12-2012

The Role of Referentially Biased and Unbiased Contexts in the Processing of Relative Clauses

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A dissertation submitted in partial fulfillment
of the requirements of the degree of
Doctor of Philosophy in Psychology

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December 2012
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Abstract

Two studies were conducted in order to examine the role of biased and unbiased contexts on the processing of object-extracted relative clauses (ORCs) (e.g., *The child that the babysitter chased squealed with delight.*) and subject-extracted relative clauses (SRCs) (e.g., *The child that chased the babysitter squealed with delight.*) In Experiment 1 ORCs and SRCs were embedded in licensing contexts that referentially supported the use of the relative clause (i.e., more than one child was present. In Experiment 2 ORCs and SRCs were embedded in context that biased towards either an ORC interpretation (e.g., *One of the children was chased by the babysitter and the other was not.*), or an SRC interpretation (e.g., *One of the children chased the babysitter and the other did not.*) The results demonstrated that the ORC-SRC difference was present and significant for Experiment 1. In Experiment 2 the results demonstrated that for late measures of sentence processing the contexts had a differential effect on the processing of ORCs and SRCs. The ORC-SRC difference was reduced for the ORC-biasing contexts but not for the SRC-biasing contexts. Moreover, cross-experiment comparisons revealed that the licensing contexts from Experiment 1 and the biased contexts from Experiment 2 had different influences on the ORC-SRC difference. The results are discussed in light of the current theories of relative clause processing.

This dissertation is approved for recommendation

to the Graduate Council.

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Acknowledgements

I would like to thank the individuals who helped me create this dissertation.

First, I would like to give sincere thanks to Dr. William Levine for his patience and efforts in helping me transform an idea into a dissertation. I would also like to thank Dr. Denise Beike and Dr. Jeffery Lohr for their helpful feedback at the dissertation proposal meeting. Finally, I would like to thank all the research assistants who helped collect and clean my data. Without these people I would still be struggling to complete this.

Dedication

This dissertation is dedicated to my parents Dr. William and Ann Battinich.

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Introduction

Many psychological studies investigating text processing are designed to explore the types of information used during comprehension. This is typically done by examining how readers process sentences in isolation. Although this presentation method is necessary for greater experimental control over extraneous variables, it does have some potential limitations due to its artificiality. One such limitation is the fact that language communication typically occurs within a discourse context that provides some of the means for understanding the expressions used, and the results seen in research on sentence processing out of context may not necessarily generalize to sentence processing in context (e.g., Altmann, van Nice, Garnham, & Henstra, 1998). For example, the underlined prepositional phrase (PP) in *The boy hit the girl* <u>*with the book*</u> is ambiguous to whether it is *hit* or *the girl* that is being modified (Rayner, Carlson, & Frazier, 1983). When read in isolation, the sentence is typically comprehended as the boy using the book to hit the girl with. However, given a context that establishes more than one girl, *with the book* may serve to identify which girl the boy is hitting, thereby reducing the ambiguity (Spivey-Knowlton & Sedivy, 1995). In short, how sentence processing occurs within a context may be different than how sentences are processed in isolation, and as a result how a sentence is comprehended may be different as well.

Thus, a central debate in the sentence-processing literature is about the role that discourse or contextual information plays in syntactic processing or *parsing* (e.g., Altmann & Steedman, 1988; Ferriera & Clifton, 1986; Grodner, Gibson, & Watson, 2005). Context refers to the information that surrounds or precedes a unit of language. All models of syntactic processing acknowledge that contextual information influences parsing; however, the models differ as to the time course in which contextual information is used. For example, delayed-discourse models of

parsing (e.g., Frazier & Fodor, 1978) relegate the use of contextual information to a later processing stage, such that its role in parsing decisions only occurs after other information (e.g., syntactic information, such as grammatical category) has been used to construct the initial syntactic structure of the sentence. Conversely, immediate-discourse models of parsing (e.g., Altman & Steedman, 1988) argue that the initial parse of the sentence is influenced, at least in part, by any readily available contextual information. The evidence that has accrued in favor of and against these two different theoretical perspectives falls into two main areas of research: the first area has to do with ambiguity in parsing, and the second with complexity effects.

