Expt 2). They compared sentences in which the object and the verb of the embedded clause were either highly semantically associated ((29)b.), such as *prune the trees*, or not associated ((29)c.), such as *caress the trees*. Note that both conditions were designed to be anomalous overall because *elephants* do not *prune trees* and *elephants* do not *caress trees*.

(29) a. Jan zag dat de olifanten de bomen *omduwden*... [Control]

Jan saw that the elephant the trees *pushed-over*...

'John saw that the elephants *pushed-over* the trees…'

b. Jan zag dat de olifanten de bomen *snoeiden*... [High semantic association]

Jan saw that the elephant the trees *pruned*...

'John saw that the elephants *pruned* the trees…'

c. Jan zag dat de olifanten de bomen *verwenden*... [Low semantic association]

Jan saw that the elephant the trees *caressed*...

'John saw that the elephants *caressed* the trees…'

The condition containing the highly semantic associated object NPs ((29)b) elicited a robust P600, whereas the condition with the low association object NPs ((29)c.) showed a highly attenuated P600 that was small at left hemisphere electrodes and absent at right hemisphere sites.

It is not clear that the semantic association manipulation in these sentences is directly comparable to the manipulations of semantic attraction and reversibility in the studies discussed previously. For one thing, in (29)b. and (29)c. the subject of the verb satisfies agentivity requirements, and the object also satisfies the broad selectional restrictions of the verb. Secondly, these sentences do not involve a conflict between a semantic analysis of the sentence and the structural analysis of the sentence. These facts suggest the need for further discussion of the processes and

representations that result in a P600 in sentence (29)b. and an N400 in (29)c. Furthermore, other ERP studies have yielded a P600 even in conditions in which the noun(s) and the verb were not semantically associated (Friederici & Frisch, 2000; Geyer et al., 2006, Expt 2). These studies suggest that the role that semantic association plays in eliciting the P600 may not be straightforward. These studies will be discussed in detail in Section 7.

The important point for present purposes is that the results of the second experiment in van Herten et al. (2006) hint that semantic association plays a role in modulating the P600. If the relevant semantic manipulation is semantic association between open class words rather than semantic attraction, this might possibly explain why the manipulation of semantic attraction in previous studies did not modulate the P600. Although the properties of semantic association and attraction are often correlated, it is possible to find semantically associated words, such as *trumpets* and *curtsey*, which are not semantically attractive. It is possible that the no-attraction conditions in the studies discussed in Sections 1-4 contained a large proportion of noun-verb pairs that were semantically associated. This is unlikely to be true of the materials in Kim and Osterhout (2005) because the no-attraction sentences were formed by splicing together the NP from one item onto the verb and post-verbal material from another item. In contrast, in the materials of the experiments presented in Chapters 2 and 3, this is an actual possibility. In the Spanish ERP study (Chapter 2), the inanimate nouns that began the semantic attraction and no-attraction conditions were both mentioned in a context sentence that preceded the target

sentences. Because the nouns had to be mentioned in a sentence depicting a natural scene, they were often drawn from the same semantic field. Similarly, in the Interference ERP study (Chapter 3), the semantic attraction and no-attraction conditions had to be able to be felicitously joined by a preposition (e.g., *The rural house with the large lawn…*), they were also often drawn from the same semantic field. In the next section, I examine whether the P600 is sensitive to semantic association in the same structures in which we found no sensitivity to semantic attraction.

4.6.2 English

At first glance, the P600 in English does not appear to be sensitive to manipulations of semantic association. Packynski et al. (2006) found that sentences such as (30)a. elicited an N400, while the conditions with inanimate nouns in (30)b. elicited an N400 plus P600 combination.

(30) a. *...the man's pain was understood by the {hypochondriac/violinist}*

b. *...the man's pain was understood by the {medicine/pens}*

There was no effect of semantic association; within the conditions that elicited a P600, the response to the semantically associated word (e.g., pain-*medicine)* was the same as the response to the non-associated word (e.g., pain-*pens)*.

In order to confirm that semantic association does not modulate the P600 in English, in contrast to the Dutch results from van Herten et al. (2006, Expt 2), I used existing materials to test the effect of semantic association using the same measure of

semantic association used in that experiment. Van Herten et al. (2006) quantified the plausibility between the adjacent noun and verb using Latent Semantic Analysis (Landauer & Dumais, 1997; Landauer et al., 1998). LSA is a statistical technique that uses analyses of large corpora to produce a measure of the extent to which words or phrases occur in the same textual situations. LSA captures close associations between words (as might be found using a rating task) as well as more general association effects such as whether two words are likely to occur in the same environment or story. For current purposes, the main point is that two words that frequently co-occur but are not semantically attractive, such as *curtsey* and *trumpet*, could have the same LSA value as two words that co-occur frequently and are also semantically attractive, such as *food* and *order*.

The English and Spanish studies discussed in the previous section explicitly manipulated whether the subject noun was a good or a poor theme of the verb, and found that generally this did not modulate P600 amplitude. However, the results from van Herten et al. (2006, expt 2) suggest that perhaps this is not the relevant measure, and that it is the general degree of semantic association (quantified by the LSA values) between the noun and the verb that should be controlled. It is possible that the semantic-attraction and no-attraction conditions from those studies contained a mixture of high-LSA and low-LSA noun-verb combinations. In the English and Spanish studies, if both semantic-attraction and no-attraction conditions contained a high number of high-LSA combinations, despite the difference in semantic attraction, then we would indeed expect to find a P600 to both conditions if general association

(as measured by LSA) is as relevant in English and Spanish as it appears to be in Dutch.

In order to investigate whether association (as measured by LSA) modulates the P600 in English in a way that semantic attraction does not, I divided the items from the Kim & Osterhout replication study (Section 2, this chapter) according to the LSA value of relatedness between the NP and the verb. The parameters for the LSA analysis were chosen to be identical to those used in van Herten et al. (2006). Specifically, the topic space used to obtain the LSA ratings was "General Reading up to 1st Year College". Within each of the conditions (semantic-attraction and no-attraction), the relatedness between each NP and verb was calculated, and the items were divided into two groups using a median split. The entire NP was input rather than just the noun because most of the items contained modifying prepositional phrases or adjectives that may also have impacted the fit between the NP and the verb. Predictably, the LSA values for the items in the semantic-attraction condition were higher overall than those in the no-attraction condition. I chose to analyze the split within the conditions rather than put all violation conditions together, in order to preserve the attraction split and see any effect of association separately. If association, rather than attraction, is the relevant semantic factor, then we would expect that the items with higher LSA relatedness should be more likely to elicit a P600, whereas those with lower LSA relatedness values should be more likely to elicit an N400.

The results of this analysis can be seen in Figure 17. Note that the waveforms show greater variability than in the other experiments presented here because each grand average response to a violation includes at most 16 items per participant. The items from the semantic-attraction condition can be seen on the left: both the high-LSA items and the low-LSA items elicited a P600. In fact, in contrast to what might be expected according to van Herten et al. (2006, expt 2), the amplitude of the low-LSA items is even greater than for the high-LSA items. Likewise, for the items from the no-attraction condition, the high- and low-LSA items both elicited an N400 and a P600. Again, if anything, the low-LSA items elicited a larger-amplitude P600 than the high-LSA items.

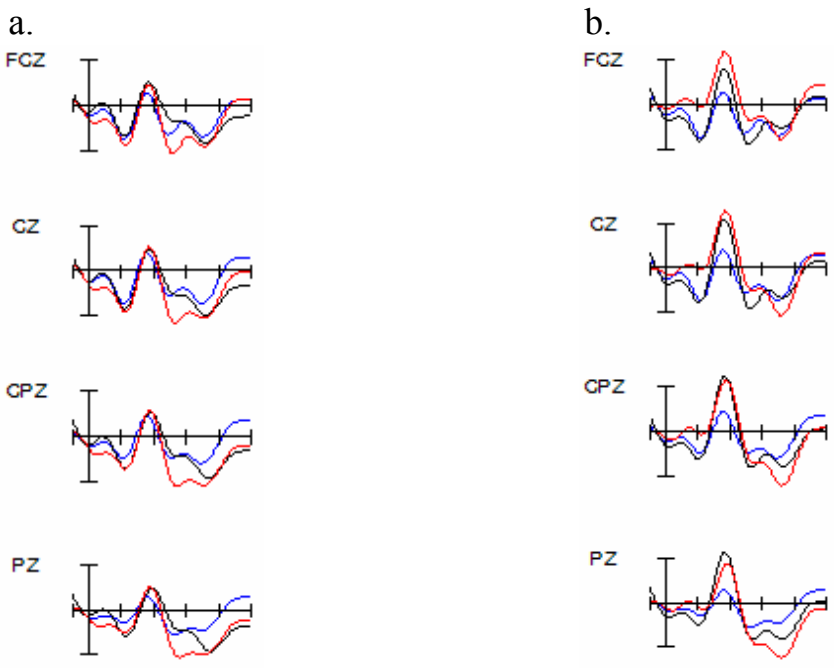

Figure 17. Grand average waveforms at the critical verb in the Replication study showing grammatical control (blue), high-LSA values (black) and low-LSA values (red) for a. semantic-attraction conditions, and b. no-attraction conditions

In summary, for this data set, low association (as measured by LSA) does not eliminate the P600. All of these violations, whether attractive or not, and whether highly associated or not, elicited a P600. This is in direct contrast to the Dutch results in van Herten et al (2006, expt 2). Because this contrast between the effect of semantic association in English and Dutch may be a crucial piece of data in the description of when, how and where semantic manipulations are relevant to the P600, and from there when semantic factors may be influential in determining the analyses that the processor pursues, it is important to consider in more detail whether the van Herten et al. (2006) manipulation of LSA values and the manipulation presented here are comparable.

In the van Herten et al. (2006, Expt 2) study, the high-LSA items all had LSA values greater than 0.25. Similarly, the high-LSA items from the semantic-attraction condition in this study all had LSA values greater than 0.27. Therefore, these two groups were comparable in terms of LSA values, and both sets of items elicited P600s. The low-LSA items in the van Herten et al. study had LSA values of less than 0.20. In the current study, 80% of the items from the no-attraction condition (both above and below the median split for LSA values) also had LSA values below 0.20. Of the items that had LSA values above 0.20, most were only slightly over that value, with 95% of all items falling below 0.25. In summary, the set of no-attraction items from the current study is largely comparable to the low-LSA items from the van Herten et al. study. Therefore, it remains unexpected that in the Dutch study the items in which the noun and verb were not semantically associated elicited an N400 but no

P600, whereas in the English study the items with a similar lack of association showed an N400 as well as a clear P600.

In summary, there is no evidence that semantic association between the open class words of a sentence is necessary for the elicitation of a P600 in the English studies under consideration here. In the next section, I move away from focusing on semantic attraction and association to look at all the studies in which an inanimate NP in subject position violates the verb's requirement that its subject be a good agent. I consider the results of studies in which this does not hold (e.g., van Herten et al., 2006, Expt 2; Friederici & Frisch, 2000; Geyer et al., 2006) in Section 7.

4.7 Violations of a verb's agentivity requirements for its subject

The majority of studies that have explicitly manipulated semantic attraction or association used sentences with inanimate nouns in the subject position of what turned out to be an active sentence. Because inanimate nouns are generally poor agents, the P600s in these studies may have resulted from a violation of the verb's requirement that its subject be a good agent. The top half of Table 20 shows that all of the studies that with an active structure and an inanimate noun in subject position elicited a P600 regardless of the semantic manipulation. This includes all the studies that have explicitly manipulated semantic attraction or reversibility in English, Spanish or Dutch, as well as the studies that have manipulated semantic association in English. The bottom half of Table 20 shows studies which do not involve a violation of the verb's agentivity requirement. These studies will be discussed in Section 7.

Table 20

Overview of thematic P600 studies according to whether they involve an agentivity violation

Intended manipulation	**Study**	**Sample sentences**	**P600 elicited independently of semantic manipulation?**
Studies with an inanimate noun in subject position of an active sentence			
Semantic attraction	Kuperberg et al. (2007)	*Every morning at breakfast the eggs would {eat/plant}*	Y
	Spanish Expt (Ch. 2)	*The {warning/apartment} fue declaring…*	Y
	Interference Expt (Ch. 3)	*The {large lawn/rural house}* {+/- intervener} *was mowing…*	Y
	Kim & Osterhout Replication (This Ch.)	*The {hearty meal/dusty tabletop} was devouring…*	Y
Transitivity/ Plausibility in passive	Kuperberg et al. (2006)	*…the trumpets would curtsey…*	Y
Semantic association	Packynski et al. (2006)	*…the man's pain was understood by the {medicine/pens}*	Y
	Kim & Osterhout Replication – divided by LSA value	*The {hearty meal/dusty tabletop} was devouring…* divided into high- and low-LSA values	Y
Reversibility	van Herten et al. (2006, Expt 1)	*The ladder that on the painter climbed.../ The apple that in the tree climbed...*	Y
	Hoeks et al. (2004)	*The javelin has the athletes {thrown/summarized}*	Y [P600 is smaller to *summarized*]
Studies in which there is no violation of the verb's agentivity requirements			**Result**
	Kolk et al. (2003); van Herten et al. (2005)	*The fox that at the poachers hunted…*	P600
Semantic association	van Herten et al. (2006, Expt 2)	*…the elephants the trees {pruned/caressed}*	P600 [*pruned*] N400 + tiny P600 [*caressed]*
	Friederici & Frisch (2000)	*Anna knows that the inspector (NOM) the banker (ACC) stained and left.*	P600
Level of implausibility	Geyer et al. (2006, Expt 2)	*Tyler cancelled the {birthday/tongue}…*	N400 [*birthday*] N400+P600 [*tongue*]
	van de Meerendonk et al. (2008)	*The eye consisting of among other things a pupil, iris and {an eyebrow/a sticker}…*	N400 [eyebrow] N400+P600 [sticker]

Because the studies from the top half of Table 20 can be explained by a standard syntactic violation, they do not provide good support for an independent semantic combinatorial stream. However, the other studies in Table 20 show that this cannot account for all the thematic P600 effects. For example, in *The fox that at the poachers hunted…* does not involve a violation of the verb's agentivity requirements, but a P600 was elicited at the verb (Kolk et al., 2003; van Herten et al., 2005). These studies provide the best opportunity for investigating whether there is strong evidence for an independent semantic composition mechanism.

4.8 Studies that do not involve an agentivity violation

In this section I discuss possible explanations for the results of studies that have elicited a P600 in the absence of an agentivity violation and whether these results can be taken as evidence for an independent semantic composition mechanism (Kolk et al., 2003; van Herten et al., 2005; van Herten et al., 2006; Friederici & Frisch, 2000; Geyer et al., 2006; van de Meerendonk et al., 2008). These studies are heterogeneous in terms of the structures, tasks and experimental manipulations Therefore, the available data is not sufficient to decide between different possible explanations, and indeed it is likely that the results do not reflect a single process or situation.

4.8.1 The role of task

Kuperberg's review article (2007) shows that the P600 is more likely to be elicited when participants perform an acceptability judgment task rather than another task such as answering comprehension questions. Geyer and colleagues explicitly manipulated the task across two experiments and yielded an N400 to sentences such as *Tyler cancelled the tongue…* with a comprehension task (Expt 1) and an N400 plus a P600 with an acceptability task (Expt 2). The judgment task may also have played a role in the elicitation of a P600 in Friederici and Frisch (2000). In that study, in which there was no semantic association between the nouns and there was no way to combine the open class words into a plausible interpretation, both an N400 and a P600 were elicited at the verb in this study, If the P600 in these studies is a result of performing a judgment task, they do not appear to provide good support for an independent semantic composition mechanism.

4.8.2 Van Herten, Chwilla & Kolk (2006), Experiment 2

Van Herten and colleagues manipulated the level of semantic association between the object NP and the verb in sentences such as (31). The sentences in which the object NP and verb were highly association ((31).b) elicited a P600, and the sentences in which the object NP and the verb were not association ((31).c) elicited an N400 and a very small positivity that was significant over some left posterior electrodes.

(31) a. Jan zag dat de olifanten de bomen *omduwden*... [Control]
Jan saw that the elephant the trees *pushed-over*...

'John saw that the elephants *pushed-over* the trees…'

b. Jan zag dat de olifanten de bomen *snoeiden*... [High association]

Jan saw that the elephant the trees *pruned*...

'John saw that the elephants *pruned* the trees…'

c. Jan zag dat de olifanten de bomen *verwenden*... [Low association]

Jan saw that the elephant the trees *caressed*...

'John saw that the elephants *caressed* the trees…'

Van Herten, Chwilla and Kolk give an account for these results that fits with their conflict monitoring hypothesis. They claim that the heuristics stream recognizes that sentences such as (30)b. contain a plausible subpart, and therefore consider that the analysis is partially successful. The algorithmic stream, however, fully processes the sentence and realizes that the sentences has an implausible interpretation, because *elephants* do not *prune trees*. The executive system detects a conflict between the two streams with regard to whether each stream considered the processing successful. This is a different kind of conflict than the conflict that is posited in sentences such as *The fox that at the poachers hunted…* (Kolk et al., 2003; van Herten et al., 2005). In those sentences, the conflict is between two competing analyses for the sentence: the interpretation proposed by the heuristics stream, and the interpretation according to the analysis of the algorithmic stream.

In *The fox that at the poachers hunted…* a P600 was elicited at the verb when there was a plausible interpretation that was not licensed by the structure. In contrast,

in *...the elephants the trees pruned...* the processor does not need to ignore the syntax in order to recognize that *the trees pruned* is a plausible subpart. Therefore, the results of this study are not relevant for the issue of whether there is an independent semantic composition system. The account given by the authors posits that the heuristic stream recognizes the plausible subpart, but it is equally possible that the processor recognized that the subpart was plausible by combining *trees* and *pruned* according to the relationship between them as dictated by the syntax.

Although this study is not relevant for the discussion about an independent semantic composition mechanism, it is still relevant for the discussion of what elicits a thematic P600. One difference between *...the elephants the trees pruned...*, which yielded a P600, and*...the elephants the trees caressed...*, which yielded an N400, may be the point at which the anomaly is detected. This discussion hinges on the order in which in which semantic composition occurs in verb-final clauses. If the processor combines the subject NP and the object NP first (*the elephants the trees...*), then the anomaly would be detected at the same point. In contrast, if the processor combines the VP first, then the anomaly would be detected at this point for *the trees caressed*, but not until the subsequent combination with the subject NP in the case of *...the elephants the trees pruned....* Looked at in this way, the results could possibly be explained using Kuperberg's (2007) notion that the P600 reflects "continued processing" that extends beyond the time interval associated with the N400, although it does not seem to be the result of conflicts between multiple streams.

