BACKWARDS AND FORWARDS:
BEHAVIORAL AND NEUROPHYSIOLOGICAL INVESTIGATIONS INTO
DEPENDENCY PROCESSING

by
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DEDICATION

This dissertation is dedicated to –

ウィッツェル 楠緒子
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ABSTRACT

This dissertation examines the processing of sentences involving long-distance linguistic dependencies, or sentences containing elements that must be linked across intervening words and phrases. Specifically, both behavioral (self-paced reading and eye tracking) and neurophysiological (electroencephalography) methods were used (a) to evaluate the relative importance of backward- and forward-looking dependency satisfaction processes in the comprehension of sentences involving \( wh \)-dependencies and (b) to determine the extent to which common neurocognitive mechanisms are involved the processing of \( wh \)-and anaphoric dependencies. With respect to the first issue, both behavioral and neurophysiological results indicated a core role for forward-looking, expectancy-based processes in the comprehension of \( wh \)-dependency sentences. Regarding the latter issue, despite considerable overlap in the reading patterns associated with \( wh \)-dependencies and (at least some types of) anaphora, the neurophysiological responses related to these dependency types indicated that their processing draws on distinct neurocognitive mechanisms.
CHAPTER 1

INTRODUCTION

Sentence comprehension involves linking, or integrating, elements into larger (meaningful) structural units. Often these links are established locally, or between contiguous or nearly contiguous elements (in time or space). A clear example of this type of local integration process is the construction of a noun phrase (NP) from the integration of an article and an immediately following noun ($\text{the, dog} \rightarrow [\text{NP the dog}]$). Other integration processes occur across some distance, or over intervening words/phrases and, in some cases, over one or more clauses/sentences. An example of such long-distance linking is subject-verb agreement, as in the sentence *The dog that the children often try to play frisbee with is well behaved.* In order for the correct representation of this sentence to be computed (though not necessarily for the sentence to be understood (see e.g., Jiang, 2004; Wagers, Lau, & Phillips, 2009)) a link must be established between the head of the subject NP (*dog*) and the verb (*is*) to check the latter element’s agreement properties (among other things). As in this example, long-distance integration processes often (though not exclusively) involve elements that are in some way dependent on each other. In the case of subject-verb agreement, for instance, the verb is dependent on properties of the subject NP for its number/person specification. These long-distance dependencies are the focus of the experiments reported in this dissertation.

Of course, there is a long history of interest in sentences of this type in linguistics and psycholinguistics. Linguists have traditionally been interested in modeling the characteristics of these dependencies and in determining the implications of these
characteristics for theories of the Grammar. For example, the relatively straightforward case of subject-verb agreement has been used as a clear example that sentences are represented as abstract, hierarchical structures, with the relationships among their component elements accounted for in terms of this structure (see e.g., Crain & Nakayama, 1987). For their part, psycholinguists have examined the real-time processing of long-distance dependencies in order to (among other things) determine the extent to which grammatical knowledge influences online sentence comprehension (see e.g., Bever & McElree, 1988; Crain & Fodor, 1985; Gibson & Warren, 2004; Kazanina, Lau, Lieberman, Yoshida & Phillips, 2007; McElree & Bever, 1989; Nicol & Swinney, 1989; Stowe, 1986) as well as to shed light on the interaction between language processing and (working) memory (see e.g., Gibson, 1998; Lewis, Vaisith, Van Dyke, 2006).

The present set of experiments sought to add to our understanding of the processing of long-distance dependencies by examining two sentence types in particular – sentences involving wh-dependencies and sentences involving anaphoric dependencies. As the name suggests, wh-dependencies usually involve wh-question words. Examples of this dependency type can be found in wh-questions and in sentences involving relative clauses. For example, in the sentence *The soldier who, the sailor roughly pushed __, smashed a bottle against the bar.*, the wh-element *who* (which is co-referential with the NP *The soldier*) must be linked with structural position that allows for its thematic specification – that is, with the position at which it is assigned its thematic role. In this case, the wh-element is understood as the patient of the verb *pushed* (i.e., the entity being pushed) by virtue of its connection with the empty internal argument (or object) position
of this verb. Only after this link is established can the relative clause be understood. In the psycholinguistics literature related to such sentences, the *wh*-element is called a *filler*, while the word that triggers its integration is said to indicate a *gap*. This type of dependency is thus often called a *filler-gap* dependency (a term that will be used throughout this dissertation). Anaphoric dependencies, on the other hand, involve linking a referentially-dependent element (or an *anaphor*) with another discourse element (an *antecedent*). An example of this dependency type is as follows: *When the king appeared, he greeted the boys.* In this sentence, the pronoun *he* is referentially dependent on the NP *the king*. Again, a link must be established between the anaphor and its antecedent in order for the sentence to be fully comprehended.

It is important to note that there are a number of differences between these dependency types. First, as mentioned above, filler-gap sentences usually involve linking an overt dependent element with a (phonetically null) gap position that must be inferred from the information provided by the sentence. Anaphoric dependency sentences, on the other hand, usually involve a connection between overt elements (e.g. between an NP and another NP, between an NP and a pronoun, or between an NP and a reflexive element (e.g., *himself/herself/themselves*)). Furthermore, although filler-gap dependencies must be satisfied in order for the sentence to be well-formed, some anaphoric dependencies can be left unsatisfied without leading to ungrammaticality. For instance, compare the following sentences:

(1) * The soldier who the sailor roughly pushed the captain smashed a bottle.

(2) He greeted the boys.
Whereas sentence (1) is jarringly ungrammatical, sentence (2) is perfectly well-formed, just not particularly informative. Along similar lines, although a filler and its gap must (at least) be in the same sentence, an anaphor and its antecedent can be separated from each other by one or more sentences. Finally, while the dependent element (the filler) is usually introduced prior to the element that satisfies the dependency (the gap) in filler-gap structures, the opposite is usually the case with anaphoric dependencies (i.e., the antecedent usually precedes the anaphor).

The overarching motivation for the present set of experiments is to examine the processing implications of this last, and arguably most important, difference between these dependency types. Indeed, the early introduction of a dependent element in filler-gap structures allows for several possible routes to dependency satisfaction. For instance, one option available to the comprehension system is to index this word/phrase for subsequent retrieval when an empty argument position (a gap) is clearly identified, with processing difficulty occurring when there is some impediment to this retrieval process. Under such a model, linking fillers to gaps is in essence a “backward-looking” dependency satisfaction process. Alternatively, once a filler enters the system, it could trigger a set of expectancies for structural properties that allow for its satisfaction, with processing difficulty occurring when these expectancies are not met. Under this type of model, establishing a link between a filler and a gap essentially involves a “forward-looking” dependency satisfaction process. It is important to note that the debate over which of these classes of models best characterizes filler-gap processing is not a new one. (For arguments in favor of backward-looking filler-gap processing, see Jackendoff &
Culicover, 1971; Grodner & Gibson, 2005; for arguments in favor of forward-looking filler-gap processing, see Aoshima, Phillips, & Weinberg, 2004; Crain & Fodor, 1985; Levy, 2008; Fodor, 1978; Frazier & Flores d'Arcais, 1989). And of course, it is not necessarily the case that these processes are mutually exclusive. In fact, a number of more recent conceptions of filler-gap processing posit some role for both forward- and backward-looking dependency satisfaction processes (Lewis, & Vasishth, 2005; Levy, 2008; Staub, submitted; and to some extent, Chen, Gibson, & Wolf, 2005; Gibson, 1998).

As far as anaphora processing is concerned, in light of the fact that the dependent element (the anaphor) usually follows the element that satisfies its referential requirements (the antecedent), one might suppose that the sentence comprehension system is limited to backward-looking dependency satisfaction. However, there are cases in which the ordering of the antecedent and anaphor can be switched, creating so-called backward anaphora sentences like the following: When he appeared, the king greeted the boys. These sentences are comparable to filler-gap sentences in that both have a dependent-element-first structure. Interestingly, behavioral investigations have yielded intriguingly similar processing characteristics for these sentence types. Specifically, consistent with the idea that these dependent-element-first structures engage comparable forward-looking processes, the introduction of a dependency in both sentence types appears to trigger an active, grammatically-constrained search for a “satisfying” element (see e.g. Aoshima et al., 2004; Clifton & Frazier, 1989; Cowart & Cairns, 1987; Crain & Fodor, 1985; Kazanina et al., 2007; Stowe, 1986; Van Gompel & Liversedge, 2003). In fact, these similarities have motivated a recent proposal that the language processor
draws on a common mechanism for the processing of all linguistic dependencies that have a dependent-element-first structure (Kazanina et al., 2007).

1.1 Research Questions

With these issues in mind, the experiments in this dissertation were designed to answer two primary research questions:

**Research Question #1:**
What is the relative importance of backward- and forward-looking dependency satisfaction processes in the comprehension of sentences involving *wh*-dependencies?

**Research Question #2:**
To what extent does the processing of different dependent-element-first structures engage common neurocognitive systems?

In order to answer the first of these questions, both behavioral and neurophysiological experiments (Experiments 1, 2, 3, and 4) were conducted to assess the extent to which disruption to forward-looking processes and difficulty during backward-looking processes account for one of the most robust asymmetries in psycholinguistics – namely, the asymmetry in the processing of (English) object- vs. subject-extracted relative clauses.

In order to address the second of these questions, both behavioral and neurophysiological experiments (Experiments 5, 6, 7, and 8) were used to examine the processing of forward anaphora sentences, or sentences with the canonical *dependent-element-later* structure (e.g., *When the king appeared, he greeted the boys.*), and backward anaphora sentences (e.g., *When he appeared, the king greeted the boys.*). Of particular interest was whether
the dependent-element-first structure of backward anaphora sentences would produce
reading patterns and neurophysiologcial responses (a) that differed from those associated
with their forward anaphora counterparts, and (b) that more closely resembled those
associated with the processing of filler-gap dependencies.

1.2 Chapter Outlines

1.2.1 Chapter 2

Chapter 2 reports on three experiments (Experiments 1, 2, and 3) examining
participants’ reading patterns on sentences involving object- and subject-extracted
relative clauses (henceforth, ORCs and SRCs) like the following:

(3a) ORC Sentence
The soldier who the sailor roughly pushed smashed a bottle against the bar.

(3b) SRC Sentence
The soldier who roughly pushed the sailor smashed a bottle against the bar.

Across a number of paradigms, ORCs have been shown to be more difficult to process
than SRCs. However, the nature of this processing asymmetry remains unclear.
Interestingly, accounts for this asymmetry attribute different levels of importance to
forward- and backward-looking dependency processing operations. One clear way to
assess the relative influence of these processes on the “ORC penalty” is to look at the
locus of this processing difficulty. To this end, Experiment 1 examined participants’ eye
movement patterns as they read ORC and SRC sentences. Experiments 2 and 3 assessed
participants’ processing of these sentence types using a variant of the self-paced reading
called the maze task. All three experiments revealed robust indications of processing
difficulty early in ORCs, while only the eye-tracking experiment revealed a hint of processing difficulty at the verb in this clause type. These results are interpreted to indicate that the bulk of the processing costs incurred by ORC sentences is attributable to disrupted forward-looking dependency processes. Furthermore, it is argued that the differences in the results of the eye-tracking and the maze task experiments (again, with respect to whether they revealed processing difficulty at the ORC verb, the point of eventual dependency satisfaction) may suggest that forward-looking and backward-looking dependency satisfaction operations are associated with complementary subprocesses in the comprehension of relative clause sentences, and of wh-dependency sentences in general.

1.2.2 Chapter 3

Chapter 3 reports on an experiment (Experiment 4) that examined participants’ neurophysiological responses during the processing of ORC and SRC sentences (again, as in examples (3a) and (3b) above). Specifically, electroencephalographic (EEG) activity was recorded while participants read these sentence types. The purpose of this experiment was to gain a clearer understanding of the nature of the processing costs incurred at the first word(s) of ORCs. One possibility is that this difficulty reflects memory storage costs. Indeed, in an earlier examination of these sentence types, King & Kutas (1995) found a sustained negative event-related potential (ERP) over anterior scalp sites during the processing of ORCs, which they interpreted as an index of these storage costs. However, these findings have been called into question in a more recent ERP examination of the processing of wh-dependency sentences (Phillips, Kazanina, & Abada, 2005). Consistent
with this latter study, Experiment 4 failed to replicate the sustained anterior negativity (SAN) for ORC sentences, while replicating an apparent N400 response at the beginning of the relative clause. These results are interpreted to suggest that the processing difficulty incurred early in the ORC is due primarily to the disconfirmation of a default SRC interpretive bias, rather than to memory storage costs per se.

1.2.3 Chapter 4

Chapter 4 details three experiments (Experiments 5, 6, and 7) investigating participants’ reading patterns on forward and backward anaphora sentences like the following (where anaphora type is indicated by Forward/Backward and “linking point”, by NP1/NP2):

(4a) Forward/NP1
When Mary spotted the mysterious UFO, she told Jeff to call the authorities.

(4b) Forward/NP2
When Jeff spotted the mysterious UFO, Mary told him to call the authorities.

(4c) Backward/NP1
When she spotted the mysterious UFO, Mary told Jeff to call the authorities.

(4d) Backward/NP2
When he spotted the mysterious UFO, Mary told Jeff to call the authorities.

Experiment 5 looked at participants’ eye movement patterns when reading these sentence types, while Experiments 6 and 7 used maze task self-paced reading to assess processing time differences among them. With regard to Research Question #2, the most important results of these experiments were as follows: First, all three experiments revealed marked
processing difficulty for Backward/NP2 sentences at and after the main clause subject 
(Mary), indicating a cost for disrupted dependency processing. Furthermore, the eye-
tracking experiment also revealed processing difficulty for the main clause subject 
(Mary) in Backward/NP1 sentences, suggesting a cost for dependency satisfaction as well. 
These findings are taken to indicate analogues to the filled-gap effect (see e.g., Aoshima 
et al., 2004; Clifton & Frazier, 1989; Crain & Fodor, 1985; Stowe, 1986) and the filler-
gap integration effect (see e.g., Gibson & Warren, 2004; Grodner & Gibson, 2005; 
Marinis, Roberts, Felser, & Clahsen, 2005) in the processing of backward anaphora 
sentences, and thus as support for the claim that comparable neurocognitive systems 
underlie the processing of these dependent-element-first structures. It is also argued that 
the similarity in the processing of these structures is underscored by the fact that only the 
eye-tracking experiment revealed a processing cost at the point of dependency 
satisfaction in backward anaphora sentences. That is, these experiments revealed an 
asymmetry in the findings for the different behavioral task types that was similar to that 
which was obtained for the wh-dependency sentences in Experiments 1, 2, and 3. 

1.2.4 Chapter 5

Chapter 5 examined the same forward and backward anaphora sentence types in 
an EEG/ERP experiment. Of particular interest was whether the comparable behavioral 
results for filler-gap and backward anaphora sentences would also be reflected in similar 
neurophysiological responses. Consistent with this hypothesis, the main clause subject in 
Backward/NP2 sentences (he..., Mary) elicited a broadly-distributed late posterior 
positivity – a response that is consistent with the P600 response that has been reported for
dependency disruption in filler-gap processing (see e.g., Hestvik, Maxfield, Schwartz, & Shafer, 2007; Hestvik, Bradley, Bradley, Kaufmann, Prescott, & Sparacino, 2009).

However, the main clause subject in Backward/NPI sentences (she..., Mary) elicited an N400-like deflection – a response that differs markedly from the P600 response associated with dependency satisfaction in filler-gap sentences (see e.g., Kaan, Harris, Gibson, & Holcomb, 2000; Phillips et al., 2005). In fact, every word at which an antecedent-anaphor connection was established in forward and backward anaphora sentences elicited similar negative-going responses. These similarities/differences are taken to indicate separate systems for the processing of filler-gap and anaphoric dependencies, but systems that nevertheless may share certain core properties.

1.2.5 Chapter 6

Chapter 6 provides a brief general discussion of the results obtained the experiments reported below. And it is to that end that we now proceed.
CHAPTER 2

RELATIVE CLAUSE PROCESSING: BEHAVIORAL EXPERIMENTS

One of the most well-established findings in psycholinguistics is that there is asymmetry in the processing of object- and subject-extracted relative clauses (ORCs and SRCs). Again, examples of sentences involving these relative clause types are as follows:

(5a) ORC Sentence
The soldier who the sailor roughly pushed smashed a bottle against the bar.

(5b) SRC Sentence
The soldier who roughly pushed the sailor smashed a bottle against the bar.

The relevant structural properties of these sentences are illustrated with partial bracketing in (5c) and (5d):

(5c) ORC Sentence
\[ [NP \text{ The soldier } [CP \text{ who}_i [TP \text{ the sailor roughly pushed } t_i]]] \text{ smashed a bottle against the bar.} \]

(5d) SRC Sentence
\[ [NP \text{ The soldier } [CP \text{ who}_i [TP t_i \text{ roughly pushed the sailor}]]] \text{ smashed a bottle against the bar.} \]

As discussed in Chapter 1, these sentences contain a wh-element (who) that must be linked to a position where it can receive its thematic specification. In ORCs, this wh-element is interpreted as the object of the relative clause. That is, to use the terminology introduced in Chapter 1, the wh-filler must be linked with a gap in the object (or internal argument) position of the verb (pushed). In SRCs, on the other hand, the filler is linked
with a gap in the subject (or external argument) position of the clause. These gap
positions are indicated by the trace (t) notation in examples (5c) and (5d).

The key finding with respect to these sentence types is that, at least in English,
ORC sentences have been shown to be more difficult to process than SRC sentences. In
fact, this asymmetry has been demonstrated across virtually all domains of
psycholinguistic inquiry. For instance, both child and adult native-speakers show
decreased fluency when producing ORC sentences relative to SRC sentences (McDaniel,
McKee, & Garrett, 2010). Similarly, in aphasiology research, agrammatic aphasic
patients have often been shown to have particular difficulty comprehending ORC
sentences (see e.g., Grodzinsky, 2000, for review). Neuroimaging studies have also
shown differences in brain activation when participants comprehend these sentence types.
Specifically, both functional magnetic resonance imaging (fMRI) and positron emission
tomography (PET) studies have revealed heightened levels of activation for ORC
sentences over brain areas linked to language processing (Caplan, Alpert, & Waters,
1998; Just, Carpenter, Keller, Eddy, & Thulborn, 1996; Stromswold, Caplan, Alpert, &
Rauch, 1996; but see also Cooke, Zurif, DeVita, Alsop, Koenig, Detre, Gee, Pinango,
Balogh, & Grossman, 2001). Comparably, in EEG studies, ORC sentences have been
shown to elicit sustained event-related negative deflections over anterior scalp sites (King
& Kutas, 1995; Mueller, King, & Kutas, 1997) as well as greater anterior-posterior
oscillatory coherence in the theta, beta, and gamma frequency bands (Weiss, Mueller,
Schack, King, Kutas, & Rappelsberger, 2005).
Although some of this neuroimaging evidence will be revisited in Chapter 3, of particular relevance to the experiments presented in this chapter are studies examining reading patterns on ORC and SRC sentences. Again, across such studies, ORC sentences have been shown to be more difficult to process than SRC sentences (Forster, Guerrera, & Elliot, 2009; Gennari & MacDonald, 2008; Gordon, Hendrick & Johnson, 2001, 2004; Gordon, Hendrick, Johnson, & Lee, 2006; Grodner & Gibson, 2005; King & Just, 1991; Staub, submitted; Traxler, Morris, & Seely, 2002; Traxler, Williams, Blozis, & Morris, 2005). In order to understand the nature of this asymmetry, a number of these studies have manipulated the semantic properties of the nouns and verbs involved in the relative and main clauses of these sentence types (King & Just, 1991; Traxler et al., 2002, 2005; Gennari & MacDonald, 2008; Gordon et al., 2001, 2004, 2006) and have investigated the interaction of these manipulations with subjects’ working memory capacity (King & Just, 1991; Traxler et al., 2005). In general, these studies have indicated that processing difficulty in ORC sentences can be modulated (a) by the animacy of the modified noun (with animate nouns, e.g., *The director that...*, producing more difficulty than inanimate nouns, e.g., *The movie that...*; see e.g., Gennari & MacDonald, 2008; Traxler et al., 2002, 2005), (b) by the semantic similarity of the modified noun and the noun in the relative clause (with semantically-similar pairs, e.g., *The banker that the barber...*, producing more difficulty than semantically-dissimilar pairs, e.g., *The banker that Sophie...*; see e.g., Gordon et al., 2001, 2004, 2006), and (c) by how well these nouns match as agents with the relative clause verb (with cases in which both are plausible agents, e.g., *The robber that the fireman detested...*, producing more difficulty than cases in which the relative
clause subject is a more plausible agent, e.g., *The robber that the fireman rescued…*; see e.g., King & Just, 1991; Traxler et al., 2002). Moreover, working memory capacity has been found to influence the extent to which readers can take advantage of these cues to interpretation (King & Just, 1991; Traxler et al., 2005).

Of course, this collection of results needs to be addressed in any complete account of the ORC/SRC processing asymmetry. And indeed, a number of accounts for the ORC penalty have been put forward. Interestingly, the dominant accounts for this asymmetry can be roughly slotted into two classes of explanation – (a) those that appeal to difficulty during backward-looking dependency processing operations and (b) those that appeal to disrupted forward-looking operations. The most prominent backward-looking theories explain the ORC penalty in terms of retrieval difficulty at the relative clause verb. Again, in both SRC and ORC sentences, a link must be made between the filler and the verb (or an empty argument position indicated by the verb) in order that a thematic role can be assigned to the filler. In ORC sentences, this link must be made across more intervening material. Grodner and Gibson (2005; see also Gibson, 1998) argue that this intervening material, and specifically the intervening discourse referent at the subject of the relative clause (e.g., …*who the sailor roughly pushed*…), makes integration between the filler and the verb more difficult. A comparable explanation for the ORC penalty is Gordon and colleagues’ (2001, 2004, 2006) similarity-based interference account, which posits that the processing costs for filler retrieval at the ORC verb are often exacerbated because of the “confusability” of the modified NP and the subject of the relative clause. Support
for this theory comes from studies demonstrating that when these NPs are semantically dissimilar, processing difficulty for ORC sentences is reduced.

Accounts that attribute the ORC penalty to disrupted forward-looking dependency processing operations are more varied. For instance, expectation-based accounts posit that the processing difficulty for ORCs is due to the fact that they occur less frequently than SRCs. The idea is essentially that the parser is sensitive to these statistical regularities and defaults to the most common processing procedures. When these statistically-based expectations are not met, processing difficulty ensues (see e.g., Gennari & MacDonald, 2008; Levy, 2008; Reali & Christianson, 2007; Roland, Dick, & Elman, 2007). Other accounts for the processing difficulty in ORC sentences appeal to the Active Filler Strategy (see e.g., Clifton & Frazier, 1989; Frazier & Flores d'Arcais, 1989; Stowe, 1986). Under these accounts, ORC sentences are difficult because they entail a disruption to a forward-looking search for the first possible gap site. Indeed, in ORCs, the first structural position that could act as the gap for the wh-filler happens to be occupied by the subject of the relative clause. Alternatively, Traxler et al. (2005) posit that there is simply a default parsing preference for treating the sentential subject as the subject of the (embedded) relative clause, and that processing difficulty occurs when this analysis is disconfirmed at the subject of the ORC.

Perhaps the most the straightforward way to test between these classes of accounts is to look at the locus of processing difficulty during the comprehension of ORC sentences. The clear prediction of the backward-looking accounts is that processing difficulty should occur at ORC verb, or when filler retrieval processes are engaged. All of
the forward-looking accounts, however, predict that processing difficulty should occur at
the NP subject that begins the ORC, or the first point at which (statistically- or
syntactically-based) structural expectancies are disconfirmed.

Unfortunately, the experimental results to date do not indicate a consistent locus
of ORC processing difficulty. For the most part, studies that have used standard self-
paced, non-cumulative reading tasks (with either moving-window or center-screen,
single-word presentation formats) have indicated processing difficulty primarily at the
ORC verb (see e.g., Gordon et al., 2001, 2004; Grodner and Gibson, 2005; King & Just,
1991) – results that are most consistent with backward-looking accounts of the ORC
penalty. However, using this same experimental method, Gennari and MacDonald (2008)
found that processing difficulty in some ORC sentences (specifically, those with animate
main clause subjects and inanimate ORC subjects, e.g., The director that the movie….
begin early in the relative clause, at the head noun of the subject NP (i.e., movie, in the
example above). Forster and colleagues (2009) found comparable results using the maze
task variant of self-paced reading (see e.g., Nicol, Forster, & Veres, 1997). In two
experiments, each of which used a different version of this task, processing difficulty for
ORC sentences was shown only at the article that introduced the relative clause subject
(e.g., The banker that the lawyer…) – results that provide clear support for forward-
looking accounts of ORC processing difficulty. Finally, the only eye-tracking experiment
to date that has examined the component words of the relative clause (Staub, submitted)
revealed reading patterns consistent with processing difficulty at both the ORC subject
and ORC verb. These results were taken as support for a hybrid model in which both
upset syntactic expectancies and retrieval difficulties contribute to the ORC penalty (see e.g., Lewis & Vasishth, 2005).

The experiments reported below attempt to clarify the locus of processing difficulty in ORC sentences using both eye-tracking and maze task methods. The purpose of these experiments is not to argue for a specific model of the ORC penalty, but rather to provide an indication of which class of models – backward-looking or forward-looking – best accounts for the processing difficulty in this sentence type.

2.1 Experiment 1: Investigating Relative Clause Processing with Eye Tracking

Experiment 1 investigated readers’ eye-movement patterns on SRC and ORC sentences similar to those introduced at the beginning of this chapter (reprinted here as examples (6a) and (6b):

(6a) ORC Sentence
The soldier who the sailor roughly pushed smashed a bottle against the bar.

(6b) SRC Sentence
The soldier who roughly pushed the sailor smashed a bottle against the bar.

These sentences are in many ways comparable to those tested in Staub (submitted, Experiment 1), examples of which are provided in (7a) and (7b):

(7a) ORC Sentence (from Staub, submitted, Experiment 1)
The employees that the fireman noticed hurried across the open field.

(7b) SRC Sentence (from Staub, submitted, Experiment 1)
The employees that noticed the fireman hurried across the open field.
The crucial difference between the sentences in (6) and (7) is that the former include an adverb (roughly) in the relative clause. Although this difference might at first blush seem rather trivial, this adverb serves an important function in that it provides a “buffer” between the subject NP (the sailor) and the verb (pushed) in the ORC. It is not uncommon in eye-tracking experiments for processing difficulty to spill over from one set words to the next. It is therefore questionable whether the difficulty detected at the ORC verb in Staub (submitted, Experiment 1) was truly due to processing costs for that word, or to the spill-over of processing difficulty from the immediately preceding ORC subject NP. The sentences tested in the present experiment thus have the potential to provide a clearer indication of the processing costs associated with the ORC subject NP and the ORC verb.

2.1.1 Method

2.1.1.1 Participants

Forty (40) University of Arizona undergraduates participated in the experiment in partial fulfillment of course requirements. All participants were native speakers of English, with normal or corrected-to-normal vision (with soft contact lenses, in adherence with the recording restrictions of the Dr. Bouis Oculometer).

2.1.1.2 Materials

The experimental sentences consisted of 28 ORC/SRC sentence pairs similar to those in examples (6a) and (6b). The complete set of experimental items is presented in Appendix A. These materials were a subset of the sentences used in Experiment 4, which were in turn created based on items used in King and Kutas (1995), Mueller et al. (1997),
and Weiss et al. (2005). These original materials were generously made available to me by Dr. Horst Mueller. As illustrated in the examples, each sentence involved two animate NPs (e.g., the soldier, the sailor), both of which were plausible agents/patients for the relative clause verb (e.g., either could roughly push the other; either could be roughly pushed by the other) and plausible agents for the main clause verb phrase (e.g., either could smash a bottle against the bar.). The versions of these sentences were counterbalanced across two lists. Also included on these lists were 84 filler sentences. Twenty-eight (28) of these fillers were included purely to distract the participants from focusing explicitly on experimental items (see Appendix B); the remaining 56 filler items were the sentences of particular interest in Experiments 5-7 (see Appendix F). These filler sentences were roughly matched with the experimental items in terms of length and complexity. Items were presented to participants in blocks of four sentences. Experimental and filler items were presented essentially at random throughout the experiment, with the only restriction being that no more than two experimental items occurred in succession in any block. Forty-two (42) of the sentences in the experiment (or 37.50%) were followed by yes-no comprehension questions. These questions followed eight experimental items and 34 filler items.

2.1.1.3 Procedure

Sentences were presented as single lines of text (with standard capitalization and punctuation) on a 21-inch CRT monitor. Participants were asked to read each sentence at their natural reading speed, making sure to comprehend well enough to accurately answer occasional yes-no questions. The participants’ eye movements were recorded from the
right eye using a Dr. Bouis Monocular Oculometer, at a sampling rate of 200 Hz. The
distance from the eye to the monitor was approximately 60cm, allowing for single
character resolution. A bite plate and headrest were used to attenuate head movements.
The eye tracker was calibrated at the beginning of the experimental session and then
recalibrated after every four trials. Each trial began with a fixation mark (an asterisk)
close to the left margin of the computer screen. A sentence would then display, with its
first letter located one character space to the left of the fixation point. After reading the
sentence, the participant pressed a button under the right hand, at which point the
sentence was removed from the screen. If the item was not followed by a yes-no
comprehension, a string of dashes appeared on the screen, signaling that the participant
could proceed to the next trial when ready by again pressing the right button. If the item
was followed by a comprehension check, participants answered ‘yes’ with the right
button or ‘no’ with a button under the left hand. The participant then received feedback,
and the next trial began automatically. At the beginning of the reading task, participants
were given eight practice trials.

2.1.1.4 Data Analysis

2.1.1.4.1 Excluded subjects and trials

The data from four participants with an error rates greater than 30% on the
comprehension checks were eliminated from the analyses. Trials with major tracker
losses were also excluded from the analyses. These trials accounted for 4.37% of the
experimental items.
2.1.1.4.2 Regions of interest

The first set of analyses was conducted with the ORC/SRC treated as a single region. Examples (8a) and (8b) illustrate the regions that were analyzed (with region boundaries indicated with “|” marks):

(8a) The soldier who the sailor roughly pushed| smashed| a bottle| against the bar.
(8b) The soldier who roughly pushed the sailor| smashed| a bottle| against the bar.

In order to shed light on the time-course of (potential) processing differences in the relative clause itself, a second set of analyses examined the component words of this clause in the two sentence types. Specifically, the relative clause NP (the sailor), adverb (roughly), and verb (pushed) were compared under the ORC and SRC sentence conditions.

2.1.1.4.3 Measures

For each region, several measures were calculated: first fixation duration, gaze duration, go-past time, right-bounded reading time (RT), (first-pass) regression rate, (first-pass) skipping rate, and total RT. As the name suggests, first fixation duration is the duration of the first fixation (of at least 50ms) in a region, provided that the region was fixated on during the reader’s initial pass through the sentence. Gaze duration is the sum of the fixation durations in a region (again, on the initial pass through the sentence) before leaving that region in either direction. It is important to point out that a number of researchers prefer to use the term first-pass RT for this measure when it applies to multi-word regions (see e.g., Rayner & Pollatsek, 2006). However, for the sake of consistency, the term gaze duration will be used throughout this dissertation, regardless of region
length. Go-past time (often also referred to as regression path duration) is the sum of the first-pass fixation durations after entering a region, before moving out of that region to the right. This measure includes regressive fixations to previous regions of the sentence. Right-bounded RT is the sum of the first-pass fixation durations in a region before moving out of that region to the right. This measure does not include regressive fixations to previous regions of the sentence. It is worth noting that right-bounded RT is not commonly reported in the eye-tracking literature. However, two of the few eye-tracking articles related to the processing of English ORC/SRC sentences (Gordon et al., 2006; Traxler et al., 2002) have included this measure. It was therefore included in order to allow for a clearer comparison of the present set of results with those of previous studies. Regression rate refers to the proportion of trials on which the reader had a regressive eye movement from a given region to a previous region during the initial pass through the sentence. Skipping rate is the proportion of trials on which the region was skipped over (i.e. not fixated on) during first-pass reading. Total RT is simply the sum of all fixation durations in the region (before the subject terminated the display of the item).

In addition to these per-region measures, the total RT for the sentence as a whole (or the sum of all of the fixation durations for the sentence) will be reported. This measure provides a global indication of the processing characteristics associated with the sentence types of interest.

2.1.1.4.4 Statistical analyses

The data for this and all subsequent behavioral experiments were analyzed by fitting linear mixed effect models to the dependent variables of interest. This was done
using the lmer function from the lme4 package in R (Baayen, 2008a, 2008b; Baayen, Davidson, & Bates, 2008; Pinheiro & Bates, 2000; R Development Core Team, 2009).

Due largely to the influence of seminal work by Clark (1973) and Forster and Dickinson (1976), the preferred method for the statistical analysis of psycholinguistics data generally, and of response time/error rates in particular, has been to conduct two statistical analyses, usually two $F$-tests, for each dependent measure – one with subjects as a random effect ($F_1$) and one with items as a random effect ($F_2$). Both statistics are then reported or are used to calculate $\text{min}F'$, with only those results that are significant in both $F$-tests and/or in the more conservative $\text{min}F'$ considered statistically reliable (for critiques of this logic, see Raaijmakers, 2003; Raaijmakers, Schrijnemakers, & Gremmen, 1999). Linear mixed effects models offer an advance over this F1/F2 method in that they allow for crossed random effects – or for both subjects and items to be treated as random effects in the same model. In another departure from the F1/F2 method, the data submitted to linear mixed effects models are not aggregated over subjects and items. Rather, these models work over the complete set of data points for each subject and item.

It is important to note, however, that linear mixed effects models do not function optimally when the data deviate dramatically from a normal distribution. This is of particular relevance in psycholinguistics studies because the data are often response times of some sort, which tend to be positively skewed. Therefore, it is often necessary to apply a transform to the raw data so that it approximates a normal distribution (Baayen, 2008a). Although a number of such transforms are available, in this experiment and in all subsequent behavioral experiments, response/reading time data were logarithmically (or}
log) transformed before analysis. This was done by generating the natural logarithm for each data point \( y = \log_e(x) \), where \( e \) is Euler’s number, or 2.7183 when taken to its 4th decimal point. The distributions of the raw and log-transformed data were then visually inspected using the MASS package in R (Venables & Ripley, 2002). In addition, a Geary’s skewness statistic was computed for each set of data using the R moments package (Komsta & Novomestky, 2007). This statistic quantifies the shape of a distribution of data points, with positive values indicating positive skew and negative values indicating negative skew. The data from whichever set (raw or log-transformed) most closely approximated a normal distribution was then submitted to the relevant model for analysis.

In the statistical analyses of the RT measures, \( p \)-values were generated by Markov Chain Monte Carlo simulation using 10,000 iterations (Baayen et al., 2008). For the analyses of the binary variables – regression rate and skipping rate – a binomial family was used to fit each model, and \( p \)-values were established based on the \( z \) distribution.

The data for this particular experiment were analyzed by fitting a model with relative clause type (ORC, SRC) as a fixed factor, and with subject and item as random factors, to each dependent measure. The results of these analyses are presented below.

### 2.1.2 Results

The mean accuracy score on the comprehension questions was 85.11\% (\( SD = 7.68 \)). The means for the dependent measures for each region of the test sentences are presented in Tables 1 and 2. Unless otherwise noted, the values for the RT measures are the millisecond equivalents of the means of the log-transformed data. Table 1 presents the
results for ORC and SRC sentences when the relative clause (without who) was treated as a single region (e.g., ...the sailor roughly pushed... vs. ...roughly pushed the sailor...).
The results of the comparisons between the component phrases/words of these relative clauses are presented in Table 2 (e.g., the sailor in the ORC vs. the sailor in the SRC; roughly in the ORC vs. roughly in the SRC; pushed in the ORC vs. pushed in the SRC).

2.1.2.1 Analyses of the Entire Sentence

Before detailing the results for each region of the experimental sentences, it is important to note that the total RTs for the sentences indicated that ORC items were read more slowly than their SRC counterparts. Specifically, the mean total RT was 4205ms for ORC sentences and 3736ms for SRC sentences (RC type effect = 469ms; \( t = 7.86, p < .001 \)). This result is of course perfectly consistent with the numerous indications of processing difficulty for ORC sentences noted in the literature. Again, in order to gain a clearer understanding the processing time disparity between these sentence types, subsequent analyses focused on specific regions.

The main clause subject. At the main clause subject (The soldier who), there were no differences between SRC and ORC sentences in measures that assess first-pass reading patterns. Of course, no such differences were predicted because the sentence types diverged from one another after this region. The total RT for this sentence-initial region, however, was longer for ORC sentences than for SRC sentences (\( t = 3.50, p < .01 \)). This pattern of results indicates that more time was spent re-examining the main clause subject in ORC sentences.
Table 1. Mean RTs (in milliseconds) and regression and skipping rates (as proportions) for the ORC and SRC sentences in Experiment 1 (p<.001***, p<.01**, p<.05*, p<.10^).