Research on syntactic ambiguity is one area in which contextual influences have received a substantial amount of attention (e.g., Altmann & Steedman, 1988; McKoon & Ratcliff, 2007; Mitchell, Corley, & Garnham, 1992; Spivey & Tanenhaus, 1998). For example, consider sentences (1) and (2) below. The bracketed portion of sentence (1) is a complement clause

(1) *The psychologist told the woman* [*that he was having trouble with her husband*].

(2) *The psychologist told the woman* [*that he was having trouble with*] *to visit him again.*

because the clause after the word *that* is a complete sentence that is predicated of the verb *told* (i.e., it is what the psychologist told the woman). Conversely, the bracketed portion of sentence (2) is a restrictive relative clause because it contains the restrictive modifier *that he was having trouble with*, which modifies *the woman* (i.e., it indicates which woman is being referred to). Furthermore, the structure of the sentences is ambiguous upon encountering the word *that*, and it is here that the parser must decide whether to analyze the rest of the sentence as a complement clause as in sentence (1) or a relative clause as in sentence (2). When these sentences are read in isolation, people tend to treat the word *that* as a complementizer (i.e., they commit to the structure in (1)) rather than a relative pronoun; data from offline comprehension tasks, reading-

time, and eye-tracking data support this (Crain & Steedman, 1985; McKoon & Ratcliff, 2007; Spivey & Tanenhaus, 1998). However, with a prior context establishing the presence of more than one woman, a referential ambiguity is created regarding which woman is being referred to, and participants then tend to interpret the word *that* as a relative pronoun, committing to the structure in (2) (Altmann & Steedman, 1988, van Berkum, Brown & Hagoort, 1999).

The two general classes of theories noted above (i.e., delayed-discourse and immediate-discourse models) attempt to explain how the parsing mechanism handles such ambiguities. These theories are important because they represent very different perspectives with respect to ambiguity resolution. In other words, the theories differ as to whether syntactic information alone determines the initial structure of a sentence, or whether contextual information in conjunction with syntactic information plays an immediate role in how the parser constructs the initial sentence representation. This distinction is central to sentence-processing research, and the results from such studies have shed light on how different kinds of information influence parsing. However, ambiguous sentences are different from complex sentences. In the case of ambiguous sentences, the ambiguity is a result of more than one possible syntactic interpretation of a word (i.e., *that*) such as seen in sentences (1) and (2) above. Conversely, complex sentences, such as the ones I have examined in the present research, do not contain syntactic ambiguities. For example, consider the non-reduced restrictive relative-clause[1] sentences in (3) and (4). In both sentences the word *that* serves as the relative pronoun and this role is not

(3) *The child* [*that chased the babysitter*] *squealed with delight.*

[1] A non-reduced relative clause is a relative clause that helps to identify the referent of the word that it modifies (Huddleston & Rodney, 2002).

(4) *The child [that the babysitter chased] squealed with delight.*

ambiguous. Instead, it functions as a signal to the reader that a restrictive modifier will follow, one which will determine (i.e., restrict) which child is being referred to. However, what is indeterminate is the remaining argument form the sentence will take. In sentence (3) the embedded clause (i.e., *that chased the babysitter*) modifies the head NP (i.e., *the child*) of the main clause. The main clause of the sentence is *The child squealed with delight*, and the embedded relative clause is *that chased the babysitter*. In this instance the NP *the child* is both the subject of the main clause and the subject of the relative clause. This type of relative clause is commonly referred to as a subject-extracted relative clause (SRC). Conversely, in sentence (4) the head NP *the child* is still the subject of the main clause but is now the object of the verb *chased* in the relative clause. This type of relative clause is referred to as an object-extracted relative clause (ORC). There is no ambiguity in these sentences because the word immediately after the relative pronoun *that* determines completely the structure of the relative clause.