4.8.3 Incremental semantic composition in head-final languages

The strongest result in favor of an independent semantic composition system appears to be the P600 in *The fox that the poachers hunted…* (Kolk et al., 2003; van Herten et al., 2005). We do not know whether a similar effect could be found in English, given that all the English studies involved an agentivity violation. However, it is also possible that particular features of processing in a verb-final clause allow for more influence of semantic information, relative to processing in a verb-medial clause.

In verb-medial languages such as English, there is extensive evidence that structure building is highly incremental and accurate (e.g., Stowe, 1986; Traxler & Pickering, 1996; Sturt, 2003; Kazanina et al. 2007). Although several recent studies have suggested that there may be some situations in which the processor is not fully faithful to the grammar (e.g., Nicol, Forster & Veres, 1997; Badecker & Straub, 2002; Drenhaus, Saddy, & Frisch, 2005; Gordon et al, 2006; Vasishth, Brüssow, Lewis, & Drenhaus, 2008), in sentences with relatively simple structures such as those that have been used in the thematic P600 studies it is relatively uncontroversial that structure building occurs incrementally and accurately (but cf. Ferreira et al., 2002; Ferreira 2003; Ferreira & Patson, 2007). Likewise, it is assumed that semantic composition is also highly incremental, although of course a central theme here is whether or not this is done in strict conjunction with the structural composition process. The crucial point for this section is that in English sentences such as {*The*

hearty meal/The dusty tabletop} was… is that all the words/phrases can be combined into a larger interpretation as soon as they are encountered.

In contrast, there continues to be debate about the extent to which incremental structure building and incremental semantic composition take place in head-final languages (for a review, see Aoshima et al., in press). It is possible that the extent to which the pre-verbal words/phrases are composed into a larger interpretation is the key difference between the Dutch and English studies, and the reason for why there may be more influence of semantic information during processing in the Dutch studies relative to the English studies. At the heart of the debate about incrementality in head-final languages is whether processing in strongly head-final languages such as Japanese and German is head-driven, in which constituents are not composed until the head is encountered (Pritchett, 1988, 1991, 1992; Mulders, 2002) or whether semantic composition occurs incrementally without waiting for the phrasal head. There is evidence that suggests that comprehenders do perform certain relatively sophisticated pre-verbal structural operations, for example, using case marking to determine clause boundaries (Miyamoto & Takahashi, 2002), using case marking to decide which clause a fronted phrase should be associated with (Kamide & Mitchell, 1999; Aoshima et al., 2004), and assigning case to a case-ambiguous pronoun (Bader & Lasser, 1994). For a detailed review of these studies, see Aoshima et al. (in press). There is also a large body of evidence that shos that comprehenders use a variety of information sources such as morphological case marking and animacy to assign the

pre-verbal nouns into a "prominence" hierarchy that can be used to assign thematic roles (for a review of these studies, see Bornkessel and Schlesewsky, 2006).

On the other hand, the evidence for pre-head compositional interpretation in head-final languages is less strong. Kamide, Altmann & Haywood (2003) showed that Japanese speakers can use case-marking on two sentence-initial nouns to anticipate a third noun, even before the head (i.e., the verb) appears. In an example trial from that study, comprehenders looked at a scene with a waitress, a customer and a hamburger and heard either *weitoresu-ga kyaku-ni…* 'waitress-nom customer-dat' or *weitoresu-ga kyaku-o…* 'waitress-nom customer-acc'. There were more looks to the hamburger after the nom-dat sequence than after the nom-acc sequence. The majority of Japanese sentences beginning with a nominative and a dative NP are 3-NP constructions in which an accusative NP follows the dative NP. The fact that there were more looks to the hamburger following the nom-dat sequence suggests that comprehenders are able to use the case markings to anticipate a third NP. This can be used to predict a ditransitive verb, which in turn is likely to describe some kind of transference of something (acc) from someone (nom) to someone else (dat). Kamide et al. argue that comprehenders take the analysis a step further and assign the agent role to the and the theme role to the customer, compose them, and conclude that the most likely thing to be transferred from the waitress to the customer is the hamburger, and therefore look to the hamburger. While it is clear that comprehenders do use case sequences to anticipate the existence of an upcoming NP, it is less clear that this study shows evidence of incremental semantic composition. Looks to the distractor item (a

dustbin) were not reported, so it is possible that looks to both inanimate objects were increased when a third NP was anticipated – this would provide evidence for prediction of an NP based on case sequences but would suggest that more complex semantic composition had not occurred. Additionally, it is possible that there were more looks to the hamburger simply because it is more closely associated with the sentence-initial nouns, but this would not be evidence that the sentence initial nouns had been semantically composed with each other and with the anticipated meaning of the verb. As the authors themselves note, the study does not clarify the precision of the pre-verbal representations and whether semantic composition took place between the two sentence-initial nouns prior to the third noun and the verb.

This is relevant to the Dutch studies of sentences such as *The fox that at the poachers hunted…* because we do not know whether the two NPs are semantically composed with each other prior to the presentation of the verb. That is not to say that no processing is done on the nouns before the verb is encountered, just that they may not be composed with each other. Although it is unclear why this would be the case, it is possible that semantic association and heuristics in general have more room to influence processing in a situation in which multiple phrases (subject NP, object NP, verb) must be composed, when compared to a situation in which the composition only involves two phrases (subject NP and verb). In the next section, I discuss the extended Argument Dependency Model (eADM, Bornkessel & Schlesewsky, 2006) which was largely designed to account for ERP results in head-final languages

(particularly German), and consider whether it provides a more detailed understanding of the kind of processing that occurs pre-verbally in the Dutch studies.

4.8.4 Incremental semantic composition in the extended Argument Dependency Model

The extended Argument Dependency Model (eADM, Bornkessel & Schlesewsky, 2006) is a model of the processing of 'core' relations in simple sentences (i.e., verb-argument and inter-argument relations in single clauses) that attempts to account for processing both in head-final languages with relatively free word order such as German and in fixed-order head-initial languages such as English. A recent review article (Borkessel-Schlesewsky & Schlesewsky, 2008) extends the eADM to attempt to account for all the thematic P600 results. In this section I discuss what the eADM, and the ERP studies that the eADM is designed to account for, might tell us about processing in verb-final clauses, and whether it sheds light on the amount and nature of the processing that might have occurred prior to the verb in the Dutch studies.

According to the eADM, for each incoming noun, the processor computes its position in a "prominence hierarchy" that orders the NPs hierarchically. The prominence hierarchy is then used to assign "agent" to the highest noun in the hierarchy and "theme" to the next noun. In fixed-word order languages such as English and Dutch, nouns are entered into the prominence hierarchy strictly based on linear order. In flexible-word order languages such as German, the hierarchy is based

on case marking on the nouns, but if the case marking is ambiguous, other information sources such as animacy and definiteness also play a role in determining the prominence hierarchy.

The claim that incoming nouns are entered into a prominence hierarchy based on case marking, animacy and definiteness is based on evidence from a large number of German ERP studies that show an electrophysiological error response (often an N400 at the noun) when the incoming nouns diverge from the optimal prominence hierarchy – e.g., a sentence in which a noun with nominative case marking is inanimate and a noun with accusative case marking is animate, when ideally the animate noun should bear nominative case and the inanimate noun would have accusative case (Frisch & Schlesewsky, 2001; Roehm et al., 2004).

There is good evidence that comprehenders are sensitive to the combinations of initial NPs, at least as far as case marking and animacy combinations. For example, when two initial nouns are marked with nominative case, an N400 followed by a late positivity is elicited, whereas separately it would be acceptable for either the first noun or the second noun to bear nominative case. This indicates that the processor performs some kind of combined analysis of the two nouns. However, there is no current evidence from this line of German ERP studies that suggests that the two initial nouns are semantically composed together prior to the processing of the verb, nor does the model have a mechanism for doing so. In summary, according to the eADM, in simple German and Dutch sentences, at the point just prior to the verb, the

two nouns have been assigned tentative thematic roles (based on case marking and animacy in German, and based on linear order in Dutch), but there is no evidence that they have been composed together. This is consistent with the findings from the Japanese study discussed above (Kamide et al., 2003).

In the eADM, all of the compositional work happens at the verb. In the version of the eADM that has been modified to incorporate the thematic P600 results (Bornkessel-Schlesewsky & Schlesewsky, 2008) two compositional processes occur at the verb. In the syntactic stream, the verb is linked to the nouns according to the roles they received through their place in the prominence hierarchy. For Dutch, the authors note that the thematic role assignment is based solely on linear order. Therefore, in Dutch the outcome of this "linking" analysis does not substantially differ from the outcome of a standard parser. In the plausibility stream, once the verb is encountered it is combined with the pre-verbal nouns according to the most plausible relations between them. This model does not incorporate semantic composition between the nouns prior to the verb, and therefore in this model there may be more room for the influence of semantic attraction in a case where all three open class words are being considered simultaneously by the plausibility stream, relative to the English cases which only involve one pre-verbal noun.

4.9 Directions for further experimental work

In the previous section, I argued that the studies that provide the clearest potential evidence for independent semantic composition are the studies that elicited a

P600 in sentences such as *The fox that at the poachers hunted…* (Kolk et al., 2003; van Herten et al., 2005). In these sentences, the most plausible relations between the open class words are inconsistent with the relations between the words according to the unambiguous, grammatical structure of the sentence. Furthermore, there is no violation of the verb's agentivity requirement for its subject, so unlike many of the other studies, the P600 cannot be attributed to a violation of that requirement. These results clearly show that the P600 does not always involve a straightforward syntactic violation. However, further experimental work is needed in order to determine whether these results definitively support the existence of an independent semantic composition mechanism. Alternatively, the results could indicate the need to refine our understanding of the processes that elicit the P600. For example, the P600 might be elicited whenever there is a problem with the assignment of thematic roles (even in cases in which the attempted assignment occurs in a manner consistent with the sentence structure).

Two further pieces of data are needed in order to determine whether the P600 in *The fox that at the poachers hunted…* should be taken as evidence for an independent semantic composition mechanism. Firstly, we would need to know whether the P600 only occurs when there is a plausible semantic analysis for the sentence that conflicts with the structure. This could be tested using Dutch versions of sentences such as, *The cat that at the poachers hunted….* The theory of independent semantic composition would not predict a P600 here, because it is not plausible to shoot cats, and therefore there is no plausible semantic analysis to compete with the

structural analysis. Secondly, we would need to know that the P600 did not simply occur because it is more frequent for *poachers* to do things to *foxes*, and not because the processor has computed the plausible relations between the nouns and the verb. This could be tested using Dutch versions of sentences such as *The fox that at the poachers saw*…. The theory of independent semantic composition would not predict a P600 here. If neither of these extension studies elicited a P600, there would be strong evidence for independent semantic composition in Dutch. Otherwise, the results would indicate a need to alter the definition of the processes that elicit a P600, but would not support an independent semantic composition mechanism.

If the Dutch studies showed definitive evidence for independent semantic composition, the next question would be whether this is specific to the Dutch sentences involving two pre-verbal nouns, or whether there is also evidence for an independent semantic composition mechanism in the kinds of sentences that have been tested English, once the agentivity violations are removed. This could be tested in sentences such as *The patient was capturing…* or *The defendant was examining*…. These sentences do not involve an agentivity violation, but the initial NPs make better themes than agents for the verbs. The theory of independent semantic composition would predict a semantic attraction effect, in which a P600 was only elicited when the NP was a good theme for the verb. Only after exploring all of these possibilities could we be sure that the results of the sentences such as *The fox that at the poachers hunted…* are evidence for widespread independent semantic composition.

Summary and overall conclusions

Three ERP studies showed that the P600 is not modulated by semantic attraction. A review of the literature revealed that many of the studies that appear to show a thematic P600 involve structures in which an inanimate noun sits in the subject position of an active sentence. In all of the studies that share this feature, the P600 does not appear to be modulated by semantic attraction, reversibility, or semantic association. Because inanimate nouns are not normally agents, the P600s in these studies may result from the syntactic violation of the verb's agentivity requirements for its subject. Therefore, these studies do not provide evidence for an independent semantic composition mechanism.

A number of studies involving a number of different manipulations in sentences with a variety of different structural properties have shown a P600 in the absence of an agentivity violation. Some of these studies do not bear on the question of whether there is an independent semantic composition system because they appear to be dependent on the task or because the analysis proposed by an independent semantic stream would not contradict the analysis proposed by the structural processor. Some Dutch studies (Kolk et al., 2003; van Herten et al., 2005) elicited a P600 in the absence of an agentivity violation in sentences in which a semantic processing stream would clearly propose a contradictory analysis to the output of the

structural stream. These studies represent the best possible support for an independent semantic composition mechanism, and clearly indicate the need to review the processes thought to underlie the P600. Nevertheless, further experimental work in Dutch is needed in order to ascertain whether these studies provide evidence to support an independent semantic composition mechanism. In addition, more tightly matched comparisons in English and Dutch are needed in order to determine whether particular features involved in processing verb-final clauses allow for more influence of semantic information, or whether it is coincidental that the potential evidence for independent semantic composition has been attested in Dutch but not in English.

Overall, the evidence for the existence of an independent semantic composition mechanism is much less strong or widespread than has previously been argued.

Appendix A: Experimental stimuli for the Spanish ERP study (Chapter 2)

The table below shows the entire set of NP + verb combinations used in this study. Due to space considerations, the full items have not been displayed but are available upon request. Each entry shows a sample version of the item. The first sentence in italics is the context sentence, and is identical for all versions of an item. The second sentence in italics is a sample version of the item showing the grammatical control condition with *fue*. The three possible NPs are shown below. In the left-hand column is the NP used in the grammatical control condition with *fue* and with the semantically-attractive NP used with both *fue* and *estaba*. In the center column is the non-attractive NP used with both *fue* and *estaba*. In the right-hand column is the animate NP used in the grammatical control condition with *estaba*.

Context sentence
Sample target sentence showing the Grammatical Control with fue condition

	Grammatical Control (*fue*) & Semantically-Attractive Violation (*fue* and *estaba*)	**Non-Attractive Violation (*fue* and *estaba*)**	**Grammatical Control (*estaba*)**
1	*Después de preparar unos pasteles y meterlos al horno, el repostero quiso preparar un bizcocho.* *El bizcocho fue endulzado por el repostero descuidadamente.*		
	El bizcocho	El horno	El repostero
2	*El año pasado, la secretaria de una empresa tuvo que preparar una carta solicitando permiso para construir encima de una iglesia histórica.* *La carta fue enviada por la secretaria a la asociación de preservación histórica, para pedirles permiso para construir.*		
	La carta	La iglesia	La secretaria

3	*Cuando el décimo cadáver tardó dos días en llegar al mortuario, el funcionario creó un programa para agilizar el proceso de transporte.* *El programa fue desarrollado por el funcionario, porque sus empleados no podían cumplir con todo el trabajo.*		
	El programa	El cadaver	El funcionario
4	*La semana pasada, Rosa habló con la banquera acerca de una transacción que tenía que hacer para poder renovar su casa.* *La transacción fue realizada por la banquera, aunque a ésta le quedaban dudas sobre su conveniencia.*		
	La transacción	La casa	La banquera
5	*El científico comenzó a indagar sobre el fenómeno de la mutación, después de observar un perro con una malformación.* *El fenómeno fue estudiado por el científico, mediante un experimento sobre moscas.*		
	El fenómeno	El perro	El científico
6	*Cuando el descubridor del gen decidió donar su archivo de resultados científicos, el bibliotecario empezó a hacer planes para adquirirlo inmediatamente.* *El archivo fue trasladado por el bibliotecario a su almacén.*		
	El archive	El gen	El bibliotecario
7	*Cuando se descubrió una estrella nueva en la galaxia, la editorial decidió producir una edición actualizada de su libro de astronomía.* *La edición fue publicada por la editorial dos meses después del descubrimento.*		
	La edición	La estrella	La editorial
8	*Antes de enviar la invitación a los jefes de estado, el presidente consultó con la policía sobre la operación de seguridad que tenía que llevarse a cabo.* *La operación fue dirigida por la policía con la ayuda de la guardia nacional.*		
	La operación	La invitación	La policía
9	*Al final de las negociaciones, los diplomáticos llamaron al presidente para decirle que habían convenido un tratado sobre el territorio disputado.* *El tratado fue ratificado por el presidente al día siguiente, en una ceremonia ilustre.*		
	El tratado	El territorio	El presidente
10	*El estudiante de física estaba preparando un experimento sobre el material del nuevo satélite.* *El experimento fue realizado por el estudiante sin éxito.*		
	El experimento	El material	El estudiante
11	*Para evitar problemas, los habitantes del barrio pactaron un acuerdo con el guerrillero.* *El barrio fue atacado por el guerrillero, a pesar del acuerdo.*		
	El barrio	El acuerdo	El guerillero
12	*Antes de empezar su demolición, la constructora preparó una lista de las ruinas de la iglesia, para poder exhibir una descripción de ésta en el museo local.* *La iglesia fue demolida por la constructora al día siguiente.*		
	La iglesia	La lista	La constructora
13	*Después de preparar la declaración de ingresos, el contador preparó un documento sobre el negocio de su cliente.* *El documento fue aprobado por el cliente, después de verificar todos los números.*		
	El documento	El negocio	El cliente