<table>
<thead>
<tr>
<th></th>
<th>ORC</th>
<th>SRC</th>
<th>RC type effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The soldier who</td>
<td>The soldier who</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the sailor roughly pushed</td>
<td>roughly pushed the sailor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>smashed a bottle against</td>
<td>smashed a bottle against</td>
<td></td>
</tr>
<tr>
<td>1st fixation duration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORC</td>
<td>211</td>
<td>221</td>
<td>3</td>
</tr>
<tr>
<td>SRC</td>
<td>208</td>
<td>219</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>RC type effect</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>RC type effect</td>
<td>RC type effect</td>
<td>RC type effect</td>
</tr>
<tr>
<td>gaze duration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORC</td>
<td>389</td>
<td>1354†</td>
<td>12</td>
</tr>
<tr>
<td>SRC</td>
<td>377</td>
<td>1244†</td>
<td>110**</td>
</tr>
<tr>
<td></td>
<td>RC type effect</td>
<td>12</td>
<td>110**</td>
</tr>
<tr>
<td>go-past time</td>
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<tr>
<td>ORC</td>
<td>1503</td>
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<td>243***</td>
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<tr>
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<td>1260</td>
<td>369</td>
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<td></td>
<td>RC type effect</td>
<td>12</td>
<td>34**</td>
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<td>right-bounded RT</td>
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<td></td>
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<td>12</td>
<td>35**</td>
</tr>
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<td></td>
<td>RC type effect</td>
<td>RC type effect</td>
<td>RC type effect</td>
</tr>
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<td>ORC</td>
<td>.19</td>
<td>.11</td>
<td>.10</td>
</tr>
<tr>
<td>SRC</td>
<td>.09</td>
<td>.12</td>
<td>.11</td>
</tr>
<tr>
<td></td>
<td>RC type effect</td>
<td>.10***</td>
<td>.01</td>
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<tr>
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<td>.01</td>
</tr>
<tr>
<td>SRC</td>
<td>.03</td>
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<td>.01</td>
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<td></td>
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<tr>
<td>SRC</td>
<td>481</td>
<td>1509</td>
<td>379***</td>
</tr>
<tr>
<td></td>
<td>RC type effect</td>
<td>60**</td>
<td>379***</td>
</tr>
</tbody>
</table>

† means generated from the raw data (all other RT means are the ms equivalents of the means of the log-transformed data)
Table 2. Mean RTs (in milliseconds) and regression and skipping rates (as proportions) for the component phrases/words of the relative clause in the ORC and SRC sentences in Experiment 1 (p<.001***, p<.01**, p<.05*, p<.10^).

<table>
<thead>
<tr>
<th></th>
<th>the sailor</th>
<th>roughly</th>
<th>pushed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st fixation duration</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>ORC</td>
<td>224</td>
<td>257</td>
<td>272</td>
</tr>
<tr>
<td>SRC</td>
<td>244</td>
<td>219</td>
<td>258</td>
</tr>
<tr>
<td>RC type effect</td>
<td>-20***</td>
<td>38***</td>
<td>14^</td>
</tr>
<tr>
<td>gaze duration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORC</td>
<td>397</td>
<td>315</td>
<td>335</td>
</tr>
<tr>
<td>SRC</td>
<td>359</td>
<td>298</td>
<td>320</td>
</tr>
<tr>
<td>RC type effect</td>
<td>38**</td>
<td>17^</td>
<td>15</td>
</tr>
<tr>
<td>go-past time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORC</td>
<td>519</td>
<td>413</td>
<td>398</td>
</tr>
<tr>
<td>SRC</td>
<td>413</td>
<td>333</td>
<td>401</td>
</tr>
<tr>
<td>RC type effect</td>
<td>106***</td>
<td>80***</td>
<td>-3</td>
</tr>
<tr>
<td>right-bounded RT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORC</td>
<td>467</td>
<td>372</td>
<td>366</td>
</tr>
<tr>
<td>SRC</td>
<td>390</td>
<td>317</td>
<td>368</td>
</tr>
<tr>
<td>RC type effect</td>
<td>77***</td>
<td>55***</td>
<td>-2</td>
</tr>
<tr>
<td>regression rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORC</td>
<td>.24</td>
<td>.19</td>
<td>.14</td>
</tr>
<tr>
<td>SRC</td>
<td>.11</td>
<td>.08</td>
<td>.16</td>
</tr>
<tr>
<td>RC type effect</td>
<td>.13***</td>
<td>.11***</td>
<td>-.02</td>
</tr>
<tr>
<td>skipping rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORC</td>
<td>.01</td>
<td>.04</td>
<td>.04</td>
</tr>
<tr>
<td>SRC</td>
<td>.01</td>
<td>.10</td>
<td>.03</td>
</tr>
<tr>
<td>RC type effect</td>
<td>0</td>
<td>-.06***</td>
<td>.01</td>
</tr>
<tr>
<td>total RT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ORC</td>
<td>675</td>
<td>503</td>
<td>468</td>
</tr>
<tr>
<td>SRC</td>
<td>474</td>
<td>425</td>
<td>468</td>
</tr>
<tr>
<td>RC type effect</td>
<td>201***</td>
<td>78***</td>
<td>0</td>
</tr>
</tbody>
</table>
The relative clause. At the relative clause (ORC: the sailor roughly pushed; SRC: roughly pushed the sailor), ORC sentences were read more slowly than SRC sentences across all RT measures except first fixation duration (gaze duration: $t=2.61, p<.01$; go-past time: $t=8.25, p<.001$; right-bounded RT: $t=7.75, p<.001$; total RT: $t=10.16, p<.001$). (It is important to note here that gaze duration for this region was the one RT measure in this experiment – and, in fact, in all of the analyses conducted for the behavioral experiments in this dissertation – for which log transformation did not yield a closer approximation to a normal distribution than the raw data. Therefore, the statistical analyses as well as the means reported for this measure were calculated over the raw data.) ORC sentences also had a higher regression rate than SRC sentences in this region ($z=4.14, p<.001$). Not surprisingly in light of its length, this region was never skipped.

The main clause verb. At the main clause verb (smashed), ORC sentences were again read more slowly than SRC sentences. This effect was statistically reliable across RT measures (first fixation duration: $t=4.63, p<.001$; gaze duration: $t=3.36, p<.01$; go-past time: $t=3.07, p<.01$; right-bounded RT: $t=3.10, p<.01$; total RT: $t=3.06, p<.01$). There were no differences between the sentence types in terms regression rate or skipping rate.

The main clause object and sentence-final region. At the main clause object (a bottle), there was a trend indicating that ORC sentences were read more quickly than SRC sentences. This trend was suggested by differences that approached significance for first fixation duration ($t=1.77, p=.08$), right-bounded RT ($t=1.79, p=.08$), and total RT
In the final region of the sentence (against the bar.), there were no statistically-reliable differences between the sentence types.

2.1.2.2 Analyses of the Relative Clause Phrases/Words

The relative clause NP. This analysis compares the NP in the relative clause (the sailor) in the two sentence types. Again, in ORC sentences this NP acts as the subject of the relative clause and occurs at the beginning of this clause; in SRC sentences, it acts as the object and occurs at the end of the clause. Consistent with the results of Staub (submitted), the results indicated a substantial processing cost at this NP in ORC sentences. Indeed, for ORC sentences, this phrase yielded longer reading times in terms of gaze duration \( (t=3.06, p<.01) \), go-past time \( (t=6.67, p<.001) \), right-bounded RT \( (t=5.77, p<.001) \), and total RT \( (t=10.70, p<.001) \). The only reading time measure that showed a different pattern was first fixation duration. In fact, the relative clause NP yielded shorter first fixation durations in ORC sentences than in SRC sentences \( (t=3.86, p<.001) \).

Although this result might seem counterintuitive in light of the generally inflated reading times for this NP in ORCs, it is not uncommon to see short first fixation durations for regions that induce relatively large numbers of first-pass regressions (see e.g., Altmann, Garnham, & Dennis, 1992; Rayner & Sereno, 1994). In line with this account, the regression rate was greater for this NP in ORC sentences than in SRC sentences \( (z=5.49, p<.001) \). Interestingly also, the pattern of results for first fixation duration and regression rate in this experiment replicate the findings of Staub (submitted, Experiment 1). Finally, it is worth noting the difference in the relative position of this phrase in the two sentence types had no discernible effect on skipping rate.
The relative clause adverb. Robust differences in the reading patterns for ORC and SRC sentences were also evident at the relative clause adverb (roughly). Again, this word was read more slowly in ORC sentences – a difference that was statistically reliable for first fixation duration ($t=6.63, p<.001$), go-past time ($t=6.07, p<.001$), right-bounded RT ($t=5.35, p<.001$), and total RT ($t=5.20, p<.001$) and that approached significance for gaze duration ($t=1.81, p=.07$). In addition, in ORC sentences, this adverb was skipped less often ($z=3.54, p<.001$) and yielded higher first-pass regression rates ($z=5.06, p<.001$).

The relative clause verb. In stark contrast to the robust reading pattern differences between ORC and SRC sentences at the relative clause NP and adverb, there was only a marginally significant effect suggesting that first fixation durations were longer at this verb in ORCs than in SRCs ($t=2.00, p=.05$).

### 2.1.3 Discussion

The results of Experiment 1 are consistent with the well-established finding that ORC sentences are more difficult to comprehend than SRC sentences. The reading patterns on these sentence types indicated that this processing difficulty was concentrated on the relative clause itself (the sailor roughly pushed) and on the main clause verb (smashed). Comparisons of the reading patterns on the component parts of the relative clause further demonstrated that the bulk of this processing difficulty was incurred at the beginning of the ORC – namely at the subject NP and at the immediately following adverb. This pattern of results therefore suggests that the primary source of processing difficulty in ORC sentences is disrupted structural expectations, and not retrieval-based integration difficulty at the relative clause verb.
This is not to say, however, that disrupted integration does not play any part in the difficulty associated with the processing of ORC sentences. Indeed, there was a marginally significant indication that first fixation durations on the relative clause verb were longer in ORCs than in SRCs. Although one might attribute this effect to the spill-over of the processing difficulty at the ORC subject, the fact that an adverb intervened between this NP and the verb makes this explanation somewhat unlikely. Furthermore, it is tempting to attribute at least some of the processing difficulty that was clearly evident at the main clause verb in ORC sentences to a delayed cost for integration at the relative clause verb. Even if this is the case, it is nevertheless clear from the present set of results that disruption to backward-looking dependency processing operations cannot fully account for the ORC penalty. Furthermore, to the extent these processes can contribute to a hybrid model of the processing difficulty for ORC sentences, their role must be considered secondary to that of forward-looking structural expectancies.

Before we accept this rough outline of a model for relative clause processing in particular and wh-dependency processing more generally, it is necessary to consider some alternatives. For instance, one might be tempted to account for the processing difficulty incurred at the subject in ORC sentences not with reference to structural expectancies, but instead in terms of memory-based processes. As discussed above, it is obvious that retrieval cannot account for this processing difficulty. However, it might be explained in terms of the memory processes of encoding and/or storage. While the latter of these processes will be considered in more detail in Experiment 4, the remaining experiments
in this chapter will address an explanation of the ORC penalty in terms of encoding difficulty.

Recall that Gordon and colleagues (2001, 2004, 2006) have proposed that the much of the processing difficulty for ORC sentences relates to similarity-based interference – or to the “confusability” in memory of the main clause subject and the subject NP of the relative clause. As indicated above, this theory seems to posit that confusability primarily influences filler retrieval processes at the relative clause verb. However, at points in the discussion of this model (see e.g., Gordon et al., 2004, p. 99), it is suggested that similarity-based interference also affects the encoding of the critical NPs – and in particular, the encoding of the second of these NPs, the subject NP of the relative clause. Recast in this way, this interference might be considered a plausible account for the processing difficulty at the ORC subject in Experiment 1.

An interference-based encoding explanation for these results would run roughly as follows: Upon encountering the subject of the ORC, the comprehension system has already identified the main clause subject, but has yet to link this element as an external argument to a predicate. When this second NP enters the system, a memory representation must be created that is similar to that of the main clause subject in many respects, but distinct enough so that it can be properly understood in the propositional structure of the sentence. That is, it must be encoded with “subject features”, but also in a manner that allows it to be unambiguously understood as the subject of its clause. Consistent with Gordon and colleagues’ proposal, the difficulty of establishing distinct memory representations for these structurally similar NPs may be heightened when they
share core semantic features. Recall that all of the sentences tested in Experiment 1 involved main clause subjects like *The soldier* and relative clause NPs like *the sailor*, or NPs that were both animate, human, and generic (i.e., in that they do not refer to a specific individual). These shared properties may have made these elements particularly confusable, and thus may have required the comprehension system to devote more processing resources to establishing distinct memory representations for them.

Of course, there are a number of ways in which this theory might be tested. However, perhaps the most straightforward way is to again look at the timing of processing difficulty in ORC sentences. If it is the case that the ORC penalty occurs primarily due to similarity-based interference during encoding, then the bulk of the processing difficulty in these sentences should be incurred at the head noun of the relative clause subject (i.e., *sailor* in the sentence beginning *The soldier who the sailor*….). It is at this word that the semantic content of this subject NP becomes available, triggering the hypothesized encoding problems. Crucially, accounts for the ORC penalty that appeal to disrupted structural expectancies make a different prediction. All of these models would predict processing difficulty at the first element that indicates that the preferred SRC analysis is not possible. In the sentences tested in Experiment 1, this element is the article in the ORC subject (i.e., *the* in the sentence beginning *The soldier who the sailor*….). These competing predictions about the locus of processing difficulty in the ORC subject are tested in Experiments 2 and 3.
2.2 Experiment 2: Investigating Relative Clause Processing with the G-maze Task

The eye-tracking methodology used in Experiment 1 is not well suited to test between the predictions outlined above. This is mainly because function words like *the* are often skipped during normal reading. And even if this word were fixated on, it is highly likely that the reader would pick up substantial information about the immediately following noun during this fixation as well. Put simply, a fixation on either the article or the noun in the ORC subject would allow information from both words to enter the comprehension system, making it impossible to conclude anything about the separable processing costs incurred by these elements from eye-tracking data. In order to test these predictions, it is therefore necessary to use a task that is sensitive to online syntactic/semantic processing, but that also allows for word-by-word presentation. The maze task variant of self-paced reading meets these criteria.

In the maze task (see e.g., Forster, Guerrera, & Eliot, 2009; Nicol, Forster, & Veres, 1997), sentences are presented as sequences of paired alternatives. In one version of this task, each pair of alternatives consists of words, only one of which is grammatical at that point in the developing sentence structure. The participant’s task is to choose the grammatical alternative as quickly and as accurately as possible. If the subject makes the correct choices throughout, the selected words form a complete sentence. For example, successfully choosing the grammatical alternative from each pair of words in Figure 1 yields the sentence *The cat drank the fresh milk*. Because this version of the task requires a series of choices based on grammaticality, it has been dubbed the Grammaticality-maze (or G-maze) task. Forster et al. (2009) have argued that the G-maze task forces readers to
integrate each word into the developing structure of the sentence before moving on, i.e., that it forces readers into a strictly incremental parsing mode. This feature potentially allows for clear indications of the processing costs associated with each word in the sentence, and thus makes this task ideally suited to investigate the processing of the component words of the ORC subject.

Figure 1. Example of a G-maze item.

Experiment 2 therefore tested the same sentences as in Experiment 1 with this G-maze task. As mentioned above, Forster et al. (2009) examined comparable sentence types using this task, and found clear indications of processing difficulty only at the article (the) in the subject of the ORC. This is of course a rather surprising result that has fairly far-reaching theoretical implications. Indeed, the replication of this result would
provide strong confirmation that the processing difficulty associated with the ORC subject NP is due to disrupted structural expectancies. More specifically, it would indicate that this processing difficulty is triggered by low-level structural cues that necessitate reanalysis of a default SRC parse. Alternatively, indications of longer selection times at the head noun of the ORC subject (again, sailor in The soldier who the sailor ….) might be taken as support for an encoding-based theory of this processing difficulty. Finally, this experiment will allow for another assessment of the relative contribution of processing disruptions at the relative clause subject (whatever its eventual explanation) and at the verb to the overall ORC penalty.

2.2.1 Method

2.2.1.1 Participants

Forty eight (48) University of Arizona undergraduates participated in the experiment in partial fulfillment of course requirements. All participants were native speakers of English.

2.2.1.2 Materials

The experimental and filler sentences were exactly the same as those in Experiment 1. The task required each word in the sentences (except for the first word) to be paired with an ungrammatical item. These alternatives were carefully selected (from a random list of words) to ensure that none would make a grammatical continuation at the point in the sentence where it occurred. The pairing of the correct alternative with the incorrect alternative was the same in both conditions for each item.
2.2.1.3 Procedure

Each sentence was presented as a series of frames. The first frame consisted of a word on the left and a string of periods on the right (e.g., [The ...]), indicating that the participant should press the left button to receive next frame. Each subsequent frame contained two words side by side, only one of which was a grammatical continuation of the sentence. These correct and incorrect alternatives appeared randomly on the left or the right. Participants were instructed to choose the word that best continued the sentence as quickly and as accurately as possible by pushing the corresponding left or right button on a button box. When the correct alternative was selected, the next pair of alternatives was automatically displayed. When the incorrect alternative was chosen, an “<<error>>” message was presented, followed by the beginning of the next item. If the participant made the correct selections throughout the frames, the final selection was followed by a “CORRECT” message, followed by the beginning of the next sentence. Unlike in Experiment 1, there were no comprehension questions. After every 14 items, the subject was encouraged to take a short rest. At the beginning of the task, the participant was given eight practice trials.

2.2.2 Results

The data from all participants contributed to the statistical analyses reported below (which followed the methods discussed for Experiment 1). For this experiment, a single dependent variable was analyzed – response times (RTs) to the words of interest. Only RTs for correct selections were analyzed. The critical words were the component
words of the relative clause and the main clause verb in ORC and SRC sentences. The results of the comparisons between these words are presented in Table 3.

Table 3. Mean RTs (in milliseconds) for the component words of the relative clause and the main clause verb in the ORC and SRC sentences in Experiment 2 (p<.001***, p<.01**, p<.05*, p<.10^).

<table>
<thead>
<tr>
<th></th>
<th>...</th>
<th>the</th>
<th>sailor</th>
<th>roughly</th>
<th>pushed</th>
<th>smashed</th>
<th>....</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORC</td>
<td>1125</td>
<td>851</td>
<td>1241</td>
<td>959</td>
<td>1208</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRC</td>
<td>708</td>
<td>903</td>
<td>1174</td>
<td>992</td>
<td>1219</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RC type</td>
<td>417</td>
<td>-52</td>
<td>67</td>
<td>-33</td>
<td>-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The main clause subject. The RTs to the two words that preceded the relative clause (soldier who) were analyzed in order to ensure that responses to ORC and SRC sentences were essentially the same before these sentences began to diverge. That was indeed the case. In ORC sentences the mean RT to the noun in the main clause subject (soldier) was 794ms, while in SRC sentences it was 813ms. The mean RT to the relativizer (who) was 933ms in ORC sentences and 923ms in SRC sentences. Neither of these differences was statistically reliable.

The relative clause article. There was a robust difference between the RTs to the article (the) in the relative clause NP in ORC and SRC sentences (t=25.22, p<.001). In fact, this article was responded to on average 417ms more slowly in ORC sentences. This result is consistent with the idea that processing difficulty at the ORC subject is triggered
by low-level structural information – that is, by the first indication that the subject position of the relative clause is occupied by an NP.

*The relative clause noun.* There was also a statistically-reliable difference between the RTs to the relative clause noun in ORC and SRC sentences ($t=3.30, p<.01$). However, this difference was in the opposite direction of the effect at the immediately preceding relative clause article. That is, this noun was responded to more quickly in ORC sentences than in SRC sentences. Although this result was not predicted, it runs in direct contradiction to an encoding-based account of the processing difficulty at the ORC subject.

*The relative clause adverb.* There was again a statistically-reliable difference between ORC and SRC sentences at the relative clause adverb ($t=2.47, p<.05$). As at the relative clause article, this difference indicated longer response times for ORC sentences than for SRC sentences at this word.

*The relative clause verb and the main clause verb.* There was a trend suggesting that the relative clause verb was responded to more quickly in ORC sentences than in SRC sentences. Recall that a similar pattern of results was found at the relative clause noun. In the case of this verb, however, this difference only approached significance ($t=1.90, p=.06$). The small difference (10ms) between the RTs for ORC and SRC sentences at the main clause verb was not statistically reliable. It is important to note that these results run contrary to the idea that filler integration accounts for some part of the difficulty in the processing ORC sentences.
2.2.3 Discussion

Replicating the findings of Forster et al. (2009), Experiment 2 revealed a robust indication of processing difficulty early in the ORC, at the article (*the*) in the subject of this clause. This result is consistent with the hypothesis that the ORC penalty is primarily due to disrupted structural expectancies. After all, this article is the first point at which a default SRC analysis of the clause is disconfirmed. An RT difference between these sentence types was also found at the head noun of the relative clause NP (*the sailor*), but in the opposite direction. That is, this noun was responded to more quickly in ORCs than in SRCs. This difference is clearly incompatible with an account for the ORC penalty that appeals to similarity-based interference during encoding, which would predict processing difficulty at this noun in ORCs. Finally, again consistent with the results of Forster et al. (2009), there was also no indication of processing difficulty for ORC sentences at the relative clause verb (*pushed*) or at the main clause verb (*smashed*). In fact, there was a trend indicating that the relative clause verb was responded to more quickly in ORC sentences than in SRC sentences. These results again suggest a somewhat limited role for filler-gap integration costs in explaining the processing difficulty for ORC sentences.

It is necessary, however, to point out an important difference between the results of Experiment 2 and those obtained in Forster et al. (2009). Although this earlier experiment found a significant difference only for the article in the relative clause, the present experiment found a difference (or at least a suggestion thereof) at each word in this clause. Interestingly also, this difference was not in consistent direction at each of these words – for the article (*the*) and the adverb (*roughly*), the RTs in ORC sentences
were longer; whereas for the noun (sailor) and the verb (pushed), the RTs in SRC sentences were longer. One possible explanation for the unexpected effects at the relative clause noun, adverb, and verb is that they again indicate the importance of structural expectations. Indeed, it may be that after the default SRC parse of the relative clause is disconfirmed by article (the) in the ORC subject, the set of structural expectations for the rest of the clause becomes especially salient, such that responses are facilitated when these expectations are met, and delayed when they are not.

The idea is that disconfirmation of the default parse by the in the ORC sets up a stronger than normal expectation for a noun, which is then responded to more quickly. Following this same logic, upon encountering the noun in the ORC, there is a strong expectation for a verb. When an adverb is provided instead, response time is delayed. The alternative explanation for this effect at the adverb is that it reflects the spill-over of processing difficulty from the article in the ORC subject. This was the account provided for the inflated reading times and regression rate at the adverb in Experiment 1. However, in light of the faster RTs to the immediately preceding noun in this maze task experiment, this account does not seem likely. Finally, when the expectation for the ORC verb is ultimately met, the response is again facilitated.

This explanation is admittedly speculative. More importantly, it begs the question as to whether the task demands of G-maze self-paced reading overestimate (local) structural expectancies. This is somewhat problematic because it leads one to question whether the robust indication of processing difficulty at the article in ORC sentences actually reflects an important characteristic of the sentence comprehension system. In
light of this question, it was deemed necessary to test these relative clause sentence types again, this time with a self-paced reading methodology that does not require explicit grammaticality decisions throughout.

2.3 Experiment 3: Investigating Relative Clause Processing with the L-maze Task

Experiment 3 tested the same predictions as in Experiment 2, but with a different version of maze self-paced reading – the Lexciality-maze (or L-maze) task. In this task, as in the G-maze, sentences are presented as sequences of paired alternatives. In this case, however, one of these alternatives is a word, while the other is a nonword. The participant's task is simply to choose the word as quickly and as accurately as possible. If the subject makes the correct choices throughout, the selected words form a complete sentence. (This need not necessarily be the case, however, since the decision can be made based on lexicality alone. See Forster et al. (2009) for an example of the use of this task to test both grammatical sentences and scrambled word sequences.) For example, successfully choosing the word from each pair of alternatives in Figure 2 again yields the sentence *The cat drank the fresh milk.* Although this task does not force incremental integration of each word into the developing sentence structure, it does require participants to at least recognize each word of the sentence before moving on. In this way, it again allows for the indication of separable processing costs for each word in the sentence.

Again, it is important to note that Forster et al. (2009) also tested ORC and SRC sentences using the L-maze task. As in their G-maze experiment, they found inflated RTs only at the article in the subject of the ORC. However, in light of the differences between
the findings of Experiment 2 and Forster et al.’s G-maze experiment, it is important to confirm these L-maze results.

Figure 2. Example of an L-maze item.

<table>
<thead>
<tr>
<th>The</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>cat</td>
<td>mip</td>
</tr>
<tr>
<td>giffly</td>
<td>quietly</td>
</tr>
<tr>
<td>strell</td>
<td>drank</td>
</tr>
<tr>
<td>the</td>
<td>ip</td>
</tr>
<tr>
<td>fresh</td>
<td>sen</td>
</tr>
<tr>
<td>lote.</td>
<td>milk.</td>
</tr>
</tbody>
</table>

2.3.1 **Method**

2.3.1.1 **Participants**

Forty eight (48) University of Arizona undergraduates participated in the experiment in partial fulfillment of course requirements. All participants were native speakers of English.

2.3.1.2 **Materials**

The sentences tested were exactly the same as those in Experiments 1 and 2. The task required each word in the sentences (except for the first word) to be paired with a
nonword. These nonword alternatives were drawn from the ARC Nonword Database (Rastle, Harrington, & Coltheart, 2002). Again, the pairing of the correct alternative with the incorrect alternative was the same in both conditions for each item.

2.3.1.3 Procedure

Each sentence was presented as a series of frames. The first frame consisted of a word on the left and a string of periods on the right (e.g., [The …]), indicating that the participant should press the left button to receive next frame. Each subsequent frame contained a word and a nonword side by side. These word and nonword alternatives appeared randomly on the left or the right. Participants were instructed to choose the word from each pair as quickly and as accurately as possible by pushing the corresponding left or right button on a button box. They were also told that the sequence of words in each set of frames would form a sentence. When the correct alternative was selected, the next pair of alternatives was automatically displayed. When the incorrect alternative was chosen, an “<<error>>” message was presented, followed by the beginning of the next item. If the participant made the correct selections throughout the frames, the final selection was followed by a “CORRECT” message, followed by the beginning of the next item. Again, as in Experiment 2, there were no comprehension questions. After every 14 items, the subject was encouraged to take a short rest. At the beginning of the task, the participant was given eight practice trials.

2.3.2 Results

The data analysis followed exactly the same procedures as in Experiment 2. As in this previous experiment, the data from all 48 subjects contributed to these analyses. The
results of the comparisons between the critical words in ORC and SRC sentences are presented in Table 4.

Table 4. Mean RTs (in milliseconds) for the component words of the relative clause and the main clause verb in the ORC and SRC sentences in Experiment 3 (p<.001***, p<.01**, p<.05*, p<.10^).

<table>
<thead>
<tr>
<th>RC type</th>
<th>effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>the</td>
</tr>
<tr>
<td>ORC</td>
<td>701</td>
</tr>
<tr>
<td>SRC</td>
<td>604</td>
</tr>
</tbody>
</table>

The main clause subject. Again, the RTs to the two words that preceded the relative clause (soldier who) were analyzed in order to ensure that the responses to ORC and SRC sentences were essentially the same before the sentences began to differ. As in Experiment 2, there were no differences between the sentence types at these words. The mean RT to the noun in the main clause subject (soldier) was 849ms in ORC sentences and 839ms in SRC sentences. The mean RT to the relativizer (who) was 631ms in ORC sentences and 643ms in SRC sentences.

The relative clause article. As in Experiment 2 and consistent with the results of Forster et al. (2009), there was a robust difference between the RTs to the relative clause article (the) in ORC and SRC sentences (t=8.93, p<.001). Again, this article was responded to much more slowly in ORC sentences than in SRC sentences.
The relative clause noun. Also, as in Experiment 2, RTs to the relative clause noun were faster in ORC sentences than in SRC sentences \((t=2.21, p<.05)\). It is important to reiterate that this difference is in the opposite direction of the clear ORC penalty found at the immediately preceding article \((the)\).

The relative clause adverb. The RTs to the relative clause adverb did not differ between ORC and SRC sentences.

The relative clause verb. As in Experiment 2, there was a trend suggesting that the relative clause verb was responded to more quickly in ORC sentences than in SRC sentences \((t=1.77, p=.07)\).

The main clause verb. There was no difference between the RTs at the main clause verb in ORC and SRC sentences.

2.3.3 Discussion

The pattern of results for Experiment 3 was very similar to that of Experiment 2. First, consistent with this previous experiment as well as with Forster et al. (2009), processing difficulty was clearly evident at the article in the ORC subject \((the\ soldier)\). However, there was no hint of such difficulty at either the noun in the ORC subject \((the\ soldier)\) or at the ORC verb \((pushed)\). In fact, as in Experiment 2, these words were responded to more quickly in ORC sentences than in SRC sentences – a difference that was again statistically reliable only for the relative clause noun. This pattern of results suggests that the ORC penalty is best accounted for not in terms of either similarity-based interference during encoding (or retrieval, of that matter) or filler-gap integration costs, but rather in terms of disrupted structural expectancies. The faster RTs for the ORC noun
and verb in this experiment also provide tentative support for the expectation-based account of comparable results in Experiment 2.

### 2.4 General Discussion

Taken together, the results of these experiments confirm the well-established finding that ORC sentences are more difficult to process than SRC sentences. Furthermore, across all three experiments, the primary locus of this processing difficulty was the subject NP of the ORC, and in some cases, only the first element of this NP (i.e., the article *the*). This is in direct contradiction to the idea that the main source of processing difficulty in ORC sentences relates to filler retrieval processes at the relative clause verb (Gibson, 1998; Gordon et al., 2001, 2004, 2006; Grodner & Gibson, 2005). Replicating the results of Forster et al. (2009), Experiments 2 and 3 indicated that the precise locus of processing difficulty in ORC sentences was the article (*the*) in the ORC subject. This result provides clear support for the hypothesis that the primary cause of the ORC penalty is disrupted structural expectancies – or, more specifically, the disconfirmation of a default SRC parse based on available structural information. Of course, the results of these experiments do not dictate the nature of the structural expectancies involved in the processing of these clauses. This issue requires further investigation.

It is worth noting that these results do not discount the role of retrieval-based integration in filler-gap processing altogether. To do so would be to ignore compelling behavioral and neurophysiological evidence for integration costs at gap sites in filler-gap structures (see e.g., Gibson & Warren, 2004; Kaan et al., 2000; Marinis et al., 2005;
Phillips et al. (2005) as well as the indications of processing difficulty at and immediately after the ORC verb in the eye-tracking experiment reported above. However, it is clear that this backward-looking dependency satisfaction process accounts for only a relatively small part of the ORC penalty, and only does so under certain task conditions.

This last point perhaps warrants further investigation. Indeed, it is interesting to consider why the only indication of integration costs at the relative clause verb was obtained in the eye-tracking experiment. It may be that this result provides an important clue as to the nature of this effect. There are, of course, a number of differences among the tasks in the experiments presented above. Two of the most salient of these differences relate to (a) the reading strategies available to subjects during the task and (b) whether the task involves comprehension questions. With regard to the former issue, the G-maze task requires incremental integration of each word into the developing sentence structure. While this mode of processing is not strictly required in the L-maze task, the likelihood of incremental integration is presumably increased as each word in the sentence demands at minimum lexical level processing. Eye tracking, however, places relatively few constraints on the reading strategies available to the subject. It is possible that this more “natural”, unconstrained reading task allows the subject to focus more on the message-level content of the sentence, and that filler-gap integration effects are most pronounced when this propositional information, rather than the incremental integration of words into the developing sentence structure, is a primary focus of attention. Along similar lines, it is important to point out that the eye-tracking experiment is the only task that involved comprehension questions. While it could be argued that the G-maze task checks
comprehension at each word in the sentence, neither the G-maze nor the L-maze involved a secondary task which required the explicit tracking of who did what to whom in the sentences. Again, it could be the case that filler-gap integration effects occur most readily when such tracking is necessary (or at least explicitly encouraged). If this argument is correct, then this integration effect would appear to index not structural computation per se, but rather something more akin to the organization of elements into the propositional structure of the sentence. In this way, the differences in the results for the behavioral tasks in the present experiment may be taken to suggest that forward-looking and backward-looking dependency satisfaction operations are associated with complementary subprocesses in the comprehension of relative clause sentences. That is, in these sentences, forward-looking processes might relate more closely to online structure-building, whereas backward-looking processes might be more tightly linked to the tracking of propositional information.
CHAPTER 3

RELATIVE CLAUSE PROCESSING:

NEUROPHYSIOLOGICAL EXPERIMENT

The behavioral experiments detailed in Chapter 2 appear to provide clear support for models of filler-gap processing in general, and relative clause processing in particular, in which the introduction of the dependency establishes a set of expectations for its efficient satisfaction. When these expectancies are met, processing proceeds relatively smoothly. When they are contradicted by the input, reanalysis is necessary and processing costs are incurred. With regard to the relative clause sentence types of particular interest, the idea is that processing difficulty occurs for ORC sentences when the subject of the relative clause disconfirms a default SRC parse (which could exist for several different reasons). In support of this model, all three experiments reported above provided robust indications of processing difficulty at the ORC subject. Moreover, the maze task experiments localized the source of this difficulty to the article in this subject NP – or to the first element that can trigger the necessary reanalysis.

However, there is another possible explanation for (at least some of) these results – one that does not appeal to structural expectancies and reanalysis, but rather to memory storage costs. This account runs roughly as follows: When the *wh*-filler is encountered, it is stored in memory until it can be integrated into the relative clause at the verb. In an SRC, the filler must be stored for a relatively short time, as the verb occurs at (or very close to) the beginning of the clause. In an ORC, the verb occurs at (or very close to) the end of the clause, necessitating the storage of the filler over more intervening material.
ORC sentences are then more difficult to comprehend because this additional storage requires more processing resources. This explanation for the ORC penalty appears to match particularly well with the eye-tracking results reported in Experiment 1. Recall that in this experiment, the reading patterns indicated processing difficulty for all the words intervening between the introduction and satisfaction of the *wh*-dependency in ORC sentences (i.e., for the subject NP and the immediately following adverb).

Support for such a model also comes from early behavioral work on the processing of relative clause sentences by Wanner and Maratsos (1978). In this study, participants memorized lists of names while listening to sentences, in preparation for comprehension questions. Accuracy for name recall and for the comprehension questions was found to differ as a function of where in the sentence the external memory load was introduced. Specifically, accuracy on both tasks decreased when this load was introduced during the words intervening between the *wh*-filler and the relative clause verb in ORC sentences. This pattern of results was taken to indicate that the working memory demands involved in maintaining a filler across intervening material depleted the memory resources available for name list memorization and overall sentence interpretation.

Another source of evidence in support of memory storage costs in filler-gap processing comes from EEG studies that have shown sustained ERP responses over the words that intervene between the introduction of a *wh*-dependency and its satisfaction. For instance, in an examination of sentences like those tested in Chapter 2, King and Kutas (1995) found that ORC sentences elicited a sustained negative-going deflection over fronto-central scalp sites. Crucially, this response began at the article of the ORC
subject (*who the sailor*) – or the point in the relative clause that indicates the need to
devote more memory resources to filler storage – and continued (with varying intensity)
into the main clause. Testing the same sentences in the auditory modality, Mueller et al.
(1997) obtained a comparable sustained negative component for ORC sentences,
although more broadly-distributed and slightly more prominent over right hemisphere
scalp sites. In both studies, these responses were taken to index the increased demands on
the working memory in sentences that necessitated filler storage over longer distances.
(For comparable results in the comprehension of German filler-gap structure, see Felser,
Clahsen, and Muente (2003) as well as Fiebach, Schlesewsky, and Friedeici (2002)).

More recent ERP research on the processing *wh*-dependency sentences, however,
has called this interpretation in question. Specifically, Phillips et al. (2005) tested the
following sentences with embedded *wh*-questions, along with matched control sentences:

(9a) Short-distance, *wh*-sentence

The detective hoped that the lieutenant knew **which accomplice** the shrewd
witness would **recognize** in the lineup.

(9b) Short-distance, control sentence

The detective hoped that the lieutenant knew that the shrewd witness would
recognize the accomplice in the lineup.

(10a) Long-distance, *wh*-sentence

The lieutenant knew **which accomplice** the detective hoped that the shrewd
witness would **recognize** in the lineup.
(10b) Long-distance, control sentence

The lieutenant knew that the detective hoped that the shrewd witness would recognize the accomplice in the lineup.

The crucial differences between these sentence types related to whether they involved a filler-gap dependency (*wh*-sentence vs. control sentence) as well as to the amount of material intervening between the introduction of this dependency and its satisfaction (short-distance vs. long-distance). In an analysis of the ERP responses to these sentences, Phillips and colleagues found sustained negative components over the words intervening between the introduction of the dependency (at *which accomplice*) and its satisfaction (at *recognize*) for both short- and long-distance *wh*-sentences (curiously, with a more posterior focus for the former sentence type, but with a more anterior focus for the latter). However, when they analyzed the contribution of each of the intervening words to this sustained component (by baseline correcting at each word), they found this negativity was largely confined to the words at the very beginning of the dependency for both sentence types. This is clearly not consistent with an account of filler-gap dependency processing that posits increasing storage costs over longer distances. Indeed, such an account would predict that this negative component would be present at all (or at least most) of the words intervening between the introduction of the dependency and its satisfaction, and moreover, that this component would become larger in magnitude with increasing distance.

In light of these findings, it is interesting to note that in Kutas and King’s (1995) earlier study as well, the sustained anterior negativity evident across the relative clause in
ORC sentences largely disappeared in analyses of the ERPs at each of its component words. Again, this finding (or lack thereof) casts doubt on the contribution of memory storage costs in \textit{wh}-dependency processing generally, and in relative clause processing in particular. These single-word analyses did, however, produce ERP responses that map fairly well onto the behavioral results obtained in Experiments 1-3. Specifically, consistent with the results of all three experiments, the article in the ORC subject (\textit{the}) revealed a larger than expected N400 response – a negative deflection that picks up 300-500ms after stimulus onset and is maximal over central and posterior scalp sites. Although this component is generally taken to index semantic integration difficulty (see e.g., Kutas & Hillyard, 1980; for review, see Kutas, Federmeier, Staab, & Kluender, 2007; Kutas & Van Petten, 1994), in this case, it could be taken as a response to disrupted structural expectancies and the ensuing difficulty of integrating the determiner. Furthermore, consistent with the results of Experiment 1, a left anterior negativity (picking up 300-500ms post-stimulus) was found at the main clause verb – a response that could be taken to index (delayed) filler-gap integration costs (see also, Kluender & Kutas, 1993; for review, see Callahan, 2008).