Research on non-reduced relative-clauses[2] has consistently shown that when encountered in isolation, ORCs are more difficult to process than SRCs. This is commonly referred to as the ORC-SRC difference (e.g., Gennari & Macdonald, 2008; Gibson, Desmet, Grodner, Watson, & Ko, 2005; Gordon, Hendrick, & Johnson, 2004; Traxler, Morris, & Seely, 2002). The ORC-SRC difference has been shown to be present across a number of languages, including at least English (e.g., King & Just, 1991), Hungarian (e.g., MacWhinney & Pléh, 1988), Dutch (e.g., Mak, Vonk, & Schriefers, 2002), French (e.g., Franck, Soare, Frauenfelder, & Rizzi, 2010), German (e.g., Diessel & Tomasello, 2005), Japanese (e.g., Miyamoto, Gibson, Pearlmutter, Aikawa, & Miyagawa, 1999), and Korean (e.g., Lee, Lee, & Gordon, 2007). Research into restrictive

[2] Unless otherwise noted I'll be talking about non-reduced RCs

relative-clause processing has frequently used conditions designed to examine why ORCs are more difficult to process than SRCs by determining under what conditions the difficulty can be reduced or eliminated. However, few studies have examined how these types of sentences are processed in context. This is surprising because the intended discourse function of SRCs and ORCs is to identify the correct referent being referred to in the relative clause portion of the sentence (but see Roland, Mauner, O'Meara, & Yun, 2012, for a different view). Therefore, SRCs, and ORCs may be particularly useful for examining the role of contextual information on sentence parsing.

In this dissertation I examined SRCs and ORCs to test whether and how discourse information plays a role in early parsing decisions. I chose this sentence structure because it does not involve any parsing ambiguity, and instead its intended discourse function is to resolve any referential ambiguity (Fox & Thompson, 1990). In Experiment 1, SRCs and ORCs were preceded by contexts like (5) that made both argument forms plausible. The first sentence

(5) *A babysitter was playing games with two children. One child was chased by the babysitter and the other child chased the babysitter.*

The child that chased the babysitter / babysitter chased squealed with delight.

introduced the discourse referents, a singleton (i.e., the babysitter) and a pair (i.e., the two children). The second sentence described the actions in which one of the pair was the recipient of the verb's action and the other was the agent of the verb's action. The final sentence was the critical SRC or ORC. Thus, in Experiment 1, one of the actions is consistent with an ORC interpretation (i.e., one child was chased by the babysitter) and the other action is consistent with an SRC interpretation (i.e., the other child chased the babysitter). In other words in Experiment 1, both the SRC and ORC argument forms are

plausible. In Experiment 2 I used SRCs and ORCs embedded in contexts that were biased towards either an SRC or an ORC interpretation, like (6) and (7) below, respectively. As in Experiment 1, the first sentence introduces the discourse referents.

(6) *A babysitter was playing games with two children. One of the children chased the babysitter and the other did not.*

The child that chased the babysitter / the babysitter chased squealed with delight.

(7) *A babysitter was playing games with two children. One of the children was chased by the babysitter and the other was not.*

The child that chased the babysitter / the babysitter chased squealed with delight.

However, in the second sentence the action of only one of the pair is described. The other member of the pair is mentioned (by 'other') but no action is ascribed to that person. For the SRC-biasing contexts like (6) it is *the child* who is the agent of the verb *chased* (i.e., the child chased), while for the ORC-biasing contexts like (7) *the child* is the so-called theme (i.e., the entity acted upon) of the verb *chased* (i.e., the child is being chased). Experiment 1 was designed to replicate the findings of two similar studies (Battinich, Levine, & Trczinski, 2012; Federenko, Piantadosi, & Gibson, 2012) in which contexts that supported both the SRC and ORC argument forms did *not* reduce the ORC-SRC difference. More importantly, Experiment 1 provides a set of comparison conditions for Experiment 2, which was designed to examine the influence of biasing contexts on the processing of SRCs and ORCs, which have not been examined previously.