14	*La guía turística tenía una película sobre la gran tormenta de 1966 para usar en sus excursiones.* *La película fue exihibida por la guía, para enseñar a los turistas algo de la historia de la cuidad.*		
	La película	La tormenta	La guía
15	*La fábrica contrató a un químico para investigar un virus que contaminó las existencias de pollo. El virus fue detectado por el químico, después de cinco años de investigación.*		
	El virus	El pollo	El químico
16	*El joven empresario tuvo mucho éxito en su trabajo y acabó con un gran capital.* *El capital fue invertido por el empresario sin cuidado y acabó perdiéndolo todo.*		
	El capital	El trabajo	El empresario
17	*Cuando el misionero entregó un suero curativo al hombre rico, tomó la oportunidad de sugerirle un donativo.* *El donativo fue destinado por el misionero para construir una escuela nueva en el pueblo.*		
	El donativo	El suero	El misionero
18	*El jefe de estado quería reunir más capital y no le gustaba el provecho que sacaba el dueño del sistema de ferrocarril.* *El sistema fue nacionalizado por el jefe de estado contra la voluntad de su dueño.*		
	El sistema	El capital	El jefe
19	*El piso de la planta más alta parecía el lugar perfecto para implementar el nuevo proyecto del congreso.* *El piso fue expropiado por el congreso, a pesar de las quejas de la familia que vivía allí.*		
	El piso	El proyecto	El congreso
20	*Cuando el hombre rico compró un valle entero, llamó a su contratista preferido para que le hiciera el trabajo necesario para urbanizar la zona.* *El trabajo fue garantizado por el contratista, pero éste recibió el dinero y huyó del país.*		
	El trabajo	El valle	El contratista
21	*La secretaria del estado preparó una declaración para celebrar la recuperación de la famosa pintura que había sido robada.* *La declaración fue emitida por la secretaria del estado en una conferencia de prensa al día siguiente.*		
	La declaración	La pintura	La secretaria
22	*Después del fuego, el bombero formuló un aviso para prohibir la entrada al piso quemado.* *El aviso fue anunciado por el bombero ante todos los vecinos.*		
	El aviso	El piso	El bombero
23	*El comerciante contrató a un compañero más jóven para buscar un cuadro precioso del país vecino, y pagar el impuesto al salir de ese país.* *El impuesto fue reembolsado por el comerciante, cuando el compañero volvió con el cuadro.*		
	El impuesto	El cuadro	El comerciante
24	*Después de un mes de entrenamiento, la almirante preparó su flota para navegar hasta una tierra enemiga.* *La flota fue enviada por la almirante para reclamar esa tierra.*		
	La flota	La tierra	La almirante

25	*Al principio de su turno, la repartidora tuvo que llevar una carga muy pesada a la residencia del embajador.* *La carga fue entregada por la repartidora de mala gana, porque le dolía mucho la espalda.*		
	La carga	La residencia	La repartidora
26	*El año pasado, en el bar preferido de un detective famoso, tuvo lugar un homicidio horrible.* *El homicidio fue investigado por el detective Hernández.*		
	El homicidio	El bar	El detective
27	*En la reunión de la semana pasada, un ejecutivo discutía un contrato importante, mientras servía café a los demás.* *El contrato fue firmado por el presidente al final de la reunión.*		
	El contrato	El café	El ejecutivo
28	*El pintor marcó con un lápiz los detalles finales en su cuadro, para que su ayudante lo pudiera preparar para la subasta.* *El cuadro fue barnizado por el ayudante, mientras el pintor reposaba.*		
	El cuadro	El lápiz	El pintor
29	*El verano pasado, un escorpión picó a Carmen e inmediatemente ella se fue al médico para buscar un suero antivenenoso.* *El suero fue administrado por el médico, para evitar efectos dañinos.*		
	El suero	El escorpión	El medico
30	*Cuando Eddie fue a la casa de su tía, ella le dio una bandeja y le pidió que preparara una ensalada.* *La ensalada fue preparada por la tía, porque a Eddie se le olvidó hacerla.*		
	La ensalada	La bandeja	La tía
31	*La emperatriz de un país lejano se enfadó con el emperador y decidió declarar su independencia y establecer una ciudad nueva.* *La ciudad fue fundada por la emperatriz en una tierra lejos del imperio del emperador.*		
	La cuidad	La independencia	La emperatriz
32	*Mario tuvo que consultar con el cirujano del hospital antes de la operación para reemplazar su corazón.* *El corazón fue transplantado por el cirujano con éxito al día siguiente.*		
	El corazón	El hospital	El cirujano
33	*Cuando su hijo despertó a medianoche porque le dolía tanto el diente, el dentista decidió operarle en la casa para ahorrar tiempo.* *El diente fue arrancado por el dentista porque tenía caries.*		
	El diente	El tiempo	El dentista
34	*El nuevo alcalde decidió patrocinar la construcción de un teatro en un barrio pobre para fomentar la renovación urbana.* *El teatro fue inaugurado por el alcalde con una ceremonia ilustre.*		
	El teatro	El barrio	El alcalde
35	*Rafael presentó su nuevo proyecto a su jefe mientras tomaban vino en un bar.* *El proyecto fue analizado por el jefe con mucho detalle.*		
	El proyecto	El vino	El jefe

36	*Cuando intentó describir la ley fiscal en un discurso, el político decidió usar un término poco conocido para explicarlo bien.* *El término fue definido por el político en su discurso.*		
	El término	El discurso	El politico
37	*Cuando quería publicar un folleto sobre su vida y su plan innovador, el político tuvo que eligir entre encargar su retrato a un artista o a un fotógrafo.* *El retrato fue pintado por el artista, para que pareciera más importante.*		
	El retrato	El plan	El artista
38	*Cuando el aparato nuclear apareció por primera vez, el ministro de ciencias decidió formar un consejo para estudiarlo.* *El consejo fue convocado por el ministro en enero del año siguiente.*		
	El consejo	El aparato	El ministro
39	*El primer día del mes, el pescador sacó su barco a primera hora y se fue en busca de salmón.* *El salmón fue ahumado por su mujer esa misma noche.*		
	El salmón	El barco	El pescador
40	*Cuando tuvieron que entrar en un territorio enemigo, el general del ejército decidió probar un nuevo método de ataque.* *El territorio fue ocupado por el ejército rápidamente y se decidió que el método funcionaba bien.*		
	El territorio	El método	El ejército
41	*El año pasado el payaso inventó un juego para el teatro en el que trabajaba.* *El juego fue presentado por el payaso al principio de su espectáculo.*		
	El juego	El teatro	El payaso
42	*La novelista iba a una plaza histórica todos los días a observar a la gente y obtener ideas para su obra.* *La obra fue escrita por la novelista desde un café en la misma plaza.*		
	La obra	La plaza	La novelista
43	*Antes de preparar el anuncio que su jefe le encargó, el secretario consultó el calendario para elegir la fecha más oportuna.* *El anuncio fue formulado por el secretario con mucha prisa, antes del regreso del jefe.*		
	El anuncio	El calendario	El secretario
44	*Al sabio le encantaba un texto griego que describía un trono antiguo e importante.* *El texto fue traducido por el sabio en su tiempo libre, para que más personas lo pudieran leer.*		
	El texto	El trono	El sabio
45	*Para enfrentarse al récord mundial, el atleta famoso se matriculó en un programa riguroso de ejercicio.* *El récord fue superado por el atleta, después de dos años de entrenamiento.*		
	El récord	El programa	El atleta
46	*Cuando el dictador asumió el poder político en el país, decretó que todo edificio público debía exhibir un retrato suyo.* *El poder fue ejercido por el dictador con tanta crueldad que el pueblo preparó una rebelión.*		
	El poder	El retrato	El dictador

47	*Los ciudadanos eligieron como presidente al candidato que prometió construir un muro alrededor del país.* *El país fue gobernado por el presidente sin problemas, a pesar de su ridícula promesa.*		
	El país	El muro	El presidente
48	*La idea de hacer una película sobre la historia de la leche se le occurrió a la guionista un día cuando tomaba el desayuno.* *La idea fue abandonada por la guionista, después de ver otra película sobre el mismo tema.*		
	La idea	La leche	La guionista
49	*Cuando la embajadora decidió renovar la residencia oficial, planeó una reunión con una decoradora de interiores famosa.* *La residencia fue ampliada por la embajadora según el consejo de la decoradora de interiores.*		
	La residencia	La reunión	La embajadora
50	*Cuando el barón amenazó al pueblo vecino con expulsar a sus habitantes, los ancianos del pueblo le propusieron un tratado.* *El pueblo fue conquistado por el barón, sin hacer caso al tratado.*		
	El pueblo	El tratado	El baron
51	*El presidente declaró que intentaba formar un tribunal con un juez importante a la cabeza, para examinar el pacto internacional.* *El tribunal fue instaurado por el presidente a las dos semanas de su declaración.*		
	El tribunal	El pacto	El juez
52	*Al príncipe le gustaba mucho el poder e inventó un complot para arrebatar el trono de su padre.* *El trono fue usurpado por el príncipe en un golpe de estado.*		
	El trono	El complot	El príncipe
53	*El dueño del restaurante hizo un acuerdo con un vendedor local para recibir un cajón de helado cada mes.* *El acuerdo fue cumplido por el vendedor, cuando envió el último paquete de mercancías.*		
	El acuerdo	El helado	El vendedor
54	*Cuando el soldado entró al pueblo, declaró que todos los habitantes tenían que pagar un impuesto por cada muro que tenían.* *El muro fue arrasado por el soldado como castigo, porque el campesino no había pagado el impuesto.*		
	El muro	El impuesto	El soldado
55	*En su nuevo espectáculo, el cómico famoso describía un viaje ficticio a un planeta lejano.* *El viaje fue narrado por el cómico con tanta gracia que la audiencia no dejaba de reír.*		
	El viaje	El planeta	El cómico
56	*La estudiante escribió su tesis final sobre la choza peruviana.* *La tesis fue revisada por la estudiante antes de entregarla al profesor.*		
	La tesis	La choza	La estudiante
57	*La periodista famosa publicó una cita que decía que la ensalada no tenía valor nutritivo.* *La cita fue atribuida por la periodista a una dietista famosa, aunque ésta lo negaba.*		
	La cita	La ensalada	La periodista
58	*En aquella mañana desafortunada, el firmamento tenía el color gris y un policía impedía el*		

	aceso a una fábrica, porque alguien la había robado. El acceso fue bloqueado por el policía porque alguien había acusado a los empleados de haber robado la empresa.		
	El acceso	El firmamento	El policía
59	*La alcadesa quería reducir la tasa de actividad criminal en la plaza y decidió que el problema se debía a la falta de luz.* *La plaza fue iluminada por la alcadesa al año siguiente, pero la tasa criminal no bajó.*		
	La plaza	La idea	La alcaldesa
60	*La viceministro debía su fama a su papel en la movilización de 1968, así que éste llenaba un capítulo entero de su biografía.* *La movilización fue apoyada por la viceministro, en contra de los deseos del ministro.*		
	La movilización	La biografía	La viceministro
61	*Después de mucho debate sobre la identidad del cadáver, llamaron al primo del alcalde que conocía a todo el mundo en el pueblo.* *El cadáver fue identificado por el primo como un amigo suyo del pueblo vecino.*		
	El cadáver	El debate	El primo
62	*La asamblea general del pueblo planeó la transformación del centro siguiendo una teoría para bajar la tasa de crímenes.* *La transformación fue postergada por la asamblea, cuando se enteraron de que la teoría era errónea.*		
	La transformación	La teoría	La asamblea
63	*Los dos hombres cometieron un delito e intentaron ofrecer un bizcocho al aduanero para que éste no sospechara nada.* *El delito fue indagado por el aduanero, después de notar que los dos hombres parecían nerviosos.*		
	El delito	El bizcocho	El aduanero
64	*La reina pensó en rendir su renuncia al trono, cuando la flota enemiga apareció en el horizonte.* *La renuncia fue oficializada por la reina al día siguiente, cuando la flota se acercó a tierra.*		
	La renuncia	La flota	La reina
65	*Sara estaba tan emocionada por la cita favorable en el periódico, que no pudo empujar la puerta pesada y le pidió ayuda a la portera.* *La puerta fue abierta por la portera inmediatamente.*		
	La puerta	La cita	La portera
66	*Mientras conducía su carro, el profesor estaba tan concentrado en el concepto de turismo intergaláctico que casi se estrelló contra una pared.* *El concepto fue imaginado por el profesor como algo que se podría realizar durante los próximos cien años.*		
	El concepto	El carro	El professor
67	*La pastelera no quiso que la inspectora viera su bandeja de pasteles, porque no cumplía con una regla de sanidad pública.* *La bandeja fue escondida por la pastelera debajo del mostrador, antes de que llegara la inspectora.*		
	La bandeja	La regla	La pastelera
68	*El niño andaba en su triciclo, cuando se encontró con un escorpión enorme.*		

	El escorpión fue aplastado por el niño en su triciclo, pero éste no murió.		
	El escorpión	El triciclo	El niño
69	*El sastre compró el material para el traje que quería confeccionar y frecuentaba el archivo casi todos los días para estudiar la ropa de antaño.* *El material fue cortado por el sastre con mucho cuidado, porque valía mucho dinero.*		
	El material	El archivo	El sastre
70	*El trabajador ya había cargado el horno hasta su camión, cuando recibió un mensaje urgente de su jefe.* *El horno fue transportado por el trabajador a la dirección que su jefe le había dictado.*		
	El horno	El mensaje	El trabajador
71	*La princesa quería independencia para su estado después de tener un conflicto con otro estado sobre la carga de un buque.* *La independencia fue proclamada por la princesa, cuando no se pudo resolver el conflicto.*		
	La independencia	La carga	La princesa
72	*La contadora para el departamento de rentas públicas reparó una irregularidad grave en los documentos de la agencia de turismo.* *La agencia fue investigada por la contadora para verificar si existían más errores.*		
	La agencia	La irregularidad	La contadora
73	*Cuando lo contrataron para trabajar en un edificio histórico, el arquitecto comenzó a leer un ensayo sobre la conservación del mármol.* *El edificio fue restaurado por el arquitecto de acuerdo con las normas que se explicaban en el ensayo.*		
	El edificio	El ensayo	El arquitecto
74	*El inspector llegó al bar y se preparó a evaluar todos los aspectos del negocio de acuerdo con el texto de los reglamentos.* *El bar fue sancionado por el inspector, cuando vio que no habían declarado todos los bienes.*		
	El bar	El texto	El inspector
75	*El corredor de bolsa llegó temprano a la reunión para discutir su contrato, así que pudo preparar el café.* *El café fue servido por el corredor de bolsa, mientras su jefe examinaba sus logros del pasado año.*		
	El café	El contrato	El corridor
76	*El presidente le pidió un escritorio a un carpintero famoso y le prometió un honorario generoso.* *El escritorio fue diseñado por el carpintero con mucho cuidado, porque quería recibir el honorario.*		
	El escritorio	El honorario	El carpintero
77	*El director del hospital sabía que a muchos pacientes, les gustaría tomar una clase sobre la música de piano.* *El hospital fue expandido por el director, para que hubiese más espacio para ofrecer clases a los pacientes.*		
	El hospital	El piano	El director
78	*A los miembros del equipo de fútbol no les gustaba el mal tiempo, pero el portavoz del equipo siempre les aconsejaba acostumbrarse a ello.*		

	El tiempo fue pronosticado por el portavoz dos semanas antes del importante partido y sabían que iba a haber tormenta.		
	El tiempo	El equipo	El portavoz
79	*Después de leer el plan que su cliente le presentó, el ingeniero se sentó en su escritorio y empezó a trabajar.* *El plan fue evaluado por el ingeniero con mucho cuidado.*		
	El plan	El escritorio	El ingeniero
80	*La enfermera examinó la herida de Pedro, justo depués de su llegada a la clínica.* *La herida fue cosida por la enfermera, para evitar una infección.*		
	La herida	La clínica	La enfermera
81	*El dueño del restaurante era tacaño y compraba vino en cajas grandes en vez de botellas.* *El vino fue embotellado por el camarero, para que pareciera más caro.*		
	El vino	El restaurante	El dueño
82	*La granjera de la finca estaba a dieta y decidió no beber la leche directamente después de ordeñarla.* *La leche fue desnatada por la granjera, para no romper la dieta.*		
	La leche	La dieta	La granjera
83	*Después del fin de la guerra que tocó la región, la campesina decidió obtener una choza nueva.* *La choza fue construida por la familia de la campesina, porque ella les había ayudado mucho.*		
	La choza	La guerra	La campesina
84	*El naturista solía aconsejar un tónico de aceite de salmón para los clientes que se presentaban con un sarpullido.* *El tónico fue utilizado por muchos clientes sin resultados.*		
	El tónico	El salmón	El naturista
85	*El canasto estaba lleno de ropa sucia, y la mujer se fue a la cocina para no tener que enfrentarse a lavarla.* *La ropa fue lavada por la esposa de muy mal humor.*		
	La ropa	La cocina	La esposa
86	*Después de averiguar que nada parecido existía, el político decidió juntar en un libro la historia de su templo hindú.* *El libro fue escrito por el político, porque quería dejar un legado a su pueblo.*		
	El libro	El templo	El politico
87	*Después de completar sus deberes, la adolescente se sentó a leer un libro sobre la historia de una controvertida estatua.* *La estatua fue destruida por el gobierno hace diez años, porque tenía un mensaje racista.*		
	La estatua	La historia	La adolescente
88	*La agencia contrató a la espia en que más confiaban para obtener más información sobre unas actividades en el extranjero.* *La información fue proporcionada por la espía, después de seis meses de investigación.*		
	La información	La agencia	La espía
89	*Gloria preparó tres pollos asados para los invitados y los dejó en el comedor para irse al mercado, olvidando que su primo era glotón.* *El pollo fue devorado por su primo, antes de que entraran los demás invitados.*		