The ERP experiment reported below examined sentences virtually identical to those tested in King and Kutas (1995). It was conducted in order to further assess the ERP responses to the words intervening between dependency introduction and satisfaction in ORC sentences as well as those to crucial words at beginning and end of the relative clause in these sentences. In doing so, this experiment sought to further
elucidate the contribution of the distinct processes indexed by these responses to the comprehension difficulty for ORC sentences.

3.1 Experiment 4

3.1.1 Method

3.1.1.1 Participants

Twenty-five (25) University of Arizona undergraduates participated in the experiment in partial fulfillment of course requirements. In addition to course credit, participants with accuracy scores of 90% or higher on the comprehension questions were entered into a raffle to receive a $30 gift certificate to the University of Arizona Bookstore. All participants were native speakers of English, with normal or corrected-to-normal vision, with no history of learning disability or cognitive impairment, and who were not taking medication that might alter the naturally-occurring electrical activity in the brain (e.g., anti-psychotics, anti-depressants, Ritalin, etc.). The data from four subjects were not analyzed because of excessive artifacts in the EEG record. The data from another subject was eliminated due to equipment failure during the last half of the experimental session. Of the remaining the 20 subjects (whose data contributed to the analyses reported below), 14 were men and six were women (mean age: 18.85; age range: 18-22).

Subjects’ handedness was determined using a thirteen item questionnaire adapted from Chapman and Chapman (1987). The items on this questionnaire are provided in Appendix C. For each item, subjects indicated whether they used the right, left, or either hand to do the activity in question. “Right” responses were scored as “1”, “either”
responses as “2”, and “left” responses as “3”. These scores were then summed to yield a handedness score for each participant, ranging from 13 (completely right-handed) to 39 (completely left-handed). The participants’ handedness scores ranged from 13 to 22, with a mean score of 13.85 ($SD=2.13$). Thus, all of the subjects’ scores were on the right-handed end of the continuum, and all but one fell within the 13-17 point range that was used to designate subjects as right-handed in Chapman and Chapman (1987). The one score that fell outside of this range – a score of 22 – was produced by a participant who selected the “either” response for nine items and the “right” response for the remaining four items. When asked to elaborate on these “either” responses, the participant indicated that although it was possible to do these activities with either hand, in all cases the right hand was preferred. In light of this explanation and the fact that the subject did not select a “left” response for any item, this participant was deemed right-handed for the purposes of this experiment.

3.1.1.2 Materials

The materials consisted of 80 ORC/SRC sentence pairs similar to those used in Experiments 1-3. In fact, the 28 SRC/ORC items used in these earlier experiments were included (with minor adjustments) in the present study. The complete set of experimental items is presented in Appendix D. Again, these materials were adapted from items used in King and Kutas (1995), Mueller et al. (1997), and Weiss et al. (2005). The versions of these sentences were counterbalanced across two lists. Also included on these lists were 240 filler sentences. Eighty (80) of these fillers were included purely to distract the participants from focusing explicitly on experimental items (see Appendix E); while the
remaining 160 filler items were the sentences of particular interest in Experiment 8 (see Appendix G). Again, filler sentences were roughly matched with experimental items in terms of length and complexity. In each list, experimental and filler sentences were divided into eight blocks of 40 items, with each block containing 10 experimental items and 30 fillers. These blocks, and the items within each block, were randomly presented. Yes-no comprehension checks followed 104 of the sentences in the experiment (or 43.33%), with 20 questions occurring after experimental items. Each block of items included 13 of these comprehension checks, with 2-3 questions targeting experimental items (and at least one question per experimental condition.)

3.1.1.3 Procedure

Participants were seated in a dimly lit room in front of a CRT screen (with ~100 cm between the participant and the screen). They were told that their task was to read sentences (silently) as they were presented one word at a time on the screen and to answer occasional yes-no comprehension questions. Participants were also told that if they performed particularly well on these comprehension questions, they would have chance to win a gift certificate prize. At the beginning of each trial, a string of plus marks (++++++++) appeared in the center of the screen (as a fixation point) for 1000ms. After a 500ms blank screen, the words of the sentence began to appear, again in the center of the screen. The presentation rate was 500ms per word, with each word presented on the screen for 300ms, followed by a 200ms blank screen. The sentences were presented with standard capitalization and punctuation (with the last word of each sentence indicated by a period). For sentences that did not involve comprehension questions, the last word was
followed by a 500ms blank screen and then the message ‘NO QUESTION’ for 1000ms. The next trial then began after a 1000ms blank screen. For sentences that involved comprehension checks, the last word was followed by a 500ms blank screen and then by the question. Participants answered ‘yes’ with a button held in the right hand, and ‘no’ with a button in the left hand. The question remained on the screen for 4000ms or until the participant responded, whichever came first. Questions that were not responded to within 4000ms were coded as errors. After responding to the question, the participant received feedback (‘CORRECT’ or ‘…Wrong…’). The next trial then began after a 1000ms blank screen. All stimuli were presented in black letters on a white background.

At the beginning of the task, participants were given 10 practice trials. Sentences were presented in blocks of 40 (described above), each lasting ~8-9 minutes. After the first twenty sentences in each block, participants were given a self-timed break. That is, the experiment paused, and could be resumed at any time by pushing either the ‘yes’ or ‘no’ button. At the completion of each block, participants were given longer breaks (which usually lasted ~3-5 minutes). Each experimental session lasted ~2 hours, including the task/EEG recording and set-up time.

3.1.1.4 **EEG Recording**

Continuous EEG was recorded from 62 Ag/AgCl electrodes mounted in an electrode cap (with a ground lead just anterior to Fz). These recording sites included both standard and extended 10-20 system positions. The relative positions and labels for these scalp electrodes are shown in Figure 3. In addition to these sites, electrodes were attached to the left and right mastoids (for offline re-referencing, see below), as well as to the
superior and inferior orbit of the left eye and the outer canthi of both eyes to monitor vertical and horizontal eye movements. (Electrocardiogram was also recorded from electrodes placed on the chest, just below the left and right clavicles.) During recording, the EEG signal was referenced to an electrode just posterior to Cz, and then re-referenced offline to linked mastoids. The signals from all channels were recorded at a sampling rate of 500Hz using a Neuroscan Synamps² amplifier in DC mode with a 30Hz low-pass filter. The impedance at each electrode was kept at less than 5 Kohms. The EEG recording was carefully monitored throughout the experimental session. If it was discovered that an

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electrode was producing a consistently aberrant signal during any of the experimental blocks, attempts were made to correct this recording problem at the end of the block.

3.1.1.5 Data Analysis

Large muscle artifacts and signal artifacts were removed from the raw EEG record based on visual inspection prior to any further pre-processing. Bad EEG channels (or channels that produced consistent artifacts) were identified in the record of each experimental block for each participant. These channels were interpolated based on the weighted average of the four nearest (good) electrode sites. No more than 7 electrodes were interpolated for any block (range=0-7), with an average of 1.84 (SD=1.92) electrodes interpolated per block. (Of the 55 electrode sites that contributed to the statistical analyses reported below, an average of 1.36 (SD=1.73; range: 0-7) electrodes were interpolated per block.) Epochs surrounding the words of interest were then extracted from the EEG record. The epochs for the cumulative analysis of the sustained ERP components (see below) were 6000ms-long sections of EEG surrounding the word who in the ORC/SRC sentences. These epochs were made up of the 1000ms preceding the presentation of this word (or a 1000ms pre-stimulus interval) and the 5000ms after its presentation (or a 5000ms post-stimulus interval). The epochs for the analyses of individual words – that is, for both the non-cumulative analysis of the sustained ERP components as well as for the single-word analyses (again, see below) – consisted of a 1000ms pre-stimulus interval and 2000ms post-stimulus interval surrounding each word of interest. For the baseline correction of the longer (6000ms) epochs, the last 500ms of the pre-stimulus interval (or the -500-0ms interval) was used; for the epochs surrounding
individual words, the -100-0ms interval was used as the baseline. In each of these sets of epochs, eye blinks were corrected for using the Ocular Artifact Reduction feature in Scan 4.3 (Semlitsch, Anderer, Schuster, & Presslich, 1986). Finally, for the longer epochs, trials that involved a shift from baseline of 150 microvolts or more in the 4000ms post-stimulus interval were eliminated from the analysis. For the epochs surrounding individual words, the same 150-microvolt threshold was applied over the 1000ms post-stimulus interval. This was done in order to eliminate any remaining trials that involved unusually large voltage fluctuations. After these artifact rejection/reduction procedures were applied, 82.31% of the trials remained for the cumulative analysis of the sustained ERP components, while 90.69% of the trials remained for analyses of the individual words.

Stimulus-locked ERPs were computed by averaging the trials for each multi-word unit and word of interest under each sentence condition separately for each subject. Statistical analyses were then conducted on the mean voltage amplitude at specified time intervals (with the interval depending on the analysis; see below) in these ERP waveforms. Following the recommendations of Dien and Santuzzi (2005) for the analysis of high-density EEG electrode arrays, eight regions of interest (ROIs) were defined along three topographic factors, each with two levels – hemisphere (right, left), anterior/posterior, and lateral/medial. Each of the ROIs defined by these factors consisted of six electrodes (Figure 4) – left anterior lateral: F7, F5, FT7, FC5, T7, C5; left anterior medial: F3, F1, FC3, FC1, C3, C1; left posterior lateral: TP7, CP5, P7, P5, PO7, PO5; left posterior medial: CP3, CP1, P3, P1, PO3, O1; right anterior lateral: F8, F6, FT8, FC6,
The ROI analysis for each time interval thus consisted of an ANOVA with hemisphere, anterior/posterior, lateral/medial, and sentence type (ORC, SRC) as within-subjects factors, and with list as a between-subjects grouping factor. In addition, for each time interval, a separate analysis of the midline scalp sites was conducted. This analysis consisted of an ANOVA with sentence type and site (7 levels, each corresponding to one of the following midline sites: Fz, FCz, Cz, CPz, Pz, POz, Oz) as within-subjects factors, and with list as a between-subjects grouping factor. Under this analysis, because interactions of sentence type and site invariably entailed violations of sphericity, Greenhouse-Geisser-corrected degrees of freedom were used to assess this effect.

Following King & Kutas (1995), the analysis of the sustained ERP components examined the waveforms for ORC and SRC sentences from the beginning the relative clause (who) until well after its completion, three words into the main clause (i.e., in an ORC sentence, over the words ...who the sailor roughly pushed smashed a bottle...; in an SRC sentence, over the words ...who roughly pushed the sailor smashed a bottle...). This was done in two ways. First, a cumulative analysis was conducted over the 4100ms interval beginning with who and ending 600ms after the presentation of the main clause object (bottle). This long time window was then divided into smaller intervals for analysis, following the procedures in Phillips et al. (2005). Specifically, the analysis took into consideration the mean voltage in the 100-600ms interval after the presentation of each word. Following King & Kutas (1995) and Phillips et al. (2005), a non-cumulative
Figure 4. Electrodes that contributed to the statistical analyses. The ROI analyses were conducted over groups of electrodes (indicated with shading) defined by the topographic factors hemisphere (right, left), anterior/posterior, and lateral/medial. The midline analysis was conducted over the midline scalp sites Fz, FCz, Cz, CPz, Pz, POz, and Oz (shaded green).

analysis was also conducted. This analysis was conducted on the ERPs generated from the (-1000-2000ms) epochs for individual words, and again targeted the mean voltage in the 100-600ms interval corresponding to each word of interest. The key difference between these analysis schemes is that they use different baselines for the calculation of the mean voltages. In the cumulative analysis, this measure was calculated for each word
relative to a common baseline – again, the -500-0ms interval, or the 500ms corresponding to the noun in the subject NP of the sentence (*soldier*). In the non-cumulative analyses, on the other hand, mean voltages were calculated relative to the -100-0ms interval for each word.

The *single-word* analyses focused on the words of particular interest in the ORC and SRC sentences – specifically, the relative clause article (*the*) and main clause verb (*smashed*). These analyses examined the average voltage differences in the -100-100ms, 100-300ms, and 300-500ms time windows.

### 3.1.2 Results

#### 3.1.2.1 Comprehension Question Accuracy

For the 20 participants included in the analyses, the mean accuracy score on the comprehension questions was 87.75% (*SD*=6.15).

#### 3.1.2.2 Analyses of the Sustained ERPs

##### 3.1.2.2.1 Cumulative analysis

An example waveform and topographic maps for this analysis are presented in Figure 5. For the word that began the relative clause (*who*), there was a significant interaction of sentence type and hemisphere, $F(1,18)=4.82, p<.05$, indicating that ORC sentences elicited more positivity over left hemisphere scalp sites and more negativity over right scalp sites. A significant three-way interaction of sentence type, hemisphere, and lateral/medial, $F(1,18)=10.62, p<.01$, further indicated that this disparity was most pronounced over lateral scalp sites. These effects are difficult to interpret in light of the fact that the ORC and SRC sentences did not diverge structurally until after this word.
Figure 5. Grand average ERP responses from the beginning of the relative clause (*who*) until the noun in the main clause object (*bottle*) in ORC and SRC sentences at the anterior midline electrode Fz. The waveform for the ORC condition is shown in red; the waveform for the SRC condition is shown in blue. Topographic maps are based on the average voltage differences between the conditions at successive 500ms intervals.
At the second word of the relative clause (ORC: *the*; SRC: *roughly*), there was a statistically-reliable three-way interaction of sentence type, hemisphere, and anterior/posterior, $F(1,18)=7.79, p<.05$. This effect indicated that although the article (*the*) in ORC sentences elicited negativity bilaterally over anterior scalp sites, this negativity was largely right-lateralized over posterior sites. The interaction of sentence type and lateral/medial also approached significance, $F(1,18)=3.05, p=.10$, suggesting that the negativity elicited by the article (*the*) in ORC sentences was most pronounced over medial sites. The midline analysis revealed an interaction of sentence type and site that approached significance, $F(2.36, 42.40)=2.50, p=.09$, and that was driven by pronounced negative amplitudes over central and anterior midline sites (Fz, FCz, Cz, and CPz).

At the next word in the relative clause (ORC: *sailor*; SRC: *pushed*), ORC sentences again appeared to elicit more negativity – in this case, over anterior scalp sites in particular. However, this apparent difference did not produce any statistically-reliable effects related to the sentence types.

At the third word of the relative clause (ORC: *roughly*; SRC: *the*), the three-way interaction of sentence type, hemisphere, and anterior/posterior approached significance, $F(1,18)=3.32, p=.09$, and there was a significant four-way interaction of sentence type, hemisphere, anterior/posterior, and lateral/medial, $F(1,18)=5.63, p<.05$. These effects were produced by a pronounced negativity over left anterior lateral scalp sites elicited for the article (*the*) in SRC sentences. It is important to note that this effect is in the opposite direction of that which is predicted under a memory storage account of the difficulty in
ORC sentences. That is, to the extent that a sustained anterior negative-going deflection can be taken as a reliable index of storage costs, there should be more negativity for ORC sentences across the words of the relative clause, not vice versa.

At the fourth and final word of the relative clause (ORC: pushed; SRC: sailor), SRC sentences again elicited a negativity. Although more broadly distributed than at the immediately preceding word, this negativity was nevertheless most pronounced over left and anterior scalp sites, as indicated by a main effect of sentence type that approached significance, $F(1,18)=2.93, p=.10$, and significant sentence type × hemisphere, $F(1,18)=4.45, p<.05$, and sentence type × anterior/posterior interactions, $F(1,18)=8.73, p<.01$. Furthermore, the three-way interaction of sentence type, hemisphere, and lateral/medial approached significance, $F(1,18)=3.70, p=.07$, suggesting a somewhat left lateral focus for this negativity. Finally, the midline analysis revealed a significant interaction of sentence type and midline site, $F(2.22, 39.95)=4.02, p<.05$, that was driven by pronounced negative amplitudes for the anterior midline sites Fz and FCz. It is worth noting that this effect is again in the opposite direction of that which is predicted under a memory storage account of the ORC penalty.

There were no statistically-reliable effects related to the sentence types in the analyses of the three main clause words following the relative clause – the main clause verb (smashed), the article in the main clause object NP (a), and the noun in this object NP (bottle).
3.1.2.2 Non-cumulative analysis

Example waveforms and topographic maps for this analysis are presented in Figure 6. This non-cumulative analysis picks up from the second word of the relative clause (ORC: *the*; SRC: *roughly*). At this word, the three-way interaction of sentence type, hemisphere, and anterior/posterior, $F(1,18)=10.09, p<.01$, and the four-way interaction of sentence type, hemisphere, anterior/posterior, and lateral/medial, $F(1,18)=10.63, p<.01$, were significant, indicating that the article (*the*) in ORC sentences elicited a pronounced negativity over left anterior scalp sites, and more specifically over lateral sites in this region. The midline analysis also indicated an anterior negativity for ORC sentences at this word. Specifically, there was a marginally significant interaction of sentence type and midline site, $F(1.70, 30.54)=3.19, p=.06$, that was driven by especially large negative amplitudes over anterior midline sites (Fz, FCz, and Cz) for ORC sentences.

At the next word of the relative clause (ORC: *sailor*; SRC: *pushed*), there was again a significant three-way interaction of sentence type, hemisphere, and anterior/posterior, $F(1,18)=5.44, p<.05$, as well as a significant four-way sentence type hemisphere × anterior/posterior × lateral/medial interaction, $F(1,18)=10.47, p<.01$. However, in contrast to the immediately preceding region, these effects indicated that the noun (*sailor*) in ORC sentences elicited greater positive amplitudes than the verb (*pushed*) in SRC sentences over left anterior lateral scalp sites.

At the third word of the relative clause, (ORC: *roughly*; SRC: *the*), the article in SRC sentences elicited a strong anterior negativity that was maximal over left anterior
Figure 6. Grand average ERP responses to word pairs from ORC and SRC sentences from the second word of the relative clause (ORC: *the*; SRC: *roughly*) until the noun in the main clause object (*bottle*) at the anterior midline electrode Fz. The waveforms for the ORC condition are shown in red; the waveforms for the SRC condition are shown in blue. Topographic maps are based on the average voltage differences between the conditions in the 100-600ms interval for each word pair.
lateral scalp sites. This response produced a significant main effect of sentence type, $F(1,18)=7.13$, $p<.05$, as well as significant sentence type × hemisphere, $F(1,18)=6.16$, $p<.05$, sentence type × anterior/posterior, $F(1,18)=26.68$, $p<.001$, sentence type × hemisphere × anterior/posterior, $F(1,18)=26.71$, $p<.001$, and sentence type × hemisphere × anterior/posterior × lateral/medial interactions, $F(1,18)=8.50, p<.01$. In the midline analysis, this anterior negativity for the article in SRC sentences produced a significant interaction of sentence type and midline site, $F(1.53, 27.59)=24.20$, $p<.001$, that was driven by large negative amplitudes for anterior midline sites (Fz, FCz, and Cz).

At the final word of the relative clause (ORC: *pushed*; SRC: *sailor*), the interaction of sentence type and lateral/medial approached significance, $F(1,18)=3.29$, $p=.09$, suggesting more negativity for SRC sentences over lateral electrodes generally. There were also significant interactions of sentence type, hemisphere, and anterior/posterior, $F(1,18)=7.92$, $p<.05$, and sentence type, hemisphere, anterior/posterior and lateral/medial, $F(1,18)=18.35$, $p<.001$. These complex interactions indicate more negativity for SRC sentences over right anterior scalp sites and left posterior scalp sites, and particularly over medial sites in this latter region.

At the main clause verb, ORC sentences elicited a negativity that was most pronounced over anterior and left hemisphere scalp sites. This response produced a main effect of sentence type, $F(1,18)=4.77, p<.05$, as well as significant sentence type × hemisphere, $F(1,18)=6.98, p<.05$, and sentence type × anterior/posterior interactions, $F(1,18)=36.52, p<.001$. This latter interaction also partially reflects a trend in the opposite direction over posterior scalp sites. In the midline analysis, this anterior
negativity also yielded a significant interaction of sentence type and site, $F(1.30, 23.46)=26.83, p<.001$. This effect was driven by especially strong negativities for the anterior midline sites Fz, FCz, and Cz, and a complementary pattern of results over the midline posterior sites CPz, Pz, POz. There were no statistically-reliable effects related to these RC sentence types at either the article or the noun in the main clause object NP.

3.1.2.2.3 Interim summary

Contrary to the predictions of a memory storage account for processing difficulty in ORC sentences, neither the cumulative analysis nor the non-cumulative analysis indicated a sustained anterior negativity for this sentence type. And while admittedly, the complete pattern of results for the words in the relative clause defies precise explanation, it is clearly the case that the most prominent negativities in these clauses occurred when a function word (the) was compared with an adverb content word (roughly). Indeed, these results match well with previous indications that function words elicit anterior negative deflections, but attenuated N400 components, relative to content words (Kutas & King, 1995; Kutas, Van Petten, & Besson, 1988; Neville, Mills, & Lawson, 1992). Although this difference in anterior negativity as function of word class is interesting in and of itself, it certainly does not speak to the nature of the ORC difficulty. However, it is important to point out here that the distribution of this “function word negativity” appeared to have a much more prominent anterior focus in SRC sentences than in ORC sentences. This may be attributable to an N400 for the article in this latter sentence type. Again, this result would replicate one of the key findings in King & Kutas (1995) and would match with the indications of processing difficulty for this word in the behavioral
experiments reported in Chapter 2. In addition to these function word effects, the non-cumulative analysis indicated a prominent anterior negativity for the main clause verb in ORC sentences – a result that again appears to match an effect found in King & Kutas (1995) and that corresponds well with the reading patterns for this word in the eye-tracking experiment reported Chapter 2. The single-word analyses below examine the ERP responses to these words in more detail.

### 3.1.2.3 Single-Word Analyses

The first comparison of interest was between the relative clause article (the) in ORC and SRC sentences. Figure 7 presents waveforms from a representative sample of electrodes and topographic maps for this analysis. At the -100-100ms time window, the main effect of sentence type was significant, $F(1,18)=8.63, p<.01$, as were the sentence type $\times$ anterior/posterior, $F(1,18)=6.13, p<.05$, and sentence type $\times$ lateral/medial interactions, $F(1,18)=5.02, p<.05$. These effects indicate that even at this earliest time window, the average voltage for the article in ORCs was more negative than for the same word in SRCs. These effects further indicated that this disparity was most pronounced over posterior and medial scalp sites. Comparably, in the midline analysis, there was a significant main effect of sentence type, $F(1,18)=8.33, p<.05$, as well as a interaction of this factor with midline site, $F(1.60, 28.86)=4.58, p<.05$, that was driven by more prominent negativities for the article in ORC sentences over centro-posterior midline sites (Cz, CPz, Pz, POz, Oz). Obviously, because this time window includes the -100-0ms baseline, this difference complicates the interpretation of the results for this word. At the 100-300ms interval, there were no reliable differences in the responses to the article
Figure 7. Grand average ERP responses at relative clause article (*the*). Waveforms for this article in ORC sentences are shown in red; waveforms for this article in SRC sentences are shown in blue. Topographic maps are based on the average voltage differences between the ORC and SRC conditions at successive 200ms time intervals.
in the two sentence types. At 300-500ms interval, however, there was a significant interaction of sentence type and lateral/medial, $F(1,18)=12.56, p<.01$, indicating that the article in ORCs elicited more negativity over medial scalp sites. Similarly, the midline analysis yielded a significant main effect of sentence type, $F(1,18)=5.60, p<.05$. The problems with the baseline notwithstanding, replicating the results of King and Kutas for this word, the article (the) in ORC sentences appears to elicit an N400 response.

Analyses at the same time intervals were conducted for the main clause verb (smashed) in ORC and SRC sentences. Waveforms from a representative sample of electrodes and topographic maps for this analysis are presented in Figure 8. At the -100-100ms interval, there was a significant interaction of sentence type and anterior/posterior, $F(1,18)=8.10, p<.05$, indicating more negativity over anterior scalp sites and more positivity over posterior sites for the main verb in ORC sentences. Again, this effect complicates the interpretation of the responses to this verb because it obtains in the region containing the baseline interval. At the 100-300ms interval, there was a significant interaction of sentence type and anterior/posterior, $F(1,18)=19.93, p<.001$, while the interaction of sentence type and lateral/medial approached significance, $F(1,18)=3.44, p=.08$. These effects again reflect more negativity over anterior scalp sites and more positivity over posterior scalp sites for the verb in ORC sentences, and suggest that these differences are most pronounced over lateral scalp sites. In the midline analysis, there was a significant interaction of sentence type and midline site, $F(1.27, 22.94)=15.67, p<.001$, that was driven by large negativities at the anterior electrodes Fz, FCz, and Cz, and pronounced positivities at the posterior sites Pz, Poz, Oz. In the 300-500ms interval,
Figure 8. Grand average ERP responses at main clause verb (*smashed*). Waveforms for this verb in ORC sentences are shown in red; waveforms for this verb in SRC sentences are shown in blue. Topographic maps are based on the average voltage differences between the ORC and SRC conditions at successive 200ms time intervals.
there was a significant main effect of sentence type, $F(1,18)=8.21, p<.05$, as well as significant sentence type × hemisphere, $F(1,18)=8.11, p<.05$, sentence type × anterior/posterior, $F(1,18)=43.03, p<.001$, and sentence type × hemisphere × lateral/medial interactions, $F(1,18)=5.38, p<.05$. These effects were produced by positivities over posterior scalp sites and prominent negativities over anterior sites, with a largely left, lateral focus. In the midline analysis, there was again a significant interaction of sentence type and midline site, $F(1.31, 23.60)=28.59, p<.001$, that was driven by large negativities at the anterior electrodes Fz, FCz, and Cz, and pronounced positivities at the posterior sites Pz, Poz, Oz. Again, ignoring the problems with the baseline interval for the time being, again replicating the results of King and Kutas (1995), the main clause verb elicited a robust LAN response.

### 3.1.3 Discussion

The results of the present study cast doubt on the assertion that the processing difficulty incurred in ORC sentences is due primarily to memory storage demands. The SAN response has been taken to index these storage costs, yet the present study failed to replicate these findings. Of course, absence of evidence should not necessarily be interpreted as evidence of absence. And, indeed, it may be that sustained ERP components are not a sensitive enough to indicate the neurophysiological consequences of sustained memory storage. Having said that, it is important to point out that these are null results in context. After all, the present experiment did (with some caveats) replicate the N400 response to the ORC article as well as the LAN response at the main clause verb. These findings are interpreted to index the key processes that are argued to be
operative in filler gap processing – disrupted structural expectancies and filler-gap integration costs.
CHAPTER 4
ANAPHORA PROCESSING: BEHAVIORAL EXPERIMENTS

The purpose of the experiments reported in this chapter is to examine the extent to which there is overlap in the processing of two long-distance dependency types – wh-dependencies and anaphoric dependencies. As discussed above, and as demonstrated in Experiments 1-4, wh-dependency sentences appear to involve both forward-looking, expectancy-based processes and backward-looking, retrieval-based integration processes. The question taken up in the present set of experiments is whether these processes are ubiquitous across sentence types that have a dependent-element-first structure.

Of particular interest in this chapter (and the next) are sentences involving anaphoric dependencies. As discussed in the Introduction, these sentences involve linking a referentially-dependent element (or an anaphor) with another discourse element (an antecedent). For instance, in the following sentence he is an anaphor that is referentially-dependent on the king, its antecedent: When the king appeared, he immediately greeted the boys very warmly. (Note, however, that the link between these elements is not strictly required, as he could refer to a different discourse referent.) In this example of so-called forward anaphora, the dependent element (the anaphor) follows its “satisfying” element (its antecedent). The possibility of precognition notwithstanding, establishing an anaphor-antecedent link in sentences of this type can only involve backward-looking dependency satisfaction processes. However, again as discussed above, there are cases in which the order of the antecedent and anaphor can be switched, creating so-called backward anaphora sentences like the following: When he appeared, the king immediately greeted
the boys very warmly. Similar to sentences involving filler-gap dependencies, this type of anaphora entails a dependent-element-first structure. Of interest in this chapter is whether the processing of dependent-element-first structures engages comparable mechanisms, regardless of dependency type.

It is argued above that the introduction of a wh-dependency sets up structural expectations for its efficient satisfaction. One way in which these expectancies have been modeled is in terms of an Active Filler Strategy (see e.g., Aoshima et al. 2004; Clifton & Frazier, 1989; Crain & Fodor, 1985; Stowe, 1986). Under this strategy, the parser does not wait until all of the necessary information becomes available before positing a gap for a filler; rather it actively searches for a gap site once a filler has been detected. This active search process is evidenced primarily by filled-gap effects, or by indications of processing difficulty when the parser posits a gap site, but is then forced to retract this analysis. Although the processing difficulty for ORC sentences can be accounted for in terms of the filled-gap effect, another example of this effect can be seen in the comparison of the following sentences (from Stowe, 1986):

(11a) My brother wanted to know who Ruth will bring us home to __ at Christmas.

(11b) My brother wanted to know if Ruth will bring us home to Mom at Christmas.

In sentence (11a), the verb bring indicates a possible gap site for the filler who in the embedded wh-question (as in My brother wanted to know who Ruth will bring __ home at Christmas.). However, this gap site is occupied by the direct object us. Consistent with
the Active Filler Strategy, Stowe (1986) found longer reading times at this direct object in sentences like (11a) compared to control sentences in which there was no filler-gap dependency, or sentences like (11b). Furthermore, in this study as well as in subsequent work by Traxler and Pickering (1996; see also, Phillips, 2006), it has been shown that this active search process is sensitive to grammatical constraints on filler-gap dependencies. Specifically, processing difficulty is not evidenced at filled gaps when they are in grammatically “inaccessible” structural positions – for example, when they are in wh-islands (see e.g., Ross, 1967, for more on the syntax of island constraints on movement operations).

Interestingly, several experiments testing backward anaphora sentences have revealed processing characteristics very similar to those found for filler-gap dependencies (Cowart & Cairns, 1987; Kazanina et al., 2007; Van Gompel & Liversedge, 2003). Specifically, in these sentences, the “unlinked” pronoun also appears to trigger an active, grammatically-constrained search for its antecedent. Van Gompel and Liversedge (2003), for example, examined the reading patterns on sentences like the following:

(12a) When he was fed up, the boy visited the girl very often.

(12b) When she was fed up, the boy visited the girl very often.

The results indicated reading patterns consistent with processing difficulty at and immediately after the main clause subject (the boy) in sentences in which the gender of this subject was incompatible with that of the preceding pronoun (she), as in sentence (12b) (for comparable results, see Cowart & Cairns, 1987). One interpretation of these
results is that they indicate an analogue to the filled-gap effect in (backward) anaphora processing.

Kazanina et al. (2007) examined exactly this proposal by looking into whether the active search for an antecedent in backward anaphora sentences is constrained by the Grammar in a way similar to that which has been demonstrated in filler-gap processing. The constraint of particular interest was Principle C, which essentially states that a referential expression cannot be co-referential with another element that occupies a higher (c-commanding) structural position in the sentence. Simply put, it is this principle that prevents *He* and *John* from referring to the same person in the sentence *He said that John likes cheese*. Kazanina et al. (2007) exploited this restriction on coreference to test sentences like the following in a self-paced reading experiment:

(13a) Principle C/match

Because last semester *she* was taking classes full-time while *Kathryn* was working two jobs to pay the bills, *Erica* felt guilty.

(13b) Principle C/mismatch

Because last semester *she* was taking classes full-time while *Russell* was working two jobs to pay the bills, *Erica* felt guilty.

(14a) No constraint/match

Because last semester while *she* was taking classes full-time *Kathryn* was working two jobs to pay the bills, *Russell* never got to see her.
(14b) No Constraint/mismatch

Because last semester while she\textsubscript{i} was taking classes full-time Russell was working two jobs to pay the bills, Erica\textsubscript{i} promised to work part-time in the future.

(15) No Constraint/name

Because last semester while Erica\textsubscript{i} was taking classes full-time Russell was working two jobs to pay the bills, she\textsubscript{i} promised to work part-time in the future.

In the Principle C sentences (13a) and (13b), this restriction prevents she from referring to the next possible referent, the name Kathryn/Russell. In the No Constraint sentences (14a) and (14b), on the other hand, the Grammar allows she and this name (Kathryn/Russell) to be coreferential. For both sentence types, the pronoun at the beginning of the sentence either matched or matched the relevant name in terms of gender.

Sentence (15) does not involve backward anaphora, and was therefore used as a control structure. Consistent with the idea that the search for an antecedent in backward anaphora sentences is grammatically constrained, there was processing difficulty for pronoun-name mismatch only under the No Constraint condition. That is, the search for an antecedent in backward anaphora sentences only appeared to target referents that occupied grammatically accessible positions. In light of this evidence, Kazanina and colleagues concluded that there is substantial overlap in the search process involved in filler-gap and backward anaphora processing, and further speculated that “the parser might draw on a single mechanism for all linguistic dependencies that share this same basic dependent-element-first structure” (2007, p. 405).
Of course, this is a quite compelling theoretical proposal in that it has the potential to unify the processing of a wide range of sentence types under a single model. And indeed a closer look at the results from Kazanina et al. (2007) offers yet another reason to suspect that it might be correct. Again, as detailed above, Kazanina et al. (2007) found clear evidence of processing costs in backward anaphora sentences when there was disruption to a (grammatically-constrained) forward-looking dependency satisfaction process – a result that matches well with findings indicating a filled-gap effect in wh-dependency processing. But as we have seen, at least under certain task conditions, there are also costs for backward-looking, integration processes in filler-gap sentences. If backward anaphora and filler-gap processing draw on the same mechanism, the clear prediction is that there should also be integration costs at the point of anaphor-antecedent integration. Interestingly, the results of Kazanina et al. (2007) appear to bear out this prediction. With reference again to the example sentences above, there was a robust effect indicating that No Constraint sentences were generally read more slowly (relative to both the Principle C sentences and the control sentence) at and immediately after the critical name (Kathryn/Russell). That is, there appeared to be an indication of costs for both dependency disruption and satisfaction – exactly as in the processing of filler-gap structures.

The experiments detailed below provided a direct test for these dependency disruption and satisfaction effects in the processing of backward anaphora sentences. They also allowed for an examination into the extent to which these effects are task dependent. Recall that the effects of disruption to expectancy-based processes were
robust across the behavioral experiments on relative clauses reported above (Experiments 1-3). However, the effects of retrieval-based processes only occurred in the eye-tracking experiment (Experiment 1) – a task that allows for relatively “natural” reading and that encouraged/required explicit monitoring of the propositional content of the sentence. This pattern of results was taken to suggest that forward-looking processes are more closely tied to the online structure building, whereas retrieval operations relate primarily to the assignment of thematic roles to elements in the propositional structure of the sentence. Whether or not this particular explanation is correct, an interesting question is whether a comparable pattern of results would obtain in the processing of backward anaphora sentences. Findings indicating that this is the case would underscore the similarities in the processing of filler-gap and backward anaphora sentences.

4.1 Experiment 5: Investigating Anaphora Processing with Eye Tracking

Experiment 5 investigated the processing of forward and backward anaphora sentences with an eye tracking methodology. The sentence types of particular interest in this experiment were as follows (where anaphora type is indicated by F(orward)/B(ackward) and “linking point”, by NP1/NP2):

(16a) F(oral)/NP1

When Mary spotted the mysterious UFO, she told Jeff to call the authorities.

(16b) F/NP2

When Jeff spotted the mysterious UFO, Mary told him to call the authorities.

(16c) B(ackward)/NP1

When she spotted the mysterious UFO, Mary told Jeff to call the authorities.
When he spotted the mysterious UFO, Mary told Jeff to call the authorities.

In the forward anaphora sentences, F/NP1 and F/NP2, the antecedent (Mary/Jeff) was the subject of the subordinate clause and preceded the anaphor (she/him). In the NP1 version of this sentence type, the anaphor was the main clause subject; in the NP2 version, the anaphor was in the more distal main clause object position. In the backward anaphora sentences, B/NP1 and B/NP2, the subordinate clause subject was a pronoun (she/he). In the NP1 version of this sentence, the main clause subject (Mary) matched the gender of the pronoun, while in the NP2 version, the pronoun and main clause subject mismatched. In this latter sentence type, a matching NP was provided at the main clause object.

The predictions for the experiment were as follows: If there is a cost for both dependency disruption and satisfaction in backward anaphora sentences, the main clause subject in both versions of this sentence type (B/NP1, B/NP2) should elicit reading patterns consistent with processing difficulty. Furthermore, consistent with the results of Van Gompel and Liversedge (2003) and Kazanina et al. (2007) these processing costs should be greater for dependency disruption (at the main clause subject in B/NP2 sentences) than for dependency satisfaction (at the main clause subject in B/NP1 sentences). In addition to these crucial comparisons, these sentences also allowed for an examination of the overall reading patterns on forward and backward anaphora sentences. If dependency processing differs fundamentally as a function of the relative ordering of the dependent and satisfying elements, the overall reading patterns on these sentence types should be quite different (despite only minor differences in overall lexical content).
4.1.1 Method

4.1.1.1 Participants

Forty (40) University of Arizona undergraduates participated in the experiment in partial fulfillment of course requirements. All participants were native speakers of English, with normal or corrected-to-normal vision (with soft contact lenses, in adherence with the recording restrictions of the Dr. Bouis Oculometer). These participants were the same as those in Experiment 1. As mentioned in Chapter 1 (and as touched on again below), Experiment 1 and the present experiment were interleaved and run in a single experimental session.