Below I first examine theories that attempt to explain relative clause processing and the studies that provide evidence that support each of these theories. Second, I

describe the current series of studies in detail and the predictions made by the differing theories. Third, I discuss the methodology used to test the role of prior discourse on the processing of relative clauses. Fourth, I present the analyses and results. And finally, I discuss the pattern of results in light of the current theories of relative clause processing.

Theories of Relative-Clause Processing

Theories that attempt to explain the ORC-SRC difference provide diverse explanations about why ORCs are more difficult to process. The different theories can be broadly classified into three types: syntax-based models (e.g., Frazier & Flores D'Arcais, 1989), memory-based models (e.g., Just & Carpenter, 1992; Gordon, Hendrick, & Johnson, 2001; Gibson, 1998), and discourse-based models (e.g., Altmann & Steedman, 1988; Juliano & Tanenhaus, 1994). The following will focus on those theories that make specific predictions about the influence of context on the processing of SRCs and ORCs.

Syntax-based Theories

The active-filler-strategy (Frazier & Clifton, 1989; Frazier & Flores D'Arcais, 1989) is a syntax-based model that proposes that the ORC-SRC difference is a result of a parsing error and the subsequent necessary reanalysis of a sentence. In an ORC like *The child that the babysitter chased squealed with delight*, the active-filler-strategy suggests that an "unbounded gap" appears after the relative pronoun *that* which must be attached to a "filler" that has been identified by the parser. A gap[3] is an empty position in a phrase structure and a filler determines how the gap will

[3] In the question, *What do you want mother to make for Mary?*, the word *what* serves the role of the direct object of the verb *make*, but because it has been moved from the usual position after *make*, there is argued to be a gap left behind that must be filled. Evidence for the psychological reality of these gaps is extensive (e.g., McElree & Bever, 1989; Nicol & Swinney, 1989).

be interpreted (e.g., Frazier & Clifton, 1989; Frazier & Flores D'Arcais, 1989). At the point at which the relative pronoun is encountered, the head NP (i.e., *the child*) is the only filler available which can be attached to the relative pronoun, and thus the parser automatically does so. In other words, when the relative pronoun is first processed, it is unattached to a referent, and therefore the parser will assign the first available filler to an identified gap as soon as possible (Frazier & Clifton, 1989; Frazier & Flores D'Arcais, 1989). In the case of an SRC this is the correct interpretation and processing proceeds smoothly. However, when the sentence contains an ORC, attaching the relative pronoun to the head NP is syntactically incorrect. When this occurs and the reader encounters the RC-internal verb, it acts as an error signal resulting in the parser initiating a reanalysis of the sentence. Sentence reanalysis is a time-consuming process (Frazier & Rayner, 1982) and is therefore argued to be the reason for the ORC-SRC difference (Frazier & Clifton, 1989; Frazier & Flores D'Arcais, 1989).

Traxler, Morris and Seely (2002) tested the predictions of the active-filler strategy by manipulating the plausibility of the NP-verb relationship. Plausibility is a form of non-syntactic lexical information that can help constrain possible interpretations of a sentence (MacDonald, Pearlmutter, Seidenberg, 1994; Wilson & Garnsey, 2009). It has been shown that the plausibility of the NP-verb relationship influences how strongly the parser will commit to an initial syntactic interpretation (Pickering & Traxler, 1998). Traxler et al. had subjects read SRCs and ORCs in which both NPs were plausible agents of the relative clause verb, as in (8), or only one of the NPs was a plausible agent of the relative clause verb, as in (9). The active-filler strategy predicts

(8) *The secretary **assisted** that the executive was angry about the stock price.*

*The secretary that the executive **assisted** was angry about the stock price.*

(9) *The secretary that **fired** the executive was angry about the stock price.*

*The secretary that the executive **fired** was angry about the stock price.*

that the ORC processing difficulty should be reduced only in (9), when reanalysis can be initiated faster because *the executive* is a highly-plausible agent for the verb *firing*, and the results supported this. For (8), when both nouns were plausible agents for the relative clause verb, ORCs were significantly more difficult to process than SRCs. The results support the active-filler strategy prediction that non-syntactic information is used only during re-analysis which helps with processing.