	El pollo	El mercado	El primo
90	*Cuando el cura observó el fenómeno del aura astral, decidió formar un culto divino que intentaría establecer contacto con lo extraterrestre.* *El culto fue implantado por el cura, porque no le gustaba que las iglesias tradicionales no admitieran la existencia de lo extraterrestre.*		
	El culto	El fenómeno	El cura
91	*El astronauta hacía las preparaciones de última hora para el viaje a un planeta lejano, donde iban a realizar unas pruebas sobre un virus.* *El planeta fue alcanzado por el astronauta después de un año de viaje.*		
	El planeta	El virus	El astronauta
92	*Cuando se enteró del homicidio del presidente, el amigo íntimo del presidente empezó a enviar un mensaje a todos sus compañeros.* *El mensaje fue transmitido por radio a toda la ciudad, así que los compañeros ya lo sabían.*		
	El mensaje	El homicidio	El amigo
93	*Al principio del semestre pasado, se hablaba de la nueva teoría que la especialista había desarollado sobre la historia de la ropa.* *La teoría fue explicada por la especialista, cuando visitó la facultad a finales del semestre.*		
	La teoría	La ropa	La especialista
94	*El autor del relato sobre el período del control militar apareció en un programa sobre actualidad política.* *El relato fue discutido por el autor, aunque muchos políticos querían frenarlo en su explicación.*		
	El relato	El período	El autor
95	*El topógrafo trabajó rápidamente para describir el valle que el ayuntamiento quería urbanizar.* *El valle fue dividido por el topógrafo en tres regiones.*		
	El valle	El ayuntamiento	El topógrafo
96	*El hombre telefoneó al director de mercadeo, cuando éste no contestó a su correo electrónico, pidiendo un encuentro para discutir el anuncio nuevo.* *El encuentro fue confirmado por la secretaria del director de mercadeo.*		
	El encuentro	El anuncio	El hombre
97	*Cuando la directora de la empresa completó el proyecto, decidió convenir una conferencia de prensa para los reporteros.* *La conferencia fue anunciada por la directora por correo electrónico.*		
	La conferencia	La empresa	La directora
98	*Durante la visita de la presidenta, los habitantes de la ciudad planearon una protesta en contra de la guerra.* *La guerra fue interrumpida por la presidenta, porque veía que todos los ciudadanos estaban en su contra.*		
	La guerra	La cuidad	La presidenta
99	*Después de su viaje en submarino, el escritor escribió un poema sobre ello.* *El poema fue editado por el escritor varias veces, antes de presentarlo al editor de una revista.*		
	El poema	El submarino	El escritor
100	*Después del crímen menor de su predecesor, el padre del templo decidió organizar varias*		

	actividades comunitarias. *El templo fue convertido por el padre en un lugar seguro y feliz.*		
	El templo	El crímen	El padre
101	*Cuando se enteró que un torrente se acercaba, el minero bajó a la mina en busca de un aparato caro.* *El aparato fue recuperado por el minero, después de dos horas de búsqueda.*		
	El aparato	El torrente	El minero
102	*Cuando examinó a un gato con corazón débil, el veterinario decidió utilizar un método avanzado para operarlo.* *El método fue perfeccionado por el veterinario a lo largo de diez años.*		
	El método	El corazón	El veterinario
103	*El erudito empezó el ensayo sobre la historia del teléfono, que una revista le había encargado.* *El ensayo fue redactado por el erudito con mucha gracia, porque le interesaba el tema.*		
	El ensayo	El teléfono	El erudito
104	*Cuando se abrió un burdel en el barrio, el juez ordenó al abogado del burdel que le visitara para determinar si era legal.* *El burdel fue vetado por el juez, pero el abogado apeló a una ley poco conocida.*		
	El burdel	El barrio	El juez
105	*Antes del último partido del año, el equipo de fútbol contrató a un administrativo para organizar el calendario del año siguiente.* *El calendario fue compilado por el administrativo a finales del mes.*		
	El calendario	El partido	El administrativo
106	*La plomera tuvo que contratar a dos hombres para transportar la lavadora desde la camioneta hasta la cocina.* *La lavadora fue instalada por la plomera sin la ayuda de los dos hombres.*		
	La lavadora	La camioneta	La plomera
107	*Nadie hablaba de la nueva norma en el club, así que el periodista decidió comenzar el debate.* *El debate fue planteado por el periodista en una pregunta de discusión.*		
	El debate	El club	El periodista
108	*Después de trabajar tres años en un campo con ruinas romanas, el arqueólogo volvió a su país para enseñar su descubrimento.* *El descubrimento fue comunicado por el arqueólogo, en una conferencia de prensa.*		
	El descubrimento	El campo	El arqueólogo
109	*Después de donar un edificio a la gente indigente, el duque decidió incluir en su testamento bastante dinero para mantener su legado.* *El legado fue continuado por la hija del duque, cuando ella compró otro edificio con el mismo propósito.*		
	El legado	El edificio	El duque
110	*Cuando el físico desarrolló un nuevo teorema sobre los misiles, le mandó un aviso al ministro de defensa.* *El teorema fue demostrado por el físico ante el ministro y su personal.*		
	El teorema	El aviso	El físico
111	*Cuando el presidente de Nigeria invitó al equipo de fútbol a un partido en su país, el*		

	entrenador eligió a los mejores jugadores. *El equipo fue seleccionado por el entrenador, con la ayuda de las estadísticas de cada jugador.*		
	El equipo	El viaje	El entrenador
112	*Cuando la agente vio la película más reciente del joven director, decidió que llegaría a ser una inversión buena.* *La inversión fue autorizada por la agente sin mucho debate.*		
	La inversión	La película	La agente
113	*Después de su triunfo con un gen de discapacidad mental, el biólogo empezó a trabajar en detectar un gen de cáncer.* *El gen fue detectado por el biólogo a las dos de la mañana y no tenía con quíen celebrarlo.*		
	El gen	El triunfo	El biólogo
114	*La ranchera se enteró de la ley que prohibía el uso de la tierra a lo largo de la carretera, pero siguió sin hacer caso.* *La tierra fue cultivada por la ranchera, hasta que llegó una carta de la comisión agrícola.*		
	La tierra	La ley	La ranchera
115	*El actor hizo un pedido de una caja de su licor favorito para su amigo, cuando éste tuvo un triunfo importante en su trabajo.* *El triunfo fue celebrado por el amigo con muchas copas del licor que le había mandado.*		
	El triunfo	El licor	El actor
116	*La escritora necesitaba dinero rápido y aceptó empleo en la lavandería local, mientras terminaba su biografía de Nelson Mandela.* *La biografía fue corregida por la escritora poco a poco en su tiempo libre.*		
	La biografía	La lavandería	La escritora
117	*Cuando unos habitantes empezaron a hablar de un levantamiento para asegurar su acceso al río, el gobernador empezó a tomar medidas severas.* *El levantamiento fue reprimido por el gobernador, con la ayuda de militares extranjeros.*		
	El levantamiento	El acceso	El gobernador
118	*La senadora luchó intensamente para aprobar una ley que ordenaba la preservación de una puerta antigua y hermosa.* *La ley fue debatida por la senadora y sus compañeros hasta medianoche.*		
	La ley	La puerta	La senadora
119	*El funcionario decidió ofrecerle un alto honorario al famoso actor para que éste asistiera a la fiesta del pueblo.* *El honorario fue pagado por el funcionario, aunque el actor no lo exigía.*		
	El honorario	El encuentro	El funcionario
120	*Cuando la madre de la novia le mandó una carta diciéndole que había engordado, ésta decidió ponerse a dieta antes de su boda.* *La dieta fue mantenida por la novia durante dos meses, pero no pudo aguantar hasta la boda.*		
	La dieta	La carta	La novia
121	*Después de formar un acuerdo entre varios países para construir un satélite, el embajador empezó los primeros pasos para realizarlo.* *El acuerdo fue ratificado por los países involucrados, en una ceremonia en la embajada.*		
	El acuerdo	El satélite	El embajador

122	*La millonaria descubrió que la pobre mujer no tenía una lavadora e hizo la promesa de darle una.* *La promesa fue reafirmada por la millonaria, cuando vio a la mujer en la calle.*		
	La promesa	La lavadora	La millonaria
123	*La activista habló con el alcalde para decirle lo que pensaba sobre la política en cuanto a la exploración de la luna.* *La política fue criticada por la activista porque prefería gastar el dinero en casas para la gente pobre. ?*		
	La política	La luna	La activista
124	*Cuando no le quedaba mucho tiempo de vida, el sombrerero empezó a hacer el sombrero que pensaba dejar como legado a su nieto.* *El sombrero fue cosido por el sombrerero con mucho cuidado, para que quedara muy bonito.*		
	El sombrero	El legado	El sombrero
125	*Cuando el dueño de la casa decidió a última hora asistir a la conferencia, pidió a la criada que preparara su camisa más formal.* *La camisa fue planchada por la criada de mala gana, porque tenía mucho que hacer ese día.*		
	La camisa	La conferencia	La criada
126	*El productor empezó a crear un documental sobre un especialista del período en que tuvo lugar el descubrimento del gen.* *El período fue recreado por el especialista con gran detalle en el documental.*		
	El período	El descubrimento	El especialista
127	*El policía preparó un cartel de aviso, después de un alto récord de homicidios en el barrio.* *El cartel fue puesto por el policía en todas partes del barrio.*		
	El cartel	El récord	El policía
128	*A las seis de la mañana, el comandante preparó para la prensa un informe sobre el satélite que se preparaba para el lanzamiento.* *El satélite fue lanzado por el comandante una hora más tarde, a las siete de la mañana.*		
	El satélite	El informe	El comandante
129	*Cuando el científico decidió pasar muchas horas en el desarollo de un teléfono más moderno, tuvo que negociar un compromiso con su esposa.* *El teléfono fue inventado por el científico, a pesar de las restricciones que su esposa le impuso.*		
	El teléfono	El compromiso	El científico
130	*La vecina salió con su tractor, tan pronto recibió la noticia que la bicicleta del niño cayó en el lago. La bicicleta fue sacada por la vecina sin problemas, aunque estaba muy mojada.*		
	La bicicleta	La noticia	La vecina
131	*La niñera estaba a punto de entrar en la casa con los niños, cuando escuchó en la radio la declaración del presidente.* *La casa fue abandonada por la niñera, porque quería bajar a la plaza y escuchar al presidente en directo.*		
	La casa	La declaración	La niñera
132	*La venta de la empresa estaba un poco baja, así que la gerente se sentó a leer una tesis sobre el mundo de los negocios.* *La empresa fue salvada por la gerente, con un plan que se basó en las ideas que encontró en la tesis.*		

	La empresa	La tesis	La gerente
133	*Cuando descubrió que a su padre le gustaba mucho una estrella específica, la hija hizo una promesa de fotografiarla.* *La estrella fue divisada por la hija después de unos diez minutos.*		
	La estrella	La promesa	La hija
134	*Cuando cumplió los quince años, la chica empezó a investigar la historia de la finca familiar donde se producía todo tipo de fruta.* *La historia fue documentada por la chica, después de entrevistar a todos los miembros de su familia.*		
	La historia	La fruta	La chica
135	*Después de descubrir un teorema famoso, el matemático loco bajó al ayuntamiento con una lata de colorante en sus manos.* *El ayuntamiento fue dañado por el matemático, cuando éste empezó a tirar el colorante por todas partes del edificio.*		
	El ayuntamiento	El teorema	El matématico
136	*Después de soñar con un torrente enorme, el astrólogo decidió mandar un formulario de aviso al alcalde para prevenirle del torrente.* *El torrente fue vaticinado por el astrólogo, pero nadie le hizo caso.*		
	El torrente	El formulario	El astrólogo
137	*El instructor quería ver un partido de fútbol importante, que estaba programado a la misma hora en que tenía que enseñar un curso.* *El partido fue grabado por el instructor para poder verlo más tarde.*		
	El partido	El curso	El instructor
138	*Después de aparecer en el tribunal, el ladrón decidió salir en busca de un helado.* *El helado fue comprado por el ladrón, para celebrar su libertad.*		
	El helado	El tribunal	El ladrón
139	*Mientras esperaba a que su ropa se lavara en la lavandería, el competidor de la estratega trabajaba en un memorándum sobre la política monetaria.* *La lavandería fue registrada por la estratega más tarde, por si acaso él había olvidado algo confidencial.*		
	La lavandería	La política	La estratega
140	*Después de que el turista se interesó en el fenómeno del poder, viajó hasta un castillo lejano.* *El castillo fue fotografiado por el turista desde todos los ángulos.*		
	El castillo	El poder	El turista
141	*A la pintora sólo le quedaba añadir la luna a su pintura, cuando decidió buscar una información en internet.* *La luna fue decorada por la pintora más tarde, cuando había acabado su búsqueda en internet.*		
	La luna	La información	La pintora
142	*Después de descubrir una equivocación con su trabajo, la contadora decidió construir una pared alrededor de su escritorio para concentrarse mejor.* *La pared fue levantada por la contadora a primera hora, para no molestar a los demás.*		
	La pared	La equivocación	La contadora
143	*Después de su operación, la paciente se mudó cerca de la clínica en que su médico trabajaba.*		

	La clínica fue frequentada por la paciente muchas veces, hasta que el médico se enojó.		
	La clínica	La operación	La paciente
144	*El estudiante más inteligente decidió establecer un club para discutir el libro más famoso de España.* *El club fue formado por el estudiante más inteligente de la clase.*		
	El club	El libro	El estudiante
145	*El mecánico había dado con tanta fuerza contra el techo de un carro, que se le había caído un diente.* *El carro fue reparado por el mecánico una semana más tarde.*		
	El carro	El diente	El mecánico
146	*El jefe le mandó a su consejero un informe sobre el burdel que éste tenía que defender en la corte al día siguiente.* *El informe fue recibido por el consejero, justo antes de su reunión con el jefe.*		
	El informe	El burdel	El consejero
147	*Al llegar al aeropuerto, el imigrante empezó a leer el formulario que le dieron y se encontró con un término que no conocía.* *El formulario fue llenado por el aduanero, porque el imigrante no conocía el término.*		
	El formulario	El término	El imigrante
148	*El cliente entró con su abogada a la reunión, usando muletas porque se hizo una herida en la pierna el día anterior.* *La reunión fue suspendida por la abogada, porque a su cliente le dolía mucho la pierna.*		
	La reunión	La herida	La abogada
149	*La periodista recibió una noticia del estreno de una estatua en el museo nacional.* *La noticia fue verificada por la periodista, antes de viajar a la capital.*		
	La noticia	La estatua	La periodista
150	*Después del concierto, un hombre le entregó a la cantante una invitación y una camisa bonita.* *La invitación fue rechazada por la cantante, porque el hombre parecía algo raro.*		
	La invitación	La camisa	La cantante
151	*Después de la renuncia imprevista de una compañera, la empleada decidió informarse de una regla importante antes de empezar de nuevo su trabajo.* *La regla fue violada por todos los empleados, menos ella porque temía mucho perder el trabajo.*		
	La regla	La renuncia	La empleada
152	*Cuando el jardinero ya había completado su trabajo, anunciaron finalmente el donativo que se había recibido para construir el camino nuevo.* *El camino fue limpiado por el jardinero, antes de la ceremonia para honrar al donante.*		
	El camino	El donativo	El jardinero
153	*Cuando los frenos del tren se rompieron, el conductor intentó mandar un comunicado antes de llegar al próximo pueblo.* *El comunicado fue propagado por el conductor mediante el radio.*		
	El comunicado	El pueblo	El conductor
154	*El marinero llegó con su barco a la orilla y se quedó esperando el comunicado de su compañero.*		

	El barco fue empujado por el marinero hacia la arena, después de recibir el comunicado.		
	El barco	El comunicado	El marinero
155	*Cuando la nueva pintura llegó al museo, la profesora bajó de su despacho para completar la transacción con el vendedor.* *La pintura fue inspeccionada por la profesora, para verificar que no era un fraude.*		
	La pintura	La transacción	La profesora
156	*El abuelo decidió escribir un poema para su nieta y empezó a buscar un lápiz rosado en su escritorio.* *El lápiz fue sujetado por el abuelo con tanta fuerza que se le rompió la punta.*		
	El lápiz	El poema	El abuelo
157	*La cocinera decidió hacer una transformación moderna de la cocina y sacó todas las ollas.* *La cocina fue quemada por la cocinera, para que el dueño del restaurante pagara la renovación.*		
	La cocina	La transformación	La cocinera
158	*La actriz había escuchado las noticias de una movilización de los activistas y fue en busca de una camioneta.* *La camioneta fue alquilada por la actriz, para ayudar a la causa de los activistas.*		
	La camioneta	La movilización	La actriz
159	*El millonario decidió invertir dinero en un negocio y pidió un folleto sobre el negocio de su sobrino.* *El negocio fue apoyado por el millonario, porque le gustó mucho la propuesta.*		
	El negocio	El folleto	El millonario
160	*El alférez se sentó frente al control del submarino, mientras el capitán se durmió con el sombrero en la cara.* *El submarino fue controlado por el alférez, mientras el capitán roncaba.*		
	El submarino	El sombrero	El alférez
161	*El delincuente preparó un complot para robar la estación de trenes, pero a la hora de realizarlo, escuchó un tren acercarse y tuvo que parar.* *El complot fue planeado por el delincuente, sin pensar que entraban trenes a la estación a las dos de la mañana.*		
	El complot	El tren	El delincuente
162	*Cuando el diplomático volvió del país en el que vivió por dos años, invitó a varios amigos para mostrarles un dibujo de su colección.* *El dibujo fue presentado por el diplomático con tanta emoción que sus amigos quedaron asustados.*		
	El dibujo	El país	El diplomático
163	*El negociador y el guerrillero con un nombre muy complicado finalmente escribieron un pacto para suspender el levantamiento.* *El nombre fue deletreado por el guerrillero, porque odiaba que alguien lo escribiese mal.*		
	El nombre	El levantamiento	El negociador
164	*El dueño tuvo que pensar, qué hacer cuando los científicos decidieron realizar un experimento en la calle, frente de su mercado.* *El mercado fue cerrado por el dueño, después de darse cuenta de que el experimento ya no estaba bajo su control.*		

	El mercado	El experimento	El dueño
165	*El amaestrador conocía un juego que pensaba enseñarle a su nuevo perro para portarse bien.* *El perro fue entrenado por el amaestrador en muy poco tiempo, porque al perro le gustaba mucho el juego.*		
	El perro	El juego	El amaestrador
166	*Cuando la cliente registraba su correo, vio una circular con información sobre una inversión que había hecho hace poco.* *La circular fue añadida por la cliente a una carta para su banquero.*		
	La circular	La inversión	La cliente
167	*La anarquista quedó todo el día repartiendo la circular que había compuesto sobre la rebelión contra el estado.* *La rebelión fue fomentada por la anarquista, porque odiaba todas las formas de gobierno.*		
	La rebelión	La circular	La anarquista
168	*Cuando la tormenta se acercaba, la directora de cine bajó al escondite en el bosque y empezó sus preparaciones para captar la luz imponente.* *La tormenta fue filmada por la directora de cine, a pesar del viento fuerte y la lluvia.*		
	La tormenta	La luz	La directora
169	*El representante del sindicato fue a negociar con la gerencia un pacto sobre el uso del camino en frente de la fábrica.* *El pacto fue negociado por el representante y la gerencia después de una hora de discusión.*		
	El pacto	El camino	El representante
170	*La dueña de la granja no pudo recoger su cosecha de fruta, porque los soldados de la rebelión vigilaban la zona.* *La fruta fue botada por la dueña, después de que los soldados se fueron, porque ya estaba dañada.*		
	La fruta	La rebelión	La dueña
171	*Dos días antes de la fiesta, el mesero empezó la preparación del restaurante y del sistema de pedidos.* *El restaurante fue decorado por el mesero con mucho cuidado, porque quería que todo quedara perfecto.*		
	El restaurante	El sistema	El mesero
172	*Cuando su cliente le dijo que la luz estaba demasiado fuerte, la oftalmóloga insertó un lente para resolver el problema.* *La luz fue desviada por el lente, para que no diera con tanta fuerza en los ojos del cliente.*		
	La luz	El lente	La oftalmóloga
173	*Cuando la empleada hizo una irregularidad en la cuenta para construir la pared, decidió confesar a la gerencia.* *La irregularidad fue perdonada por la gerencia, porque la empleada había confesado inmediatamente.*		
	La irregularidad	La pared	La gerencia
174	*El alquimista se sentó bajo el firmamento azul y decidió que ya era la hora de realizar el experimento que iba a hacer famoso su nombre.* *El firmamento fue coloreado por el humo de la reacción química y el alquimista quedó feliz.*		
	El firmamento	El nombre	El alquimista