4.1.1.2 Materials

The materials consisted of 56 sentence sets similar to those in example set (16a)-(16d) above. These items were drawn from the sentences used in Experiment 8. The complete list of experimental items is presented in Appendix F. The four versions of each item were divided into counterbalanced lists. A number of factors were taken into consideration in the creation of these items and lists: First, each experimental sentence began with a subordinate adverbial clause (e.g., *After Mary saw the mysterious UFO,* ......). Five words were selected to introduce these clauses: *After, As, When, Because,* and *Although.* These words allowed for the creation of sentences in which the event/proposition expressed by the subordinate clause preceded (or was not temporally ordered with respect to) the event/proposition in the main clause. (See Muente, Schiltz, & Kutas (1998) for an indication that the “reversed” temporal ordering of a subordinate and main clause (e.g., *Before x…, y.*) induces processing difficulty.) Although these words
introduced different numbers of items in the experiment – After (16 items), As (16), When (12), Because (8), and Although (4) – the lists were organized such that each word occurred equally often in the four experimental sentence types. For example, in each list After introduced four F/NP1 sentences, four F/NP2 sentences, four B/NP1 sentences, and four B/NP2 sentences. Furthermore, again as illustrated in the example sentence set, each sentence involved a man and a woman (or possibly a boy and a girl, depending on the sentence context) who were referred to using 20 common four-letter names (male names: Adam, Bill, Greg, Jack, Jeff, John, Matt, Mark, Mike, Paul; female names: Anne, Beth, Jane, Jill, Judy, Kate, Lisa, Lucy, Mary, Sara). These names were applied at random to the experimental items (as well as to the fillers, see below), such that each occurred roughly equally often and such that no two names occurred systematically in combination with each other. In addition, each sentence involved a gender marked pronoun – she/her, he/him – which occurred either as the subordinate clause subject or as the main clause subject/object, depending on the sentence type. Pronoun gender (and thus whether it referred to the man/boy or woman/girl in the sentence) was also counterbalanced such that pronouns of each type appeared equally often under each of the experimental conditions (as well as equally often in combination with the five subordinate clause types). The remainder of the subordinate clause consisted of verb phrase that was four words long and separated from the main clause by a comma. The main clause began with the sequence x verbed y, where x/y was a name or pronoun, depending on the experimental condition. This sequence was then followed by the remainder of the sentence, which was 4-6 words in length (and always began with a function word). Also
included on the experimental lists were 56 filler sentences. Twenty-eight (28) of these fillers were included purely to distract the participants from focusing explicitly on experimental items (see Appendix B); the remaining 28 were the sentences of particular interest in Experiments 1-3 (see Appendix A). These filler sentences were roughly matched with the experimental items in terms of length and complexity. Forty-two (42) of the sentences in the experiment (or 37.50%) were followed by yes-no comprehension checks. These questions followed 14 experimental items and 28 filler items.

4.1.1.3 Procedure

The procedures followed exactly those detailed for Experiment 1.

4.1.1.4 Data Analysis

4.1.1.4.1 Excluded subjects and trials

The data from four participants with an error rates greater than 30% on the comprehension checks were eliminated from the analyses. Trials with major tracker losses were also excluded from the analyses. These trials accounted for 6.40% of the experimental items.

4.1.1.4.2 Regions of interest

The first set of analyses was conducted on each of the following regions in the experimental sentences, with the critical initial portion of the main clause treated as a single region. Examples (17a)-(17d) illustrate the regions that were analyzed (with region boundaries indicated with “|” marks):

(5a) F/NP1

When Mary spotted the mysterious UFO, she told Jeff to call the authorities.
When Jeff spotted the mysterious UFO, Mary told him to call the authorities.

When she spotted the mysterious UFO, Mary told Jeff to call the authorities.

When he spotted the mysterious UFO, Mary told Jeff to call the authorities.

In order to shed light on processing differences in the initial section of the main clause (F/NP1: she told Jeff; F/NP2: Mary told him; B/NP1: Mary told Jeff; B/NP2: Mary told Jeff), analyses were also conducted on the component words in this region. These consisted of an examination of the first two words of the clause (she told / Mary told) as well as separate analyses for each of the component words in this region (she / Mary, told, Jeff / him).

4.1.1.4.3 Measures

The measures calculated and analyzed were the same as those in Experiment 1. The per-region measures were first fixation duration, gaze duration, go-past time, right-bounded RT, (first-pass) regression rate, (first-pass) skipping rate, and total RT (for definitions of these measures, see Chapter 2, section 2.1.1.4.3). Again, in addition to these per-region measures, the total RT over the entire sentence is reported as a global indication of the processing characteristics associated with each item type.

4.1.1.4.4 Statistical analyses

The statistical analysis procedures were largely the same as those used in Experiments 1-3. The only salient difference between the analyses in the present
experiment and the experiments reported above relates to the number of fixed factors involved. In the relative clause experiments, the only fixed factor of interest was the two-level factor of (relative clause) sentence type (ORC, SRC). In the present experiment, the primary statistical analyses for each dependent measure took into consideration two fixed factors, each with two levels – anaphora type (forward, backward) and linking point (NP1, NP2). Specifically, two linear mixed effects models were fit to each dependent measure, each of which included the fixed factors identified above, as well as subject and item as random factors. The first of these models – the interaction model – was fit to the data by positing an interaction between the fixed factors; the second – the main effects model – was fit to the data by taking into consideration only the main effects of these factors. When the interaction of the fixed factors was significant, the results of the interaction model are reported. When this interaction was not significant and when examination of the Bayesian Inference Criterion (BIC) for each of the models indicated that the main effects model provided a better fit to the data, the results of this second analysis are reported. Furthermore, tests of simple effects are reported only when there was an indication of an interaction between the fixed factors.

4.1.2 Results

The mean accuracy score on the comprehension questions was 85.11% ($SD=7.68$). Table 5 presents the means for the dependent measures for each region of the experimental sentences. Table 6 presents the means for the dependent measures at the critical region consisting of the main clause subject, verb, and object. The values presented for all RT measures are the millisecond equivalents of the means of the log-
transformed data.

4.1.2.1 Analyses of the Entire Sentence

Before detailing the results for each region of the experimental sentences, it is important to note that the total RTs for the sentences (F/NP1: 3340 ms; F/NP2: 3436; B/NP1: 3540; B/NP2: 3687) indicated that more time was spent reading backward anaphora sentences than forward anaphora sentences. Furthermore, for both forward and backward anaphora, sentences in which the anaphor-antecedent link was established at the main clause NP2 were read more slowly than when this link was established at NP1. This pattern of results produced statistically-reliable main effects of anaphora type \( (t=4.31, p<.001) \) and linking point \( (t=3.11, p<.01) \). These overall RTs are therefore consistent with the idea that backward and forward anaphora sentences engage different dependency satisfaction processes. However, they also suggest that there is a cost for more establishing more distal anaphor-antecedent links, regardless of anaphora type (forward or backward).

Again, in order to gain a clearer understanding the processing time disparity among these sentence types, subsequent analyses focused on specific regions, the results of which are presented below.

The subordinate clause subject. At the subordinate clause subject (and immediately preceding word; F: After Mary/John, B: After she/he), forward anaphora sentences were read more slowly than backward anaphora sentences. This difference was reflected in a statistically-reliable main effect of anaphora type for first fixation duration \( (t=2.14, p<.05) \), gaze duration \( (t=5.21, p<.001) \), and total RT \( (t=4.61, p<.001) \). This
Table 5. Mean RTs (in milliseconds) and regression and skipping rates (as proportions) for each region of the F/NP1, F/NP2, B/NP1, and B/NP2 sentences in Experiment 5.

<table>
<thead>
<tr>
<th></th>
<th>F/NP1</th>
<th>F/NP2</th>
<th>B/NP1</th>
<th>B/NP2</th>
</tr>
</thead>
<tbody>
<tr>
<td>When Mary</td>
<td><strong>231</strong></td>
<td><strong>234</strong></td>
<td><strong>223</strong></td>
<td><strong>226</strong></td>
</tr>
<tr>
<td>the mysterious</td>
<td><strong>224</strong></td>
<td><strong>219</strong></td>
<td><strong>210</strong></td>
<td><strong>219</strong></td>
</tr>
<tr>
<td>UFO, she told</td>
<td><strong>234</strong></td>
<td><strong>233</strong></td>
<td><strong>224</strong></td>
<td><strong>224</strong></td>
</tr>
<tr>
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Table 6. Mean RTs (in milliseconds) and regression and skipping rates (as proportions) for each region of the F/NP1, F/NP2, B/NP1, and B/NP2 sentences in Experiment 5.

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reading time disparity can be attributed in large part to the fact that forward anaphora sentences had proper names as the subject of this clause, while backward anaphora sentences had pronouns in this position. Thus, this effect may simply indicate faster reading times for shorter, higher frequency lexical items. Interestingly also, in total RT, the main effect of linking point approached significance ($t=1.80, p=.07$), suggesting that more time was spent reexamining the subordinate clause subject when this element was involved in more distal (NP2) anaphor-antecedent relationships.

The subordinate clause verb. At the subordinate clause verb (*spotted*), the only significant effect among measures that assess first-pass reading patterns was a main effect of anaphora type for skipping rate ($t=3.90, p<.001$). This effect indicated that the subordinate clause verb was skipped more often in backward anaphora sentences. One explanation for this difference is that it is a continued reflection of the ease of processing the immediately preceding pronoun subject in backward anaphora sentences. Indeed, it could be that when fixating on the pronoun subject in these sentences, readers were regularly able to divert sufficient attentional resources to the following verb such that it could be indexed and skipped. A very different effect was found for total RT. Under this measure, as at the immediately preceding region, there was a significant main effect of linking point ($t=2.19, p<.05$), indicating that more time was spent reexamining the verb in sentences involving more distal (NP2) anaphor-antecedent links.

The subordinate clause verb+1. In the two-word region immediately following the subordinate clause verb (*the mysterious*), there was a significant main effect of anaphora type for first fixation duration ($t=2.36, p<.05$), again indicating that backward
anaphora sentences were read more quickly than forward anaphora sentences. Furthermore, as indicated by a significant main effect of linking point for total RT ($t=2.47, p<.05$), readers again spent more time reexamining this region of the subordinate clause in sentences involving more distal (NP2) anaphor-antecedent links.

**The subordinate clause verb+2.** At the final word in the subordinate clause (*UFO*), the effect of anaphora type approached significance for right-bounded RT ($t=1.81, p=.08$), suggesting that even at the end of the subordinate clause, backward anaphora sentences were read more quickly than forward anaphora sentences. Another set of effects in this region, however, does not lend itself to clear interpretation. Specifically, in the regression rate analysis, there was a significant main effect of anaphora type ($t=2.04, p<.05$) and a significant interaction of anaphora type and linking point ($t=2.05, p<.05$). These effects suggest a greater regression rate for F/NP2 sentences relative to their NP1 counterparts, as well as for B/NP1 sentences relative to their NP2 counterparts. In the tests of simple effects, both of (and only) these differences approached significance (F/NP2 vs. F/NP1: $t=1.76, p=.08$; B/NP1 vs. B/NP2: $t=1.95, p=.05$).

**The first part of the main clause (or the critical main clause region).** In the critical region of the beginning of the main clause (F/NP1: *she told Jeff;* F/NP2: *Mary told him;* B/NP1: *Mary told Jeff;* B/NP2: *Mary told Jeff*), there was a significant main effect of anaphora type across virtually all reading time measures (gaze duration: $t=11.37, p<.001$; go-past time: $t=14.89, p<.001$; right-bounded RT: $t=16.26, p<.001$; total RT: $t=16.77, p<.001$). One simple explanation for this effect is that it reflects the same pronoun vs. proper name reading time difference found earlier in these sentences. Recall that in this
region, forward anaphora sentences contained a proper name, verb, and a pronoun, while backward anaphora sentences contained two proper names and a verb. More interestingly, the main effect of linking point was significant for total RT ($t=3.21, p<.01$) and approached significance in go-past time ($t=1.99, p=.06$), indicating a processing cost for establishing more distal (NP2) anaphor-antecedent links in both anaphora sentence types.

It is important to note that the results for first fixation duration were not consistent with the pattern reported above. For this measure, there was a significant interaction of anaphora type and linking point ($t=2.02, p<.05$). This interaction was driven by longer first fixation durations for F/NP1 sentences relative to F/NP2 sentences ($t=2.34, p<.05$); none of the other tests of simple effects revealed a statistically-reliable difference. This relatively long first fixation duration is somewhat surprising in light of the generally (though not statistically-reliably) shorter reading times for F/NP1 sentences in this region. However, as discussed in more detail below, the pronoun that began the main clause in F/NP1 sentences was often skipped. As a consequence, for many F/NP1 trials, the first fixation in this region was on the main clause verb, while for the other sentence types, it was on a proper name subject. Therefore, the somewhat inflated first fixation durations for F/NP1 sentences might reflect a word class effect, rather than an indication of difficulty associated with anaphoric dependency processing per se.

The critical main clause region+1. At the next region of the main clause (to call), the main effect of linking point was significant for go-past time ($t=2.79, p<.01$) and right-bounded RT ($t=2.62, p<.01$) and approached significance for gaze duration ($t=1.72, p=.09$). This effect indicates a somewhat delayed processing cost for establishing more
distal (NP2) anaphor-antecedent links. In the regression rate analysis, the main effects of anaphora type and linking point approached significance (anaphora type: $t=1.81, p=.07$; linking point: $t=1.81, p=.07$), suggesting more regressive eye movements for forward anaphora sentences and, consistent with the first-pass reading time results, for sentences involving NP2 anaphor-antecedent linking.

The total RT analysis revealed a slightly different pattern of results. For this measure, there was again a significant main effect of linking point ($t=2.77, p<.01$). However, in this case, the effect was driven largely by inflated total RTs for B/NP2 sentences. Indeed, the interaction of anaphora type and linking point was a marginally significant ($t=1.96, p=.06$), and tests of simple effects confirmed that the total RT for B/NP2 sentences was significantly longer than for any of the other conditions (vs. F/NP1: $t=2.39, p<.05$; vs. F/NP2: $t=2.33, p<.05$; vs. B/NP1: $t=2.80, p<.01$). Therefore, although the first-pass reading measures indicated a processing cost for establishing more distal anaphor-antecedent links generally, the total time measure indicated marked processing difficulty for sentences involving disrupted backward anaphora processing.

The critical main clause region+2. In this final region of the sentence (the authorities), the main effect of anaphora type was significant for gaze duration ($t=4.05, p<.001$), go-past time ($t=3.52, p<.001$), right-bounded RT ($t=3.82, p<.001$), total RT ($t=3.55, p<.001$) and approached significance for first fixation duration ($t=2.95, p=.07$). For all of these measures, this effect indicated that backward anaphora sentences were read significantly more slowly in this sentence-final region. This robust reading time disparity can be taken to indicate processing difficulty at sentence wrap-up for sentences
involving anaphoric dependencies in which the anaphor (the dependent element) precedes its antecedent (the satisfying element).

4.1.2.2 Analyses of the Critical Region

The main clause subject and verb. At the first two words of the main clause (F/NP1: she told; F/NP2: Mary told; B/NP1: Mary told; B/NP2: Mary told), there was a fairly consistent pattern of results across first-pass RT measures. Specifically, the main effect of anaphora type was significant for gaze duration ($t=9.15, p<.001$), go-past time ($t=10.98, p<.001$), and right-bounded RT ($t=12.01, p<.001$), and in each case was qualified by a significant interaction of anaphora type and linking point (gaze duration $t=3.48, p<.001$; go-past time $t=5.21, p<.001$; right-bounded RT $t=5.62, p<.001$). Under all of these measures, tests of simple effects revealed that F/NP1 sentences were read significantly faster than the other three sentence types (gaze duration $t=5.94, p<.001$; vs. F/NP2: $t=9.56, p<.001$; vs. B/NP1: $t=10.56, p<.001$; go-past time $t=9.04, p<.001$; vs. B/NP1: $t=10.82, p<.001$; vs. B/NP2: $t=12.22, p<.001$; right-bounded RT $t=9.37, p<.001$; vs. B/NP1: $t=11.65, p<.001$; vs. B/NP2: $t=13.18, p<.001$). This effect is likely attributable to the fact that this region contained a pronoun in F/NP1 sentences (she told), but proper names in the other three sentence types (Mary told). More importantly, again under all of these measures, this region was read more slowly in backward anaphora sentences than in F/NP2 sentences (gaze duration $t=2.99, p<.01$; vs. F/NP2: $t=4.11, p<.001$; go-past time $t=2.13, p<.05$; vs. F/NP2: $t=3.71, p<.001$; right-bounded RT $t=2.70, p<.01$; vs. F/NP2: $t=4.26, p<.001$). However, none
these measures revealed a reliable difference between the backward anaphora sentences.

For total RT, there was a slightly different pattern of results. Under this measure, there were significant main effects of both anaphora type ($t=12.27, p<.001$) and linking point ($t=2.96, p<.01$) as well as a significant interaction of these factors ($t=2.93, p<.01$). As in the first-pass RT measures, the tests of simple effects revealed that F/NP1 sentences were read more quickly than the other three sentence types (vs. F/NP2: $t=7.02, p<.001$; vs. backward/NP1: $t=12.40, p<.001$; vs. backward/NP2: $t=14.78, p<.001$) that both backward anaphora sentences were read more quickly than F/NP2 sentences (B/NP1 vs. F/NP2: $t=5.36, p<.001$; B/NP2 vs. F/NP2: $t=8.09, p<.001$). However, unlike in the first-pass RT measures, B/NP2 sentences were read more slowly than B/NP1 sentences ($t=3.03, p<.01$). Therefore, although the first-pass reading time measures indicated a clear and essentially equivalent processing cost for both dependency satisfaction and disruption, the total time analysis revealed an especially large cost for dependency disruption.

For first fixation duration, there was also an interaction of anaphora type and linking point ($t=2.06, p<.05$). However, in contrast to the results for the measures reported above, this effect was driven by inflated times for F/NP1 sentences, which tests of simple effects revealed was statistically reliably different from F/NP2 ($t=2.36, p<.05$). This pattern of results mirrors that which was obtained for the larger (three-word) region and is likely due to differences in the words that were targeted by this first fixation among the sentence types (the verb in F/NP1 sentences; the proper name subject in the other three sentence types). The analysis of skipping rates revealed a comparable pattern
of results. For this measure, there was a significant main effect of anaphora type (z=2.59, p<.01) that appeared to be driven by a larger skipping rate for F/NP1 sentences. Indeed, although the interaction of anaphora type and linking point was not statistically reliable (z=1.38), tests of simple effects revealed that the skipping rate for F/NP1 sentences was significantly larger than for each of the other sentence types (vs. F/NP2: z=2.09, p<.05; vs. B/NP1: z=2.41, p<.05; vs. B/NP2: z=2.54, p<.05).

The main clause subject. The analyses of the main clause subject (F/NP1: *she*; F/NP2: *Mary*; B/NP1: *Mary*; B/NP2: *Mary*) were conducted only on sentences that had proper names in this position, namely for sentence types F/NP2, B/NP1, and B/NP2. Specifically, comparisons between each of these sentence conditions were conducted. This was done largely out of necessity, as the pronoun subject in F/NP1 sentences was apparently skipped so often that the analysis software simply could not generate measures for this word. However, it is also important to note that these comparisons are well motivated, in part because they act as appropriate follow-up tests of the pattern of results obtained for the two-word region consisting of the main clause subject and verb (which revealed reliable differences among F/NP2, B/NP1, and B/NP2 sentences) and, more importantly, because they bear on the principal theoretical questions at issue in this experiment.

For both first fixation duration and gaze duration, only the differences between the B/NP2 and F/NP2 sentences approached significance (first fixation duration: \(t=1.78, p=.07\); gaze duration: 1.81, \(p=.08\)). In total time, the subject in B/NP2 sentences was read more slowly than in either B/NP1 (\(t=3.35, p<.01\)) or F/NP2 sentences (\(t=4.87, p<.001\)).
The difference between B/NP1 and F/NP2 only approached significance \((t=1.87, p=.07)\) under this measure. This analysis of the main clause subject therefore revealed a suggestion of a processing difficulty for backward anaphora dependency satisfaction, but a clear cost for dependency disruption in this sentence type (at least under total time).

**The main clause verb.** At the main clause verb (*told*), the main effect of anaphora type was significant for go-past time \((t=3.30, p<.01)\), right-bounded RT \((t=2.87, p<.01)\), and total time \((t=5.85, p<.001)\), indicating that backward anaphora sentences were read more slowly than forward anaphora sentences. There were also more regressive eye movements from this verb in backward anaphora sentences \((z=2.36, p<.05)\). The only measure that deviated from this general pattern was gaze duration, which yielded a main effect of linking point that approached significance \((t=1.90, p=.06)\), suggesting that NP1 sentences tended to be read more slowly than NP2.

**The main clause object.** For gaze duration, there was a significant main effect of anaphora type \((t=2.20, p<.05)\), with the names in backward anaphora sentences read more slowly than the name/pronoun in forward anaphora sentences. It is interesting to point out that this early RT measure did not yield an interaction comparable to that which was found in the comparisons of the pronoun and names at the main clause subject position (i.e., in the analysis of the region consisting of the main clause subject and verb). This suggests a processing cost for the pronoun in object position. This pattern of results also suggests a continued cost for both dependency satisfaction and disruption in backward anaphora sentences.

Especially fast reading times for this pronoun were, however, indicated by
significant interactions of anaphora type and linking point for go-past reading ($t=2.35$, $p<.05$) and right-bounded RT ($t=2.10$, $p<.05$). Indeed, the tests of simple effects for these measures showed that the pronoun in F/NP2 sentences was read more quickly than the name in the other sentence types (go-past time $\Rightarrow$ vs. F/NP1: $t=2.77$, $p<.01$; vs. B/NP1: $t=3.41$, $p<.01$; vs. B/NP2: $t=3.26$, $p<.01$; right-bounded RT $\Rightarrow$ vs. F/NP1: $t=2.20$, $p<.05$; vs. B/NP1: $t=2.93$, $p<.01$; vs. B/NP2: $t=2.99$, $p<.01$). The same pattern of results was found for regression rate and skipping rate. For regression rate, there was a significant interaction of anaphora type and linking point ($z=3.15$, $p<.01$), which tests of simple effect indicated was due to fewer regressive eye movements for the pronoun in F/NP2 sentences than for the name in the other three conditions (vs. F/NP1: $z=4.11$, $p<.001$; vs. B/NP1: $t=4.34$, $p<.001$; vs. B/NP2: $t=3.90$, $p<.001$). Comparably, for skipping rate, there was also a significant interaction of anaphora type and linking point ($z=4.79$, $p<.001$), with the pronoun in F/NP2 sentences skipped more often than the proper name in the other three sentence types (vs. F/NP1: $z=8.51$, $p<.001$; vs. B/NP1: $t=9.32$, $p<.001$; vs. B/NP2: $t=8.42$, $p<.001$).

In the total RT analysis, there was also an interaction of anaphora type and linking point ($t=3.16$, $p<.01$). Again, the pronoun in F/NP2 sentences was read more quickly than the names in the other sentence types (vs. F/NP1: $t=3.20$, $p<.01$; vs. B/NP1: $t=5.05$, $p<.001$; vs. B/NP2: $t=5.08$, $p<.001$). However, at least some of this interaction can also be attributed to an especially long reading time for the name object B/NP2 sentences, which tests of simple effects revealed was longer than the same name in F/NP1 sentences ($t=2.10$, $p<.05$).
4.1.3 Discussion

The reading patterns on these sentences indicated some overlap in the processing of forward and backward anaphora sentences, in that they revealed processing costs for more distal NP2 anaphor-antecedent links for both anaphora types. It is important to note here that although this cost has been discussed in terms of anaphor-antecedent distance up to this point, these results could also be explained in terms of parallel vs. non-parallel functions for the pronoun and its referent. That is, in both NP1 sentence types (F/NP1 and B/NP1), the pronoun and its referent act as the subject of their respective clauses; while in NP2 sentences (F/NP2 and B/NP2), the pronoun and its referent have different grammatical functions. Specifically, in F/NP2 sentences, the pronoun is the object of the main clause, and its antecedent is the subject of the subordinate clause; in B/NP2 sentences, the pronoun is the subject of the subordinate clause, and its antecedent is the object of the main clause (for comparable findings and for more on this interpretation, see e.g., Gordon & Scearce, 1995; Streb, Roesler, & Hennighausen, 1999). The current set of experiments, however, does not allow for a clear way to distinguish between these interpretations.

Despite this overlap in the processing of forward and backward anaphora sentences, the reading patterns also indicated processing costs for backward anaphora sentences generally, suggesting that the relative ordering of the dependent and satisfying elements in these sentence types engaged different processing procedures. Crucially, some of these effects occurred at the end of the sentence, where the comparisons between the backward and forward anaphora sentences were in no way confounded by lexical
differences among the sentence types. With regard to the processing procedures brought
to bear on backward anaphora sentences, reading time differences consistent with
processing difficulty were found at the main clause subject in both B/NP1 and B/NP2
sentences, or at points of both dependency disruption and satisfaction. Furthermore,
B/NP2 sentences produced especially long total RTs at this main clause subject position,
indicating a pronounced processing cost for dependency disruption. Again, this pattern of
results matches well with the filled-gap and filler-gap integration effects found in the
processing of wh-dependency sentences, and thus lends support that idea that the
processing of these dependent-element-first structures engages common (or at least
comparable) mechanisms.

4.2 Experiment 6: Investigating Anaphora Processing with the G-maze Task

It is important to reiterate that, in the eye-tracking experiment reported above, the
especially large processing costs for dependency disruption in backward anaphora
sentences were most clearly evident not in first-pass reading measures, but rather in total
RT measures. In order to gain a clearer understanding of the time-course of this
processing difficulty, a G-maze follow-up experiment was conducted. As discussed in
Chapter 2, this task forces the incremental integration words into the developing sentence
structure. In this way, it has the potential to reveal highly “localized” indications of
processing difficulty during online sentence comprehension. This task also allowed for a
examination of the hypothesis that integration costs in dependent-element-first structures
are more closely associated with tracking/organizing elements into the propositional
structure of the sentence, rather than structure-building operations per se. Recall that
in the experiments reported in Chapter 2, processing costs for \(wh\)-dependency disruption were evident across tasks, while the costs for filler-gap integration were evident only in the eye-tracking experiment. A comparable pattern of results in the processing of backward anaphora would not only underscore the similarities between \(wh\)-dependency and backward anaphora processing, but would also shed further light on the nature of retrieval-based integration costs in dependent-element-first structures.

4.2.1 Method

4.2.1.1 Participants

Forty eight (48) University of Arizona undergraduates participated in the experiment in partial fulfillment of course requirements. All participants were native speakers of English. These participants were the same as those in Experiment 2. As mentioned in Chapter 1, Experiment 2 and the present experiment were interleaved and run in a single experimental session.

4.2.1.2 Materials

The sentences tested were exactly the same as in Experiment 5. The selection of ungrammatical alternatives for each word in the sentences followed the procedures outlined for Experiment 2.

4.2.1.3 Procedure

The procedures followed those detailed for Experiment 2.

4.2.2 Results

The data from all participants contributed to the statistical analyses reported below. The analysis procedures followed those detailed for Experiment 5 above. However,
for this experiment, these procedures were applied to a single dependent measure – RT to the words of interest. As in Experiment 5, the critical words were at the beginning of the main clause – the primary locus of dependency processing in these sentences. The words up to and including this critical region were analyzed. The mean RTs for these regions/words in each of the sentence types of interest are presented in Table 7.

The subordinate clause subject. There was a significant main effect of anaphora type \((t=9.19, p<.001)\) indicating that the pronoun in backward anaphora sentences \((\text{she/he})\) was read significantly more slowly than the proper name \((\text{Mary/Jeff})\) in forward anaphora sentences. It is important to point out that this is exactly the opposite of the pattern of results obtained in the eye-tracking experiment reported above, Experiment 5. This disparity will be discussed further below.

The subordinate clause. There was also a main effect of anaphora type in the analysis of the average RT to the remaining words in the subordinate clause \((\text{saw the mysterious \textit{UFO}; } t=2.43, p<.05)\). The RT pattern was the opposite of that which was obtained at the subordinate clause subject. That is, RTs for the words in backward anaphora sentences were faster than those in forward anaphora sentences.

The first part of the main clause (or the critical main clause region). In the critical region of the beginning of the main clause \((\text{F/NP1: she told Jeff; F/NP2: Mary told him; B/NP1: Mary told Jeff; B/NP2: Mary told Jeff})\), there was a significant main effect of linking point \((t=2.84, p<.01)\) and a significant interaction of anaphora type and linking point \((t=2.05, p<.05)\). These effects were driven by especially long average RTs for B/NP2 sentences, which tests of simple effects revealed were longer than for each of the
Table 7. Mean RTs (in milliseconds) for each region/word of the F/NP1, F/NP2, B/NP1, and B/NP2 sentences in Experiment 6.

<table>
<thead>
<tr>
<th>F/NP1</th>
<th>(When)</th>
<th>Mary</th>
<th>spotted the mysterious UFO</th>
<th>she told Jeff</th>
<th>(to…)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/NP2</td>
<td>(When)</td>
<td>Jeff</td>
<td></td>
<td>Mary told him</td>
<td></td>
</tr>
<tr>
<td>B/NP1</td>
<td>(When)</td>
<td>she</td>
<td></td>
<td>Mary told Jeff</td>
<td></td>
</tr>
<tr>
<td>B/NP2</td>
<td>(When)</td>
<td>he</td>
<td></td>
<td>Mary told Jeff</td>
<td></td>
</tr>
</tbody>
</table>

|     |       |      |                           |               |       |
| F/NP1 | 703   | 909  | 845                        |               |       |
| F/NP2 | 711   | 910  | 845                        |               |       |
| B/NP1 | 789   | 899  | 839                        |               |       |
| B/NP2 | 796   | 885  | 872                        |               |       |

<table>
<thead>
<tr>
<th>F/NP1</th>
<th>(When Mary…)</th>
<th>she told</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F/NP2</td>
<td>(When Jeff…)</td>
<td>Mary told</td>
<td></td>
</tr>
<tr>
<td>B/NP1</td>
<td>(When she…)</td>
<td>Mary told</td>
<td></td>
</tr>
<tr>
<td>B/NP2</td>
<td>(When he…)</td>
<td>Mary told</td>
<td></td>
</tr>
</tbody>
</table>

|     |       |      |        |        |       |
| F/NP1 | 887   |       |        |        |       |
| F/NP2 | 881   |       |        |        |       |
| B/NP1 | 872   |       |        |        |       |
| B/NP2 | 911   |       |        |        |       |

<table>
<thead>
<tr>
<th>F/NP1</th>
<th>(When Mary…)</th>
<th>she</th>
<th>told</th>
<th>Jeff</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/NP2</td>
<td>(When Jeff…)</td>
<td>Mary</td>
<td>him</td>
<td></td>
</tr>
<tr>
<td>B/NP1</td>
<td>(When she…)</td>
<td>Mary</td>
<td>Jeff</td>
<td></td>
</tr>
<tr>
<td>B/NP2</td>
<td>(When he…)</td>
<td>Mary</td>
<td>Jeff</td>
<td></td>
</tr>
</tbody>
</table>

|     |       |      |      |      |       |
| F/NP1 | 759   | 988  | 722  |      |       |
| F/NP2 | 776   | 957  | 731  |      |       |
| B/NP1 | 745   | 976  | 737  |      |       |
| B/NP2 | 785   | 1000 | 759  |      |       |
other three sentence types (vs. F/NP1: \( t=2.34, p<.05 \); vs. F/NP2: \( t=2.36, p<.05 \); vs. B/NP1: \( t=2.76, p<.01 \)). This pattern of results differs from that which was obtained in the eye-tracking experiment, in that there was no main effect of anaphora type – forward anaphora sentences were not responded to more quickly than backward anaphora sentences. There was, however, a clear indication that the disruption of the dependency in backward anaphora sentences incurred processing costs over this region.

The main clause subject and verb. Recall that in the eye-tracking experiment, the most robust effects indicating dependency satisfaction and disruption costs were obtained at the region of the main clause subject and verb (F/NP1: *she told*; F/NP2: *Mary told*; B/NP1: *Mary told*; B/NP2: *Mary told*). An analysis of this region in the present experiment, however, revealed an RT pattern indicating processing costs only for dependency disruption. Specifically, there was a significant main effect of linking point (\( t=2.90, p<.01 \)) and a significant interaction of anaphora type and linking point (\( t=2.32, p<.05 \)), both of which were driven by especially long RTs for B/NP2 sentences (vs. F/NP1: \( t=1.84, p=.07 \); vs. F/NP2: \( t=2.17, p<.05 \); vs. backward/NP1: \( t=2.77, p<.01 \).

The main clause subject. At the main clause subject (F/NP1: *she*; F/NP2: *Mary*; B/NP1: *Mary*; B/NP2: *Mary*), there was a significant main effect of linking point (\( t=2.80, p<.01 \)), indicating that the subjects in F/NP2 and B/NP2 sentences were responded to more slowly than in their NP1 counterparts. Thus, there was again a suggestion of processing costs for dependency disruption in backward anaphora sentences. This was not a robust effect, however, as RTs to the subject in B/NP2 sentences were not reliably different from those in F/NP2 sentences, the sentence type that could be considered the
control condition at this region.

*The main clause verb.* At the main clause verb (*told*), there was an interaction of anaphora type and linking point \(t=2.27, p<.05\). The test of simple effects revealed that this interaction was driven in part by the particularly long RTs for B/NP2 sentences – which was significantly longer than for F/NP2 \(t=2.43, p<.05\) sentences. Surprisingly, the RT to the verb in F/NP1 sentences was also long – in the test of simple effects it approached a significant difference when compared with forward/NP2 \(t=1.93, p=.06\).

*The main clause object.* At the main clause object (F/NP1: *Jeff*; F/NP2: *him*; B/NP1: *Jeff*; B/NP2: *Jeff*), there was a main effect of anaphora type \(t=2.20, p<.05\) indicating that backward anaphora sentences were read more slowly than their forward anaphora counterparts. While this might be taken to indicate a cost for more distal integration in the B/NP2 case, this cannot be the case for B/NP1 sentences. Rather this effect might be taken to indicate a delayed indication of processing costs for positing and satisfying a dependency in a backward anaphora sentence.

**4.2.3 Discussion**

The results of this experiment helped to localize at least one of the effects seen in Experiment 5 – the effects related to dependency disruption in backward anaphora sentences. Specifically, B/NP2 sentences had longer RTs picking up at the point of dependency disruption and persisting across the next two words. There was some hint of integration effects in B/NP1 sentences as well, but this effect was delayed and rather weak. This pattern of results thus provides further support for an analogue to the filled-gap effect in backward anaphora processing. These findings also suggest that in backward
anaphora sentences as well, robust indications of integration costs occur only in tasks that allow for relatively unconstrained reading and/or that require explicit tracking of the propositional content of the sentence.

Several other findings from this experiment are worthy of note. First, the RTs to pronouns in this experiment indicated that, unlike in the eye-tracking experiment, these elements were not read especially quickly. In fact, at the subordinate clause subject, the pronouns in backward anaphora sentences were read much more slowly than the proper names in forward anaphora sentences. This difference might be taken to suggest processing difficulty when a dependent element is encountered in backward anaphora sentences. In this way, the forced incremental integration of words into the sentence structure appeared to reveal processing difficulty that may be masked in tasks that allow for relatively unconstrained reading.

Another interesting and unexpected finding was the difference in RTs over the remainder of the subordinate clause for forward and backward anaphora sentences. As in the eye-tracking experiment, these words were read more quickly in backward anaphora sentences than in forward anaphora sentences. In the eye-tracking experiment, this effect was simply attributed to the carry-over of reading ease at the subordinate clause pronoun. However, the same explanation is not possible in the present experiment in light of the longer reading times for this pronoun. One possible explanation for this ease of processing is that once this “unlinked” pronoun is encountered, the system enters into a goal state in which the efficient satisfaction of the anaphoric dependency is prioritized. The behavioral consequence of this state might be that the reader “rushes” to find an
antecedent, or to the first structural position at which an antecedent could occur.

Admittedly, this account is somewhat speculative, and replication of this result would be important in order to determine whether this is a reliable effect. Having said that, this effect clearly runs contrary to any account of dependency processing in which storage of a dependent element depletes resources available for the processing of words prior to satisfaction. This result also casts some doubt on the simple “carry-over” explanation for the comparable effect in the eye-tracking experiment.

4.3  Experiment 7: Investigating Anaphora Processing with the L-maze Task

In Experiment 7, the sentence types of interest were examined using the L-maze version of self-paced reading. This experiment was conducted to test the same predictions as in Experiment 6, but with a word-by-word reading tasks that does not explicitly require incremental integration.

4.3.1  Method

4.3.1.1  Participants

Forty eight (48) University of Arizona undergraduates participated in the experiment in partial fulfillment of course requirements. All participants were native speakers of English. These participants were the same as those in Experiment 3. As mentioned in Chapter 2, Experiment 3 and the present experiment were interleaved and run in a single experimental session.

4.3.1.2  Materials

The sentences tested were exactly the same as in Experiments 5 and 6. The selection of non-word alternatives for each word in the sentences followed the procedures
outlined for Experiment 3.

4.3.1.3 Procedure

The procedures followed those detailed for Experiment 3.

4.3.2 Results

The data from all participants contributed to the statistical analyses reported below. The analysis procedures followed those used in Experiment 6. Again, the critical words were at the beginning of the main clause, and the words up to and including this region were analyzed. The mean RTs for these regions/words in each of the sentence types of interest are presented in Table 8.