175	*El líder del culto puso un piano en el salón, y todos los niños tuvieron que asistir a clases de piano.* *El piano fue tocado por varios niños durante la hora de cenar, para entretener a los demás.*		
	El piano	El culto	El líder
176	*Después de descubrir la equivocación en la nueva edición, la editora fue directamente a los ejecutivos para contarselo.* *La equivocación fue disculpada por todos los ejecutivos y no tuvieron que cancelar la nueva edición.*		
	La equivocación	La edición	La editora
177	*El autor entró en la farmacía y dijo al farmaceútico, que no podía seguir con su libro porque le molestaba mucho uno de sus lentes de contacto.* *El lente fue desinfectado por el farmaceútico y el autor pudo seguir con el libro.*		
	El lente	El libro	El farmaceútico
178	*La ciclista fijó la lista de compras para el club en la pared, donde solía guardar su bicicleta.* *La lista fue aumentada por varios miembros del club, que querían añadir más cosas para comprar.*		
	La lista	La bicicleta	La ciclista
179	*El granjero decidió posponer el trabajo que tenía que hacer en su campo, para visitar un castillo medieval.* *El campo fue sembrado por los vecinos mientras el granjero estaba fuera, porque le tenían mucho cariño.*		
	El campo	El castillo	El granjero
180	*El pintor llegó dos horas antes de la salida de su tren, así que se sentó y empezó un dibujo de la estación.* *El tren fue escuchado por todos los demás viajeros, pero el pintor no lo escuchó porque estaba muy concentrado.*		
	El tren	El dibujo	El pintor

Appendix B: Experimental stimuli for the Interference ERP Study (Chapter 3)

The table below shows the entire set of NP + verb combinations used in this study. Due to space considerations, the full items have not been displayed but are available upon request. Each entry shows a sample version of the item showing the grammatical control condition without an intervener. The six possible NPs are shown below. In the left-hand column are the NPs in which the head noun is a good theme for the verb. These are the nouns used in the grammatical control and semantically-attractive head noun conditions. In the right-hand column are the NPs in which the head noun is not a good theme for the verb. Within each column, the first NP is the NP used in the no-intervener condition, the second NP is used in the semantically-attractive intervener condition, and the third NP is used in the non-attractive intervener condition.

Sample sentence showing the Grammatical Control with No Intervener condition

N-I = No intervener

SA-I = Semantically-attractive intervener

NA-I = Non-attractive intervener

	Grammatical Control & Semantically-Attractive Head Noun Violation	**Non-Attractive Head Noun Violation**
1	*The homicide investigation was conducted by the police chief.*	
N-I	The homicide investigation	The contaminated medicine
SA-I	The careful analysis of the homicide	The deadly poison from the homicide

	investigation	investigation
NA-I	The careful analysis of the contaminated medicine	The deadly poison in the contaminated medicine
2	*The contaminated medicine was swallowed by the young child.*	
N-I	The contaminated medicine	The homicide investigation
SA-I	The deadly poison from the homicide investigation	The careful analysis of the homicide investigation
NA-I	The deadly poison in the contaminated medicine	The careful analysis of the contaminated medicine
3	*The overgrown lawn was mowed by the teenage boy.*	
N-I	The overgrown lawn	The brass statue
SA-I	The tangled weeds on the overgrown lawn	The copper fountain on the overgrown lawn
NA-I	The tangled weeds around the brass statue	The copper fountain beside the brass statue
4	*The brass statue was polished by the gardener.*	
N-I	The brass statue	The overgrown lawn
SA-I	The copper fountain on the overgrown lawn	The tangled weeds on the overgrown lawn
NA-I	The copper fountain beside the brass statue	The tangled weeds around the brass statue
5	*The birthday cake was baked by the young girl's mother.*	
N-I	The birthday cake	The birthday candle
SA-I	The frosted cupcake beside the birthday cake	The small sparklers on the birthday cake
NA-I	The frosted cupcake with the birthday candle	The small sparklers beside the birthday cake
6	*The birthday candle was lit by the boy's sister*	
N-I	The birthday candle	The birthday cake
SA-I	The small sparklers on the birthday cake	The frosted cupcake beside the birthday cake
NA-I	The small sparklers beside the birthday cake	The frosted cupcake with the birthday candle
7	*The financial contract was signed by the president of the company.*	
N-I	The financial contract	The annual conference
SA-I	The urgent memo about the financial contract	The important meeting about the financial contract
NA-I	The urgent memo about the annual conference	The important meeting about the annual conference
8	*The annual conference was attended by all the senior employees.*	
N-I	The annual conference	The financial contract
SA-I	The important meeting about the financial contract	The urgent memo about the financial contract
NA-I	The important meeting about the annual conference	The urgent memo about the annual conference
9	*The waffle maker was unplugged by the teenage girl.*	
N-I	The waffle maker	The sugary cake
SA-I	The toaster oven beside the waffle maker	The plump cherries beside the waffle maker
NA-I	The toaster oven beside the sugary cake	The plump cherries on the sugary cake
10	*The sugary cake was eaten by the hungry guest.*	
N-I	The sugary cake	The waffle maker
SA-I	The plump cherries beside the waffle maker	The toaster oven beside the waffle maker
NA-I	The plump cherries on the sugary cake	The toaster oven beside the sugary cake

11	*The new car was washed by the college student.*	
N-1	The new car	The electric bill
SA-1	The waterproof cover for the new car	The final invoice for the new car
NA-1	The waterproof cover for the electric bill	The final invoice for the electric bill
12	*The electric bill was read by the careful accountant.*	
N-1	The electric bill	The new car
SA-1	The final invoice for the new car	The waterproof cover for the new car
NA-1	The final invoice for the electric bill	The waterproof cover for the electric bill
13	*The dull novel was published by a large company in Chicago.*	
N-1	The dull novel	The creamy fudge
SA-1	The beautiful illustrations for the dull novel	The delicious bonbons beside the dull novel
NA-1	The beautiful illustrations of the creamy fudge	The delicious bonbons near the creamy fudge
14	*The creamy fudge was devoured by the greedy guest.*	
N-1	The creamy fudge	The dull novel
SA-1	The delicious bonbons beside the dull novel	The beautiful illustrations for the dull novel
NA-1	The delicious bonbons near the creamy fudge	The beautiful illustrations of the creamy fudge
15	*The instruction manual was photocopied by the spy.*	
N-1	The instruction manual	The deadly bomb
SA-1	The detailed blueprints in the instruction manual	The explosive material beside the instruction manual
NA-1	The detailed blueprints for the deadly bomb	The explosive material beside the deadly bomb
16	*The deadly bomb was detonated by the soldier.*	
N-1	The deadly bomb	The explosive material beside the deadly bomb
SA-1	The explosive material beside the instruction manual	The detailed blueprints in the instruction manual
NA-1	The explosive material beside the deadly bomb	The detailed blueprints for the deadly bomb
17	*The pocket knife was sharpened by the boy scout.*	
N-1	The pocket knife	The leather case
SA-1	The long blade of the pocket knife	The canvas strap for the pocket
NA-1	The long blade in the leather case	The canvas strap for the leather case
18	*The leather case was stitched by the army recruit.*	
N-1	The leather case	The pocket knife
SA-1	The canvas strap for the pocket	The long blade of the pocket knife
NA-1	The canvas strap for the leather case	The long blade in the leather case
19	*The garlic bread was delivered by the restaurant earlier that day.*	
N-1	The garlic bread	The concrete floor
SA-1	The pepperoni pizza with the garlic bread	The dorm room with the garlic bread
NA-1	The pepperoni pizza on the concrete floor	The dorm room with the concrete floor
20	*The concrete floor was vacuumed by the student before his mom arrived.*	

N-1	The concrete floor	The garlic bread
SA-1	The dorm room with the garlic bread	The pepperoni pizza with the garlic bread
NA-1	The dorm room with the concrete floor	The pepperoni pizza on the concrete floor
21	*The toy train was manufactured by a factory in china.*	
N-1	The toy train	The thin greyhound
SA-1	The plastic figure beside the toy train	The young puppies near the toy train
NA-1	The plastic figurine of the thin greyhound	The young puppies near the thin greyhound
22	*The thin greyhound was petted by the little kid.*	
N-1	The thin greyhound	The toy train
SA-1	The young puppies near the toy train	The plastic figure beside the toy train
NA-1	The young puppies near the thin greyhound	The plastic figurine of the thin greyhound
23	*The strategic meeting was overheard by a sneaky employee.*	
N-1	The strategic meeting	The famous baseball
SA-1	The quiet conversation at the strategic meeting	The short letter about the strategic meeting
NA-1	The quiet conversation about the famous baseball	The short letter about the famous baseball
24	*The famous baseball was signed by the ball player.*	
N-1	The famous baseball	The strategic meeting
SA-1	The short letter about the strategic meeting	The quiet conversation at the strategic meeting
NA-1	The short letter about the famous baseball	The quiet conversation about the famous baseball
25	*The thick envelope was mailed by the secretary.*	
N-1	The thick envelope	The long conversation
SA-1	The typed notes in the thick envelope	The whispered comment about the thick envelope
NA-1	The typed notes from the long conversation	The whispered comment about the long conversation
26	*The long conversation was overheard by the person in the next office.*	
N-1	The long conversation	The thick envelope
SA-1	The whispered comment about the thick envelope	The typed notes in the thick envelope
NA-1	The whispered comment about the long conversation	The typed notes from the long conversation
27	*The large field was plowed by the farmer.*	
N-1	The large field	The red barn
SA-1	The rich soil in the large field	The wooden fence around the large field
NA-1	The rich soil near the red barn	The wooden fence around the red barn
28	*The red barn was erected by the workers on the farm.*	
N-1	The red barn	The large field
SA-1	The wooden fence around the large field	The rich soil in the large field
NA-1	The wooden fence around the red barn	The rich soil near the red barn
29	*The classical symphony was composed by the young musician.*	
N-1	The classical symphony	The grand stage

SA-1	The simple melody in the classical symphony	The concert hall for the classical symphony
NA-1	The simple melody on the grand stage	The concert hall for the grand stage
30	*The grand stage was conducted by a local company.*	
N-1	The grand stage	The classical symphony
SA-1	The concert hall for the classical symphony	The simple melody in the classical symphony
NA-1	The concert hall for the grand stage	The simple melody on the grand stage
31	*The bulging suitcase was carried by the tourist.*	
N-1	The bulging suitcase	The severe thunderstorm
SA-1	The yellow umbrella from the bulging suitcase	The heavy rain on the bulging suitcase
NA-1	The yellow umbrella from the severe thunderstorm	The heavy rain from the severe thunderstorm
32	*The severe thunderstorm was forecast by the local weatherman.*	
N-1	The severe thunderstorm	The bulging suitcase
SA-1	The heavy rain on the bulging suitcase	The yellow umbrella from the bulging suitcase
NA-1	The heavy rain from the severe thunderstorm	The yellow umbrella from the severe thunderstorm
33	*The warm toast was buttered by the cook.*	
N-1	The warm toast	The hot coffee
SA-1	The golden waffles beside the warm toast	The thick cream beside the warm toast
NA-1	The golden waffles beside the hot coffee	The thick cream for the hot coffee
34	*The hot coffee was poured by the waitress.*	
N-1	The hot coffee	The warm toast
SA-1	The thick cream beside the warm toast	The golden waffles beside the warm toast
NA-1	The thick cream for the hot coffee	The golden waffles beside the hot coffee
35	*The leftover food was refrigerated by the woman before she went on vacation.*	
N-1	The leftover food	The kitchen cabinet
SA-1	The perishable item of the leftover food	The wooden counter for the leftover food
NA-1	The perishable items in the kitchen cabinet	The wooden counter below the kitchen cabinet
36	*The kitchen cabinet was constructed by the owner of the house.*	
N-1	The kitchen cabinet	The leftover food
SA-1	The wooden counter for the leftover food	The perishable item of the leftover food
NA-1	The wooden counter below the kitchen cabinet	The perishable items in the kitchen cabinet
37	*The exciting event was attended by the director.*	
N-1	The exciting event	The theater poster
SA-1	The important meeting about the exciting event	The catchy banner about the exciting event
NA-1	The important meeting about the theater poster	The catchy banner above the theater poster
38	*The theater poster was printed by the manager.*	

N-1	The theater poster	The exciting event
SA-1	The catchy banner about the exciting event	The important meeting about the exciting event
NA-1	The catchy banner above the theater poster	The important meeting about the theater poster
39	*The high-tech safe was invented by an engineer.*	
N-1	The high-tech safe	The large diamond
SA-1	The security system in the high-tech safe	The blue sapphires in the high-tech safe
NA-1	The security system for the large diamond	The blue sapphires around the large diamond
40	*The large diamond was mined by an international company.*	
N-1	The large diamond	The high-tech safe
SA-1	The blue sapphires in the high-tech safe	The security system in the high-tech safe
NA-1	The blue sapphires around the large diamond	The security system for the large diamond
41	*The large chalkboard was erased by the eccentric professor.*	
N-1	The large Chalkboard	The papyrus basket
SA-1	The lecture notes on the large chalkboard	The fabric cover for the large chalkboard
NA-1	The lecture notes about the papyrus basket	The fabric cover for the papyrus basket
42	*The papyrus basket was woven by the craftsmen.*	
N-1	The papyrus basket	The large Chalkboard
SA-1	The fabric cover for the large chalkboard	The lecture notes on the large chalkboard
NA-1	The fabric cover for the papyrus basket	The lecture notes about the papyrus basket
43	*The poisonous vapor was inhaled by many students in the chemistry lab.*	
N-1	The poisonous vapor	The test tube
SA-1	The unpleasant smell from the poisonous vapor	The glass lid over the poisonous vapor
NA-1	The unpleasant smell inside the test tube	The glass lid for the test tube
45	*The model train was built by the retiree.*	
N-1	The model train	The ancient manuscript
SA-1	The display case for the model train	The ownership certificate for the model train
NA-1	The display case for the ancient manuscript	The ownership certificate for the ancient manuscript
46	*The ancient manuscript was forged by the owner of the antique store.*	
N-1	The ancient manuscript	The model train
SA-1	The ownership certificate for the model train	The display case for the model train
NA-1	The ownership certificate for the ancient manuscript	The display case for the ancient manuscript
47	*The warm bread was sliced by the café worker.*	
N-1	The warm bread	The Italian market
SA-1	The green apples beside the warm bread	The stone counter beneath the warm bread
NA-1	The green apples from the Italian market	The stone counter at the Italian market
48	*The Italian market was demolished by the construction crew.*	
N-1	The Italian market	The warm bread
SA-1	The stone counter beneath the warm bread	The green apples beside the warm bread
NA-1	The stone counter at the Italian market	The green apples from the Italian market

49	*The hearty meal was devoured by the men in the restaurant.*	
N-1	The hearty meal	The blue tablecloth
SA-1	The dishes for the hearty meal	The pink napkins for the hearty meal
NA-1	The dishes on the blue tablecloth	The pink napkins on the blue tablecloth
50	*The blue tablecloth was embroidered by the grandmother.*	
N-1	The blue tablecloth	The hearty meal
SA-1	The pink napkins for the hearty meal	The dishes for the hearty meal
NA-1	The pink napkins on the blue tablecloth	The dishes on the blue tablecloth
51	*The cooking technique was learnt by all the students in the class.*	
N-1	The cooking technique	The lab equipment
SA-1	An important skill for the cooking technique	The essential materials for the cooking technique
NA-1	An important skill for the lab equipment	The essential materials for the lab equipment
52	*The lab equipment was shipped by the manufacturer.*	
N-1	The lab equipment	The cooking technique
SA-1	The essential materials for the cooking technique	An important skill for the cooking technique
NA-1	The essential materials for the lab equipment	An important skill for the lab equipment
53	*The wheat grain was ground by the baker.*	
N-1	The wheat grain	The burlap sack
SA-1	The cornmeal beside the wheat grain	The canvas sheet under the wheat grain
NA-1	The cornmeal in the burlap sack	The canvas sheet inside the burlap sack
54	*The burlap sack was sewed by the farmer's assistant.*	
N-1	The burlap sack	The wheat grain
SA-1	The canvas sheet under the wheat grain	The cornmeal beside the wheat grain
NA-1	The canvas sheet inside the burlap sack	The cornmeal in the burlap sack
55	*The carpeted bedroom was vacuumed by the helpful nanny.*	
N-1	The carpeted bedroom	The potted flower
SA-1	The dusty rug in the carpeted bedroom	The prickly cactus in the carpeted bedroom
NA-1	The dusty rug under the potted flower	The prickly cactus beside the potted flower
56	*The potted flower was watered by the quiet gardener.*	
N-1	The potted flower	The carpeted bedroom
SA-1	The prickly cactus in the carpeted bedroom	The dusty rug in the carpeted bedroom
NA-1	The prickly cactus beside the potted flower	The dusty rug under the potted flower
57	*The graduation ceremony was attended by all the students.*	
N-1	The graduation ceremony.	The full keg
SA-1	The loud party after the graduation ceremony	The light beer at the graduation ceremony
NA-1	The loud party with the full keg	The light beer in the full keg
58	*The full keg was refrigerated by the host of the celebration.*	
N-1	The full keg	The graduation ceremony.
SA-1	The light beer at the graduation ceremony	The loud party after the graduation ceremony
NA-1	The light beer in the full keg	The loud party with the full keg
59	*The ancient war was fought by the fierce warriors.*	
N-1	The ancient war	The spirited ballad

SA-1	The violent battle during the ancient war	The catchy chorus about the ancient war
NA-1	The violent battle in the spirited ballad	The catchy chorus of the spirited ballad
60	*The spirited ballad was sung by the local choir.*	
N-1	The spirited ballad	The ancient war
SA-1	The catchy chorus about the ancient war	The violent battle during the ancient war
NA-1	The catchy chorus of the spirited ballad	The violent battle in the spirited ballad
61	*The beef steak was ground by the butcher.*	
N-1	The beef steak	The black charcoal
SA-1	The lean turkey beside the beef steak	The barbeque grill under the beef steak
NA-1	The lean turkey above the black charcoal	The barbeque grill with the black charcoal
62	*The black charcoal was lit by the neighbor.*	
N-1	The black charcoal	The beef steak
SA-1	The barbeque grill under the beef steak	The lean turkey beside the beef steak
NA-1	The barbeque grill with the black charcoal	The lean turkey above the black charcoal
63	*The kiddie pool was inflated by John's father.*	
N-1	The kiddie pool	The overgrown field
SA-1	The old tires beside the kiddie pool	The soft soil beside the kiddie pool
NA-1	The old tires in the overgrown field	The soft soil in the overgrown field
64	*The overgrown field was fertilized by the young farmer.*	
N-1	The overgrown field	The kiddie pool
SA-1	The soft soil beside the kiddie pool	The old tires beside the kiddie pool
NA-1	The soft soil in the overgrown field	The old tires in the overgrown field
65	*The pine board was sanded by the carpenter.*	
N-1	The pine board	The chainsaw
SA-1	The oak planks near the pine board	The electric drill near the pine board
NA-1	The oak planks near the chainsaw	The electric drill near the chainsaw
66	*The chainsaw was unplugged by the construction worker.*	
N-1	The chainsaw	board
SA-1	The electric drill near the pine board	The oak planks near the pine board
NA-1	The electric drill near the pine board	The oak planks near the chainsaw
67	*The important letter was scribbled by the grumpy teacher.*	
N-1	The important letter	The computer monitor
SA-1	The short note about the important letter	The table lamp beside the important letter
NA-1	The short note about the computer monitor	The table lamp behind the monitor
68	*The computer monitor was unplugged by the technician.*	
N-1	The computer monitor	The important letter
SA-1	The table lamp beside the important letter	The short note about the important letter
NA-1	The table lamp behind the monitor	The short note about the computer monitor
69	*The metal fence was repaired by the handyman.*	
N-1	The metal fence	The tall hedge
SA-1	The broken rake behind the metal fence	The overgrown plant behind the tall hedge
NA-1	The broken rake near the tall hedge	The overgrown plant near the tall hedge

70	*The tall hedge was trimmed by the gardener.*	
N-1	The tall hedge	The metal fence
SA-1	The overgrown plant behind the metal fence	The broken rake behind the metal fence
NA-1	The overgrown plant near the tall hedge	The broken rake near the tall hedge
71	*The spicy shrimp was devoured by the diners at the restaurant.*	
N-1	The spicy shrimp	The dirty tabletop
SA-1	The chicken wings near the spicy shrimp	The large platter for the spicy shrimp
NA-1	The chicken wings on the dirty tabletop	The large platter on the dirty tabletop
72	The dirty tabletop was wiped by the attentive waiter	
N-1	The dirty tabletop	The spicy shrimp
SA-1	The large platter for the spicy shrimp	The chicken wings near the spicy shrimp
NA-1	The large platter on the dirty tabletop	The chicken wings on the dirty tabletop
73	*The famous play was narrated by the popular actress.*	
N-1	The famous play	The movie theater
SA-1	The blockbuster film of the famous play	The large stage for the famous play
NA-1	The blockbuster film in the movie theater	The large stage in the movie theater
74	*The movie theater was mopped by the custodian*	
N-1	The movie theater	The famous play
SA-1	The large stage for the famous play	The blockbuster film of the famous play
NA-1	The large stage in the movie theater	The blockbuster film in the movie theater
75	*The town square was built by a local construction company.*	
N-1	The town square	The thick hedge
SA-1	The new house beside the town square	The oak tree in the town square
NA-1	The new house behind the thick hedge	The oak tree behind the thick hedge
76	*The thick hedge was pruned by the gardener every month.*	
N-1	The thick hedge	The town square
SA-1	The oak tree in the town square	The new house beside the town square
NA-1	The oak tree behind the thick hedge	The new house behind the thick hedge
77	*The fresh bread was buttered by the nanny.*	
N-1	The fresh bread	The toaster oven
SA-1	The sesame bagel beside the fresh bread	The powerful beside the fresh bread
NA-1	The sesame bread in the toaster oven	The powerful microwave near the toaster
78	*The toaster oven was unplugged by the electrician.*	
N-1	The toaster oven	The fresh bread
SA-1	The powerful beside the fresh bread	The sesame bagel beside the fresh bread
NA-1	The powerful microwave near the toaster	The sesame bread in the toaster oven
79	*The flower bouquet was watered by the careful florist.*	
N-1	The flower bouquet	The sparkling diamond
SA-1	The beautiful roses in the flower bouquet	The red rubies beside the flower bouquet
NA-1	The beautiful roses and the sparkling diamond	The red rubies beside the sparkling diamond
80	*The sparkling diamond was mined by the experienced miners.*	
N-1	The sparkling diamond	The flower bouquet
SA-1	The red rubies beside the flower bouquet	The beautiful roses in the flower bouquet

NA-1	The red rubies beside the sparkling diamond	The beautiful roses and the sparkling diamond
81	*The handmade scarf was embroidered by the kind grandmother.*	
N-1	The handmade scarf	The wooden chair
SA-1	The soft fabric of the handmade scarf	The oak table under the handmade scarf
NA-1	The soft fabric on the wooden chair	The oak table beside the wooden chair
82	*The wooden chair was varnished by the owner of the antique store.*	
N-1	The wooden chair	The handmade scarf
SA-1	The oak table under the handmade scarf	The soft fabric of the handmade scarf
NA-1	The oak table beside the wooden chair	The soft fabric on the wooden chair
83	*The old carpet was vacuumed by the landlord.*	
N-1	The old carpet	The small window
SA-1	The dirty rug on the old carpet	The tarnished mirror above the old carpet
NA-1	The dirty rug below the small window	The tarnished mirror beside the small window
84	*The small window was shattered by the boy's baseball.*	
N-1	The small window	The old carpet
SA-1	The tarnished mirror above the old carpet	The dirty rug on the old carpet
NA-1	The tarnished mirror beside the small window	The dirty rug below the small window
85	*The hallway carpet was woven by a skilled craftsmen*	
N-1	The hallway carpet	The heavy door
SA-1	The welcome mat on the hallway carpet	The wooden trim around the hallway carpet
NA-1	The welcome mat by the heavy door	The wooden trim around the heavy door
86	*The heavy door was carved by the talented carpenter.*	
N-1	The heavy door	The hallway carpet
SA-1	The wooden trim around the hallway carpet	The welcome mat on the hallway carpet
NA-1	The wooden trim around the heavy door	The welcome mat by the heavy door
87	*The fresh fish was filleted by the restaurant employee.*	
N-1	The fresh fish	The big kitchen
SA-1	The roast chicken beside the fresh fish	The wooden shelf above the fresh fish
NA-1	The roast chicken in the big kitchen	The wooden shelf in the big kitchen
88	*The big kitchen was repainted by the interior decorator.*	
N-1	The big kitchen	The fresh fish
SA-1	The wooden shelf above the fresh fish	The roast chicken beside the fresh fish
NA-1	The wooden shelf in the big kitchen	The roast chicken in the big kitchen
89	*The religious war was conducted by the general.*	
N-1	The religious war	The counterfeit money
SA-1	The crucial battle in the religious war	The looted riches from the religious war
NA-1	The crucial battle over the counterfeit money	The looted riches beside the counterfeit money
90	*The counterfeit money was hidden by the clever criminal.*	
N-1	The counterfeit money	The religious war
SA-1	The looted riches from the religious war	The crucial battle in the religious war

NA-1	The looted riches beside the counterfeit money	The crucial battle over the counterfeit money
91	*The wedding dress was sewed very quickly.*	
N-1	The wedding dress	The clothing rack
SA-1	The dust cover for the wedding dress	The silver coat-hanger for the wedding dress
NA-1	The dust cover on the clothing rack	The silver coat-hanger on the clothing rack
92	*The clothing rack was polished very carefully.*	
N-1	The clothing rack	The wedding dress
SA-1	The silver coat-hanger for the wedding dress	The dust cover for the wedding dress
NA-1	The silver coat-hanger on the clothing rack	The dust cover on the clothing rack
93	*The cosy sweater was knit in just one evening.*	
N-1	The cosy sweater	The leather jacket
SA-1	The wool hood for the cosy sweater	The gold buttons on the cosy sweater
NA-1	The wool hood on the leather jacket	The gold buttons on the leather jacket
94	*The leather jacket was polished after the walk in the rain.*	
N-1	The leather jacket	The cosy sweater
SA-1	The gold buttons on the cosy sweater	The wool hood for the cosy sweater
NA-1	The gold buttons on the leather jacket	The wool hood on the leather jacket
95	*The warm soup was poured into a large bowl.*	
N-1	The warm soup	The roasted lamb
SA-1	The salty broth from the warm soup	The chicken chunks in the warm soup
NA-1	The salty broth from the roasted lamb	The chicken chunks beside the roasted lamb
96	*The roasted lamb was skewered with great care.*	
N-1	The roasted lamb	The warm soup
SA-1	The chicken chunks in the warm soup	The salty broth from the warm soup
NA-1	The chicken chunks beside the roasted lamb	The salty broth from the roasted lamb
97	*The large lawn was cut every weekend.*	
N-1	The large lawn	The rural house
SA-1	The tall grass on the large lawn	The front porch beside the large lawn
NA-1	The tall grass around the rural house	The front porch of the rural house
98	*The rural house was repainted at the end of the summer.*	
N-1	The rural house	The large lawn
SA-1	The front porch beside the large lawn	The tall grass on the large lawn
NA-1	The front porch of the rural house	The tall grass around the rural house
99	*The office desk was varnished in the backyard.*	
N-1	The office desk	The new computer
SA-1	The sturdy shelf for the office desk	The copyrighted software on the office desk
NA-1	The sturdy shelf for the new computer	The copyrighted software for the new computer
100	*The new computer was programmed in about an hour.*	
N-1	The new computer	The office desk
SA-1	The copyrighted software on the office desk	The sturdy shelf for the office desk
NA-1	The copyrighted software for the new computer	The sturdy shelf for the new computer

101	*The iron ore was mined from a steep hillside.*	
N-1	The iron ore	The cotton pouch
SA-1	The gold nuggets near the iron ore	The burlap sack for the iron ore
NA-1	The gold nuggets in the cotton pouch	The burlap sack with the cotton pouch
102	*The cotton pouch was sewed very carefully.*	
N-1	The cotton pouch	The iron ore
SA-1	The burlap sack for the iron ore	The gold nuggets near the iron ore
NA-1	The burlap sack with the cotton pouch	The gold nuggets in the cotton pouch
103	*The television show was broadcast all evening.*	
N-1	The television show	The decrepit slum
SA-1	The radio announcement about the television show	The prominent billboard about the television show
NA-1	The radio announcement about the decrepit slum	The prominent billboard in the decrepit slum
104	*The decrepit slum was bulldozed with no warning.*	
N-1	The decrepit slum	The television show
SA-1	The prominent billboard about the television show	The radio announcement about the television show
NA-1	The prominent billboard in the decrepit slum	The radio announcement about the decrepit slum
105	*The baby outfit was knit before the baby was born.*	
N-1	The baby outfit	The clothes closet
SA-1	The little socks for the baby outfit	The wooden drawer for the baby outfit
NA-1	The little socks in the clothes closet	The wooden drawer in the clothes closet
106	*The clothes closet was constructed in a single day.*	
N-1	The clothes closet	The baby outfit
SA-1	The wooden drawer for the baby outfit	The little socks for the baby outfit
NA-1	The wooden drawer in the clothes closet	The little socks in the clothes closet
107	*The spicy stew was seasoned with lots of salt.*	
N-1	The spicy stew	The glass lid
SA-1	The beef cubes in the spicy stew	The large pot for the spicy stew
NA-1	The beef cubes under the glass lid	The large pot with the glass lid
108	*The glass lid was washed very quickly.*	
N-1	The glass lid	The spicy stew
SA-1	The large pot for the spicy stew	The beef cubes in the spicy stew
NA-1	The large pot with the glass lid	The beef cubes under the glass lid
109	*The spacious apartment was swept after the big party.*	
N-1	The spacious apartment	The steel sink
SA-1	The dining room in the spacious apartment	The ceramic bathtub in the spacious apartment
NA-1	The dining room with the steel sink	The ceramic bathtub near the steel sink
110	*The steel sink was unclogged quickly with a special liquid*	
N-1	The steel sink	The spacious apartment
SA-1	The ceramic bathtub in the spacious	The dining room in the spacious apartment

	apartment	
NA-1	The ceramic bathtub near the steel sink	The dining room with the steel sink
111	*The soft wood was sanded very carefully.*	
N-1	The soft wood	The satin cord
SA-1	The small block of the soft wood	The thick rope around the soft wood
NA-1	The small block underneath the satin cord	The thick rope beside the satin cord
112	*The satin cord was woven very tightly.*	
N-1	The satin cord	The soft wood
SA-1	The thick rope around the soft wood	The small block of the soft wood
NA-1	The thick rope beside the satin cord	The small block underneath the satin cord
113	*The front lawn was mowed very sloppily.*	
N-1	The front lawn	The front door
SA-1	The green grass on the front lawn	The wooden gate to the front lawn
NA-1	The green grass by the front door	The wooden gate beside the front door
114	*The front door was latched very loosely.*	
N-1	The front door	The front lawn
SA-1	The wooden gate to the front lawn	The green grass on the front lawn
NA-1	The wooden gate beside the front door	The green grass by the front door
115	*The elegant needlepoint was stitched very neatly.*	
N-1	The elegant needlepoint	The elegant sculpture
SA-1	The simple ruffles around the elegant needlepoint	The marble block beneath the elegant needlepoint
NA-1	The simple ruffles around the elegant sculpture	The marble block under the elegant sculpture
116	*The elegant sculpture was chiseled very gradually.*	
N-1	The elegant sculpture	The elegant needlepoint
SA-1	The marble block beneath the elegant needlepoint	The simple ruffles around the elegant needlepoint
NA-1	The simple ruffles around the elegant sculpture	The simple ruffles around the elegant sculpture
117	*The vintage dress was ironed very carelessly.*	
N-1	The vintage dress	The frayed seatbelt
SA-1	The rough fabric of the vintage dress	The metal buckle on the vintage dress
NA-1	The rough fabric of the frayed seatbelt	The metal buckle on the frayed seatbelt
118	*The frayed seatbelt was unbuckled very quickly.*	
N-1	The frayed seatbelt	The vintage dress
SA-1	The metal buckle on the vintage dress	The rough fabric of the vintage dress
NA-1	The metal buckle on the frayed seatbelt	The rough fabric of the frayed seatbelt
119	*The minestrone soup was seasoned with great care.*	
N-1	The minestrone soup	The deep bowl
SA-1	The thick broth for the minestrone soup	The large spoon for the minestrone soup
NA-1	The thick broth in the deep bowl	The large spoon near the deep bowl
120	*The deep bowl was washed very thoroughly.*	
N-1	The deep bowl	The minestrone soup

SA-1	The large spoon for the minestrone soup	The thick broth for the minestrone soup
NA-1	The large spoon near the deep bowl	The thick broth in the deep bowl
121	*The flaky pastry was rolled until it was flat.*	
N-1	The flaky pastry	The rectangular dish
SA-1	The thin crust of the flaky pastry	The sharp knife for the flaky pastry
NA-1	The thin crust inside the rectangular dish	The sharp knife beside the rectangular dish
122	*The rectangular dish was washed until it was clean.*	
N-1	The rectangular dish	The flaky pastry
SA-1	The sharp knife for the flaky pastry	The thin crust of the flaky pastry
NA-1	The sharp knife beside the rectangular dish	The thin crust inside the rectangular dish
123	*The powerless regime was overthrown quickly and easily.*	
N-1	The powerless regime	The anti-ballistic missile
SA-1	The violent leadership of the powerless regime	The heavy guns of the powerless regime
NA-1	The violent leadership with the anti-ballistic missile	The heavy guns near the anti-ballistic missile
124	*The anti-ballistic missile was confiscated before the fighting started.*	
N-1	The anti-ballistic missile	The powerless regime
SA-1	The heavy guns of the powerless regime	The violent leadership of the powerless regime
NA-1	The heavy guns near the anti-ballistic missile	The violent leadership with the anti-ballistic missile
125	*The tall mountain was scaled very quickly.*	
N-1	The tall mountain	The wide river
SA-1	The icy peak of the tall mountain	The fast rapids beside the tall mountain
NA-1	The ice peak near the wide river	The fast rapids in the wide river
126	*The wide river was kayaked every day during the summer.*	
N-1	The wide river	The tall mountain
SA-1	The fast rapids beside the tall mountain	The icy peak of the tall mountain
NA-1	The fast rapids in the wide river	The ice peak near the wide river
127	*The white paper was shredded in the office.*	
N-1	The white paper	The blue crayon
SA-1	The brown cardboard near the white paper	The green pencil near the white paper
NA-1	The brown cardboard near the blue crayon	The green pencil near the blue crayon
128	*The blue crayon was sharpened to a fine point.*	
N-1	The blue crayon	The white paper
SA-1	The green pencil near the white paper	The brown cardboard near the white paper
NA-1	The green pencil near the blue crayon	The brown cardboard near the blue crayon
129	*The apple pie was eaten very quickly.*	
N-1	The apple pie	The iced coffee
SA-1	The cinnamon buns beside the apple pie	The cold soda beside the apple pie
NA-1	The cinnamon buns beside the iced coffee	The cold soda beside the iced coffee
130	*The iced coffee was poured into a tall glass.*	
N-1	The iced coffee	The apple pie