The subordinate clause subject. There was a significant main effect of anaphora type ($t=7.45, p<.001$) indicating that unlike in the G-maze experiment but as in the eye-tracking experiment, the pronoun subordinate clause subject in backward anaphora sentences (she/he) was read more quickly than the proper name subject in forward anaphora sentences (Mary/Jeff).

The subordinate clause. There were no statistically reliable effects for the remaining words of the subordinate clause (saw the mysterious UFO).

The first part of the main clause (or the critical main clause region). Over this three word region (F/NP1: she told Jeff; F/NP2: Mary told him; B/NP1: Mary told Jeff; B/NP2: Mary told Jeff), there was a statistically-reliable main effect of anaphora type ($t=2.24, p<.05$), indicating that forward anaphora sentences were responded to more quickly than backward anaphora sentences. In light of the RT differences reported below for pronouns and proper names, this effect can be largely attributed to differences in
Table 8. Mean RTs (in milliseconds) for each region/word of the F/NP1, F/NP2, B/NP1, and B/NP2 sentences in Experiment 7.

<table>
<thead>
<tr>
<th></th>
<th>(When)</th>
<th>Mary</th>
<th>spotted the mysterious UFO</th>
<th>she told Jeff</th>
<th>(to…)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/NP1</td>
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<tr>
<td>F/NP2</td>
<td></td>
<td>Jeff</td>
<td></td>
<td>Mary told Jeff</td>
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<tr>
<td>B/NP1</td>
<td>(When)</td>
<td>she</td>
<td></td>
<td>Mary told Jeff</td>
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<tr>
<td>B/NP2</td>
<td>(When)</td>
<td>he</td>
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<td>Mary told Jeff</td>
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<td>F/NP1</td>
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<td>B/NP1</td>
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<td>B/NP2</td>
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<tr>
<th></th>
<th>(When Mary…)</th>
<th>she told</th>
<th>(When Jeff…)</th>
<th>Mary told</th>
<th>(When she…)</th>
<th>Mary told</th>
<th>(When he…)</th>
<th>Mary told</th>
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<tr>
<td>F/NP1</td>
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<th>told</th>
<th>Jeff</th>
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<td>F/NP1</td>
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<td>F/NP2</td>
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<td>B/NP1</td>
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<td>B/NP2</td>
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<table>
<thead>
<tr>
<th></th>
<th>(When Mary…)</th>
<th>she</th>
<th>told</th>
<th>Jeff</th>
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<td>F/NP1</td>
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<tr>
<td>F/NP2</td>
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<tr>
<td>B/NP1</td>
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<td></td>
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<tr>
<td>B/NP2</td>
<td></td>
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</tbody>
</table>
There was also a significant main effect of linking point, with NP2 sentences responded to more slowly than NP1 sentences. Although the interaction of anaphora type and linking point was not significant ($t=1.35$), this linking point effect seems to be driven in large part by especially long RTs to B/NP2 sentences. It is important to point out that although the interaction was not significant, BIC scores revealed that the interaction model provided a better fit to the data than the main effects model. Consistent with this suggestion of an interaction, an analysis of simple effects revealed no significant difference between the forward anaphora sentences ($t=.31$), but a statistically reliable difference between B/NP2 and B/NP1 sentences ($t=2.24, p<.05$).

*The main clause subject and verb.* At the region of the main clause subject and verb (F/NP1: *she told*; F/NP2: *Mary told*; B/NP1: *Mary told*; B/NP2: *Mary told*), there was a significant main effect of anaphora type ($t=2.75, p<.01$) indicating that backward anaphora sentences were generally responded to more slowly than forward anaphora sentences. There was also a significant main effect of linking point ($t=2.10, p<.05$) indicating that NP2 sentences in both anaphora conditions were responded to more slowly than their NP1 counterparts. This pattern of results was driven by especially fast RTs for forward/NP1 sentences, and especially slow RTs for B/NP2 sentences. Indeed, an analysis of the simple effects indicated that F/NP1 sentences were responded to more quickly than each of the other sentence types (vs. F/NP2: $t=2.72, p<.01$; vs. B/NP1: $t=2.66, p<.01$; vs. B/NP2: $t=4.81, p<.001$) while B/NP2 sentences were responded to more slowly than each of the other sentences types (vs. F/NP1: see above; vs. F/NP2: $t=2.31, p<.05$; vs. B/NP1: $t=2.17, p<.05$). Thus, as in the eye-tracking experiment, there
were faster RTs over the main clause subject and verb when the subject was a pronoun. Presumably, this simply indexes a word frequency/length effect. Of greater theoretical interest, there was again an indication of a significant cost for dependency disruption in B/NP2 sentences. As in the G-maze experiment and unlike in the eye tracking experiment, however, there was no indication of an integration cost for B/NP1 sentences.

The main clause subject. At the main clause subject (F/NP1: *she*; F/NP2: *Mary*; B/NP1: *Mary*; B/NP2: *Mary*), there was a reliable effect of anaphora type ($t=7.32$, $p<.001$) as well as an interaction of anaphora type and linking point ($t=3.50$, $p<.001$). The tests of simple effects showed a reliable difference between F/NP1 sentences and each of the other sentence types (vs. F/NP2: $t=6.25$, $p<.001$; vs. B/NP1: $t=7.34$, $p<.001$; vs. B/NP2: $t=8.52$, $p<.001$) while B/NP2 sentences produced longer RTs than each of the forward anaphora sentences (vs. F/NP1: see above; vs. F/NP2 sentences: $t=2.43$, $p<.05$). These results again indicate that pronouns were read much more quickly than names. Of greater theoretical interest, these results again indicate processing costs for dependency disruption in the case of B/NP2 sentences, but no effect for dependency satisfaction in B/NP1 sentences.

The main clause verb. There were no statistically-reliable effects at the main clause verb (*told*).

The main clause object. At the main clause object (F/NP1: *Jeff*; F/NP2: *him*; B/NP1: *Jeff*; B/NP2: *Jeff*), there was a significant interaction of anaphora type and linking point ($t=4.25$, $p<.001$). This effect was driven by faster RTs to the pronoun in F/NP2 sentences relative to the proper names in the other sentence types (vs. F/NP1: $t=5.10$, $p<.001$).
4.3.3 Discussion

As in Experiments 5 and 6, there was a clear cost associated with disrupted dependency processing in backward anaphora sentences. Crucially, this processing difficulty picked up at the main clause subject, or the first point at which the dependency could be satisfied. Furthermore, as in the G-maze experiment (Experiment 6), but unlike in the eye-tracking experiment (Experiment 5), there were no reliable indications of integration costs in backward anaphora (B/NP1) sentences. Therefore, these results again provide further support for an analogue to the filled-gap effect in backward anaphora processing. They also again suggest that as in filler-gap processing, integration costs are largely task dependent. Finally, it is important to note that the response times to pronouns in this experiment closely mirrored the results of the eye-tracking experiment, as these words were read more quickly than names across the board.
CHAPTER 5

ANAPHORA PROCESSING:

NEUROPHYSIOLOGICAL EXPERIMENT

In Chapter 4, it was shown that there is considerable overlap between the processing of backward anaphora and filler-gap structures. Specifically, these reading experiments revealed analogues to the filled-gap effect and, at least under certain task conditions, to the filler-gap integration effect in the processing of backward anaphora sentences. These experiments thus lend support to the idea that dependent-element-first structures engage comparable processing mechanisms. However, this begs the question as to whether the processing of these structures draws on the same mechanism or on separate mechanisms that adhere to largely the same architectural constraints (and that, as a consequence, elicit similar behavioral responses). One way to investigate this question is to examine the neurophysiological responses during the processing of these dependency types. If the parser engages the same dependency processing mechanism in the comprehension of all dependent-element-first structures, the obvious prediction is that these structures should elicit the same (or very similar) neurophysiological responses. This prediction is tested in the experiment reported below. Of particular interest are the ERP responses to backward anaphora sentences. Consistent with the prediction outlined above, these responses should match well with those commonly reported for the processing of filler-gap dependencies.

The ERP literature on filler-gap sentences has identified a number of responses associated with this sentence type. For instance, Kluender & Kutas (1993) reported a
LAN response (a negative deflection over left anterior scalp sites at roughly 300-500ms post-stimulus) at or soon after the introduction of the *wh*-dependency. Also, as detailed in Chapter 3, the words intervening between the introduction of a *wh*-dependency and its satisfaction have been found to elicit sustained negativity over anterior electrodes (see e.g., Kutas & King, 1995; Mueller et al., 1997; but see also, Phillips et al., 2005; Experiment 4 above). At points of filler-gap integration, a number of studies have reported a late (~500-700ms post-stimulus) central-parietal positivity (or P600, otherwise known as the syntactic positive shift, or SPS; see e.g., Felser et al., 2002; Fiebach et al., 2002; Kaan et al., 2000; Phillips et al., 2005), while others have again reported LAN responses (Kluender & Kutas, 1993). With respect to *wh*-dependency disruption, Hestvik and colleagues (2007, 2009) have shown both an early (100-300ms post-stimulus) left anterior negativity (or eLAN) and a P600 response to sentences involving filled gap sites.

The question then is whether backward anaphora sentences will elicit comparable responses after the introduction of the anaphoric dependency as well as at points of dependency disruption and satisfaction. Again, such a pattern of results would suggest that the processing of dependent-element-first structures relies on the same underlying mechanism. Furthermore, if dependency processing differs fundamentally as a function of the relative ordering of the dependent and satisfying elements, the neurophysiological responses to backward anaphora sentences should differ from those elicited by their forward anaphora counterparts, particularly at points where an antecedent-anaphor link is established in these sentences.
5.1 Experiment 8

Experiment 8 examined the same sentence types as in Experiments 5-7, reprinted here for the sake of clarity (where, again, anaphora type is indicated by F(orward)/B(ackward) and “linking point” by NP1/NP2):

(17a) F(oral)/NP1
When Mary spotted the mysterious UFO, she told Jeff to call the authorities.

(17b) F/NP2
When Jeff spotted the mysterious UFO, Mary told him to call the authorities.

(17c) B(ackward)/NP1
When she spotted the mysterious UFO, Mary told Jeff to call the authorities.

(17d) B/NP2
When he spotted the mysterious UFO, Mary told Jeff to call the authorities.

The predictions followed directly from the literature reviewed above. Specifically, it was predicted that if backward anaphora engages the same processing mechanism as filler-gap sentences, (some or all of) the following effects should obtain: (a) a LAN response at the unanchored pronoun in the subordinate clause subject position (he/she), (b) a SAN over the words intervening between the introduction of this dependency and its satisfaction (i.e., over the remainder of the subordinate clause), (c) an eLAN and/or P600 at the point of dependency disruption (i.e., at the main clause subject in B/NP2 sentences), and (d) a P600 at points of dependency satisfaction (i.e., at the main clause subject in B/NP1 sentences and at the main clause object in B/NP2 sentences). Furthermore, it was predicted that the last of these responses would differ markedly from that which is
produced for antecedent-anaphor linking in forward anaphora sentences. This is because the processing of these anaphora types should be fundamentally different under a unified account of the comprehension of dependent-element-first structures.

5.1.1 Method

5.1.1.1 Participants

Twenty-five (25) University of Arizona undergraduates participated in the experiment in partial fulfillment of course requirements and for the chance to win a gift certificate prize. All participants were native speakers of English, with normal or corrected-to-normal vision, with no history of learning disability or cognitive impairment, and who were not taking medication that might alter the naturally-occurring electrical activity in the brain (e.g., anti-psychotics, anti-depressants, Ritalin, etc.). The data from four subjects were not analyzed because of excessive artifacts in the EEG record. The data from another subject was eliminated due to equipment failure during the last half of the experimental session. Of the remaining the 20 subjects (whose data contributed to the analyses reported below), 14 were men and six were women (mean age: 18.85; age range: 18-22). These participants were the same as those in Experiment 4. As mentioned in Chapter 3, Experiment 4 and the present experiment were interleaved and run in a single experimental session.

5.1.1.2 Materials

The materials consisted of 160 sentence sets similar to those in example set (17a)-(17d) above. The complete list of experimental items is presented in Appendix G. The creation of these items followed the procedures outlined for the behavioral experiments
on these sentence types (see section 4.1.1.2). In fact, the 56 anaphora items in these earlier experiments also appeared in the present experiment. These items were divided into four counterbalanced lists (again, according the guidelines detailed in section 4.1.1.2). Also included on these lists were 160 filler sentences. Eighty (80) of these fillers were included purely to distract the participants from focusing explicitly on experimental items (see Appendix E); while the remaining 80 filler items were the sentences of particular interest in Experiment 4 (see Appendix D). These filler sentences were roughly matched with experimental items in terms of length and complexity. In each list, experimental and filler sentences were divided into eight blocks of 40 items, with each block containing 20 experimental items and 20 fillers. These blocks, and the items within each block, were randomly presented. Yes-no comprehension checks followed 104 of sentences in the experiment (or 43.33%), with 40 questions occurring after experimental items. Each block of items included 13 of these comprehension checks, with 4-6 questions targeting experimental items (and at least one question per experimental condition.)

5.1.1.3 Procedure

The procedures followed exactly those detailed in Chapter 3, section 3.1.1.3.

5.1.1.4 EEG Recording

The EEG recording procedures followed exactly those detailed in Chapter 3, section 3.1.1.4.

5.1.1.5 Data Analysis

The data analysis procedures largely followed those detailed in Chapter 3, section
3.1.1.4. However, because there were some differences due to the different sentence types of interest, the complete set of these procedures will be reviewed in some detail. The initial artifact rejection procedures and procedures for interpolating bad EEG channels followed those outlined in section 3.1.1.4. As in Experiment 4, 6000ms sections of EEG were extracted in order to conduct a cumulative analysis of the sustained ERP components over the words intervening between dependency introduction and satisfaction. These epochs consisted of the 1000ms before the subordinate clause subject (Mary/Jeff, he/she; or a 1000ms pre-stimulus interval) and the 5000ms after its presentation (or a 5000ms post-stimulus interval). The epochs for the analyses of individual words – that is, for both the non-cumulative analysis of the sustained ERP components as well as for the single-word analyses (again, see below) – consisted of a 1000ms pre-stimulus interval and 2000ms post-stimulus interval surrounding each word of interest. For the baseline correction of the longer (6000ms) epochs, the last 500ms of the pre-stimulus interval (or the -500-0ms interval) was used; for the epochs surrounding individual words, the -100-0ms interval was used as the baseline. In each of these sets of epochs, eyeblinks were corrected for using the Ocular Artifact Reduction feature in Scan 4.3 (Semlitsch et al., 1986). Finally, for the longer epochs, trials that involved a shift from baseline of 150 microvolts or more in the 4000ms post-stimulus interval were eliminated from the analysis. For the epochs surrounding individual words, the same 150-microvolt threshold was applied over the 1000ms post-stimulus interval. This was done in order to eliminate any remaining trials that involved unusually large voltage fluctuations. After these artifact rejection/reduction procedures were applied, 82.31% of the trials remained
for the cumulative analysis of the sustained ERP components, while 90.69% of the trials remained for analyses of the individual words.

The statistical analysis procedures followed those detailed in section 3.1.1.4. For this experiment, however, these analyses were conducted over slightly different time windows. The analysis of the sustained ERP components examined the waveforms for backward anaphora sentences (B/NP1 and B/NP2 sentences combined) and forward anaphora sentences (F/NP1 and F/NP2 sentences combined) from the subordinate clause subject until the last word of the subordinate clause (i.e., Mary/Jeff/he/she saw the mysterious UFO). This was again done in two ways. First, a cumulative analysis was conducted over the 2600ms interval beginning with the subordinate clause subject and ending 600ms after the presentation of the last word in this clause (UFO). This long time window was then divided into smaller intervals for analysis, following the procedures in Phillips et al. (2005). Specifically, the analysis took into consideration the mean voltage in the 100-600ms interval after the presentation of each word. Following both King & Kutas (1995) and Phillips et al. (2005), a non-cumulative analysis was also conducted. This analysis was conducted on the ERPs generated from the (-1000-2000ms) epochs for individual words, and targeted the mean voltage in the 100-600ms interval corresponding to each word of interest. As previously discussed, the key difference between these analysis schemes is that they use different baselines for the calculation of the mean voltages. In the cumulative analysis, this measure was calculated for each word relative to a common baseline – the -500-0ms interval, or the 500ms corresponding to word immediately preceding the subordinate clause subject (e.g., After). In the non-cumulative
analyses, on the other hand, mean voltages were calculated relative to the -100-0ms interval for each word.

The single-word analyses focused on the words of particular interest in the backward and forward anaphora sentences – specifically, the subordinate clause subject, the main clause subject, and the main clause object. These analyses examined the average voltage differences in the -100-100ms, 100-300ms, 300-500ms, 500-700ms, and 700-900ms time intervals (with minor adjustments to these time intervals when warranted by the data).

5.1.2 Results

5.1.2.1 Comprehension Question Accuracy

For the 20 participants included in the analyses, the mean accuracy score on the comprehension questions was 87.75% (SD=6.15).

5.1.2.2 Single-Word Analyses

5.1.2.2.1 Subordinate clause subject

The first word of interest was the subject of the subordinate clause. This subject was a pronoun (she/he) in backward anaphora sentences (B/NP1, B/NP2) and a proper name (Mary/Jeff) in forward anaphora sentences (F/NP1, F/NP2). Waveforms from a representative sample of electrodes and topographic maps are shown in Figure 9. At the -100-100ms interval, there was a significant interaction of sentence type and hemisphere, $F(1,16)=5.36$, $p<.05$, as well as a significant 3-way interaction of sentence type, hemisphere, and anterior/posterior, $F(1,16)=4.55$, $p<.05$, indicating that pronouns produced more positivity than proper names over left, anterior channels and more
Figure 9. Grand average ERP responses at the subordinate clause subject. Waveforms for the pronoun subject in backward anaphora sentences (B/NP1, B/NP2) are shown in red; waveforms for the proper name subject in forward anaphora sentences (F/NP1, F/NP2) are shown in blue. Topographic maps are based on the average voltage differences between the backward and forward anaphora conditions at successive 200ms time intervals.
negativity over right, anterior channels. Effects at this earliest time window (which includes the baseline -100-0ms interval) were not predicted and are thus difficult to interpret. Having said that, these particular effects do not appear to relate in any systematic way to the results for the subsequent intervals. In the 100-300ms interval, pronouns produced a broadly distributed negativity that was reflected in significant main effects of sentence type in the midline analysis, \(F(1,16)=6.64, \ p<.05\), and in the ROI analysis, \(F(1,16)=7.51, \ p<.05\). This effect was strongest over right, medial sites as indicated by significant interactions of sentence type and hemisphere, \(F(1,16)=6.05, \ p<.05\), and sentence type and lateral/medial, \(F(1,16)=5.29, \ p<.05\), as well as by a sentence type × hemisphere × lateral/medial interaction that approached significance, \(F(1,16)=3.59, \ p=.08\). In the 300-500ms interval, pronouns again produced more negativity than proper names, but in this case, with a centro-posterior focus. Indeed, in the midline analysis, there was a significant interaction of sentence type and midline site, \(F(1.47,23.61)=4.29, \ p<.05\), that was driven by pronounced negativity over posterior channels (CPz, Pz, POz, and Oz). Comparably, in the ROI analysis, there were significant sentence type × anterior/posterior, \(F(1,16)=6.75, \ p<.05\), and sentence type × lateral/medial interactions, \(F(1,16)=5.95, \ p<.05\). In the last two time windows, this negativity for pronouns appeared to continue, but did not produce statistically-reliable effects. At the 500-700ms interval, the sentence type × anterior/posterior interaction, \(F(1,16)=3.07, \ p=.10\), and sentence type × hemisphere × anterior/posterior × lateral/medial interaction, \(F(1,16)=3.79, \ p=.07\), approached significance, suggesting more negativity for pronouns over right, posterior, lateral scalp sites. In the 700-900ms
time window, the interaction of sentence type and lateral/medial also approached significance, $F(1,16)=3.89, p=.07$, suggesting that pronouns elicited more negativity than proper names over medial scalp sites.

With respect to the predictions for this experiment, it is important to note that the neurophysiological response at this word does not match particularly well with that which has been reported for the introduction of $\textit{wh}$-dependencies, which again has been found to elicit a LAN response. In this case, although a negativity was elicited by the pronoun that introduced the (backward) anaphoric dependency, this response had a central-posterior distribution more commonly associated with the N400.

This response is also interesting in light of the reading time patterns found for the subordinate clause pronoun in the behavioral experiments reported in Chapter 4. As detailed above, in the G-maze experiment, this pronoun was read more slowly than proper name subordinate clause subjects; whereas in the eye-tracking experiment, this word was often skipped and was fixated on for a very short time, much like a function word. The neurophysiological response to this pronoun, however, differed markedly from those commonly associated with function words, which (as shown in Chapter 3) tend to elicit left anterior negativities and an attenuated N400.

As a final note, it is important to point out that the response to this subordinate clause pronoun establishes a baseline (albeit somewhat rough) for the analyses of the other pronouns involved in the test sentences – specifically those in the main clause of the forward anaphora sentences, F/NP1 and F/NP2. Each of these forward anaphora pronouns is a point at which an antecedent-anaphor link is possible. Therefore, by
comparing the responses to these “anchored” pronouns with the response to the
“unanchored” pronoun in the subordinate clause of backward anaphora sentences, it is
possible to determine the neurophysiological consequences of establishing an antecedent-
anaphor link.

5.1.2.2.2 Main clause subject

The pronoun subject in F/NP1 sentences. The pronoun in the main clause subject
of F/NP1 sentences (she) was analyzed relative to the proper name subject in F/NP2
sentences (Mary) in order to assess the response to forward anaphora dependency
processing. Waveforms from a representative sample of electrodes and topographic maps
are shown in Figure 10. At the 100-300ms interval, the main effect of sentence type
approached significance, \( F(1,16)=3.40, p=.08 \), in the ROI analysis, suggesting that
pronoun main clause subjects elicited a broadly distributed negativity. The interaction of
sentence type, hemisphere, and anterior/posterior also approached significance,
\( F(1,16)=3.41, p=.08 \), suggesting that although this negativity was evident across
posterior regions, it was more left lateralized for anterior scalp sites. In the 300-500ms
time window, there was again a negativity for pronouns, but with a more centro-posterior
focus. In the midline analysis, this produced a marginally significant main effect of
sentence type, \( F(1,16)=4.49, p=.05 \), and a significant interaction of sentence type and
midline site, \( F(1.80,28.84)=6.98, p<.01 \). These effects were driven by pronounced
negative deflections over central and posterior midline sites (Cz, CPz, Pz, POz, Oz) for
pronouns. In the ROI analysis, this centro-posterior negativity produced a trend
suggesting a main effect of sentence type, \( F(1,16)=3.34, p=.09 \), as well as significant
Figure 10. Grand average ERP responses at the main clause subject in F/NP1 and F/NP2 sentences. Waveforms for the pronoun subject in F/NP1 sentences are shown in red; waveforms for the proper name subject in F/NP2 sentences are shown in blue. Topographic maps are based on the average voltage differences between the F/NP1 and F/NP2 conditions at successive 200ms time intervals.
interactions of this factor with anterior/posterior, \( F(1,16)=15.18, p<.01 \), and lateral/medial, \( F(1,16)=6.06, p<.05 \). A comparable pattern of results was found at the 500-700ms interval. The midline analysis revealed a significant main effect of sentence type, \( F(1,16)=14.51, p<.01 \), and an interaction of sentence type and midline site, \( F(1.53,24.50)=3.76, p<.05 \). Again, these effects were largely due to pronounced negative amplitudes over central and posterior midline sites (Cz, CPz, Pz, POz, Oz). In the ROI analysis, there was a significant main effect of sentence type \( (F(1,16)=15.03, p<.01) \) and significant interactions of this factor with anterior/posterior, \( F(1,16)=8.12, p<.05 \), and lateral/medial, \( F(1,16)=11.55, p<.01 \), indicating a negativity for pronouns that was most prominent over medial and posterior scalp sites. This negativity continued into the 700-900ms interval as well, producing a marginally significant main effect of sentence type in the midline analysis, \( F(1,16)=4.11, p=.06 \), a significant main effect of sentence type in the ROI analysis, \( F(1,16)=5.21, p<.05 \), as well as a significant interaction of this factor and lateral/medial \( (F(1,16)=11.29, p<.01) \).

In sum, the results for this “anchored” pronoun in the main clause subject were different than those for the “unanchored” pronoun in the subordinate clause subject of backward anaphora sentences. Whereas the latter elicited an early, broadly distributed negativity followed by an N400, the main clause subject pronoun seemed to elicit prominent N400, followed by a sustained negative deflection that was broadly distributed, but most prominent over medial and posterior scalp sites.

**The proper name subject in B/NP1 sentences.** The main clause subject in B/NP1 sentences (Mary) was analyzed relative to the subject in F/NP2 sentences (Mary) in order
to assess the response to backward anaphora dependency satisfaction. Waveforms from a representative sample of electrodes and topographic maps are shown in Figure 11. There were no statistically-reliable effects in the -100-100ms, 100-300ms, 300-500ms, 500-700ms, or 700-900ms time windows. However, further examination of the waveforms indicated a negative deflection for the proper name in B/NP1 sentences that appeared to be most prominent toward the end of the 300-500ms interval and toward the beginning of the 500-700ms interval. Therefore, the analysis windows were shifted by 100ms to examine the 400-600ms interval as well as the immediately following 600-800ms interval. Topographic maps for both of these intervals are provided in Figure 12. Indeed, at the 400-600ms interval, the main effect of sentence type was significant in the midline analysis, $F(1,16)=7.19, p<.05$, and in the ROI analysis, $F(1,16)=7.09, p<.05$, indicating a broadly distributed negativity for the proper name in B/NP1 sentences. No statistically-reliable effects were found for the sentence types of interest in the 600-800ms time window.

With regard to the predictions for this experiment, it is important to point out that the response to dependency satisfaction in backward anaphora sentences does not appear to match well with the dependency satisfaction effects commonly reported for filler-gap sentences. Again, P600 responses and/or LAN responses have been found to index filler-gap dependency satisfaction, both of which differ markedly from the broadly distributed negativity elicited for backward anaphora dependency satisfaction.
Figure 11. Grand average ERP responses at the main clause subject in B/NP1 and F/NP2 sentences. Waveforms for the proper name subject in B/NP1 sentences are shown in red; waveforms for the proper name subject in F/NP2 sentences are shown in blue. Topographic maps are based on the average voltage differences between the B/NP1 and F/NP2 conditions at successive 200ms time intervals.
Figure 12. Topographic maps at the main clause subject in B/NP1 and F/NP2 sentences based on the average voltage differences between these conditions over the 400-600ms and 600-800ms intervals.

The proper name subject in B/NP2 sentences. The main clause subject in B/NP2 sentences (Mary) was analyzed relative to the subject in F/NP2 sentences (Mary) in order to assess the response to backward anaphora dependency disruption. Waveforms from a representative sample of electrodes and topographic maps are shown in Figure 13. At the 500-700ms interval, there was a significant interaction of sentence type, anterior/posterior, and lateral/medial, $F(1,16)=5.44, p<.05$, indicating that the proper name in B/NP2 sentences elicited a positivity over anterior, medial scalp sites. In the 700-900ms time
Figure 13. Grand average ERP responses at the main clause subject in B/NP2 and F/NP2 sentences. Waveforms for the proper name subject in B/NP2 sentences are shown in red; waveforms for the proper name subject in F/NP2 sentences are shown in blue. Topographic maps are based on the average voltage differences between the B/NP2 and F/NP2 conditions at successive 200ms time intervals.
window, there was again significant interaction of sentence type, anterior/posterior, and lateral/medial, $F(1,16) = 5.08, p < .05$, which in this case indicated that the positivity elicited by disrupting names was broadly distributed over posterior scalp sites, but was more localized to medial regions for anterior sites.

Further inspection of the waveforms for this comparison, however, indicated that there was a negative deflection associated with the proper names in B/NP2 sentences that was most pronounced toward the end of the 300-500ms interval and at the beginning of the 500-700ms interval. Thus, analyses over these time windows again appeared to have the unfortunate effect of masking a negativity associated with the sentence type of interest. Moreover, because this negativity bled into an interval in which B/NP2 sentences began to produce a late positivity, these analyses do not appear to provide an accurate indication of the strength, timing, and distribution of this positive deflection. In order to redress these problems, the time intervals were shifted by 100ms, and the 400-600ms and 600-800ms time windows were analyzed. Topographic maps for these intervals are shown in Figure 14. At the first of these intervals, there was a significant interaction of sentence type and hemisphere, $F(1,16) = 6.50, p < .05$, indicating a largely left lateralized negative deflection for the proper names in B/NP2 sentences. In the 600-800ms time window, there was again a significant interaction of sentence type, anterior/posterior, and lateral/medial, $F(1,16) = 9.11, p < .01$, indicating a positivity for the proper names in B/NP2 sentences that had a medial focus for anterior scalp sites, but that was broadly distributed over posterior sites. Note that this effect is largely the same as that which was reported for the 700-900ms interval, but, in this case, more robust.
In sum, for dependency disruption as well, there was a negativity in the 400-600ms time interval. In this case, however, this response was followed by a relatively broadly-distributed positive deflection. This latter component may be considered comparable to the P600 component reported for dependency disruption in filler-gap processing.

The main clause subject in B/NP2 sentences (*Mary*) was also analyzed relative to the subject in B/NP1 sentences (*Mary*) in order to provide another indication of the
response to backward anaphora dependency disruption. Waveforms from a representative sample of electrodes and topographic maps are shown in Figure 15. At the 500-700ms interval, there was a broadly distributed positivity for B/NP2 sentences. This produced main effects of sentence type that approached significance in both the midline analysis, $F(1,16)=3.44$, $p=.08$, and ROI analysis, $F(1,16)=3.12$, $p=.10$. As in the other analyses for the proper name subjects reported above, analyses were also conducted over the 400-600ms and 600-800ms time windows. Topographic maps for these intervals are shown in Figure 16. In the 400-600ms time window, there was a significant interaction of sentence type and hemisphere, $F(1,16)=5.77$, $p<.05$, indicating that while B/NP2 sentences elicited more negativity on the left hemisphere, B/NP1 elicited more negativity over right hemisphere scalp sites. In the 600-800ms time window, the positivity for B/NP2 sentences again produced main effects of sentence type that only approached significance in the midline analysis, $F(1,16)=3.53$, $p=.08$, and ROI analysis, $F(1,16)=3.03$, $p=.10$. Further inspection of the waveforms and topographic maps for this comparison indicated that these marginal results were due in large part to differences in the magnitude and distribution of this positivity at the beginning and end of the 600-800ms interval. Indeed, an analysis of the 600-700ms time window revealed a main effect of sentence type that was significant in the midline analysis, $F(1,16)=5.31$, $p<.05$, and marginally significant in the ROI analysis, $F(1,16)=3.93$, $p=.07$. Analyses of the 700-800ms interval revealed no statistically-reliable effects. Topographic maps for these 600-700ms and 700-800ms intervals are shown in Figure 17.
Figure 15. Grand average ERP responses at the main clause subject in B/NP2 and B/NP1 sentences. Waveforms for the proper name subject in B/NP2 sentences are shown in red; waveforms for the proper name subject in B/NP1 sentences are shown in blue. Topographic maps are based on the average voltage differences between the B/NP2 and B/NP1 conditions at successive 200ms time intervals.
Figure 16. Topographic maps at the main clause subject in B/NP2 and B/NP1 sentences based on the average voltage differences between these conditions over the 400-600ms and 600-800ms intervals.
Figure 17. Topographic maps at the main clause subject in B/NP2 and B/NP1 sentences based on the average voltage differences between these conditions over the 600-700ms and 700-800ms intervals.

This comparison again yielded a late and fairly broadly-distributed positivity for dependency disruption in backward anaphora sentences. As mentioned above, this response is comparable to that which has been obtained for disrupted filler-gap processing as well.

5.1.2.2.3 Main clause object

The pronoun object in F/NP2 sentences. The pronoun in the main clause object of F/NP2 sentences (him) was analyzed relative to the proper name object in F/NP1
sentences (Mary) in order to assess the response to forward anaphora dependency processing at a more distal antecedent-anaphor linking point. Waveforms from a representative sample of electrodes and topographic maps are shown in Figure 18. At the 100-300ms interval, there was a marginally significant main effect of sentence type in the midline analysis, $F(1,16)=4.06, p=.06$, and a significant interaction of sentence type and lateral/medial, $F(1,16)=9.70, p<.01$, in the ROI analysis. These effects reflect a broadly distributed negativity for the pronoun object that was most pronounced over medial scalp sites. In the 300-500ms time window, the object pronoun elicited a negativity with a centro-posterior focus. In the midline analysis, this negativity produced a significant main effect of sentence type, $F(1,16)=10.23, p<.01$, and a significant sentence type × midline site interaction, $F(1.29,20.65)=5.65, p<.05$. These effects were driven by prominent negative amplitudes over central and posterior midline sites (Cz, CPz, Pz, POz, Oz). Comparably, in the ROI analysis, there was a significant main effect of sentence type, $F(1,16)=4.64, p<.05$, and significant interactions of this factor with anterior/posterior, $F(1,16)=12.80, p<.01$, and lateral/medial, $F(1,16)=18.61, p<.01$. A comparable effect was found in the 500-700ms interval. Specifically, the ROI analysis revealed a significant main effect of sentence type, $F(1,16)=10.11, p<.01$, and significant sentence type × anterior/posterior, $F(1,16)=6.19, p<.05$, and sentence type × lateral/medial interactions, $F(1,16)=14.47, p<.01$, indicating that pronoun objects again elicited a broadly distributed negativity with a centro-posterior focus. In the midline analysis, there was a significant main effect of sentence type, $F(1,16)=14.33, p<.01$, but no interaction of this factor and midline site – a pattern of results that suggests a somewhat more distributed effect than in
Figure 18. Grand average ERP responses at the main clause object in F/NP2 and F/NP1 sentences. Waveforms for the pronoun object in F/NP2 sentences are shown in red; waveforms for the proper name object in F/NP1 sentences are shown in blue. Topographic maps are based on the average voltage differences between the F/NP2 and F/NP1 conditions at successive 200ms time intervals.
the immediately preceding (300-500ms) time window. At the 700-900ms interval, the broadly distributed negativity for pronoun objects continued, and was most prominent over medial scalp sites. Again, the main effect of sentence type was significant in both the midline analysis, $F(1,16)=9.18, p<.01$, and the ROI analysis, $F(1,16)=7.42, p<.05$. The ROI analysis also revealed a significant interaction of sentence type and lateral/medial, $F(1,16)=19.94, p<.001$. In sum, dependency satisfaction in forward anaphora sentences elicited a N400-like response followed by a sustained broadly-distributed negativity. This response is very much comparable to that which was obtained at the pronoun subject in F/NP1 sentences.

The proper name object in B/NP2 sentences. The proper name main clause object in B/NP2 sentences (Mary) was analyzed relative to the proper name object in B/NP1 sentences (Mary) in order to assess the response to backward anaphora dependency satisfaction from a more distal position. The waveforms from a representative sample of electrodes and topographic maps are shown in Figure 19. At the 100-300ms window, there was a significant interaction of sentence type and anterior/posterior, $F(1,16)=4.71, p<.05$, with proper names in B/NP2 sentences eliciting a negativity with a posterior focus. This negativity continued into the next time window as well, again producing a significant sentence type × anterior/posterior interaction, $F(1,16)=7.13, p<.05$. In the 500-700ms interval, a somewhat more distributed negativity was elicited by B/NP2 sentences. This was reflected in significant main effects of sentence type in both the midline analysis, $F(1,16)=4.87, p<.05$, and the ROI analysis, $F(1,16)=7.74, p<.05$. In the ROI analysis, interaction of sentence type, hemisphere, and anterior/posterior approached
Figure 19. Grand average ERP responses at the main clause object in B/NP2 and B/NP1 sentences. Waveforms for the proper name object in B/NP2 sentences are shown in red; waveforms for the proper name object in B/NP1 sentences are shown in blue. Topographic maps are based on the average voltage differences between the B/NP2 and B/NP1 conditions at successive 200ms time intervals.
significance \((F(1,16)=3.81, p=.07)\), suggesting that while this negativity was broadly distributed across posterior scalp sites, it was more left lateralized over anterior sites.

This response to backward anaphora dependency satisfaction at the main clause object was strikingly different from that which was obtained for the satisfaction of this dependency at the main clause subject. Negativities were produced in both cases, but at the object this response began earlier, lasted longer, and was greater in magnitude. Again, this effect does not match the P600 responses commonly reported for dependency satisfaction in filler-gap sentences. However, it also differs from this response in another way. Phillips et al. (2005) found that filler-gap integration across greater distance influenced only the latency of the P600 response – with this response occurring slightly later in cases in which filler-gap integration occurred across a longer distance – but not its magnitude.

5.1.2.3 Multi-Word Analyses

The ERP responses throughout the subordinate clause were also analyzed. Of particular interest was whether backward anaphora sentences would elicit a SAN response over the words intervening between the introduction the anaphoric dependency, at the pronoun subject of the subordinate clause, and its (potential) satisfaction, at the main clause subject. As discussed above, these words were analyzed in two ways. The cumulative analysis examined the 2600ms-long waveforms generated from the subordinate clause subject through to the final word of this clause. Figure 20 shows the grand average waveforms from Fz (a midline, anterior site) over these words as well as topographic maps of the average voltage differences between the conditions at 500ms
Figure 20. Grand average ERP responses throughout the words of the subordinate clause in backward anaphora (B/NP1, B/NP2) and forward anaphora (F/NP1, F/NP2) sentences at the anterior, midline electrode Fz. The waveform for the backward anaphora condition is shown in red; the waveform for the forward anaphora condition is shown in blue. Topographic maps are based on the average voltage differences between the backward anaphora and forward anaphora conditions at successive 500ms intervals.