SA-1	The cold soda beside the apple pie	The cinnamon buns beside the apple pie
NA-1	The cold soda beside the iced coffee	The cinnamon buns beside the iced coffee
131	*The car floor was vacuumed very hastily.*	
N-1	The car floor	The small engine
SA-1	The sturdy mat on the car floor	The wheel axle below the car floor
NA-1	The sturdy mat under the small engine	The wheel axle behind the small engine
132	*The small engine was oiled with the wrong kind of oil.*	
N-1	The small engine	The car floor
SA-1	The wheel axle below the car floor	The sturdy mat on the car floor
NA-1	The wheel axle behind the small engine	The sturdy mat under the small engine
133	*The credit card was swiped very quickly.*	
N-1	The credit card	The handwritten paragraph
SA-1	The magnetic strip on the credit card	The fancy signature on the credit card
NA-1	The magnetic strip below the handwritten paragraph	The fancy signature below the handwritten paragraph
134	*The handwritten paragraph was written in a hurry.*	
N-1	The handwritten paragraph	The credit card
SA-1	The fancy signature on the credit card	The magnetic strip on the credit card
NA-1	The fancy signature below the handwritten paragraph	The magnetic strip below the handwritten paragraph
135	*The steep driveway was paved every ten years.*	
N-1	The steep driveway	The tall fence
SA-1	The narrow sidewalk by the steep driveway	The wooden posts by the steep driveway
NA-1	The narrow sidewalk by the tall fence	The wooden posts for the tall fence
136	*The tall fence was erected very carelessly.*	
N-1	The tall fence	The steep driveway
SA-1	The wooden posts by the steep driveway	The narrow sidewalk by the steep driveway
NA-1	The wooden posts for the tall fence	The narrow sidewalk by the tall fence
137	*The editorial page was proofread very thoroughly.*	
N-1	The editorial page	The downtown building
SA-1	The opinion column on the editorial page	The meeting room for the editorial page
NA-1	The opinion column about the downtown building	The meeting room in the downtown building
138	*The downtown building was ransacked very violently*	
N-1	The downtown building	The editorial page
SA-1	The meeting room for the editorial page	The opinion column on the editorial page
NA-1	The meeting room in the downtown building	The opinion column about the downtown building
139	*The metal pot was polished until it was shiny.*	
N-1	The metal pot	The green spinach
SA-1	The serving spoon in the metal pot	The pungent onion in the metal pot
NA-1	The serving spoon for the green spinach	The pungent onions beside the green spinach
140	*The green spinach was chopped into tiny pieces*	
N-1	The green spinach	The metal pot

SA-1	The pungent onion in the metal pot	The serving spoon in the metal pot
NA-1	The pungent onions beside the green spinach	The serving spoon for the green spinach
141	*The bicycle chain was oiled before the race.*	
N-1	The bicycle chain	The bicycle tire
SA-1	The metal cogs on the bicycle chain	The inner tube beside the bicycle chain
NA-1	The metal cogs beside the bicycle tire	The inner tube in the bicycle tire
142	*The bicycle tire was inflated at the store.*	
N-1	The bicycle tire	The bicycle chain
SA-1	The inner tube beside the bicycle chain	The metal cogs on the bicycle chain
NA-1	The inner tube in the bicycle tire	The metal cogs beside the bicycle tire
143	*The tropical plant was watered every day.*	
N-1	The tropical plant	The vacation home
SA-1	The fertile soil underneath the tropical plant	The sunny room with the tropical plant
NA-1	The fertile soil around the vacation home	The sunny room in the vacation room.
144	*The vacation home was locked every night.*	
N-1	The vacation home	The tropical plant
SA-1	The sunny room with the tropical plant	The fertile soil underneath the tropical plant
NA-1	The sunny room in the vacation room.	The fertile soil around the vacation home
145	*The newspaper article was written in only one hour.*	
N-1	The newspaper article	The scandalous photograph
SA-1	The first paragraph of the newspaper article	The vivid image in the newspaper article
NA-1	The first paragraph about the scandalous photograph	The vivid image in the scandalous photograph
146	*The scandalous photograph was photoshopped with great skill*	
N-1	The scandalous photograph	The newspaper article
SA-1	The vivid image in the newspaper article	The first paragraph of the newspaper article
NA-1	The vivid image in the scandalous photograph	The first paragraph about the scandalous photograph
147	*The oversized couch was reupholstered after it as sold.*	
N-1	The oversized couch	The wooden figurine
SA-1	The fat pillow on the oversized couch	The antique table near the oversized couch
NA-1	The fat pillow beside the wooden figurine	The antique table beneath the wooden figurine
148	*The wooden figurine was carved very elegantly.*	
N-1	The wooden figurine	The oversized couch
SA-1	The antique table near the oversized couch	The fat pillow on the oversized couch
NA-1	The antique table beneath the wooden figurine	The fat pillow beside the wooden figurine
149	*The short off-ramp was paved during the month of June.*	
N-1	The short off-ramp	The oak tree
SA-1	The interstate highway with the short off-ramp	The yellow daffodils near the short off-ramp
NA-1	The interstate highway near the oak tree	The yellow daffodils around the oak tree
150	*The oak tree was planted at the end of the winter.*	

N-1	The oak tree	The short off-ramp
SA-1	The yellow daffodils near the short off-ramp	The interstate highway with the short off-ramp
NA-1	The yellow daffodils around the oak tree	The interstate highway near the oak tree
151	*The fresh broccoli was harvested when it was ripe.*	
N-1	The fresh broccoli	The farmer's market
SA-1	The large zucchini near the fresh broccoli	The vegetarian café with the fresh broccoli
NA-1	The large zucchini in the farmer's market	The vegetarian café near the farmer's market
152	*The farmer's market was built very quickly.*	
N-1	The farmer's market	The fresh broccoli
SA-1	The vegetarian café with the fresh broccoli	The large zucchini near the fresh broccoli
NA-1	The vegetarian café near the farmer's market	The large zucchini in the farmer's market
153	*The check-out counter was constructed out of scrap wood.*	
N-1	The check-out counter	The fresh produce
SA-1	The long shelf below the check-out counter	The juicy raspberries on the check-out counter
NA-1	The long shelf for the fresh produce	The juicy raspberries in the fresh produce
154	*The fresh produce was refrigerated to keep it fresh.*	
N-1	The fresh produce	The check-out counter
SA-1	The juicy raspberries on the check-out counter	The long shelf below the check-out counter
NA-1	The juicy raspberries in the fresh produce	The long shelf for the fresh produce
155	*The green apple was sliced into thin pieces.*	
N-1	The green apple	The cutting board
SA-1	The yellow bananas near the green apple	The wooden spoon near the green apple
NA-1	The yellow bananas on the cutting board	The wooden spoon on the cutting board
156	*The cutting board was varnished in the backyard.*	
N-1	The cutting board	The green apple
SA-1	The wooden spoon near the green apple	The yellow bananas near the green apple
NA-1	The wooden spoon on the cutting board	The yellow bananas on the cutting board
157	*The soccer field was mowed in the early morning.*	
N-1	The soccer field	The soccer game
SA-1	The grass turf on the soccer field	The penalty shot on the soccer field
NA-1	The grass turf for the soccer game	The penalty shot during the soccer game
158	*The soccer game was refereed very fairly.*	
N-1	The soccer game	The soccer field
SA-1	The penalty shot on the soccer field	The grass turf on the soccer field
NA-1	The penalty shot during the soccer game	The grass turf for the soccer game
159	*The stuffed turkey was sliced very carefully*	
N-1	The stuffed turkey	The wine glass
SA-1	The roast beef beside the stuffed turkey	The glass platter for the stuffed turkey
NA-1	The roast beef near the wine glass	The glass platter near the wine glass
160	*The wine glass was shattered into many pieces.*	
N-1	The wine glass	The stuffed turkey

SA-1	The glass platter for the stuffed turkey	The roast beef beside the stuffed turkey
NA-1	The glass platter near the wine glass	The roast beef near the wine glass
161	*The indoor plant was watered every morning.*	
N-1	The indoor plant	The brick wall
SA-1	The soft soil for the indoor plant	The wooden door behind the indoor plant
NA-1	The soft soil below the brick wall	The wooden door beside the brick wall
162	*The brick wall was painted with green paint.*	
N-1	The brick wall	The indoor plant
SA-1	The wooden door behind the indoor plant	The soft soil for the indoor plant
NA-1	The wooden door beside the brick wall	The soft soil below the brick wall
163	*The vintage whiskey was poured very cautiously*	
N-1	The vintage whiskey	The black-tie dinner
SA-1	The expensive vodka beside the vintage whiskey	The silent auction for the vintage whiskey
NA-1	The expensive vodka at the black-tie dinner	The silent auction at the black-tie dinner
164	*The black-tie dinner was attended happily by all the guests.*	
N-1	The black-tie dinner	The vintage whiskey
SA-1	The silent auction for the vintage whiskey	The expensive vodka beside the vintage whiskey
NA-1	The silent auction at the black-tie dinner	The expensive vodka at the black-tie dinner
165	*The wool rug was woven in a foreign country.*	
N-1	The wool rug	The work bench
SA-1	The thick yarn for the wool rug	The wooden shelf above the wool rug
NA-1	The thick yarn on the work bench	The wooden shelf above the work bench
166	*The work bench was varnished really carefully.*	
N-1	The work bench	The wool rug
SA-1	The wooden shelf above the wool rug	The thick yarn for the wool rug
NA-1	The wooden shelf above the work bench	The thick yarn on the work bench
167	*The urgent payment was calculated using a calculator.*	
N-1	The urgent payment	The dented door
SA-1	The final invoice for the urgent payment	The used car with the urgent payment
NA-1	The final invoice for the dented door	The used car with the dented door
168	*The dented door was repainted with red paint.*	
N-1	The dented door	The urgent payment
SA-1	The used car with the urgent payment	The final invoice for the urgent payment
NA-1	The used car with the dented door	The final invoice for the dented door
169	*The expensive cocktail was stirred with a spoon.*	
N-1	The expensive cocktail	The smelly cheese
SA-1	The fine liqueur for the expensive cocktail	The salty crackers beside the expensive cocktail
NA-1	The fine liqueur near the smelly cheese	The salty crackers for the smelly cheese
170	*The smelly cheese was eaten with gusto.*	
N-1	The smelly cheese	The expensive cocktail
SA-1	The salty crackers beside the expensive	The fine liqueur for the expensive cocktail

	cocktail	
NA-1	The salty crackers for the smelly cheese	The fine liqueur near the smelly cheese
171	*The white snow was shoveled with a metal spade.*	
N-1	The white snow	The thorny rosebush
SA-1	The wet dirt under the white snow	The pretty daisies near the white snow
NA-1	The wet dirt around the thorny rosebush	The pretty daisies near the thorny rosebush
172	*The thorny rosebush was planted in a window box.*	
N-1	The thorny rosebush	The white snow
SA-1	The pretty daisies near the white snow	The wet dirt under the white snow
NA-1	The pretty daisies near the thorny rosebush	The wet dirt around the thorny rosebush
173	*The formal invitation was written using a special pen.*	
N-1	The formal invitation	The rehearsal dinner
SA-1	The friendly message in the formal invitation	The delicious meal with the formal invitation
NA-1	The friendly message about the rehearsal dinner	The delicious meal at the rehearsal dinner
174	*The rehearsal dinner was catered without regard to cost.*	
N-1	The rehearsal dinner	The formal invitation
SA-1	The delicious meal with the formal invitation	The friendly message in the formal invitation
NA-1	The delicious meal at the rehearsal dinner	The friendly message about the rehearsal dinner
175	*The veterinary textbook was edited with great caution.*	
N-1	The veterinary textbook	The cat's body
SA-1	The first chapter in the veterinary textbook	The diseased kidney beside the veterinary textbook
NA-1	The first chapter about the cat's body	The diseased kidney from the cat's body
176	*The cat's body was dissected in the laboratory.*	
N-1	The cat's body	The veterinary textbook
SA-1	The diseased kidney beside the veterinary textbook	The first chapter in the veterinary textbook
NA-1	The diseased kidney from the cat's body	The first chapter about the cat's body
177	*The stuffed turkey was carved into thin slices.*	
N-1	Thee stuffed turkey	The handwritten recipe
SA-1	The orange pumpkin beside the stuffed turkey	The ingredient list for the stuffed turkey
NA-1	The orange pumpkin for the handwritten recipe	The ingredient list from the handwritten recipe
178	*The handwritten recipe was photocopied many times.*	
N-1	The handwritten recipe	Thee stuffed turkey
SA-1	The ingredient list for the stuffed turkey	The orange pumpkin beside the stuffed turkey
NA-1	The ingredient list from the handwritten recipe	The orange pumpkin for the handwritten recipe
179	*The granite countertop was cleaned very thoroughly.*	
N-1	The granite countertop	The lemon sherbet
SA-1	The metal scoop on the granite countertop	The waffle cones on the granite countertop

NA-1	The metal scoop for the lemon sherbet	The waffle cones for the lemon sherbet
180	*The lemon sherbet was devoured with pleasure.*	
N-1	The lemon sherbet	The granite countertop
SA-1	The waffle cones on the granite countertop	The metal scoop on the granite countertop
NA-1	The waffle cones for the lemon sherbet	The metal scoop for the lemon sherbet

Bibliography

Allen, M., Badecker, B. & Osterhout, L. (2003). Morphological analysis in sentence processing: and ERP study. *Language and Cognitive Processes, 18*, 405-430.

Andrews, S., Miller, B. & Rayner, K. (2004). Eye movements and morphological segmentation of compound words: There is a mouse in mousetrap. *European Journal of Cognitive Psychology, 16*, 285-311.

Aoshima, S., Phillips, C. & Weinberg, A. (2004). Processing filler-gap dependencies in a head-final language. *Journal of Memory and Language, 51*, 23-54.

Aoshima, S., Yoshida, M. & Phillips, C. (in press). Incremental processing of coreference and binding in Japanese. *Syntax*.

Badecker, W. & Straub, K. (2002). The processing role of structural constraints on the interpretations of pronouns and anaphors. *Journal of Experimental Psychology – Learning, Memory and Cognition, 28*, 748-769.

Bader, M. & Lasser, L. (1994). German verb-final clauses and sentence processing: Evidence for immediate attachment. In *Perspectives on sentence processing*, ed. C. Clifton, Jr., L. Frazier & K. Rayner, 225-242. Hillsdale, NJ: Lawrence Erlbaum Associates.

Barber, H. & Carreiras, M. (2003). Integrating gender and number information is Spanish word pairs: An ERP study. *Cortex, 39*, 465-482.

Barber, H. & Carreiras, M. (2005). Grammatical gender and number agreement in Spanish: An ERP Comparison. *Journal of Cognitive Neuroscience, 17*, 137-153.

Beltrán, D. Carreiras, M., Álvarez, M. & Santamaría, C. (2006). Verification of quantified sentences: An ERP study. *Poster presented at the Cognitive Neuroscience Society annual meeting*, San Francisco.

Bentin, S., McCarthy, G. & Wood, C.C. (1985). Event-related potentials, lexical decision and semantic priming. *Electroencephalography and Clinical Neurophysiology, 60*, 343-355.

Bever, T.G. (1970). The cognitive basis for linguistic structures. In J.R. Hayes (Ed.), *Cognition and the development of language* (pp. 279-362). New York: Wiley.

Bornkessel, I. & Schlesewsky, M. (2006). The extended argument dependency model: A neurocognitive approach to sentence comprehension across languages. *Psychological Review, 113*, 787-821.

Bornkessel-Schlesewsky, I. & Schlesewsky, M. (2008). An alternative perspective on "semantic P600" effects in language comprehension. *Brain Research Reviews*.

Brown, C. & Hagoort, P. (1993). The processing nature of the N400: Evidence from masked priming. *Journal of Cognitive Neuroscience, 5*, 34-44.

Bybee, J. (1995). Regular morphology and the lexicon. *Language and Cognitive Processes, 10*, 425-455.

Camblin, C.C., Gordon, P.C. & Swaab, T.Y. (2007). The interplay of discourse congruence and lexical association during sentence processing: Evidence from ERPs and eye tracking. *Journal of Memory and Language, 56*, 103-128.

Caramazza, A., Laudanna, A. & Romani, C. (1988). Lexical access and inflectional morphology. *Cognition, 28*, 297-332.

Carlson, G.N. (1977). A unified analysis of the English bare plural. *Linguistics and Philosophy, 1*, 413-458.

Demiral, S.B., Schlesewsky, M. & Bornkessel-Schlesewsky, I. (2008). On the universality of language comprehension strategies. *Cognition, 106*, 484-500.

De Vincenzi, M., Job, R., Di Matteo, R., Angrilli, A., Penolazzi, B., Ciccarelli, L. & Vespignani, F. (2003) Differences in the perception and time course of syntactic and semantic violations. *Brain and Language, 85*, 280-296.

Drenhaus, H., Graben, P. beim & Frisch, S. (2006). Not all but some ERP results on the scalar expressions 'some' and 'all'. *Poster presented at the Cognitive Neuroscience Society annual meeting*, San Francisco.

Drenhaus, H., Saddy, D. & Frisch, S. (2005). Processing negative polarity items: when negation comes through the backdoor. In: Kepser, S. & Reis, M. (eds.) *Linguistic Evidence - Empirical, Theoretical, and Computational Perspectives,* Berlin, New York: Mouton de Gruyter, pp.145-165.

Federmeier, K.D. & Kutas, M. (1999). A rose by any other name: Long-term memory structure and sentence processing. *Journal of Memory and Language, 41*, 469-495.

Ferreira, F. (2003). The misinterpretation of noncanonical sentences. *Cognitive Psychology, 47*, 164-203.

Ferreira, F., Bailey, K.G.D. & Ferraro, V. (2002). Good-enough representations in language comprehension. *Current Directions in Psychological Science, 11*, 11-15.

Ferreira, F. & Clifton, C. (1986). The independence of syntactic processing. *Journal of Memory and Language, 25*, 348-368.

Ferreira, F. & Henderson, J.M. (1990). Use of verb information in syntactic parsing – Evidence from eye-movements and word-by-word self-paced reading. *Journal of Experimental Psychology – Learning, Memory and Cognition, 16*, 555-568.

Ferreira, F. & Patson, N. (2007). The good enough approach to language comprehension. *Language and Linguistics Compass, 1*, 71-83.

Fiebach, C., Schlesewsky, M., & Friederici, A. (2002). Separating syntactic memory costs and syntactic integration costs during parsing: The processing of German WH-questions. *Journal of Memory and Language, 47,* 250-272.

Fischler, I., Bloom, P., Childers, D.G., Roucos, S.E. & Perry, N.W. (1983). Brain potentials related to stages of sentence verification. *Psychophysiology, 20*, 400-409.

Fowler, C.A., Napps, S.E. & Feldman, L. (1985). Relations among regular and irregular morphologically related words in the lexicon as revealed by repetition priming. *Memory and Cognition, 13*, 241-255.

Frazier, L. & Clifton, C. (1996). *Construal*. Cambridge, MA: MIT Press.

Friederici, A. D. & Frisch, S. (2000). Verb argument structure processing: The role of verb-specific and argument-specific information. *Journal of Memory and Language, 43*, 476-507.

Friederici, A. D., Hahne, A., & Mecklinger, A. (1996). The temporal structure of syntactic parsing: Early vs. late effects elicited by syntactic anomalies. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*, 1219-1248.

Friederici, A.D., Hahne, A. & von Cramon, D.Y. (1998). First-pass versus second-pass parsing processes in a Wernicke's and a Broca's aphasic: Electrophysiological evidence for a double dissociation. *Brain and Language, 62*, 311-341.

Friederici, A. D., Pfeifer, E., & Hahne, A. (1993). Event-related brain potentials during natural speech processing: Effects of semantic, morphological, and syntactic violations. *Cognitive Brain Research, 1*, 183-192.

Friederici, A.D., Steinhauer, K. & Frisch, S. (1999). Lexical integration: Sequential effects of syntactic and semantic information. *Memory and Cognition, 27*, 438-453.

Frisch, S. & Schlesewsky, M. (2001). The N400 reflects problems of thematic hierarchizing. *Neuroreport, 12*, 3391-3394.

Frisch, S., Schlesewsky, M., Saddy, D., & Alpermann, A. (2002). The P600 as an indicator of syntactic ambiguity. *Cognition, 85*, B83-B92.

Garnsey, S.M., Pearlmutter, N.J., Myers, E. & Lotocky, M.A. (1997). The contributions of verb bias and plausibility to the comprehension of temporarily ambiguous sentences. *Journal of Memory and Language, 37*, 58-93.

Geyer, A., Holcomb, P., Kuperberg, G. & Perlmutter, N. (2006). Plausibility and sentence comprehension. An ERP study. *Cognitive Neuroscience Supplement, Abstract*.

Giraudo, H. & Grainger, J. (2000). Effects of prime word frequency and cumulative root frequency in masked morphological priming. *Language and Cognitive Processes, 15*, 421-444.

Gordon, P.C., Hendrick, R., Johnson, M., & Lee, Y. (2006). Similarity-based interference during language comprehension: Evidence from eye tracking during reading. *Journal of Experimental Psychology – Learning, Memory and Cognition, 32,* 1304-1321

Greenhouse, S. & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 24*, 95-112.

Hagoort, P. (2008). The fractionation of spoken language understanding by measuring electrical and magnetic brain signals. *Philosophical Transactions of the Royal Society B – Biological Sciences, 363*, 1055-1069.

Hagoort, P., Brown, C. M., & Groothusen, J. (1993). The Syntactic Positive Shift (SPS) as an ERP measure of syntactic processing. *Language and Cognitive Processes, 8*, 439-484.

Hagoort, P., Hald, L., Bastiaansen, M.C.M. & Petersson, K.M. (2004). Integration of word meaning and world knowledge in language comprehension. *Science, 304*, 438-440.

Hahne, A., & Friederici, A. D. (1999). Electrophysiological evidence for two steps in syntactic analysis: Early automatic and late controlled processes. *Journal of Cognitive Neuroscience, 11*, 193-204.

Hahne, A. & Friederici, A. (2002). Differential task effects on semantic and syntactic processes as revealed by ERPs. *Cognitive Brain Research, 13*, 339-356.

Heim, I. & Kratzer, A. (1998). *Semantics in Generative Grammar*. Oxford: Blackwell.

Hoeks, J.C.J., Stowe, L.A. & Doedens, G. (2004). Seeing words in context: the interaction of lexical and sentence level information during reading. *Cognitive Brain Research, 19*, 59-73.

Holcomb, P.J. (1988). Automatic and attentional processing: an event-related brain potential analysis of semantic priming. *Brain and Language, 35*, 66-85.

Holcomb, P.J. (1993). Semantic priming and stimulus degradation: implications for the role of the N400 in language processing. *Psychophysiology, 30*, 47-61.

Hyönä, J. & Pollatsek, A. (1998). Reading Finnish compound words: Eye fixations are affected by compound morphemes. *Journal of Experimental Psychology – Human Perception and Performance, 24*, 1612-1627.

Jackendoff, R. (2002). *Foundations of Language: Brain, Meaning, Grammar, Evolution.* Oxford, New York: Oxford University Press.

Kaan, E. (2002). Investigating the effects of distance and number interference in processing subject-verb dependencies: An ERP study. *Journal of Psycholinguistic Research, 31*, 165-193.

Kaan, E., Harris, A., Gibson, E. & Holcomb, P. (2000). The P600 as an index of syntactic integration difficulty. *Language & Cognitive Processes, 15*, 159-201.

Kaan, E., & Swaab, T. Y. (2003). Electrophysiological evidence for serial sentence processing: A comparison between non-preferred and ungrammatical continuations. *Cognitive Brain Research, 17,* 621-635.

Kamide, Y., Altmann, G.T.M. & Haywood, S. (2003). The time-course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory and Language, 49*, 133-156.

Kamide, Y. & Mitchell, D.C. (1999). Incremental pre-head attachment in Japanese parsing. *Language and Cognitive Processes, 14*, 631-662.

Kazanina, N., Lau, E., Lieberman, M., Yoshida, M. & Phillips, C. (2007). The effect of syntactic constraints on the processing of backwards anaphora. *Journal of Memory and Language, 56*, 384-409.

Kennison, S.M. (2001). Limitations on the use of verb information during sentence comprehension. *Psychonomic Bulletin & Review, 8*, 132-138.

Kim, A. & Osterhout, L. (2005). The independence of combinatory semantic processing: Evidence from event-related potentials. *Journal of Memory and Language, 52*, 205-225.

Kim, A. & Osterhout, L. (2005b). The modulation of "semantic attraction" P600 effects by syntactic factors during sentence comprehension. Poster at Amlap, Sept. 7.

Kolk, H.H.J., Chwilla, D.J., Van Herten, M. & Oor, P. (2003). Structure and limited capacity in verbal working memory: a study with event-related potentials. *Brain and Language, 85*, 1-36.

Kounios, J. (1996). On the continuity of thought and the representation of knowledge: Electrophysiological and behavioral time-course measures reveal levels of structure in semantic memory. *Psychonomic Bulletin & Review, 3*, 265-286.

Kounios, J. & Holcomb, P.J. (1992). Structure and process in semantic memory: evidence from event-related brain potentials and reaction times. *Journal of Experimental Psychology: General, 121*, 459-479.

Kuperberg, G.K. (2007). Neural mechanisms of language comprehension: Challenges to syntax. *Brain Research, 1146*, 23-49.

Kuperberg, G., Caplan D., Sitnikova, T., Eddy, M. & Holcomb, P. (2006). Neural correlates of processing syntactic, semantic and thematic relationships in sentences. *Language and Cognitive Processes, 21*, 489-530.

Kuperberg, G., Kreher, D.A., Sitnikova, T., Caplan, D. & Holcomb, P. (2007). The role of animacy and thematic relationships in processing active English sentences: Evidence from event-related potentials. *Brain and Language, 100*, 223-238.

Kuperberg, G.R., Sitnikova, T., Caplan, P. & Holcomb, P.J. (2003). Electrophysiological distinctions in processing conceptual relationships within simple sentences. *Cognitive Brain Research, 17*, 117-129.

Kutas, M. & Federmeier, K.D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends on Cognitive Science, 4*, 463-470.

Kutas, M. & Hillyard, S.A. (1980). Reading senseless sentences: brain potentials reflect semantic incongruity. *Science, 207*, 203-205.

Kutas, M. & Hillyard, S.A. (1983). Event-related brain potentials to grammatical errors and semantic anomalies. *Memory and Cognition, 11*, 539-550.

Kutas, M. & Hillyard, S.A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature, 307*, 161-163.

Kutas, M., Van Petten, C. & Besson, M. (1988) Event-related potential asymmetries during the reading of sentences. *Electroencephaolography and Clinical Neurophysiology, 69*, 218-233.

Landauer, T.K. & Dumais, S.T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review, 104*, 211-240.

Landauer, T.K., Foltz, P.W. & Laham, D. (1998). An introduction to latent semantic analysis. *Discourse Processes, 25*, 259-284.

Lau, E., Phillips, C. & Poeppel, D. (to appear). A cortical network for semantics: (de)constructing the N400. *Nature Reviews Neuroscience*.

MacDonald, M.C., Pearlmutter, N.J. & Seidenberg, M.S. (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review, 101*, 676-703.

Martín-Loeches, M., Nigbur, R., Casado, P., Hohlfeld, A. & Sommer, W. (2006). Semantics prevalence over syntax during sentence processing: A brain potential study of noun-adjective agreement in Spanish. *Brain Research, 1093*, 178-189.

McKoon, G. & Ratcliff, R. (2007). Interactions of meaning and syntax: Implications for models of sentence comprehension. *Journal of Memory and Language, 56*, 270-290.

Miyamoto, E.T. & Takahashi, S. (2002). Sources of difficulty in the processing of scrambling in Japanese. In *Sentence processing in East Asian languages*, ed. M. Nakayama, 167-188. Stanford, CA: CSLI.

Mulders, I.C.M.C. (2002). *Transparent parsing: head-driven processing of verb-final structures.* Doctoral dissertation, Utrecht: LOT.

Münte, T.F., Heinze, H.J., Matzke, M., Wieringa, B.M. & Johannes, S. (1998). Brain potentials and syntactic violations revisited: no evidence for specificity of the syntactic positive shift. *Neuropsychologia, 36*, 217-226.

Nicol, J.L., Forster, K.I. & Veres, C. (1997). Subject-verb agreement processes in comprehension. *Journal of Memory and Language, 36*, 569-587.

Niemi, J., Laine, M. & Tuominen, J. (1994). Cognitive morphology in Finnish: Foundations of a new model. *Language and Cognitive Processes, 9*, 423-446.

Niswander, E., Pollatsek, A. & Rayner, K. (2000). The processing of derived and inflected suffixed words during reading. *Language and Cognitive Processes, 15*, 389-420.

Noveck, I.A. & Posada, A. (2003). Characterizing the time course of an implicature: an evoked potentials study. *Brain and Language, 85*, 203-210.

Oldfield, R.C. (1971). Assessment and analysis of handedness – Edinburgh Inventory. *Neuropsychologia, 9*, 97.

Osterhout, L., & Holcomb, P. J. (1992). Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language, 31*, 785-806.

Osterhout, L., Holcomb, P. J., & Swinney, D. A. (1994). Brain potentials elicited by garden path sentences: evidence of the application of verb information during parsing. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 20*, 768-803.

Osterhout, L. & Nicol, J. (1999). On the distinctiveness, independence, and time course of the brain responses to syntactic and semantic anomalies. *Language and Cognitive Processes, 14*, 283-317.

Paczynski, M., Kreher, D.A., Ditman, T., Holcomb, P. & Kuperberg, G.R. (2006). Electrophysiological evidence for the role of animacy and lexico-semantic associations in processing nouns within passive structures. *Cognitive Neuroscience Supplement, Abstract.*

Philipp, M., Bornkessel-Schlesewsky, I. & Bisang, W. (2008). The role of animacy in real time comprehension of Mandarin Chinese: Evidence from auditory event-related brain potentials. *Brain and Language, 105*, 112-133.

Phillips, C., Kazanina, N., & Abada, S. H. (2005). ERP effects of the processing of syntactic long-distance dependencies. *Cognitive Brain Research, 22,* 407-428.

Pickering, M.J., Traxler, M.J. & Crocker, M.W. (2000). Ambiguity resolution in sentence processing: Evidence against frequency-based accounts. *Journal of Memory and Language, 43*, 447-475.

Pollard, C. & Sag, I.A. (1994). *Head-Driven Phrase Structure Grammar*. Chicago: University of Chicago Press.

Pollatsek, A., Hyönä, J. & Bertram, R. (2000). The role of morphological constituents in reading Finnish compound words. *Journal of Experimental Psychology – Human Perception and Performance, 26*, 820-833.

Pritchett, B.L. (1988). Garden path phenomena and the grammatical basis of language processing. *Language, 64*, 539-576.

Pritchett, B.L. (1991). Head position and parsing ambiguity. *Journal of Psycholinguistic Research, 20*, 251-270.

Pritchett, B.L. (1992). *Grammatical competence and parsing performance*. Chicago, IL: The University of Chicago Press.

Rayner, K. (1979). Eye guidance in reading – fixation locations within words. *Perception, 8*, 21-30.

Roehm, D., Schlesewsky, M., Bornkessel, I., Frisch, S. & Haider, H. (2004). Fractionating language comprehension via frequency characteristics of the human EEG. *Neuroreport, 15*, 409-412.

Rösler, F., Putz, P., Friederici, A. & Hahne, A. (1993). Event-related brain potentials while encountering semantic and syntactic constraint violations. *Journal of Cognitive Neuroscience, 5*, 345-362.

Rugg, M.D. (1987). Dissociation of semantic priming, word and nonword repetition effects by Event-Related Potentials. *The Quarterly Journal of Experimental Psychology, 39A*, 123-148.

Rugg, M.D. (1990). Event-related potentials dissociate repetition effects of high- and low-frequency words. *Memory and Cognition, 18*, 367-379.

Schreuder, R. and Baayen R. (1995) Modeling morphological processing. In Feldman, L.B. (Ed), *Morphological Aspects of Language Processing*. Lawrence Erlbaum, Hillsdale, New Jersey, pp. 131–154.

Seidenberg, M.S. & Gonnerman, L.M. (2000). Explaining derivational morphology as the convergence of codes. *Trends in Cognitive Science, 4*, 353-361.

Smith, M.E. & Halgren, E. (1987). Event-related potentials during lexical decision: effects of repetition, word frequency, pronounceability, and correctness. *Electroencephalography and Clinical Neurophysiology Supplement, 40*, 417-421.

Spivey, M.J. & Tanenhaus, M.K. (1998). Syntactic ambiguity resolution in discourse: Modeling the effects of referential context and lexical frequency. *Journal of Experimental Psychology – Learning, Memory and Cognition, 24*, 1521-1543.

Staub, A. (2007). The parser doesn't ignore intransitivity, after all. *Journal of Experimental Psychology – Learning, Memory and Cognition, 33*, 550-569.

St. George, M., Mannes, S. & Hoffman, J.E. (1994). Global semantic expectancy and language comprehension. *Journal of Cognitive Neuroscience, 6*, 70-83.

Stowe, L. (1986). Evidence for online gap creation. *Language and Cognitive Processes, 1*, 227-245.

Sturt, P. (2003). The time-course of the application of binding constraints in reference resolution. *Journal of Memory and Language, 48*, 542-562.

Swaab, T.Y., Camblin, C.C. & Gordon, P.C. (2004). Electrophysiological evidence for reversed lexical repetition effects in language processing. *Journal of Cognitive Neuroscience, 16*, 715-726.

Taft, M. (1994). Interactive-activation as a framework for understanding morphological processing. *Language and Cognitive Processes, 9*, 271-294.

Taft, M. & Forster, K.I. (1976). Lexical storage and retrieval of polymorphemic and polysyllabic words. *Journal of Verbal Learning and Verbal Behavior, 15*, 607-620.

Townsend, D.J. & Bever, T.G. (2001). *Sentence Comprehension: The Integration of Habits and Rules*. Cambridge, MA: MIT Press.

Traxler, M.J., Morris, R.K. & Seely, R.E. (2002). Processing subject and object relative clauses: Evidence from eye movements. *Journal of Memory and Language, 47*, 69-90.

Traxler, M.J. & Pickering, M.J. (1996). Plausibility and the processing of unbounded dependencies: an eye-tracking study. *Journal of Memory and Language, 35*, 454-475.

Trueswell, J.C., Tanenhaus, M.K. & Garnsey, S.M. (1994). Semantic influences on parsing: Use of thematic role information in syntactic disambiguation. *Journal of Memory and Language, 33*, 285-318.

Trueswell, J.C., Tanenhaus, M.K. & Kello, C. (1993). Verb-specific constraints in sentence processing – separating effects of lexical preference from garden-paths. *Journal of Experimental Cognition – Learning, Memory and Cognition, 19*, 528-553.

Van Berkum, J.J.A., Hagoort, P. & Brown, C.M. (1999). Semantic integration in sentences and discourse: evidence from the N400. *Journal of Cognitive Neuroscience, 11*, 657-671.

Van Berkum, J.J.A., Zwitserlood, P., Hagoort, P. & Brown, C.M. (2003). When and how do listeners relate a sentence to the wider discourse? Evidence from the N400 effect. *Brain Research – Cognitive Brain Research, 17*, 701-718.

Van de Meerendonk, N., Kolk, H.H.J., Vissers, C.T.W.M. & Chwilla, D.J. (submitted). Monitoring in language perception: Mild and strong conflicts elicit different ERP patterns.

Van Herten, M., Chwilla, D.J. & Kolk, H.H. (2006). When heuristics clash with parsing routines: ERP evidence for conflict monitoring in sentence perception. *Journal of Cognitive Neuroscience, 18*, 1181-1197.

Van Herten, M., Kolk, H.H.J. & Chwilla, D. (2005). An ERP study of P600 effects elicited by semantic anomalies. *Cognitive Brain Research, 22*, 241-255.

Van Petten, C. & Kutas, M. (1990). Interactions between sentence context and word frequency in event-related potentials. *Memory and Cognition, 18*, 380-393.

Vasishth, S., Brussow, S., Lewis, R.L. & Drenhaus, H. (2008). Processing polarity: How the ungrammatical intrudes on the grammatical. *Cognitive Science, 32*, 685-712.

Vissers, C.T.W.M., Chwilla, D.J. & Kolk, H.H.J. (2006). Monitoring in language perception: The effect of misspellings of words in highly constrained sentences. *Brain Research, 1106*, 150-163.

Vissers, C.T.W.M, Kolk, H.H.J, van de Meerendonk, N. & Chwilla, D.J. (2008). Monitoring in language perception: Evidence from ERPs in a picture-sentence matching task. *Neuropsychologia, 46*, 967-982.

Weckerly, J. & Kutas, M. (1999). An electrophysiological analysis of animacy effects in the processing of object relative sentences. *Psychophysiology, 36*, 559-570.

Wicha, N.Y.Y. (2003) Potato not pope: human brain potentials to gender expectation and agreement in Spanish spoken sentences. *Neuroscience Letters, 346*: 165-168.

Wicha, N.Y.Y., Moreno, E.M. & Kutas, M. (2003). Expecting gender: An event-related potential study on the role of grammatical gender in comprehending a line drawing within a written sentence in Spanish. *Cortex, 39*, 483-508.