Intervals corresponding to each word. The non-cumulative analysis examined the ERP responses to each of the words of interest. However, unlike in the first analysis, this was done not with reference to a common baseline, but with the -100-0ms interval before each word serving as its baseline. Figure 21 shows the grand average waveforms from Fz...
for each of the words in the subordinate clause as well as topographic maps of the voltage difference between the conditions for each word.

Figure 21. Grand average ERP responses at each word of the subordinate clause (except the first word) in backward anaphora (B/NP1, B/NP2) and forward anaphora (F/NP1, F/NP2) sentences at the anterior, midline electrode Fz. The waveforms for the backward anaphora condition are shown in red; the waveforms for the forward anaphora condition are shown in blue. Topographic maps are based on the average voltage differences between the backward anaphora and forward anaphora conditions in the 100-600ms interval for each word.
5.1.2.3.1  Cumulative analysis

At the subordinate clause subject, the interaction of sentence type and anterior/posterior approached significance, $F(1,16)=3.91, p=.07$, suggesting that backward anaphora sentences elicited more negativity than forward anaphora sentences over posterior sites. This posterior negativity was also suggested by a marginally significant interaction of sentence type and site, $F(1.57, 25.15)=3.66, p=.05$, in the midline analysis. Consistent with the results of the ROI analysis, this interaction was driven by pronounced negative amplitudes over posterior, midline electrodes (CPz, Pz, POz, Oz). It is important to note, however, that this pattern of results likely does not indicate the onset of a sustained negative component at this point in backward anaphora sentences. Rather it appears to be driven in large part by the N400-like effect reported for the unanchored pronoun in the single-word analyses. There were no statistically-reliable effects related to the sentence types at any of the other words in the subordinate clause.

5.1.2.3.2  Non-cumulative analysis

At the subordinate clause subject, there was a significant main effect of sentence type in the midline analysis, $F(1,16)=4.75, p<.05$, and a significant interaction of sentence type and lateral/medial in the ROI analysis, $F(1,16)=8.15, p<.05$. Consistent with the results of the single-word analyses, these results indicate that pronoun subordinate clause subjects elicited a broadly-distributed negativity with a centro-posterior focus.

At the subordinate clause verb ($spotted$), the midline analysis revealed a marginally significant main effect of sentence type, $F(1,16)=4.41, p=.05$, and a
significant interaction of sentence type and site, $F(1.68, 26.86)=10.16, p<.01$. These effects were driven by large differences in the responses elicited by the verbs in backward anaphora sentences over anterior and posterior midline sites. Specifically, although this verb elicited a positivity over central and posterior sites (Cz, CPz, Pz, POz, and Oz), it elicited a negativity at the anterior sites FCz and Fz. In the ROI analysis, this pattern of results produced a significant sentence type × anterior/posterior interaction, $F(1,16)=15.73, p<.01$. There was also a significant sentence type × lateral/medial interaction, $F(1,16)=7.93, p<.05$, indicating that the positivity elicited by the verb in backward anaphora sentences was most pronounced over medial scalp sites. Although it is tempting to interpret the negativity over anterior scalp sites as an indication of the onset of an anterior negativity associated with dependency maintenance, the posterior positivity for this word complicates this interpretation. Indeed, in light of the fact that the pattern of results for this word is so different from the analysis in the sustained ERPs, and in light of the fact that there were clear differences between the immediately preceding words at precisely the baseline interval for this word, it appears that these effects might be artifacts of the baseline correction procedures, rather than reflections of any interesting cognitive processes.

At the first word following the verb (the), the interactions of sentence type with hemisphere, $F(1,16)=3.84, p=.07$, and lateral/medial, $F(1,16)=3.40, p=.08$, approached significance, suggesting that this word in backward anaphora sentences elicited more positivity over left hemisphere sites but more negativity over right hemisphere sites, and that this positivity was most pronounced over medial scalp sites generally. There was also
a significant three-way interaction of sentence type, anterior/posterior, and lateral/medial, $F_{1(1,16)}=9.79$, $p<.01$, indicating that although this word in backward anaphora sentences elicited positive deflections over posterior lateral, posterior medial, and anterior medial regions, it elicited a negative deflection over anterior lateral scalp sites.

At the second word following the verb (*mysterious*), the three-way interaction of sentence type, hemisphere, and anterior/posterior approached significance ($F_{1(16)}=4.07$, $p=.06$, suggesting that this word in backward anaphora sentences elicited relatively pronounced negative amplitudes over left posterior scalp sites.

At the final word of the subordinate clause (*UFO*), there was a significant sentence type × anterior/posterior × lateral/medial interaction, $F_{1(16)}=4.60$, $p<.05$, indicating that this word in backward anaphora sentences elicited more negativity over anterior medial sites, but more positivity of posterior medial sites.

In sum, while the cumulative analysis indicated essentially no hint of a SAN response, in the non-cumulative analysis, there were some indications of negativities for the words in the subordinate clause in backward anaphora sentences. However, because these responses were not consistent across the words of interest, they should be interpreted with caution.

### 5.1.3 Discussion

Although the results of the behavioral experiments reported in Chapter 4 indicated significant overlap between backward anaphora and filler-gap processing, the neurophysiological responses to dependency introduction and satisfaction for this anaphora type were quite different from those associated with filler-gap sentences.
Particularly striking was the difference in the responses to dependency satisfaction. In contrast to a P600 response for filler-gap integration that is relatively insensitive to distance, there was a negativity associated with backward anaphora dependency satisfaction that was highly sensitive to the distance manipulation in this experiment. This negativity is also interesting in light of the responses to the pronouns in forward anaphora sentences. Indeed, it was the case that a negativity was elicited at each antecedent-anaphor linking point. This comparable response suggests a common underlying mechanism for the processing of anaphora, regardless of the relative ordering of the antecedent and anaphor. It is important to note, however, that the response elicited for dependency disruption in backward anaphora sentences was similar to that which is commonly reported for filler-gap processing – a P600 response in both cases. These similarities/differences are therefore taken to indicate separate systems for the processing of filler-gap and anaphoric dependencies, but systems that nevertheless may share certain core properties.
CHAPTER 6

GENERAL DISCUSSION

The experiments reported in this dissertation set out to examine the neurocognitive consequences of receiving a dependent element early in a sentence. Of particular interest were sentences involving *wh*-dependencies (or filler-gap dependencies) and sentences involving anaphoric dependencies. These sentence types were investigated in order to answer two fundamental questions:

(a) What is the relative importance of forward- and backward-looking dependency satisfaction processes in the comprehension of sentences involving *wh*-dependencies?

(b) To what extent does the early introduction of a dependency engage common neurocognitive systems, regardless of dependency type (*wh*- or anaphoric)?

In order to answer to the first of these questions, Experiments 1-4 looked at participants’ reading patterns and neurophysiological responses during the processing of sentences with a specific type of *wh*-dependency – sentences containing subject- and object-extracted relative clauses (SRCs and ORCs). As detailed in Chapter 2, ORC sentences have been shown to be more difficult to process than SRC sentences across virtually all domains of psycholinguistic inquiry. The present set of experiments indicated that the bulk of this processing difficulty is incurred early in the ORC, and more specifically at the first indication that the subject position of this clause is occupied. This pattern of results indicates that the ORC processing penalty is attributable primarily to disrupted forward-looking dependency satisfaction operations, or to the disconfirmation
of structural expectations that allow for efficient dependency satisfaction. These findings therefore suggest a core role for forward-looking, expectation-based processes in the processing of relative clause structures in particular, and of \textit{wh}-dependency sentences in general.

In order to answer the second question, Experiments 4-8 examined the processing of sentences containing forward and backward anaphoric dependencies. The latter sentence type was of particular interest because the dependent element (the anaphor; in this case, a pronoun) is introduced prior to the “satisfying” element (the antecedent) – just as is the case in most \textit{wh}-dependency sentences. Interestingly, the behavioral experiments (Experiments 4-7) revealed analogues to effects characteristic of \textit{wh}-dependency processing during the online comprehension of backward anaphora sentences. Specifically, effects comparable to the filled-gap effect (see above) and, at least under certain task conditions, to the filler-gap integration effect (again, see above) were revealed during the processing of these backward anaphora sentences. These findings were thus taken as support for the idea that the introduction of a dependent element early in a sentence engages comparable processing mechanisms, regardless of dependency type. However, despite this apparent overlap, the neurophysiological responses to backward anaphora sentences were shown to be (a) rather different from those associated with \textit{wh}-dependency sentences and (b) surprisingly similar to the responses elicited by their forward anaphora counterparts. These similarities/differences were taken to indicate separate systems for the processing of \textit{wh}- and anaphoric dependencies, but systems that
may nevertheless share certain core properties with respect to the processing of dependent-element-first structures.

In sum, this project attempted to shed light on aspects of the processing of long-distance dependencies – structures that have enjoyed a long history of interest in linguistics and psycholinguistics. It is hoped that the experiments reported in this dissertation have helped to elucidate the processing characteristics associated with these structures and that they will open up new avenues of inquiry into how elements are linked across intervening words and phrases during online sentence comprehension.
APPENDIX A: Experimental items for Experiments 1-3

In each experimental item pair, the (a) version is the SRC sentence and the (b) version is the ORC sentence. The prompts used for the true/false comprehension are also listed below, with each appearing under its associated item pair.

(1a) The soldier who roughly pushed the sailor smashed a bottle against the bar.
(1b) The soldier who the sailor roughly pushed smashed a bottle against the bar.

   T/F Prompt: The soldier pushed the sailor.

(2a) The killer who severely injured the policeman squeezed the trigger of the rifle.
(2b) The killer who the policeman severely injured squeezed the trigger of the rifle.

(3a) The tourist who angrily insulted the merchant tossed the money onto the counter.
(3b) The tourist who the merchant angrily insulted tossed the money onto the counter.

   T/F Prompt: The merchant insulted the tourist.

(4a) The bandit who sharply kicked the thief stole a motorcycle from the warehouse.
(4b) The bandit who the thief sharply kicked stole a motorcycle from the warehouse.

(5a) The farmer who closely followed the hunter spotted a hole in the ground.
(5b) The farmer who the hunter closely followed spotted a hole in the ground.

(6a) The fireman who speedily rescued the cop sued the city over working conditions.
(6b) The fireman who the cop speedily rescued sued the city over working conditions.

   T/F Prompt: The fireman sued the city.

(7a) The poet who harshly criticized the novelist wrote a review in the new journal.
(7b) The poet who the novelist harshly criticized wrote a review in the new journal.

(8a) The ambassador who truly admired the king arranged the meeting in total secrecy.
(8b) The ambassador who the king truly admired arranged the meeting in total secrecy.
(9a) The lawyer who flatly challenged the detective produced an alibi on the spot.
(9b) The lawyer who the detective flatly challenged produced an alibi on the spot.

(10a) The cowboy who purposely shoved the rancher pulled a pistol out of his holster.
(10b) The cowboy who the rancher purposely shoved pulled a pistol out of his holster.

(11a) The captain who personally comforted the general folded the flag on the casket.
(11b) The captain who the general personally comforted folded the flag on the casket.
   T/F Prompt: The general folded the flag.

(12a) The ghost who bitterly threatened the witch uttered a curse in the darkness.
(12b) The ghost who the witch bitterly threatened uttered a curse in the darkness.

(13a) The writer who bluntly attacked the critic sipped a beer at the literary event.
(13b) The writer who the critic bluntly attacked sipped a beer at the literary event.

(14a) The mentor who extensively advised the scholar finished the work on schedule.
(14b) The mentor who the scholar extensively advised finished the work on schedule.

(15a) The forward who excitedly kicked the goalie misplayed the ball near the goal.
(15b) The forward who the goalie excitedly kicked misplayed the ball near the goal.
   T/F Prompt: The forward kicked the goalie.

(16a) The butler who blindly loved the maid unwrapped a box of chocolate peanuts.
(16b) The butler who the maid blindly loved unwrapped a box of chocolate peanuts.

(17a) The gambler who deeply hated the gangster buried a trunk behind the restaurant.
(17b) The gambler who the gangster deeply hated buried a trunk behind the restaurant.

(18a) The clerk who madly adored the secretary completed the task ahead of schedule.
(18b) The clerk who the secretary madly adored completed the task ahead of schedule.

(19a) The carpenter who helpfully advised the electrician finished the work on time.
(19b) The carpenter who the electrician helpfully advised finished the work on time.
(20a) The singer who warmly praised the actress received a part in the new production.
(20b) The singer who the actress warmly praised received a part in the new production.
   T/F Prompt: The actress praised the singer.

(21a) The artist who acutely resented the designer secured a commission for the mural.
(21b) The artist who the designer acutely resented secured a commission for the mural.

(22a) The waiter who kindly assisted the busboy stacked the glasses near the sink.
(22b) The waiter who the busboy kindly assisted stacked the glasses near the sink.

(23a) The host who overtly ridiculed the guest ignored the gift despite its value.
(23b) The host who the guest overtly ridiculed ignored the gift despite its value.

(24a) The outlaw who gravely injured the sheriff rode a horse around the sleepy town.
(24b) The outlaw who the sheriff gravely injured rode a horse around the sleepy town.
   T/F Prompt: The outlaw rode a horse.

(25a) The prisoner who openly shoved the guard registered a complaint with the warden.
(25b) The prisoner who the guard openly shoved registered a complaint with the warden.
   T/F Prompt: The guard registered a complaint.

(26a) The cyclist who silently followed the driver noticed the tracks on the road.
(26b) The cyclist who the driver silently followed noticed the tracks on the road.

(27a) The painter who quickly rescued the roofer threw a tarp on the muddy ground.
(27b) The painter who the roofer quickly rescued threw a tarp on the muddy ground.

(28a) The musician who casually consulted the composer suggested a change of tempo.
(28b) The musician who the composer casually consulted suggested a change of tempo.
APPENDIX B: Filler items for Experiments 1-3, 5-6

(1) Because Mary had to run an errand, Mike had to wait for an hour to be picked up.
(2) When Paul entered the dark house, Lisa suddenly turned on all of the lights.
   T/F Prompt: Lisa turned on the lights.
(3) As Anne swam in the swimming pool, Mark relaxed in the sun and drank margaritas.
   T/F Prompt: Mark swam in the pool.
(4) After the preacher finished the sermon, the old woman knelt and prayed silently.
   T/F Prompt: The preacher prayed silently.
(5) After the pirate sailed into the harbor, the fisherman drove in with his catch.
(6) As the patrol attacked the fort, the sergeant rang headquarters to request help.
(7) Jack was able to avoid the traffic jam because Judy provided great directions.
   T/F Prompt: Judy’s directions were bad.
(8) Jane set up a plastic fence around the lawn as Matt planted the grass seed.
   T/F Prompt: Jane set up the fence.
(9) Greg hated live theater although Sara always talked about plays so passionately.
(10) The soldier stood in shocked silence as the commander issued the brutal orders.
    T/F Prompt: The soldier spoke out against the orders.
(11) The professor distributed the make-up exam when all of the students were seated.
(12) The thief started to sweat as the policeman asked questions about the crime.
    T/F Prompt: The thief asked the policeman questions.
(13) The old man jokingly gossiped with Beth about the changes at the university.
    T/F Prompt: The old man gossiped about the university.
(14) Jill became increasingly angry with the politician as the speech went on and on.
    T/F Prompt: Jill enjoyed the politician’s speech.
(15) Mike acted impulsively and asked the cute waitress out on a date last night.
    T/F Prompt: Mike asked the waitress out on a date.
(16) The nurse entered the room, and Mark asked for extra pillow and some ice water.
(17) The model shamelessly flirted with Sara during the party at the art gallery.
    T/F Prompt: Sara flirted with the model.
(18) Matt called the travel agent to purchase a ticket to Hawaii for spring break.
    T/F Prompt: Matt bought a ticket to Hawaii.
(19) The burglar noticed the boy and the girl watching quietly from the window.
    T/F Prompt: The burglar saw the kids in the window.
(20) The gardener was happy with the flowers, but the owner of the house was not.  
   T/F Prompt: The owner was happy with the flowers.
(21) The semester will start next week, but the students and teachers are not ready.  
   T/F Prompt: The students and teachers are not prepared for the semester.
(22) The nurse carefully guided the elderly woman down the steps and into the car.  
   T/F Prompt: The nurse helped the elderly woman into the car.
(23) The pilot fought bravely to keep the plane in the sky during the violent storm.
(24) The doctor calmly told the patient that the surgery would need to be redone.  
   T/F Prompt: The doctor spoke to the patient calmly.
(25) Judy had dated Adam and Jeff but ended up marrying Greg in Las Vegas last week.  
   T/F Prompt: Judy married Greg.
(26) Sara will open bakeries in Chicago and New York after getting a loan next year.  
   T/F Prompt: Sara will open a bakery in Los Angeles.
(27) Jeff and Jill studied math intensely yesterday, but the exam was just too hard.
(28) Mary quickly typed up the term paper and uploaded it onto the course website.  
   T/F Prompt: Mary uploaded the paper.
**APPENDIX C:** Items from handedness test

With which hand do you:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Left</th>
<th>Either</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Write?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use a bottle opener?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throw a snowball to hit a tree?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use a hammer?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use a toothbrush?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use a screwdriver?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use an eraser on paper?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use a tennis racket?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use a scissors?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold a match when striking it?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stir a can of paint?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On which shoulder do you rest a bat before swinging?</td>
<td>Left</td>
<td>Either</td>
<td>Right</td>
</tr>
</tbody>
</table>
APPENDIX D: Experimental items for Experiment 4

In each experimental item pair, the (a) version is the SRC sentence and the (b) version is the ORC sentence. The prompts used for the true/false comprehension are also listed below, with each appearing under its associated item pair.

(1a) The soldier who roughly pushed the sailor smashed a bottle against the bar.
(1b) The soldier who the sailor roughly pushed smashed a bottle against the bar.
   T/F Prompt: The soldier pushed the sailor.

(2a) The killer who severely injured the policeman squeezed the trigger of the rifle.
(2b) The killer who the policeman severely injured squeezed the trigger of the rifle.

(3a) The tourist who angrily insulted the merchant tossed the money onto the counter.
(3b) The tourist who the merchant angrily insulted tossed the money onto the counter.
   T/F Prompt: The merchant insulted the tourist.

(4a) The bandit who sharply kicked the thief stole the motorcycle from the warehouse.
(4b) The bandit who the thief sharply kicked stole the motorcycle from the warehouse.

(5a) The farmer who closely followed the hunter spotted a hole in the ground.
(5b) The farmer who the hunter closely followed spotted a hole in the ground.

(6a) The fireman who speedily rescued the cop sued the city over working conditions.
(6b) The fireman who the cop speedily rescued sued the city over working conditions.
   T/F Prompt: The fireman sued the city.

(7a) The poet who harshly criticized the novelist wrote a review in the new journal.
(7b) The poet who the novelist harshly criticized wrote a review in the new journal.
   T/F Prompt: The novelist wrote the review.

(8a) The ambassador who truly admired the king arranged the meeting in total secrecy.
(8b) The ambassador who the king truly admired arranged the meeting in total secrecy.
   T/F Prompt: The ambassador arranged the meeting.
(9a) The lawyer who flatly challenged the detective produced an alibi on the spot.
(9b) The lawyer who the detective flatly challenged produced an alibi on the spot.

(10a) The cowboy who viciously shoved the rancher pulled a pistol out of his holster.
(10b) The cowboy who the rancher viciously shoved pulled a pistol out of his holster.

(11a) The captain who personally comforted the general folded the flag on the casket.
(11b) The captain who the general personally comforted folded the flag on the casket.
T/F Prompt: The general folded the flag.

(12a) The ghost who bitterly threatened the witch uttered a curse in the darkness.
(12b) The ghost who the witch bitterly threatened uttered a curse in the darkness.

(13a) The writer who bluntly attacked the critic sipped a beer at the literary event.
(13b) The writer who the critic bluntly attacked sipped a beer at the literary event.

(14a) The scholar who extensively advised the researcher finished the book on schedule.
(14b) The scholar who the researcher extensively advised finished the book on schedule.

(15a) The forward who excitedly kicked the goalie misplayed the ball near the goal.
(15b) The forward who the goalie excitedly kicked misplayed the ball near the goal.
T/F Prompt: The forward kicked the goalie.

(16a) The butler who truly loved the maid unwrapped the box of chocolates.
(16b) The butler who the maid truly loved unwrapped the box of chocolates.

(17a) The gambler who deeply hated the gangster buried a trunk behind the restaurant.
(17b) The gambler who the gangster deeply hated buried a trunk behind the restaurant.
T/F Prompt: The gangster buried the trunk.

(18a) The clerk who madly adored the secretary completed the task ahead of schedule.
(18b) The clerk who the secretary madly adored completed the task ahead of schedule.
(19a) The carpenter who helpfully advised the electrician finished the work on time.
(19b) The carpenter who the electrician helpfully advised finished the work on time.

(20a) The singer who warmly praised the actress received a part in the new production.
(20b) The singer who the actress warmly praised received a part in the new production.
    T/F Prompt: The actress praised the singer.

(21a) The artist who acutely deeply the designer secured a commission for the mural.
(21b) The artist who the designer deeply resented secured a commission for the mural.

(22a) The waiter who kindly assisted the busboy stacked the glasses near the sink.
(22b) The waiter who the busboy kindly assisted stacked the glasses near the sink.
    T/F Prompt: The waiter assisted the busboy.

(23a) The host who overtly ridiculed the guest ignored the gift despite its value.
(23b) The host who the guest overtly ridiculed ignored the gift despite its value.
    T/F Prompt: The host ignored the gift.

(24a) The outlaw who gravely injured the sheriff rode a horse around the sleepy town.
(24b) The outlaw who the sheriff gravely injured rode a horse around the sleepy town.
    T/F Prompt: The outlaw rode a horse.

(25a) The prisoner who openly shoved the guard registered a complaint with the warden.
(25b) The prisoner who the guard openly shoved registered a complaint with the warden.
    T/F Prompt: The guard registered a complaint.

(26a) The cyclist who silently followed the driver noticed the tracks of another car on the road.
(26b) The cyclist who the driver silently followed noticed the tracks of another car on the road.
(27a) The painter who quickly rescued the roofer repaired the ladder with some scrap metal.
(27b) The painter who the roofer quickly rescued repaired the ladder with some scrap metal.

(28a) The musician who casually consulted the composer suggested a change of tempo.
(28b) The musician who the composer casually consulted suggested a change of tempo.

(29a) The commando who critically wounded the terrorist hurled a grenade at the disabled tank.
(29b) The commando who the terrorist critically wounded hurled a grenade at the disabled tank.

T/F Prompt: The commando hurled the grenade.

(30a) The criminal who seriously hurt the officer retrieved the weapon from the sidewalk.
(30b) The criminal who the officer seriously hurt retrieved the weapon from the sidewalk.

(31a) The minister who repeatedly ignored the priest accepted an award from the hospital.
(31b) The minister who the priest repeatedly ignored accepted an award from the hospital.

(32a) The surgeon who wisely advised the physician cured the patient despite the complications.
(32b) The surgeon who the physician wisely advised cured the patient despite the complications.

(33a) The mechanic who truthfully accused the welder left the company after the incident.
(33b) The mechanic who the welder truthfully accused left the company after the incident.
(34a) The Democrat who eagerly confronted the Republican rejected the money from the interest group.
(34b) The Democrat who the Republican eagerly confronted rejected the money from the interest group.

(35a) The director who thoroughly hated the producer ruined the production out of spite.
(35b) The director who the producer thoroughly hated ruined the production out of spite.

(36a) The attorney who stubbornly opposed the judge invented a reason to disqualify the juror.
(36b) The attorney who the judge stubbornly opposed invented a reason to disqualify the juror.

(37a) The salesman who fiercely accused the executive denied the charge of embezzling company funds.
(37b) The salesman who the executive fiercely accused denied the charge of embezzling company funds.

(38a) The porter who graciously praised the bellhop won the prize for employee of the month.
(38b) The porter who the bellhop graciously praised won the prize for employee of the month.

(39a) The architect who regularly hired the builder discussed the plans for the new project.
(39b) The architect who the builder regularly hired discussed the plans for the new project.

(40a) The diplomat who completely ignored the politician altered the policy without approval.
(40b) The diplomat who the politician completely ignored altered the policy without approval.
(41a) The expert who cautiously warned the technician discovered a problem with the space probe.
(41b) The expert who the technician cautiously warned discovered a problem with the space probe.

(42a) The painter who sincerely adored the sculptor created the artwork for the special exhibition.
(42b) The painter who the sculptor sincerely adored created the artwork for the special exhibition.

(43a) The politician who firmly supported the mayor proposed a change in the city charter.
(43b) The politician who the mayor firmly supported proposed a change in the city charter.

(44a) The player who quietly despised the coach abandoned the team after another losing season.
(44b) The player who the coach quietly despised abandoned the team after another losing season.

(45a) The engineer who cruelly ridiculed the scientist tested the machine for defects.
(45b) The engineer who the scientist cruelly ridiculed tested the machine for defects.

(46a) The historian who politely introduced the librarian discussed the changes to the conference plans.
(46b) The historian who the librarian politely introduced discussed the changes to the conference plans.

(47a) The governor who savagely attacked the reporter admitted the error after the hearing.
(47b) The governor who the reporter savagely attacked admitted the error after the hearing.
(48a) The accountant who anxiously hired the lawyer resolved the issue without much trouble.
(48b) The accountant who the lawyer anxiously hired resolved the issue without much trouble.

(49a) The comedian who violently criticized the musician dominated the conversation with sarcastic remarks.
(49b) The comedian who the musician violently criticized dominated the conversation with sarcastic remarks.

(50a) The communist who frankly admired the socialist edited the article about the bitter strike.
(50b) The communist who the socialist frankly admired edited the article about the bitter strike.

(51a) The barber who patiently loved the waitress examined the ring studded with diamonds.
(51b) The barber who the waitress patiently loved examined the ring studded with diamonds.

(52a) The senator who frequently opposed the governor captured the nomination at the convention.
(52b) The senator who the governor frequently opposed captured the nomination at the convention.

(53a) The lecturer who openly supported the dean ignored an invitation to address the students.
(53b) The lecturer who the dean openly supported ignored an invitation to address the students.
(54a) The doctor who greatly respected the professor prepared a report on the strange phenomenon.
(54b) The doctor who the professor greatly respected prepared a report on the strange phenomenon.
T/F Prompt: The professor respected the doctor.

(55a) The actor who proudly nominated the director delivered a speech to the packed auditorium.
(55b) The actor who the director proudly nominated delivered a speech to the packed auditorium.
T/F Prompt: The director delivered the speech.

(56a) The chemist who vigorously challenged the physicist devised the machine for the critical experiment.
(56b) The chemist who the physicist vigorously challenged devised the machine for the critical experiment.
T/F Prompt: The chemist challenged the physicist.

(57a) The nurse who sternly questioned the therapist reported a change in the patient's condition.
(57b) The nurse who the therapist sternly questioned reported a change in the patient's condition.
T/F Prompt: The therapist questioned the nurse.

(58a) The researcher who absolutely despised the professor presented the results of the experiments.
(58b) The researcher who the professor absolutely despised presented the results of the experiments.
T/F Prompt: The researcher presented the results.
(59a) The violinist who furiously insulted the pianist performed the concerto badly during the concert.
(59b) The violinist who the pianist furiously insulted performed the concerto badly during the concert.

T/F Prompt: The pianist performed badly.

(60a) The teacher who secretly threatened the principal demanded an investigation by the school board.
(60b) The teacher who the principal secretly threatened demanded an investigation by the school board.

(61a) The general who keenly respected the admiral upheld the decision to invade the island.
(61b) The general who the admiral keenly respected upheld the decision to invade the island.

(62a) The author who constantly consulted the editor revised the chapter before publication.
(62b) The author who the editor constantly consulted revised the chapter before publication.

(63a) The suspect who tenderly comforted the convict purchased a cigarette from another inmate.
(63b) The suspect who the convict tenderly comforted purchased a cigarette from another inmate.

(64a) The foreman who suddenly pushed the striker unlocked the gate without further incident.
(64b) The foreman who the striker suddenly pushed unlocked the gate without further incident.
(65a) The psychic who intensely disliked the magician reviewed the performance for the newspaper.
(65b) The psychic who the magician intensely disliked reviewed the performance for the newspaper.

(66a) The attorney who soberly warned the analyst attended a meeting of concerned professionals.
(66b) The attorney who the analyst soberly warned attended a meeting of concerned professionals.

(67a) The knight who inevitably confronted the wizard demanded a fight to the death.
(67b) The knight who the wizard inevitably confronted demanded a fight to the death.

(68a) The journalist who publicly questioned the official delayed a vacation until the controversy ended.
(68b) The journalist who the official publicly questioned delayed a vacation until the controversy ended.

(69a) The player who viciously insulted the referee taunted the fans at the game.
(69b) The player who the referee viciously insulted taunted the fans at the game.

(70a) The landlord who cheerfully greeted the businessman explained the deal in great detail.
(70b) The landlord who the businessman cheerfully greeted explained the deal in great detail.

(71a) The councilman who intensely despised the treasurer controlled the debate over the zoning regulations.
(71b) The councilman who the treasurer intensely despised controlled the debate over the zoning regulations.

(72a) The American who overtly ridiculed the European spilled a beer at the outdoor cafe.
(72b) The American who the European overtly ridiculed spilled a beer at the outdoor cafe.
(73a) The monkey who obviously loved the trainer peeled an orange with a little knife.
(73b) The monkey who the trainer obviously loved peeled an orange with a little knife.

(74a) The artist who impulsively married the model hosted the fundraiser for the charity.
(74b) The artist who the model impulsively married hosted the fundraiser for the charity.

(75a) The teacher who foolishly kissed the student discussed the incident with the administration.
(75b) The teacher who the student foolishly kissed discussed the incident with the administration.

(76a) The agent who completely fooled the spy retrieved the package from the rebel.
(76b) The agent who the spy completely fooled retrieved the package from the rebel.

(77a) The woman who bitterly rejected the prince left the country for a long vacation.
(77b) The woman who the prince bitterly rejected left the country for a long vacation.

(78a) The manager who unexpectedly hired the supervisor scolded the employee for the mistake.
(78b) The manager who the supervisor unexpectedly hired scolded the employee for the mistake.

(79a) The dancer who regularly consulted the instructor taught a class on ballet.
(79b) The dancer who the instructor regularly consulted taught a class on ballet.

(80a) The Baptist who profoundly resented the Catholic disputed the interpretation of the bible passage.
(80b) The Baptist who the Catholic profoundly resented disputed the interpretation of the bible passage.
APPENDIX E: Filler items for Experiments 4 and 8

(1) As Anne swam in the swimming pool, Mark relaxed in the sun and drank margaritas.
   T/F Prompt: Mark swam in the pool.
(2) When Paul entered the dark house, Lisa suddenly turned on all of the lights.
   T/F Prompt: Lisa turned on the lights.
(3) Because Mary had to run an errand, Mike had to wait for an hour to be picked up.
(4) After Kate submitted the final version of the screenplay, Paul contacted the studio to discuss the status of the film.
(5) Because Jill thought the entrance exam was easy, Paul was sure that Jack would pass.
(6) After John repeated the instructions twice, Lucy understood exactly what to do.
(7) As Adam sidestepped the bullet, Judy jumped behind the dumpster looking for cover.
(8) When Matt got off of the rollercoaster, Kate asked what the ride was like.
(9) After the preacher finished the sermon, the old woman knelt and prayed silently.
   T/F Prompt: The preacher prayed silently.
(10) As the patrol attacked the fort, the sergeant rang headquarters to request help.
    T/F Prompt: The sergeant called for help.
(11) After the pirate sailed into the harbor, the fisherman drove in with his catch.
(12) When the baby fell into the well, the nanny ran to the house yelling for help.
(13) As the surgeon prepared for the operation, the nurse sterilized the instruments.
(14) After the detective solved the case, the police chief congratulated the precinct on a job well done.
(15) When the teacher finished the lesson, the new student asked several clarification questions.
(16) Because the physicist botched the demonstration, the other scientists sighed disapprovingly.
(17) Jack was able to avoid the traffic jam because Judy provided great directions.
    T/F Prompt: Judy’s directions were bad.
(18) Jane set up a plastic fence around the lawn as Matt planted the grass seed.
    T/F Prompt: Jane set up the fence.
(19) Greg hated live theater although Sara always talked about plays so passionately.
(20) Jeff was able to submit the proposal on time because Kate helped to write the concluding paragraphs.
(21) Greg drove to the nearest pharmacy after Jane complained of stomach pains.
(22) Kate ordered coffee and dessert after Adam finally returned from the restroom.
(23) Judy questioned the elderly witness as Jack looked over the legal documents.
(24) Anne had to walk to work in the rain because Adam went to the store with the car.
(25) The soldier stood in shocked silence as the commander issued the brutal orders.
T/F Prompt: The soldier spoke out against the orders.
(26) The engineer carefully dismantled the circuit boards when the student detected the glitch.
T/F Prompt: The student noticed the problem.
(27) The thief started to sweat as the policeman asked questions about the crime.
(28) The researcher revised the manuscript after the editor proofread the draft.
(29) The injured man asked for more anesthetic after the doctor began the complicated procedure.
(30) The chef prepared the delicate pastry as the waiter walked around joking with the rest of the staff.
(31) The famous novelist dined with the poet after the ceremony concluded.
(32) The professor distributed the make-up exam when all of the students were seated.
(33) The old man jokingly gossiped with Beth about the changes at the university.
T/F Prompt: The old man gossiped about the university.
(34) Jill became increasingly angry with the politician as the speech went on and on.
T/F Prompt: Jill enjoyed the politician’s speech.
(35) Mike acted impulsively and asked the cute waitress out on a date last night.
T/F Prompt: Mike asked the waitress out on a date.
(36) The model shamelessly flirted with Sara during the party at the art gallery.
T/F Prompt: Sara flirted with the model.
(37) Matt called the travel agent to purchase a ticket to Hawaii for spring break.
T/F Prompt: Matt bought a ticket to Hawaii.
(38) The infant surprised Bill by standing for the very first time yesterday.
T/F Prompt: Bill expected the infant to stand.
(39) Lisa argued with the mechanic over the price of the transmission repairs.
T/F Prompt: Lisa and the mechanic argued.
(40) Judy impressed the party guests by playing the piano very well.
T/F Prompt: Judy played the piano poorly.
(41) Jeff has worked on the farm for much longer than any of the other workers.
T/F Prompt: Jeff has worked on the farm the longest.
(42) Beth cried as the bride slowly walked down the aisle toward the groom.
   T/F Prompt: The bride was crying.
(43) The judge at the dance competition was not impressed with Greg’s performance.
   T/F Prompt: The judge did not like Greg’s performance.
(44) The waiter informed Sara that the restaurant was out of tomatoes.
   T/F Prompt: The restaurant had tomatoes.
(45) The veterinarian asked Judy to help carry the wounded dog into the clinic.
(46) The robbers entered the convenience store, and Mark escaped out the back door.
(47) The nurse entered the room, and Mark asked for an extra pillow and some water.
(48) John asked the math tutor to explain the solution to the equation once more.
(49) The burglar noticed the boy and the girl watching quietly from the window.
   T/F Prompt: The burglar saw the kids in the window.
(50) The gardener was happy with the flowers, but the owner of the house was not.
   T/F Prompt: The owner was happy with the flowers.
(51) The semester will start next week, but the students and teachers are not ready.
   T/F Prompt: The students and teachers are not prepared for the semester.
(52) The nurse carefully guided the elderly woman down the steps and into the car.
   T/F Prompt: The elderly woman got onto a bus.
(53) The doctor calmly told the patient that the surgery would need to be redone.
   T/F Prompt: The doctor spoke to the patient calmly.
(54) The driver carefully stopped at the crosswalk and let the pedestrian cross the street.
   T/F Prompt: The driver stopped suddenly.
(55) The artist was desperately hoping to sell the painting, but the gallery refused to display the work.
   T/F Prompt: The gallery did not show the artist’s work.
(56) The congressman angrily denied the allegations and left the room in a hurry.
   T/F Prompt: The congressman admitted wrongdoing.
(57) The coach loudly scolded the player for not completing all twenty laps.
   T/F Prompt: The player did not finish his laps.
(58) The knight killed the dragon, and the kingdom was safe once again.
   T/F Prompt: The dragon killed the knight.
(59) The mortician prepared the body, and the widow wept silently in the back of the room.
(60) Jeff looked over the patient’s records, and Jane administered the shot.

T/F Prompt: Jeff examined the patient’s records.

(61) The restaurant manager consulted with the cook about the evening’s menu.

(62) The psychiatrist prescribed the new medication and scheduled another appointment with the patient.

(63) The golfer lined up the difficult putt, and the caddy took the flag out from the hole.

(64) The mother of the prisoner delivered packages containing cookies and novels to the jail.

(65) The pilot fought bravely to keep the plane in the sky during the violent storm.

(66) Judy had dated Adam and Jeff but ended up marrying Greg in Las Vegas last week.

T/F Prompt: Judy married Greg.

(67) Sara will open bakeries in Chicago and New York after getting a loan next year.

T/F Prompt: Sara will open a bakery in Los Angeles.

(68) Mary quickly typed up the term paper and uploaded it onto the course website.

T/F Prompt: Mary uploaded the paper.

(69) John rashly quit the newspaper last year and now cannot find any work at all.

T/F Prompt: John has found a job.

(70) Matt got a bonus and a raise, and Lucy was finally able to buy the expensive dress.

T/F Prompt: Lucy got a bonus.

(71) Jane made a sandwich, and Adam cut vegetables for a salad.

T/F Prompt: Jane made a sandwich.

(72) Mike missed an easy shot during the billiards game, and Jill began to laugh.

T/F Prompt: Jill missed the easy shot.

(73) Paul fixed the pipe, and Kate installed the new faucet on the bathroom sink.

T/F Prompt: Kate installed the faucet.

(74) Sara and Jeff spent the weekend looking for an apartment to rent for the summer.

T/F Prompt: Sara and Jeff bought a house.

(75) Greg broke up with Mary last week and began seeing another woman.

(76) Lucy worked very hard all four years in college and was accepted to medical school yesterday.

(77) Jeff and Jill studied math intensely yesterday, but the exam was just too hard.

(78) John took too long to propose, and Mary decided to start dating someone else.

(79) Beth hurriedly left the office and ran to catch the last express train back home.

(80) Beth and Jack played frisbee in the park on the pleasant spring afternoon.
APPENDIX F: Experimental items for Experiments 5-7

In each experimental item set, (a) is the F/NP1 sentence, (b) is the F/NP2 sentence, (c) is the B/NP1 sentence, and (d) is the B/NP2 sentence. The prompts used for the true/false comprehension are also listed below, with each appearing under its associated item set.

(1a) After John planned the beach party, he reminded Mary to mail the invitations.  
(1b) After Mary planned the beach party, John reminded her to mail the invitations.  
(1c) After he planned the beach party, John reminded Mary to mail the invitations.  
(1d) After she planned the beach party, John reminded Mary to mail the invitations.  
T/F Prompt: Mary planned the party.

(2a) After Lisa made the chocolate cake, she helped Mike to put on the frosting.  
(2b) After Mike made the chocolate cake, Lisa helped him to put on the frosting.  
(2c) After she made the chocolate cake, Lisa helped Mike to put on the frosting.  
(2d) After he made the chocolate cake, Lisa helped Mike to put on the frosting.

(3a) After Jeff left the campus bookstore, he walked Lucy to class in the storm.  
(3b) After Lucy left the campus bookstore, Jeff walked her to class in the storm.  
(3c) After he left the campus bookstore, Jeff walked Lucy to class in the storm.  
(3d) After she left the campus bookstore, Jeff walked Lucy to class in the storm.

(4a) After Anne read the mystery novel, she called Paul to discuss the complex plot.  
(4b) After Paul read the mystery novel, Anne called him to discuss the complex plot.  
(4c) After she read the mystery novel, Anne called Paul to discuss the complex plot.  
(4d) After he read the mystery novel, Anne called Paul to discuss the complex plot.

(5a) After Mark washed the filthy van, he asked Judy to inflate the worn tires.  
(5b) After Judy washed the filthy van, Mark asked her to inflate the worn tires.  
(5c) After he washed the filthy van, Mark asked Judy to inflate the worn tires.  
(5d) After she washed the filthy van, Mark asked Judy to inflate the worn tires.  
T/F Prompt: Mark washed the van.
(6a) After Jane pruned the rose bushes, she helped Jack to rake the fallen leaves.
(6b) After Jack pruned the rose bushes, Jane helped him to rake the fallen leaves.
(6c) After she pruned the rose bushes, Jane helped Jack to rake the fallen leaves.
(6d) After he pruned the rose bushes, Jane helped Jack to rake the fallen leaves.

(7a) After Matt baked the oatmeal cookies, he told Sara to package each dozen.
(7b) After Sara baked the oatmeal cookies, Matt told her to package each dozen.
(7c) After he baked the oatmeal cookies, Matt told Sara to package each dozen.
(7d) After she baked the oatmeal cookies, Matt told Sara to package each dozen.

(8a) After Kate wrote the beautiful song, she begged Greg to sing a few verses.
(8b) After Greg wrote the beautiful song, Kate begged him to sing a few verses.
(8c) After she wrote the beautiful song, Kate begged Greg to sing a few verses.
(8d) After he wrote the beautiful song, Kate begged Greg to sing a few verses.

(9a) After Adam saw the kung-fu movie, he coaxed Jill into practicing martial arts.
(9b) After Jill saw the kung-fu movie, Adam coaxed her into practicing martial arts.
(9c) After he saw the kung-fu movie, Adam coaxed Jill into practicing martial arts.
(9d) After she saw the kung-fu movie, Adam coaxed Jill into practicing martial arts.

(10a) After Beth threw the homemade boomerang, she warned Bill to duck and find cover.
(10b) After Bill threw the homemade boomerang, Beth warned him to duck and find cover.
(10c) After she threw the homemade boomerang, Beth warned Bill to duck and find cover.
(10d) After he threw the homemade boomerang, Beth warned Bill to duck and find cover.

(11a) After Mike composed a love poem, he entertained Anne by reciting a few lines.
(11b) After Anne composed a love poem, Mike entertained her by reciting a few lines.
(11c) After he composed a love poem, Mike entertained Anne by reciting a few lines.
(11d) After she composed a love poem, Mike entertained Anne by reciting a few lines.

T/F Prompt: Mike recited the poetry.
(12a) After Judy robbed the armored car, she called John to discuss sharing the loot.
(12b) After John robbed the armored car, Judy called him to discuss sharing the loot.
(12c) After she robbed the armored car, Judy called John to discuss sharing the loot.
(12d) After he robbed the armored car, Judy called John to discuss sharing the loot.

(13a) After Jack exited the elegant limo, he greeted Sara with kisses on both cheeks.
(13b) After Sara exited the elegant limo, Jack greeted her with kisses on both cheeks.
(13c) After he exited the elegant limo, Jack greeted Sara with kisses on both cheeks.
(13d) After she exited the elegant limo, Jack greeted Sara with kisses on both cheeks.

(14a) After Sara closed the business deal, she rang Paul to discuss what to do next.
(14b) After Paul closed the business deal, Sara rang him to discuss what to do next.
(14c) After she closed the business deal, Sara rang Paul to discuss what to do next.
(14d) After he closed the business deal, Sara rang Paul to discuss what to do next.

(15a) After Bill cleaned the cluttered garage, he helped Lucy to organize the tools.
(15b) After Lucy cleaned the cluttered garage, Bill helped her to organize the tools.
(15c) After he cleaned the cluttered garage, Bill helped Lucy to organize the tools.
(15d) After she cleaned the cluttered garage, Bill helped Lucy to organize the tools.

(16a) After Mary drove the rental car, she asked Adam to fill up the tank with gas.
(16b) After Adam drove the rental car, Mary asked him to fill up the tank with gas.
(16c) After she drove the rental car, Mary asked Adam to fill up the tank with gas.
(16d) After he drove the rental car, Mary asked Adam to fill up the tank with gas.

T/F Prompt: Adam asked Mary to fill up the tank.

(17a) Because Greg had a prior engagement, he asked Jill to meet for a quick drink.
(17b) Because Jill had a prior engagement, Greg asked her to meet for a quick drink.
(17c) Because he had a prior engagement, Greg asked Jill to meet for a quick drink.
(17d) Because she had a prior engagement, Greg asked Jill to meet for a quick drink.
(18a) Because Lucy found a great job, she invited Greg to celebrate with champagne.
(18b) Because Greg found a great job, Lucy invited him to celebrate with champagne.
(18c) Because she found a great job, Lucy invited Greg to celebrate with champagne.
(18d) Because he found a great job, Lucy invited Greg to celebrate with champagne.

T/F Prompt: Lucy found a great job.

(19a) Because Paul felt a little sick, he convinced Judy to cancel the appointment.
(19b) Because Judy felt a little sick, Paul convinced her to cancel the appointment.
(19c) Because he felt a little sick, Paul convinced Judy to cancel the appointment.
(19d) Because she felt a little sick, Paul convinced Judy to cancel the appointment.

(20a) Because Jill hated the extravagant limo, she urged Jack to take a taxi cab.
(20b) Because Jack hated the extravagant limo, Jill urged him to take a taxi cab.
(20c) Because she hated the extravagant limo, Jill urged Jack to take a taxi cab.
(20d) Because he hated the extravagant limo, Jill urged Jack to take a taxi cab.

(21a) Because John teased the stray cats, he warned Anne to avoid the angry animals.
(21b) Because Anne teased the stray cats, John warned her to avoid the angry animals.
(21c) Because he teased the stray cats, John warned Anne to avoid the angry animals.
(21d) Because she teased the stray cats, John warned Anne to avoid the angry animals.

(22a) Because Judy received a large bonus, she consulted Mike about getting a new car.
(22b) Because Mike received a large bonus, Judy consulted him about getting a new car.
(22c) Because she received a large bonus, Judy consulted Mike about getting a new car.
(22d) Because he received a large bonus, Judy consulted Mike about getting a new car.

T/F Prompt: Mike received the bonus.

(23a) Because Mark witnessed a bad accident, he advised Sara to drive very carefully.
(23b) Because Sara witnessed a bad accident, Mark advised her to drive very carefully.
(23c) Because he witnessed a bad accident, Mark advised Sara to drive very carefully.
(23d) Because she witnessed a bad accident, Mark advised Sara to drive very carefully.
(24a) Because Jane studies the ancient Greeks, she persuaded Paul to travel to Athens.
(24b) Because Paul studies the ancient Greeks, Jane persuaded him to travel to Athens.
(24c) Because she studies the ancient Greeks, Jane persuaded Paul to travel to Athens.
(24d) Because he studies the ancient Greeks, Jane persuaded Paul to travel to Athens.

(25a) Although Matt bought a new car, he encouraged Jill to ride the bus to work.
(25b) Although Jill bought a new car, Matt encouraged her to ride the bus to work.
(25c) Although he bought a new car, Matt encouraged Jill to ride the bus to work.
(25d) Although she bought a new car, Matt encouraged Jill to ride the bus to work.

(26a) Although Kate has an exam tomorrow, she invited Jack to go out on the town.
(26b) Although Jack has an exam tomorrow, Kate invited him to go out on the town.
(26c) Although she has an exam tomorrow, Kate invited Jack to go out on the town.
(26d) Although he has an exam tomorrow, Kate invited Jack to go out on the town.

T/F Prompt: Jack has an exam tomorrow.

(27a) Although Greg drank many tequila shots, he woke Beth up early to go jogging.
(27b) Although Beth drank many tequila shots, Greg woke her up early to go jogging.
(27c) Although he drank many tequila shots, Greg woke Beth up early to go jogging.
(27d) Although she drank many tequila shots, Greg woke Beth up early to go jogging.

(28a) Although Lucy had a terrible cold, she asked Adam to schedule the study session.
(28b) Although Adam had a terrible cold, Lucy asked him to schedule the study session.
(28c) Although she had a terrible cold, Lucy asked Adam to schedule the study session.
(28d) Although he had a terrible cold, Lucy asked Adam to schedule the study session.

(29a) When Bill picked the white rose, he warned Mary to avoid the prickly thorns.
(29b) When Mary picked the white rose, Bill warned her to avoid the prickly thorns.
(29c) When he picked the white rose, Bill warned Mary to avoid the prickly thorns.
(29d) When she picked the white rose, Bill warned Mary to avoid the prickly thorns.
(30a) When Lisa heard the weather forecast, she advised Jeff to wear snow boots.
(30b) When Jeff heard the weather forecast, Lisa advised him to wear snow boots.
(30c) When she heard the weather forecast, Lisa advised Jeff to wear snow boots.
(30d) When he heard the weather forecast, Lisa advised Jeff to wear snow boots.

(31a) When Mike entered the swanky club, he gave Jane a friendly kiss on the cheek.
(31b) When Jane entered the swanky club, Mike gave her a friendly kiss on the cheek.
(31c) When he entered the swanky club, Mike gave Jane a friendly kiss on the cheek.
(31d) When she entered the swanky club, Mike gave Jane a friendly kiss on the cheek.

(32a) When Lisa won the big account, she promoted John for working hard on the sale.
(32b) When John won the big account, Lisa promoted him for working hard on the sale.
(32c) When she won the big account, Lisa promoted John for working hard on the sale.
(32d) When he won the big account, Lisa promoted John for working hard on the sale.

T/F Prompt: Lisa promoted John.

(33a) When Jeff lost an important document, he convinced Anne to forge another copy.
(33b) When Anne lost an important document, Jeff convinced her to forge another copy.
(33c) When he lost an important document, Jeff convinced Anne to forge another copy.
(33d) When she lost an important document, Jeff convinced Anne to forge another copy.

(34a) When Jane won the yacht regatta, she hugged Mark and began to cheer loudly.
(34b) When Mark won the yacht regatta, Jane hugged him and began to cheer loudly.
(34c) When she won the yacht regatta, Jane hugged Mark and began to cheer loudly.
(34d) When he won the yacht regatta, Jane hugged Mark and began to cheer loudly.

T/F Prompt: Jane won the regatta.

(35a) When Adam deleted the crucial files, he begged Mary to recover the lost data.
(35b) When Mary deleted the crucial files, Adam begged her to recover the lost data.
(35c) When he deleted the crucial files, Adam begged Mary to recover the lost data.
(35d) When she deleted the crucial files, Adam begged Mary to recover the lost data.

T/F Prompt: Mary begged Adam to recover the data.
(36a) When Kate heard the tornado alert, she told Matt to hurry into the basement.
(36b) When Matt heard the tornado alert, Kate told him to hurry into the basement.
(36c) When she heard the tornado alert, Kate told Matt to hurry into the basement.
(36d) When he heard the tornado alert, Kate told Matt to hurry into the basement.

(37a) When Jack finished the popular novel, he urged Jill to watch the film version.
(37b) When Jill finished the popular novel, Jack urged her to watch the film version.
(37c) When he finished the popular novel, Jack urged Jill to watch the film version.
(37d) When she finished the popular novel, Jack urged Jill to watch the film version.

(38a) When Mary spotted the mysterious UFO, she told Jeff to call the authorities.
(38b) When Jeff spotted the mysterious UFO, Mary told him to call the authorities.
(38c) When she spotted the mysterious UFO, Mary told Jeff to call the authorities.
(38d) When he spotted the mysterious UFO, Mary told Jeff to call the authorities.

(39a) When Paul entered the noisy bar, he recognized Sara at once despite the crowd.
(39b) When Sara entered the noisy bar, Paul recognized her at once despite the crowd.
(39c) When he entered the noisy bar, Paul recognized Sara at once despite the crowd.
(39d) When she entered the noisy bar, Paul recognized Sara at once despite the crowd.

(40a) When Lisa visited the tropical island, she met Bill for dinner at the hotel.
(40b) When Bill visited the tropical island, Lisa met him for dinner at the hotel.
(40c) When she visited the tropical island, Lisa met Bill for dinner at the hotel.
(40d) When he visited the tropical island, Lisa met Bill for dinner at the hotel.

(41a) As Mike checked the weather report, he warned Lisa to prepare for a rainy day.
(41b) As Lisa checked the weather report, Mike warned her to prepare for a rainy day.
(41c) As he checked the weather report, Mike warned Lisa to prepare for a rainy day.
(41d) As she checked the weather report, Mike warned Lisa to prepare for a rainy day.
(42a) As Mary examined the accident scene, she told John to call for an ambulance.
(42b) As John examined the accident scene, Mary told him to call for an ambulance.
(42c) As she examined the accident scene, Mary told John to call for an ambulance.
(42d) As he examined the accident scene, Mary told John to call for an ambulance.

T/F Prompt: Mary told John to call for an ambulance.

(43a) As Paul approached the lake house, he advised Anne to look out for road signs.
(43b) As Anne approached the lake house, Paul advised her to look out for road signs.
(43c) As he approached the lake house, Paul advised Anne to look out for road signs.
(43d) As she approached the lake house, Paul advised Anne to look out for road signs.

(44a) As Judy climbed the steep slope, she pestered Mark to walk much more quickly.
(44b) As Mark climbed the steep slope, Judy pestered him to walk much more quickly.
(44c) As she climbed the steep slope, Judy pestered Mark to walk much more quickly.
(44d) As he climbed the steep slope, Judy pestered Mark to walk much more quickly.

(45a) As Jack folded the clean laundry, he asked Jane to iron the shirts and pants.
(45b) As Jane folded the clean laundry, Jack asked her to iron the shirts and pants.
(45c) As he folded the clean laundry, Jack asked Jane to iron the shirts and pants.
(45d) As she folded the clean laundry, Jack asked Jane to iron the shirts and pants.

T/F Prompt: Jane folded the laundry.

(46a) As Sara explored the musty cavern, she asked Matt to turn on the flashlight.
(46b) As Matt explored the musty cavern, Sara asked him to turn on the flashlight.
(46c) As she explored the musty cavern, Sara asked Matt to turn on the flashlight.
(46d) As he explored the musty cavern, Sara asked Matt to turn on the flashlight.

(47a) As Greg decorated the Christmas tree, he asked Kate to put up the golden star.
(47b) As Kate decorated the Christmas tree, Greg asked her to put up the golden star.
(47c) As he decorated the Christmas tree, Greg asked Kate to put up the golden star.
(47d) As she decorated the Christmas tree, Greg asked Kate to put up the golden star.
(48a) As Jill washed the water filter, she blamed Adam for neglecting the fish tank.
(48b) As Adam washed the water filter, Jill blamed him for neglecting the fish tank.
(48c) As she washed the water filter, Jill blamed Adam for neglecting the fish tank.
(48d) As he washed the water filter, Jill blamed Adam for neglecting the fish tank.

(49a) As Bill reviewed the tax law, he asked Beth to explain the complex regulations.
(49b) As Beth reviewed the tax law, Bill asked her to explain the complex regulations.
(49c) As he reviewed the tax law, Bill asked Beth to explain the complex regulations.
(49d) As she reviewed the tax law, Bill asked Beth to explain the complex regulations.

(50a) As Lucy climbed the dangerous cliff, she signaled Jeff to try a different route.
(50b) As Jeff climbed the dangerous cliff, Lucy signaled him to try a different route.
(50c) As she climbed the dangerous cliff, Lucy signaled Jeff to try a different route.
(50d) As he climbed the dangerous cliff, Lucy signaled Jeff to try a different route.

(51a) As John admitted the nasty lie, he expected Jane to break down in bitter tears.
(51b) As Jane admitted the nasty lie, John expected her to break down in bitter tears.
(51c) As he admitted the nasty lie, John expected Jane to break down in bitter tears.
(51d) As she admitted the nasty lie, John expected Jane to break down in bitter tears.
T/F Prompt: John admitted the lie.

(52a) As Sara sang the sappy ballad, she held Mike and swayed to the slow music.
(52b) As Mike sang the sappy ballad, Sara held him and swayed to the slow music.
(52c) As she sang the sappy ballad, Sara held Mike and swayed to the slow music.
(52d) As he sang the sappy ballad, Sara held Mike and swayed to the slow music.

(53a) As Mark played the background music, he urged Jill to improvise some lyrics.
(53b) As Jill played the background music, Mark urged her to improvise some lyrics.
(53c) As he played the background music, Mark urged Jill to improvise some lyrics.
(53d) As she played the background music, Mark urged Jill to improvise some lyrics.
(54a) As Anne crossed the rose garden, she welcomed Bill to join the company picnic.
(54b) As Bill crossed the rose garden, Anne welcomed him to join the company picnic.
(54c) As she crossed the rose garden, Anne welcomed Bill to join the company picnic.
(54d) As he crossed the rose garden, Anne welcomed Bill to join the company picnic.

(55a) As Lucy cleaned the filthy kitchen, she scolded Matt for being such a slob.
(55b) As Matt cleaned the filthy kitchen, Lucy scolded him for being such a slob.
(55c) As she cleaned the filthy kitchen, Lucy scolded Matt for being such a slob.
(55d) As he cleaned the filthy kitchen, Lucy scolded Matt for being such a slob.

T/F Prompt: Matt scolded Lucy for being a slob.

(56a) As Adam barbequed the sirloin steaks, he asked Lisa to grill the vegetables.
(56b) As Lisa barbequed the sirloin steaks, Adam asked her to grill the vegetables.
(56c) As he barbequed the sirloin steaks, Adam asked Lisa to grill the vegetables.
(56d) As she barbequed the sirloin steaks, Adam asked Lisa to grill the vegetables.
APPENDIX G: Experimental items for Experiment 8

In each experimental item set, (a) is the F/NP1 sentence, (b) is the F/NP2 sentence, (c) is the B/NP1 sentence, and (d) is the B/NP2 sentence. The prompts used for the true/false comprehension are also listed below, with each appearing under its associated item set.

(1a) After Mike composed a love poem, he entertained Anne by reciting a few lines.
(1b) After Anne composed a love poem, Mike entertained her by reciting a few lines.
(1c) After he composed a love poem, Mike entertained Anne by reciting a few lines.
(1d) After she composed a love poem, Mike entertained Anne by reciting a few lines.
T/F Prompt: Mike recited the poetry.

(2a) After Mark washed the filthy van, he asked Judy to inflate the worn tires.
(2b) After Judy washed the filthy van, Mark asked her to inflate the worn tires.
(2c) After he washed the filthy van, Mark asked Judy to inflate the worn tires.
(2d) After she washed the filthy van, Mark asked Judy to inflate the worn tires.
T/F Prompt: Mark washed the van.

(3a) After Sara repaired the office computer, she pestered John about buying some new desktops.
(3b) After John repaired the office computer, Sara pestered him about buying some new desktops.
(3c) After she repaired the office computer, Sara pestered John about buying some new desktops.
(3d) After he repaired the office computer, Sara pestered John about buying some new desktops.
T/F Prompt: John repaired the computer.

(4a) After Mary drove the rental car, she asked Adam to fill up the tank with gas.
(4b) After Adam drove the rental car, Mary asked him to fill up the tank with gas.
(4c) After she drove the rental car, Mary asked Adam to fill up the tank with gas.
(4d) After he drove the rental car, Mary asked Adam to fill up the tank with gas.
T/F Prompt: Adam asked Mary to fill up the tank.
(5a) After Beth rescued the damaged boat, she asked Mike to drive the passengers to the hospital.
(5b) After Mike rescued the damaged boat, Beth asked him to drive the passengers to the hospital.
(5c) After she rescued the damaged boat, Beth asked Mike to drive the passengers to the hospital.
(5d) After he rescued the damaged boat, Beth asked Mike to drive the passengers to the hospital.

T/F Prompt: Mike rescued the boat.

(6a) After Lucy heard the rolling thunder, she scared Mark with stories about violent storms.
(6b) After Mark heard the rolling thunder, Lucy scared him with stories about violent storms.
(6c) After she heard the rolling thunder, Lucy scared Mark with stories about violent storms.
(6d) After he heard the rolling thunder, Lucy scared Mark with stories about violent storms.

T/F Prompt: Mark scared Lucy with the stories.

(7a) After Paul unloaded the grocery bags, he passed Jane some vegetables to store in the refrigerator.
(7b) After Jane unloaded the grocery bags, Paul passed her some vegetables to store in the refrigerator.
(7c) After he unloaded the grocery bags, Paul passed Jane some vegetables to store in the refrigerator.
(7d) After she unloaded the grocery bags, Paul passed Jane some vegetables to store in the refrigerator.

T/F Prompt: Paul passed the vegetables to Jane.
(8a) After Bill stitched the deep cut, he asked Judy to clean and bandage the wound.
(8b) After Judy stitched the deep cut, Bill asked her to clean and bandage the wound.
(8c) After he stitched the deep cut, Bill asked Judy to clean and bandage the wound.
(8d) After she stitched the deep cut, Bill asked Judy to clean and bandage the wound.
   T/F Prompt: Bill stitched the cut.

(9a) After Bill failed the difficult test, he called Anne to discuss the results.
(9b) After Anne failed the difficult test, Bill called her to discuss the results.
(9c) After he failed the difficult test, Bill called Anne to discuss the results.
(9d) After she failed the difficult test, Bill called Anne to discuss the results.
   T/F Prompt: Anne called Bill.

(10a) After John planned the beach party, he reminded Mary to mail the invitations.
(10b) After Mary planned the beach party, John reminded her to mail the invitations.
(10c) After he planned the beach party, John reminded Mary to mail the invitations.
(10d) After she planned the beach party, John reminded Mary to mail the invitations.
   T/F Prompt: Mary planned the party.

(11a) After Anne painted the bedroom walls, she asked Greg to wash out the brushes.
(11b) After Greg painted the bedroom walls, Anne asked him to wash out the brushes.
(11c) After she painted the bedroom walls, Anne asked Greg to wash out the brushes.
(11d) After he painted the bedroom walls, Anne asked Greg to wash out the brushes.
   T/F Prompt: Anne painted the bedroom walls.

(12a) After Mary told the tasteless joke, she upset Matt by getting terribly drunk.
(12b) After Matt told the tasteless joke, Mary upset him by getting terribly drunk.
(12c) After she told the tasteless joke, Mary upset Matt by getting terribly drunk.
(12d) After he told the tasteless joke, Mary upset Matt by getting terribly drunk.
   T/F Prompt: Mary got drunk.

(13a) After Lisa made the chocolate cake, she helped Mike to put on the frosting.
(13b) After Mike made the chocolate cake, Lisa helped him to put on the frosting.
(13c) After she made the chocolate cake, Lisa helped Mike to put on the frosting.
(13d) After he made the chocolate cake, Lisa helped Mike to put on the frosting.
(14a) After Lisa left the post office, she met Jack for lunch at the botanical garden.
(14b) After Jack left the post office, Lisa met him for lunch at the botanical garden.
(14c) After she left the post office, Lisa met Jack for lunch at the botanical garden.
(14d) After he left the post office, Lisa met Jack for lunch at the botanical garden.

(15a) After Jeff left the campus bookstore, he walked Lucy to class in the storm.
(15b) After Lucy left the campus bookstore, Jeff walked her to class in the storm.
(15c) After he left the campus bookstore, Jeff walked Lucy to class in the storm.
(15d) After she left the campus bookstore, Jeff walked Lucy to class in the storm.

(16a) After Matt baked the oatmeal cookies, he told Sara to package each dozen.
(16b) After Sara baked the oatmeal cookies, Matt told her to package each dozen.
(16c) After he baked the oatmeal cookies, Matt told Sara to package each dozen.
(16d) After she baked the oatmeal cookies, Matt told Sara to package each dozen.

(17a) After Adam attempted the new recipe, he persuaded Kate to sample the first serving.
(17b) After Kate attempted the new recipe, Adam persuaded her to sample the first serving.
(17c) After he attempted the new recipe, Adam persuaded Kate to sample the first serving.
(17d) After she attempted the new recipe, Adam persuaded Kate to sample the first serving.

(18a) After Jeff examined the city's budget, he contacted Jill to talk about some accounting problems.
(18b) After Jill examined the city's budget, Jeff contacted her to talk about some accounting problems.
(18c) After he examined the city's budget, Jeff contacted Jill to talk about some accounting problems.
(18d) After she examined the city's budget, Jeff contacted Jill to talk about some accounting problems.
(19a) After Anne had a temper tantrum, she made Jack a nice dinner and dessert.
(19b) After Jack had a temper tantrum, Anne made him a nice dinner and dessert.
(19c) After she had a temper tantrum, Anne made Jack a nice dinner and dessert.
(19d) After he had a temper tantrum, Anne made Jack a nice dinner and dessert.

(20a) After Lucy finished the abstract painting, she talked Paul into analyzing the piece.
(20b) After Paul finished the abstract painting, Lucy talked him into analyzing the piece.
(20c) After she finished the abstract painting, Lucy talked Paul into analyzing the piece.
(20d) After he finished the abstract painting, Lucy talked Paul into analyzing the piece.

(21a) After Anne read the mystery novel, she called Paul to discuss the complex plot.
(21b) After Paul read the mystery novel, Anne called him to discuss the complex plot.
(21c) After she read the mystery novel, Anne called Paul to discuss the complex plot.
(21d) After he read the mystery novel, Anne called Paul to discuss the complex plot.

(22a) After Jane pruned the rose bushes, she helped Jack to rake the fallen leaves.
(22b) After Jack pruned the rose bushes, Jane helped him to rake the fallen leaves.
(22c) After she pruned the rose bushes, Jane helped Jack to rake the fallen leaves.
(22d) After he pruned the rose bushes, Jane helped Jack to rake the fallen leaves.

(23a) After Mark administered the lethal injection, he called Anne to discuss the terrible experience.
(23b) After Anne administered the lethal injection, Mark called her to discuss the terrible experience.
(23c) After he administered the lethal injection, Mark called Anne to discuss the terrible experience.
(23d) After she administered the lethal injection, Mark called Anne to discuss the terrible experience.

(24a) After Adam saw the kung-fu movie, he coaxed Jill into practicing martial arts.
(24b) After Jill saw the kung-fu movie, Adam coaxed her into practicing martial arts.
(24c) After he saw the kung-fu movie, Adam coaxed Jill into practicing martial arts.
(24d) After she saw the kung-fu movie, Adam coaxed Jill into practicing martial arts.
(25a) After John drank the last cola, he expected Beth to buy drinks at the store.
(25b) After Beth drank the last cola, John expected her to buy drinks at the store.
(25c) After he drank the last cola, John expected Beth to buy drinks at the store.
(25d) After she drank the last cola, John expected Beth to buy drinks at the store.

(26a) After Jack washed the breakfast dishes, he helped Kate to scrub the kitchen floor.
(26b) After Kate washed the breakfast dishes, Jack helped her to scrub the kitchen floor.
(26c) After he washed the breakfast dishes, Jack helped Kate to scrub the kitchen floor.
(26d) After she washed the breakfast dishes, Jack helped Kate to scrub the kitchen floor.

(27a) After Jane scored the winning goal, she gave Greg a high five and a hug.
(27b) After Greg scored the winning goal, Jane gave him a high five and a hug.
(27c) After she scored the winning goal, Jane gave Greg a high five and a hug.
(27d) After he scored the winning goal, Jane gave Greg a high five and a hug.

(28a) After Lisa planned the birthday party, she asked Paul to buy the present.
(28b) After Paul planned the birthday party, Lisa asked him to buy the present.
(28c) After she planned the birthday party, Lisa asked Paul to buy the present.
(28d) After he planned the birthday party, Lisa asked Paul to buy the present.

(29a) After Anne exited the passenger train, she hugged Mike for several minutes on the platform.
(29b) After Mike exited the passenger train, Anne hugged him for several minutes on the platform.
(29c) After she exited the passenger train, Anne hugged Mike for several minutes on the platform.
(29d) After he exited the passenger train, Anne hugged Mike for several minutes on the platform.

(30a) After Kate wrote the beautiful song, she begged Greg to sing a few verses.
(30b) After Greg wrote the beautiful song, Kate begged him to sing a few verses.
(30c) After she wrote the beautiful song, Kate begged Greg to sing a few verses.
(30d) After he wrote the beautiful song, Kate begged Greg to sing a few verses.
(31a) After Jeff decorated the Christmas tree, he asked Lisa to put out the presents.
(31a) After Lisa decorated the Christmas tree, Jeff asked her to put out the presents.
(31a) After he decorated the Christmas tree, Jeff asked Lisa to put out the presents.
(31a) After she decorated the Christmas tree, Jeff asked Lisa to put out the presents.

(32a) After Jack exited the elegant limo, he greeted Sara with kisses on both cheeks.
(32b) After Sara exited the elegant limo, Jack greeted her with kisses on both cheeks.
(32c) After he exited the elegant limo, Jack greeted Sara with kisses on both cheeks.
(32d) After she exited the elegant limo, Jack greeted Sara with kisses on both cheeks.

(33a) After Bill cleaned the cluttered garage, he helped Lucy to organize the tools.
(33b) After Lucy cleaned the cluttered garage, Bill helped her to organize the tools.
(33c) After he cleaned the cluttered garage, Bill helped Lucy to organize the tools.
(33d) After she cleaned the cluttered garage, Bill helped Lucy to organize the tools.

(34a) After Adam skied the expert slope, he met Jane for hot chocolate at the lodge.
(34b) After Jane skied the expert slope, Adam met her for hot chocolate at the lodge.
(34c) After he skied the expert slope, Adam met Jane for hot chocolate at the lodge.
(34d) After she skied the expert slope, Adam met Jane for hot chocolate at the lodge.

(35a) After Lisa developed the new vaccine, she begged Mark to keep quiet about the discovery.
(35b) After Mark developed the new vaccine, Lisa begged him to keep quiet about the discovery.
(35c) After she developed the new vaccine, Lisa begged Mark to keep quiet about the discovery.
(35d) After he developed the new vaccine, Lisa begged Mark to keep quiet about the discovery.

(36a) After Kate watered the tomato plants, she asked Jeff to weed the vegetable garden.
(36b) After Jeff watered the tomato plants, Kate asked him to weed the vegetable garden.
(36c) After she watered the tomato plants, Kate asked Jeff to weed the vegetable garden.
(36d) After he watered the tomato plants, Kate asked Jeff to weed the vegetable garden.
(37a) After Beth threw the homemade boomerang, she warned Bill to duck and find cover.
(37b) After Bill threw the homemade boomerang, Beth warned him to duck and find cover.
(37c) After she threw the homemade boomerang, Beth warned Bill to duck and find cover.
(37d) After he threw the homemade boomerang, Beth warned Bill to duck and find cover.

(38a) After Judy robbed the armored car, she called John to discuss sharing the loot.
(38b) After John robbed the armored car, Judy called him to discuss sharing the loot.
(38c) After she robbed the armored car, Judy called John to discuss sharing the loot.
(38d) After he robbed the armored car, Judy called John to discuss sharing the loot.

(39a) After Mike organized the holiday party, he telephoned Sara to discuss the menu.
(39b) After Sara organized the holiday party, Mike telephoned her to discuss the menu.
(39c) After he organized the holiday party, Mike telephoned Sara to discuss the menu.
(39d) After she organized the holiday party, Mike telephoned Sara to discuss the menu.

(40a) After Mark destroyed the incriminating pictures, he convinced Beth to bury the remaining evidence.
(40b) After Beth destroyed the incriminating pictures, Mark convinced her to bury the remaining evidence.
(40c) After he destroyed the incriminating pictures, Mark convinced Beth to bury the remaining evidence.
(40d) After she destroyed the incriminating pictures, Mark convinced Beth to bury the remaining evidence.

(41a) After John painted the little nursery, he helped Lisa to arrange the furniture.
(41b) After Lisa painted the little nursery, John helped her to arrange the furniture.
(41c) After he painted the little nursery, John helped Lisa to arrange the furniture.
(41d) After she painted the little nursery, John helped Lisa to arrange the furniture.
(42a) After Matt proposed the curriculum committee, he appointed Beth to chair the group.
(42b) After Beth proposed the curriculum committee, Matt appointed her to chair the group.
(42c) After he proposed the curriculum committee, Matt appointed Beth to chair the group.
(42d) After she proposed the curriculum committee, Matt appointed Beth to chair the group.

(43a) After Sara closed the business deal, she rang Paul to discuss what to do next.
(43b) After Paul closed the business deal, Sara rang him to discuss what to do next.
(43c) After she closed the business deal, Sara rang Paul to discuss what to do next.
(43d) After he closed the business deal, Sara rang Paul to discuss what to do next.

(44a) After Mary watched the baseball game, she asked Mark to play catch in the yard.
(44b) After Mark watched the baseball game, Mary asked him to play catch in the yard.
(44c) After she watched the baseball game, Mary asked Mark to play catch in the yard.
(44d) After he watched the baseball game, Mary asked Mark to play catch in the yard.

(45a) After Anne rearranged the bedroom furniture, she asked Matt to clean the carpet.
(45b) After Matt rearranged the bedroom furniture, Anne asked him to clean the carpet.
(45c) After she rearranged the bedroom furniture, Anne asked Matt to clean the carpet.
(45d) After he rearranged the bedroom furniture, Anne asked Matt to clean the carpet.

(46a) After Mary performed the experimental concerto, she asked Paul to compose a new ending to the piece.
(46b) After Paul performed the experimental concerto, Mary asked him to compose a new ending to the piece.
(46c) After she performed the experimental concerto, Mary asked Paul to compose a new ending to the piece.
(46d) After he performed the experimental concerto, Mary asked Paul to compose a new ending to the piece.
(47a) After Bill kicked the ironing board, he scolded Sara for leaving things on the floor.
(47b) After Sara kicked the ironing board, Bill scolded her for leaving things on the floor.
(47c) After he kicked the ironing board, Bill scolded Sara for leaving things on the floor.
(47d) After she kicked the ironing board, Bill scolded Sara for leaving things on the floor.

(48a) After Jack hosted an extravagant party, he asked Beth to clean up the mess.
(48b) After Beth hosted an extravagant party, Jack asked her to clean up the mess.
(48c) After he hosted an extravagant party, Jack asked Beth to clean up the mess.
(48d) After she hosted an extravagant party, Jack asked Beth to clean up the mess.

(49a) Because Paul missed the international flight, he asked Mary to arrange for a refund.
(49b) Because Mary missed the international flight, Paul asked her to arrange for a refund.
(49c) Because he missed the international flight, Paul asked Mary to arrange for a refund.
(49d) Because she missed the international flight, Paul asked Mary to arrange for a refund.

T/F Prompt: Paul missed the flight.

(50a) Because Paul enjoyed the flower garden, he served Jill a picnic lunch on the patio.
(50b) Because Jill enjoyed the flower garden, Paul served her a picnic lunch on the patio.
(50c) Because he enjoyed the flower garden, Paul served Jill a picnic lunch on the patio.
(50d) Because she enjoyed the flower garden, Paul served Jill a picnic lunch on the patio.

T/F Prompt: Jill served the picnic lunch. –

(51a) Because Lucy found a great job, she invited Greg to celebrate with champagne.
(51b) Because Greg found a great job, Lucy invited him to celebrate with champagne.
(51c) Because she found a great job, Lucy invited Greg to celebrate with champagne.
(51d) Because he found a great job, Lucy invited Greg to celebrate with champagne.

T/F Prompt: Lucy invited Greg to celebrate.+
(52a) Because Judy received a large bonus, she consulted Mike about getting a new car.
(52b) Because Mike received a large bonus, Judy consulted him about getting a new car.
(52c) Because she received a large bonus, Judy consulted Mike about getting a new car.
(52d) Because he received a large bonus, Judy consulted Mike about getting a new car.

T/F Prompt: Mike received the bonus.

(53a) Because Judy misplaced the relevant documents, she asked Adam to reschedule the appointment.
(53b) Because Adam misplaced the relevant documents, Judy asked him to reschedule the appointment.
(53c) Because she misplaced the relevant documents, Judy asked Adam to reschedule the appointment.
(53d) Because he misplaced the relevant documents, Judy asked Adam to reschedule the appointment.

(54a) Because Jill skipped the annual meeting, she told Greg to get a copy of the secretary’s transcription.
(54b) Because Greg skipped the annual meeting, Jill told him to get a copy of the secretary’s transcription.
(54c) Because she skipped the annual meeting, Jill told Greg to get a copy of the secretary’s transcription.
(54d) Because he skipped the annual meeting, Jill told Greg to get a copy of the secretary’s transcription.

(55a) Because Greg had a prior engagement, he asked Jill to meet for a quick drink.
(55b) Because Jill had a prior engagement, Greg asked her to meet for a quick drink.
(55c) Because he had a prior engagement, Greg asked Jill to meet for a quick drink.
(55d) Because she had a prior engagement, Greg asked Jill to meet for a quick drink.
(56a) Because Adam liked the humorous play, he invited Lucy to see the production again.
(56b) Because Lucy liked the humorous play, Adam invited her to see the production again.
(56c) Because he liked the humorous play, Adam invited Lucy to see the production again.
(56d) Because she liked the humorous play, Adam invited Lucy to see the production again.

(57a) Because Jeff finished the important project, he emailed Sara about going to dinner.
(57b) Because Sara finished the important project, Jeff emailed her about going to dinner.
(57c) Because he finished the important project, Jeff emailed Sara about going to dinner.
(57d) Because she finished the important project, Jeff emailed Sara about going to dinner.

(58a) Because Paul took some gorgeous pictures, he promised Lucy to frame the nicest shots.
(58b) Because Lucy took some gorgeous pictures, Paul promised her to frame the nicest shots.
(58c) Because he took some gorgeous pictures, Paul promised Lucy to frame the nicest shots.
(58d) Because she took some gorgeous pictures, Paul promised Lucy to frame the nicest shots.

(59a) Because Kate enjoys the holiday season, she invited Mark to see a Christmas movie.
(59b) Because Mark enjoys the holiday season, Kate invited him to see a Christmas movie.
(59c) Because she enjoys the holiday season, Kate invited Mark to see a Christmas movie.
(59d) Because he enjoys the holiday season, Kate invited Mark to see a Christmas movie.
(60a) Because Lisa quit the swimming club, she telephoned Greg about starting a new hobby.
(60b) Because Greg quit the swimming club, Lisa telephoned him about starting a new hobby.
(60c) Because she quit the swimming club, Lisa telephoned Greg about starting a new hobby.
(60d) Because he quit the swimming club, Lisa telephoned Greg about starting a new hobby.

(61a) Because Beth likes most psychedelic music, she brought Paul to see the Pink Floyd laser show.
(61b) Because Paul likes most psychedelic music, Beth brought him to see the Pink Floyd laser show.
(61c) Because she likes most psychedelic music, Beth brought Paul to see the Pink Floyd laser show.
(61d) Because he likes most psychedelic music, Beth brought Paul to see the Pink Floyd laser show.

(62a) Because Mary doubted the research findings, she consulted Greg about examining the issue further.
(62b) Because Greg doubted the research findings, Mary consulted him about examining the issue further.
(62c) Because she doubted the research findings, Mary consulted Greg about examining the issue further.
(62d) Because he doubted the research findings, Mary consulted Greg about examining the issue further.

(63a) Because Paul felt a little sick, he convinced Judy to cancel the appointment.
(63b) Because Judy felt a little sick, Paul convinced her to cancel the appointment.
(63c) Because he felt a little sick, Paul convinced Judy to cancel the appointment.
(63d) Because she felt a little sick, Paul convinced Judy to cancel the appointment.
(64a) Because John received the foreclosure notice, he invited Jill to have a consolation drink at the club.
(64b) Because Jill received the foreclosure notice, John invited her to have a consolation drink at the club.
(64c) Because he received the foreclosure notice, John invited Jill to have a consolation drink at the club.
(64d) Because she received the foreclosure notice, John invited Jill to have a consolation drink at the club.

(65a) Because Jeff canceled the budget meeting, he asked Judy to submit a full financial report.
(65b) Because Judy canceled the budget meeting, Jeff asked her to submit a full financial report.
(65c) Because he canceled the budget meeting, Jeff asked Judy to submit a full financial report.
(65d) Because she canceled the budget meeting, Jeff asked Judy to submit a full financial report.

(66a) Because John teased the stray cats, he warned Anne to avoid the angry animals.
(66b) Because Anne teased the stray cats, John warned her to avoid the angry animals.
(66c) Because he teased the stray cats, John warned Anne to avoid the angry animals.
(66d) Because she teased the stray cats, John warned Anne to avoid the angry animals.

(67a) Because Jill hated the extravagant limo, she urged Jack to take a taxi cab.
(67b) Because Jack hated the extravagant limo, Jill urged him to take a taxi cab.
(67c) Because she hated the extravagant limo, Jill urged Jack to take a taxi cab.
(67d) Because he hated the extravagant limo, Jill urged Jack to take a taxi cab.
(68a) Because Mary studied the psychic hoaxes, she ridiculed Bill for actually believing ghosts.
(68c) Because she studied the psychic hoaxes, Mary ridiculed Bill for actually believing in ghosts.
(68b) Because Bill studied the psychic hoaxes, Mary ridiculed him for actually believing in ghosts.
(68d) Because he studied the psychic hoaxes, Mary ridiculed Bill for actually believing in ghosts.

(69a) Because Jane studies the ancient Greeks, she persuaded Paul to travel to Athens.
(69b) Because Paul studies the ancient Greeks, Jane persuaded him to travel to Athens.
(69c) Because she studies the ancient Greeks, Jane persuaded Paul to travel to Athens.
(69d) Because he studies the ancient Greeks, Jane persuaded Paul to travel to Athens.

(70a) Because Kate started a strict diet, she pestered Bill about eating too many starches.
(70b) Because Bill started a strict diet, Kate pestered him about eating too many starches.
(70c) Because she started a strict diet, Kate pestered Bill about eating too many starches.
(70d) Because he started a strict diet, Kate pestered Bill about eating too many starches.

(71a) Because Greg got a big promotion, he took Anne to dinner at a five-star restaurant.
(71b) Because Anne got a big promotion, Greg took her to dinner at a five-star restaurant.
(71c) Because he got a big promotion, Greg took Anne to dinner at a five-star restaurant.
(71d) Because she got a big promotion, Greg took Anne to dinner at a five-star restaurant.

(72a) Because Mark witnessed a bad accident, he advised Sara to drive very carefully.
(72b) Because Sara witnessed a bad accident, Mark advised her to drive very carefully.
(72c) Because he witnessed a bad accident, Mark advised Sara to drive very carefully.
(72d) Because she witnessed a bad accident, Mark advised Sara to drive very carefully.
(73a) Although Jeff wrote an eloquent speech, he disappointed Mary by delivering the address poorly.
(73b) Although Mary wrote an eloquent speech, Jeff disappointed her by delivering the address poorly.
(73c) Although he wrote an eloquent speech, Jeff disappointed Mary by delivering the address poorly.
(73d) Although she wrote an eloquent speech, Jeff disappointed Mary by delivering the address poorly.

T/F Prompt: Mary delivered the speech poorly.

(74a) Although John prefers very sophisticated comedy, he tells Sara only silly kid jokes at work.
(74b) Although Sara prefers very sophisticated comedy, John tells her only silly kid jokes at work.
(74c) Although he prefers very sophisticated comedy, John tells Sara only silly kid jokes at work.
(74d) Although she prefers very sophisticated comedy, John tells Sara only silly kid jokes at work.

T/F Prompt: John tells kid jokes at work.

(75a) Although Beth witnessed a mob killing, she urged John to refrain from calling the police.
(75b) Although John witnessed a mob killing, Beth urged him to refrain from calling the police.
(75c) Although she witnessed a mob killing, Beth urged John to refrain from calling the police.
(75d) Although he witnessed a mob killing, Beth urged John to refrain from calling the police.

T/F Prompt: Beth witnessed the killing.
(76a) Although Kate has an exam tomorrow, she invited Jack to go out on the town.
(76b) Although Jack has an exam tomorrow, Kate invited him to go out on the town.
(76c) Although she has an exam tomorrow, Kate invited Jack to go out on the town.
(76d) Although he has an exam tomorrow, Kate invited Jack to go out on the town.

T/F Prompt: Kate has an exam tomorrow.

(77a) Although Sara extinguished the campfire carefully, she warned Bill to watch out for hidden embers.
(77b) Although Bill extinguished the campfire carefully, Sara warned him to watch out for hidden embers.
(77c) Although she extinguished the campfire carefully, Sara warned Bill to watch out for hidden embers.
(77d) Although he extinguished the campfire carefully, Sara warned Bill to watch out for hidden embers.

(78a) Although Anne hated the crowded concert, she convinced Jeff to stay until the end.
(78b) Although Jeff hated the crowded concert, Anne convinced him to stay until the end.
(78c) Although she hated the crowded concert, Anne convinced Jeff to stay until the end.
(78d) Although he hated the crowded concert, Anne convinced Jeff to stay until the end.

(79a) Although Mark enjoyed the fashion show, he annoyed Mary by flirting with the designer.
(79b) Although Mary enjoyed the fashion show, Mark annoyed her by flirting with the designer.
(79c) Although he enjoyed the fashion show, Mark annoyed Mary by flirting with the designer.
(79d) Although she enjoyed the fashion show, Mark annoyed Mary by flirting with the designer.

(80a) Although Matt bought a new car, he encouraged Jill to ride the bus to work.
(80b) Although Jill bought a new car, Matt encouraged her to ride the bus to work.
(80c) Although he bought a new car, Matt encouraged Jill to ride the bus to work.
(80d) Although she bought a new car, Matt encouraged Jill to ride the bus to work.
(81a) Although John plays the classical guitar, he urged Judy to hire another guitarist for the office party.
(81b) Although Judy plays the classical guitar, John urged her to hire another guitarist for the office party.
(81c) Although he plays the classical guitar, John urged Judy to hire another guitarist for the office party.
(81d) Although she plays the classical guitar, John urged Judy to hire another guitarist for the office party.

(82a) Although Matt broke the heirloom vase, he convinced Mary to consider the loss no big deal.
(82b) Although Mary broke the heirloom vase, Matt convinced her to consider the loss no big deal.
(82c) Although he broke the heirloom vase, Matt convinced Mary to consider the loss no big deal.
(82d) Although she broke the heirloom vase, Matt convinced Mary to consider the loss no big deal.

(83a) Although Lucy dented the family car, she allowed Mike to drive the vehicle to work.
(83b) Although Mike dented the family car, Lucy allowed him to drive the vehicle to work.
(83c) Although she dented the family car, Lucy allowed Mike to drive the vehicle to work.
(83d) Although he dented the family car, Lucy allowed Mike to drive the vehicle to work.

(84a) Although Jill avoided the controversial topic, she asked Mark to discuss the issue later.
(84b) Although Mark avoided the controversial topic, Jill asked him to discuss the issue later.
(84c) Although she avoided the controversial topic, Jill asked Mark to discuss the issue later.
(84d) Although he avoided the controversial topic, Jill asked Mark to discuss the issue later.
(85a) Although Lisa likes very elegant food, she asked Adam to make pizza for the party.
(85b) Although Adam likes very elegant food, Lisa asked him to make pizza for the party.
(85c) Although she likes very elegant food, Lisa asked Adam to make pizza for the party.
(85d) Although he likes very elegant food, Lisa asked Adam to make pizza for the party.

(86a) Although Lucy had a terrible cold, she asked Adam to schedule the study session.
(86b) Although Adam had a terrible cold, Lucy asked him to schedule the study session.
(86c) Although she had a terrible cold, Lucy asked Adam to schedule the study session.
(86d) Although he had a terrible cold, Lucy asked Adam to schedule the study session.

(87a) Although Greg drank many tequila shots, he woke Beth up early to go jogging.
(87b) Although Beth drank many tequila shots, Greg woke her up early to go jogging.
(87c) Although he drank many tequila shots, Greg woke Beth up early to go jogging.
(87d) Although she drank many tequila shots, Greg woke Beth up early to go jogging.

(88a) Although Mark dislikes most rock songs, he invited Jane to attend the charity concert.
(88b) Although Jane dislikes most rock songs, Mark invited her to attend the charity concert.
(88c) Although he dislikes most rock songs, Mark invited Jane to attend the charity concert.
(88d) Although she dislikes most rock songs, Mark invited Jane to attend the charity concert.

(89a) When Paul received a speeding ticket, he warned Beth to watch out for speed traps.
(89b) When Beth received a speeding ticket, Paul warned her to watch out for speed traps.
(89c) When he received a speeding ticket, Paul warned Beth to watch out for speed traps.
(89d) When she received a speeding ticket, Paul warned Beth to watch out for speed traps.

T/F Prompt: Beth got a ticket for speeding.
(90a) When Adam deleted the crucial files, he begged Mary to recover the lost data.
(90b) When Mary deleted the crucial files, Adam begged her to recover the lost data.
(90c) When he deleted the crucial files, Adam begged Mary to recover the lost data.
(90d) When she deleted the crucial files, Adam begged Mary to recover the lost data.
    T/F Prompt: Adam begged Mary to recover the data.

(91a) When Lisa won the big account, she promoted John for working hard on the sale.
(91b) When John won the big account, Lisa promoted him for working hard on the sale.
(91c) When she won the big account, Lisa promoted John for working hard on the sale.
(91d) When he won the big account, Lisa promoted John for working hard on the sale.
    T/F Prompt: John promoted Lisa.

(92a) When Jane won the yacht regatta, she hugged Mark and began to cheer loudly.
(92b) When Mark won the yacht regatta, Jane hugged him and began to cheer loudly.
(92c) When she won the yacht regatta, Jane hugged Mark and began to cheer loudly.
(92d) When he won the yacht regatta, Jane hugged Mark and began to cheer loudly.
    T/F Prompt: Jane won the regatta.

(93a) When Jill questioned the potential witnesses, she told Matt to take careful notes.
(93b) When Matt questioned the potential witnesses, Jill told him to take careful notes.
(93c) When she questioned the potential witnesses, Jill told Matt to take careful notes.
(93d) When he questioned the potential witnesses, Jill told Matt to take careful notes.
    T/F Prompt: Jill questioned the witnesses.

(94a) When Anne broke the glass bowl, she scolded John for placing dishes on the table’s edge.
(94b) When John broke the glass bowl, Anne scolded him for placing dishes on the table’s edge.
(94c) When she broke the glass bowl, Anne scolded John for placing dishes on the table’s edge.
(94d) When he broke the glass bowl, Anne scolded John for placing dishes on the table’s edge.
    T/F Prompt: John broke the bowl.
(95a) When Jack ended the year-long engagement, he accused Lucy of lying about an affair.
(95b) When Lucy ended the year-long engagement, Jack accused her of lying about an affair.
(95c) When he ended the year-long engagement, Jack accused Lucy of lying about an affair.
(95d) When she ended the year-long engagement, Jack accused Lucy of lying about an affair.

T/F Prompt: Lucy accused Jack of lying.

(96a) When Bill entered the lively reception, he ignored Lisa and behaved very rudely.
(96b) When Lisa entered the lively reception, Bill ignored her and behaved very rudely.
(96c) When he entered the lively reception, Bill ignored Lisa and behaved very rudely.
(96d) When she entered the lively reception, Bill ignored Lisa and behaved very rudely.

T/F Prompt: Bill behaved rudely at the reception.

(97a) When Jack broke the plastic castle, he scolded Anne for placing toys in the hall.
(97b) When Anne broke the plastic castle, Jack scolded her for placing toys in the hall.
(97c) When he broke the plastic castle, Jack scolded Anne for placing toys in the hall.
(97d) When she broke the plastic castle, Jack scolded Anne for placing toys in the hall.

(98a) When Adam discarded the sour milk, he criticized Beth for leaving the carton out too long.
(98b) When Beth discarded the sour milk, Adam criticized her for leaving the carton out too long.
(98c) When he discarded the sour milk, Adam criticized Beth for leaving the carton out too long.
(98d) When she discarded the sour milk, Adam criticized Beth for leaving the carton out too long.

(99a) When Beth spilled the chocolate milk, she asked Greg to mop the floor thoroughly.
(99b) When Greg spilled the chocolate milk, Beth asked him to mop the floor thoroughly.
(99c) When she spilled the chocolate milk, Beth asked Greg to mop the floor thoroughly.
(99d) When he spilled the chocolate milk, Beth asked Greg to mop the floor thoroughly.
(100a) When Kate visited the military cemetery, she asked John to lay a wreath on the grave.
(100b) When John visited the military cemetery, Kate asked him to lay a wreath on the grave.
(100c) When she visited the military cemetery, Kate asked John to lay a wreath on the grave.
(100d) When he visited the military cemetery, Kate asked John to lay a wreath on the grave.

(101a) When Jill won the poker hand, she encouraged John to continue playing the game.
(101b) When John won the poker hand, Jill encouraged him to continue playing the game.
(101c) When she won the poker hand, Jill encouraged John to continue playing the game.
(101d) When he won the poker hand, Jill encouraged John to continue playing the game.

(102a) When Sara boarded the cruise ship, she told Adam to participate in the lifeboat drill.
(102b) When Adam boarded the cruise ship, Sara told him to participate in the lifeboat drill.
(102c) When she boarded the cruise ship, Sara told Adam to participate in the lifeboat drill.
(102d) When he boarded the cruise ship, Sara told Adam to participate in the lifeboat drill.

(103a) When Bill spotted the killer whales, he asked Jane to take photos of the scene.
(103b) When Jane spotted the killer whales, Bill asked her to take photos of the scene.
(103c) When he spotted the killer whales, Bill asked Jane to take photos of the scene.
(103d) When she spotted the killer whales, Bill asked Jane to take photos of the scene.
(104a) When John discovered the huge crack, he warned Mary to beware of the old sidewalk.
(104b) When Mary discovered the huge crack, John warned her to beware of the old sidewalk.
(104c) When he discovered the huge crack, John warned Mary to beware of the old sidewalk.
(104d) When she discovered the huge crack, John warned Mary to beware of the old sidewalk.

(105a) When Mike entered the swanky club, he gave Jane a friendly kiss on the cheek.
(105b) When Jane entered the swanky club, Mike gave her a friendly kiss on the cheek.
(105c) When he entered the swanky club, Mike gave Jane a friendly kiss on the cheek.
(105d) When she entered the swanky club, Mike gave Jane a friendly kiss on the cheek.

(106a) When Jeff lost an important document, he convinced Anne to forge another copy.
(106b) When Anne lost an important document, Jeff convinced her to forge another copy.
(106c) When he lost an important document, Jeff convinced Anne to forge another copy.
(106d) When she lost an important document, Jeff convinced Anne to forge another copy.

(107a) When Lisa heard the weather forecast, she advised Jeff to wear snow boots.
(107b) When Jeff heard the weather forecast, Lisa advised him to wear snow boots.
(107c) When she heard the weather forecast, Lisa advised Jeff to wear snow boots.
(107d) When he heard the weather forecast, Lisa advised Jeff to wear snow boots.

(108a) When Kate heard the tornado alert, she told Matt to hurry into the basement.
(108b) When Matt heard the tornado alert, Kate told him to hurry into the basement.
(108c) When she heard the tornado alert, Kate told Matt to hurry into the basement.
(108d) When he heard the tornado alert, Kate told Matt to hurry into the basement.

(109a) When Kate lost the travel itinerary, she asked Mike to reprint the flight schedule.
(109b) When Mike lost the travel itinerary, Kate asked him to reprint the flight schedule.
(109c) When she lost the travel itinerary, Kate asked Mike to reprint the flight schedule.
(109d) When he lost the travel itinerary, Kate asked Mike to reprint the flight schedule.
(110a) When Jane scratched the van’s fender, she scolded Jeff for parking the vehicle incorrectly.
(110b) When she scratched the van’s fender, Jane scolded Jeff for parking the vehicle incorrectly.
(110c) When Jeff scratched the van’s fender, Jane scolded him for parking the vehicle incorrectly.
(110d) When he scratched the van’s fender, Jane scolded Jeff for parking the vehicle incorrectly.

(111a) When Bill picked the white rose, he warned Mary to avoid the prickly thorns.
(111b) When Mary picked the white rose, Bill warned her to avoid the prickly thorns.
(111c) When he picked the white rose, Bill warned Mary to avoid the prickly thorns.
(111d) When she picked the white rose, Bill warned Mary to avoid the prickly thorns.

(112a) When Greg completed the half marathon, he reminded Mary to record the finishing time.
(112b) When he completed the half marathon, Greg reminded Mary to record the finishing time.
(112c) When Mary completed the half marathon, Greg reminded her to record the finishing time.
(112d) When she completed the half marathon, Greg reminded Mary to record the finishing time.

(113a) When John entered the rain-soaked tent, he handed Kate the driest towel left in the backpack.
(113b) When Kate entered the rain-soaked tent, John handed her the driest towel left in the backpack.
(113c) When he entered the rain-soaked tent, John handed Kate the driest towel left in the backpack.
(113d) When she entered the rain-soaked tent, John handed Kate the driest towel left in the backpack.
(114a) When Jack finished the popular novel, he urged Jill to watch the film version.
(114b) When Jill finished the popular novel, Jack urged her to watch the film version.
(114c) When he finished the popular novel, Jack urged Jill to watch the film version.
(114d) When she finished the popular novel, Jack urged Jill to watch the film version.

(115a) When Mary spotted the mysterious UFO, she told Jeff to call the authorities.
(115b) When she spotted the mysterious UFO, Mary told Jeff to call the authorities.
(115c) When Jeff spotted the mysterious UFO, Mary told him to call the authorities.
(115d) When he spotted the mysterious UFO, Mary told Jeff to call the authorities.

(116a) When Lucy found the wild berries, she persuaded Jack to pick some of the fruit.
(116b) When Jack found the wild berries, Lucy persuaded him to pick some of the fruit.
(116c) When she found the wild berries, Lucy persuaded Jack to pick some of the fruit.
(116d) When he found the wild berries, Lucy persuaded Jack to pick some of the fruit.

(117a) When Lisa visited the tropical island, she met Bill for dinner at the hotel.
(117b) When Bill visited the tropical island, Lisa met him for dinner at the hotel.
(117c) When she visited the tropical island, Lisa met Bill for dinner at the hotel.
(117d) When he visited the tropical island, Lisa met Bill for dinner at the hotel.

(118a) When Kate finished the crossword puzzle, she expected Paul to check all the answers.
(118b) When Paul finished the crossword puzzle, Kate expected him to check all the answers.
(118c) When she finished the crossword puzzle, Kate expected Paul to check all the answers.
(118d) When he finished the crossword puzzle, Kate expected Paul to check all the answers.
(119a) When Mike purchased the opera tickets, he asked Jill to make dinner reservations.
(119b) When Jill purchased the opera tickets, Mike asked her to make dinner reservations.
(119c) When he purchased the opera tickets, Mike asked Jill to make dinner reservations.
(119d) When she purchased the opera tickets, Mike asked Jill to make dinner reservations.

(120a) When Paul entered the noisy bar, he recognized Sara at once despite the crowd.
(120b) When Sara entered the noisy bar, Paul recognized her at once despite the crowd.
(120c) When he entered the noisy bar, Paul recognized Sara at once despite the crowd.
(120d) When she entered the noisy bar, Paul recognized Sara at once despite the crowd.

(121a) As Adam walked the obedient dogs, he credited Anne for teaching the mutts to behave.
(121b) As Anne walked the obedient dogs, Adam credited her for teaching the mutts to behave.
(121c) As he walked the obedient dogs, Adam credited Anne for teaching the mutts to behave.
(121d) As she walked the obedient dogs, Adam credited Anne for teaching the mutts to behave.

\[ T/F \text{ Prompt: Anne taught the dogs to behave.} \]

(122a) As Matt installed the new stereo, he surprised Lisa by suddenly turning up the volume.
(122b) As Lisa installed the new stereo, Matt surprised her by suddenly turning up the volume.
(122c) As he installed the new stereo, Matt surprised Lisa by suddenly turning up the volume.
(122d) As she installed the new stereo, Matt surprised Lisa by suddenly turning up the volume.

\[ T/F \text{ Prompt: Matt installed the stereo.} \]
(123a) As Judy repaired the garbage disposal, she criticized Paul for stuffing corn husks in there.
(123b) As Paul repaired the garbage disposal, Judy criticized him for stuffing corn husks in there.
(123c) As she repaired the garbage disposal, Judy criticized Paul for stuffing corn husks in there.
(123d) As he repaired the garbage disposal, Judy criticized Paul for stuffing corn husks in there.

T/F Prompt: Paul repaired the garbage disposal.

(124a) As Lucy stocked the supermarket shelves, she lectured John about unions and workers’ rights.
(124b) As John stocked the supermarket shelves, Lucy lectured him about unions and workers’ rights.
(124c) As she stocked the supermarket shelves, Lucy lectured John about unions and workers’ rights.
(124d) As he stocked the supermarket shelves, Lucy lectured John about unions and workers’ rights.

T/F Prompt: John lectured about workers’ rights.

(125a) As Mary examined the accident scene, she told John to call for an ambulance.
(125b) As John examined the accident scene, Mary told him to call for an ambulance.
(125c) As she examined the accident scene, Mary told John to call for an ambulance.
(125d) As he examined the accident scene, Mary told John to call for an ambulance.

T/F Prompt: Mary told John to call for an ambulance.

(126a) As Lucy cleaned the filthy kitchen, she scolded Matt for being such a slob.
(126b) As Matt cleaned the filthy kitchen, Lucy scolded him for being such a slob.
(126c) As she cleaned the filthy kitchen, Lucy scolded Matt for being such a slob.
(126d) As he cleaned the filthy kitchen, Lucy scolded Matt for being such a slob.

T/F Prompt: Matt scolded Lucy for being a slob.
(127a) As Jack folded the clean laundry, he asked Jane to iron the shirts and pants.
(127b) As Jane folded the clean laundry, Jack asked her to iron the shirts and pants.
(127c) As he folded the clean laundry, Jack asked Jane to iron the shirts and pants.
(127d) As she folded the clean laundry, Jack asked Jane to iron the shirts and pants.

T/F Prompt: Jane folded the laundry.

(128a) As John admitted the nasty lie, he expected Jane to break down in bitter tears.
(128b) As he admitted the nasty lie, John expected Jane to break down in bitter tears.
(128c) As Jane admitted the nasty lie, John expected her to break down in bitter tears.
(128d) As she admitted the nasty lie, John expected Jane to break down in bitter tears.

T/F Prompt: John admitted the lie.

(129a) As Jack pitched the small tent, he asked Lisa to find kindling for the fire.
(129b) As Lisa pitched the small tent, Jack asked her to find kindling for the fire.
(129c) As he pitched the small tent, Jack asked Lisa to find kindling for the fire.
(129d) As she pitched the small tent, Jack asked Lisa to find kindling for the fire.

T/F Prompt: Lisa asked Jack to find kindling.

(130a) As Adam barbequed the sirloin steaks, he asked Lisa to grill the vegetables.
(130b) As Lisa barbequed the sirloin steaks, Adam asked her to grill the vegetables.
(130c) As he barbequed the sirloin steaks, Adam asked Lisa to grill the vegetables.
(130d) As she barbequed the sirloin steaks, Adam asked Lisa to grill the vegetables.

T/F Prompt: Lisa was asked to grill the vegetables.

(131a) As Lucy taunted the bungling umpires, she splashed Bill with beer in all the excitement.
(131b) As Bill taunted the bungling umpires, Lucy splashed him with beer in all the excitement.
(131c) As she taunted the bungling umpires, Lucy splashed Bill with beer in all the excitement.
(131d) As he taunted the bungling umpires, Lucy splashed Bill with beer in all the excitement.

T/F Prompt: Lucy splashed beer on Bill.
(132a) As Jane read the difficult article, she annoyed Bill by tapping a pencil on the desk.
(132b) As Bill read the difficult article, Jane annoyed him by tapping a pencil on the desk.
(132c) As she read the difficult article, Jane annoyed Bill by tapping a pencil on the desk.
(132d) As he read the difficult article, Jane annoyed Bill by tapping a pencil on the desk.

T/F Prompt: Bill was tapping a pencil.

(133a) As Judy climbed the steep slope, she pestered Mark to walk much more quickly.
(133b) As Mark climbed the steep slope, Judy pestered him to walk much more quickly.
(133c) As she climbed the steep slope, Judy pestered Mark to walk much more quickly.
(133d) As he climbed the steep slope, Judy pestered Mark to walk much more quickly.

(134a) As Jill watched the gorgeous sunset, she encouraged Jeff to relax and enjoy the moment.
(134b) As Jeff watched the gorgeous sunset, Jill encouraged him to relax and enjoy the moment.
(134c) As she watched the gorgeous sunset, Jill encouraged Jeff to relax and enjoy the moment.
(134d) As he watched the gorgeous sunset, Jill encouraged Jeff to relax and enjoy the moment.

(135a) As Mike checked the weather report, he warned Lisa to prepare for a rainy day.
(135b) As Lisa checked the weather report, Mike warned her to prepare for a rainy day.
(135c) As he checked the weather report, Mike warned Lisa to prepare for a rainy day.
(135d) As she checked the weather report, Mike warned Lisa to prepare for a rainy day.
(136a) As Matt approached the isolated campsite, he reminded Jane to watch out for poison ivy.
(136b) As Jane approached the isolated campsite, Matt reminded her to watch out for poison ivy.
(136c) As he approached the isolated campsite, Matt reminded Jane to watch out for poison ivy.
(136d) As she approached the isolated campsite, Matt reminded Jane to watch out for poison ivy.

(137a) As Paul approached the lake house, he advised Anne to look out for road signs.
(137b) As Anne approached the lake house, Paul advised her to look out for road signs.
(137c) As he approached the lake house, Paul advised Anne to look out for road signs.
(137d) As she approached the lake house, Paul advised Anne to look out for road signs.

(138a) As Mike collected the unusual seashells, he asked Beth to look out for sand dollars.
(138b) As Beth collected the unusual seashells, Mike asked her to look out for sand dollars.
(138c) As he collected the unusual seashells, Mike asked Beth to look out for sand dollars.
(138d) As she collected the unusual seashells, Mike asked Beth to look out for sand dollars.

(139a) As Sara explored the musty cavern, she asked Matt to turn on the flashlight.
(139b) As Matt explored the musty cavern, Sara asked him to turn on the flashlight.
(139c) As she explored the musty cavern, Sara asked Matt to turn on the flashlight.
(139d) As he explored the musty cavern, Sara asked Matt to turn on the flashlight.

(140a) As Jill prepared the fishing reel, she scolded Mike for baiting the hook incorrectly.
(140b) As Mike prepared the fishing reel, Jill scolded him for baiting the hook incorrectly.
(140c) As she prepared the fishing reel, Jill scolded Mike for baiting the hook incorrectly.
(140d) As he prepared the fishing reel, Jill scolded Mike for baiting the hook incorrectly.
As Jill washed the water filter, she blamed Adam for neglecting the fish tank.
As Adam washed the water filter, Jill blamed him for neglecting the fish tank.
As she washed the water filter, Jill blamed Adam for neglecting the fish tank.
As he washed the water filter, Jill blamed Adam for neglecting the fish tank.

As Sara removed the cancerous tumor, she handed Jack the scalpel and an extra clamp.
As Jack removed the cancerous tumor, Sara handed him the scalpel and an extra clamp.
As she removed the cancerous tumor, Sara handed Jack the scalpel and an extra clamp.
As he removed the cancerous tumor, Sara handed Jack the scalpel and an extra clamp.

As Greg decorated the Christmas tree, he asked Kate to put up the golden star.
As Kate decorated the Christmas tree, Greg asked her to put up the golden star.
As he decorated the Christmas tree, Greg asked Kate to put up the golden star.
As she decorated the Christmas tree, Greg asked Kate to put up the golden star.

As Bill reviewed the tax law, he asked Beth to explain the complex regulations.
As Beth reviewed the tax law, Bill asked her to explain the complex regulations.
As he reviewed the tax law, Bill asked Beth to explain the complex regulations.
As she reviewed the tax law, Bill asked Beth to explain the complex regulations.

As Mike examined the ancient mummies, he taught Judy about Egyptian burial rituals.
As Judy examined the ancient mummies, Mike taught her about Egyptian burial rituals.
As he examined the ancient mummies, Mike taught Judy about Egyptian burial rituals.
As she examined the ancient mummies, Mike taught Judy about Egyptian burial rituals.
(146a) As Bill launched the toy rocket, he encouraged Kate to film the occasion.
(146b) As Kate launched the toy rocket, Bill encouraged her to film the occasion.
(146c) As he launched the toy rocket, Bill encouraged Kate to film the occasion.
(146d) As she launched the toy rocket, Bill encouraged Kate to film the occasion.

(147a) As Lucy climbed the dangerous cliff, she signaled Jeff to try a different route.
(147b) As Jeff climbed the dangerous cliff, Lucy signaled him to try a different route.
(147c) As she climbed the dangerous cliff, Lucy signaled Jeff to try a different route.
(147d) As he climbed the dangerous cliff, Lucy signaled Jeff to try a different route.

(148a) As Sara sang the sappy ballad, she held Mike and swayed to the slow music.
(148b) As Mike sang the sappy ballad, Sara held him and swayed to the slow music.
(148c) As she sang the sappy ballad, Sara held Mike and swayed to the slow music.
(148d) As he sang the sappy ballad, Sara held Mike and swayed to the slow music.

(149a) As Judy sold the worthless stocks, she advised Greg to avoid investing in start-up companies.
(149b) As Greg sold the worthless stocks, Judy advised him to avoid investing in start-up companies.
(149c) As she sold the worthless stocks, Judy advised Greg to avoid investing in start-up companies.
(149d) As he sold the worthless stocks, Judy advised Greg to avoid investing in start-up companies.

(150a) As Beth ate the low-calorie soup, she lectured Mark about healthy eating habits.
(150b) As Mark ate the low-calorie soup, Beth lectured him about healthy eating habits.
(150c) As she ate the low-calorie soup, Beth lectured Mark about healthy eating habits.
(150d) As he ate the low-calorie soup, Beth lectured Mark about healthy eating habits.

(151a) As Mark played the background music, he urged Jill to improvise some lyrics.
(151b) As Jill played the background music, Mark urged her to improvise some lyrics.
(151c) As he played the background music, Mark urged Jill to improvise some lyrics.
(151d) As she played the background music, Mark urged Jill to improvise some lyrics.
(152a) As Jack engraved the silver cup, he complimented Mary on developing a keen eye for detail.
(152b) As Mary engraved the silver cup, Jack complimented her on developing a keen eye for detail.
(152c) As he engraved the silver cup, Jack complimented Mary on developing a keen eye for detail.
(152d) As she engraved the silver cup, Jack complimented Mary on developing a keen eye for detail.

(153a) As Mark fed the hungry chickens, he educated Kate on organic farming techniques.
(153b) As Kate fed the hungry chickens, Mark educated her on organic farming techniques.
(153c) As he fed the hungry chickens, Mark educated Kate on organic farming techniques.
(153d) As she fed the hungry chickens, Mark educated Kate on organic farming techniques.

(154a) As Greg inspected the damaged house, he gave Lucy an assessment of the rebuilding costs.
(154b) As Lucy inspected the damaged house, Greg gave her an assessment of the rebuilding costs.
(154c) As he inspected the damaged house, Greg gave Lucy an assessment of the rebuilding costs.
(154d) As she inspected the damaged house, Greg gave Lucy an assessment of the rebuilding costs.

(155a) As Anne crossed the rose garden, she welcomed Bill to join the company picnic.
(155b) As Bill crossed the rose garden, Anne welcomed him to join the company picnic.
(155c) As she crossed the rose garden, Anne welcomed Bill to join the company picnic.
(155d) As he crossed the rose garden, Anne welcomed Bill to join the company picnic.
(156a) As Jane played a video game, she informed John about recent events at work.
(156b) As John played a video game, Jane informed him about recent events at work.
(156c) As she played a video game, Jane informed John about recent events at work.
(156d) As he played a video game, Jane informed John about recent events at work.

(157a) As Judy comforted the crying children, she criticized Bill for having been cruel to the boys.
(157b) As Bill comforted the crying children, Judy criticized him for having been cruel to the boys.
(157c) As she comforted the crying children, Judy criticized Bill for having been cruel to the boys.
(157d) As he comforted the crying children, Judy criticized Bill for having been cruel to the boys.

(158a) As Mary toured the art museum, she encountered Jack about four times in just an hour.
(158b) As Jack toured the art museum, Mary encountered him about four times in just an hour.
(158c) As she toured the art museum, Mary encountered Jack about four times in just an hour.
(158d) As he toured the art museum, Mary encountered Jack about four times in just an hour.

(159a) As Mike diagnosed the sick patients, he convinced Mary to consider the disease contagious.
(159b) As Mary diagnosed the sick patients, Mike convinced her to consider the disease contagious.
(159c) As he diagnosed the sick patients, Mike convinced Mary to consider the disease contagious.
(159d) As she diagnosed the sick patients, Mike convinced Mary to consider the disease contagious.
(160a) As Mike played the tennis match, he asked Kate to keep score very accurately.
(160b) As Kate played the tennis match, Mike asked her to keep score very accurately.
(160c) As he played the tennis match, Mike asked Kate to keep score very accurately.
(160d) As she played the tennis match, Mike asked Kate to keep score very accurately.
REFERENCES


Staub, A. (submitted) *Eye movements and processing difficulty in object relative clauses*.