One critical problem, however, is that the active-filler strategy wrongly predicts the location of increased processing difficulty for ORCs and SRCs. If ORCs and SRCs are disambiguated at the word immediately following the relative pronoun, as predicted by the active-filler strategy, then reading times for ORCs should increase at the first word after the relative pronoun, compared to SRCs. Rather, reading times for ORCs and SRCs increase consistently at two locations. For SRCs like (10), reading times increase at the NP of the relative clause and the matrix verb, and reading times for ORCs as in (11) increase at the relative clause verb (i.e., *chased*) and the matrix verb (i.e., *squealed*) (King & Just, 1991).

(10) *The child that chased the **{babysitter squealed}** with delight.*

(11) *The child that the babysitter **{chased squealed}** with delight.*

This finding is inconsistent with the active-filler strategy's prediction of the timing of syntactic misanalysis and recovery. For both SRCs and ORCs, reading times increased three words after the relative pronoun, instead of immediately after the relative pronoun. Furthermore, the active-

filler strategy does not predict a reading time increase at the matrix verb. Moreover, King and Just grouped subjects based on working memory capacity and found that low-span subjects had longer reading times in the relative clause region and more comprehension errors than high-span subjects, but only for ORCs (Just & Carpenter, 1992; King & Just, 1991). This finding suggests that memory limitations may influence the processing of the more-complex ORC structure and contribute to the ORC-SRC difference. The active-filler-strategy does not predict a processing difference between high span and low-span subjects. Therefore, Just and Carpenter proposed that the ORC-SRC difference was due to limitations inherent to working memory capacity rather than syntactic misanalysis and reanalysis. In summary, the active-filler strategy wrongly predicts the location of increased processing difficulty for ORCs and SRCs. The processing difficulty for ORCs does not appear immediately after the relative pronoun at the NP of the relative clause. Instead, reading slows down at the relative clause verb which follows the NP. The differences in reading time of the relative-clause region seen in high-span and low-span subjects is instead argued to reflect the increased storage and computational demands of ORCs, which exceeds the resources available to low-span subjects (Just & Carpenter, 1992; King & Just, 1991).

Memory-Based Theories

Generally, memory-based accounts of relative-clause processing propose that ORCs are more difficult to process because they require increased storage and computational demands that tax working-memory resources (Frazier & Fodor, 1978; King & Just, 1991; Just & Carpenter, 1992). ORCs require the comprehender to retain their mental representations of the two NPs in memory for a longer period of time than for SRCs. For example, in the ORC, *The child that the babysitter chased squealed with delight*, the head NP *the child* has to be stored in memory until it

can be integrated with the matrix verb *squealed* and with the RC-verb *chased*, and *the babysitter* must be stored until it can be integrated with the RC-verb *chased*. Conversely, demands on memory are reduced for an SRC because the head NP can be integrated with the RC verb before the NP of the relative clause is encountered. In the SRC *The child that chased the babysitter squealed with delight*, *the child* can be integrated with *chased* before *the babysitter* is encountered. Thus, a critical assumption of memory-based accounts is that the longer an unattached referent has to be stored in memory, the more difficult it will be to recall due to limitations of working memory (Hitch & Baddeley, 1976; Just & Carpenter, 1992). What is disputed, however, is whether the ORC difficulty is due to higher processing costs (Gibson, 1998; Warren & Gibson, 2002) or interference between similar representations (Gordon et al., 2001).

One memory-based explanation, the dependency locality theory (DLT; Gibson, 1998, 2000; Warren & Gibson, 2002), proposes that the processing difficulty for ORCs is due to two processing costs: storage and integration. Consistent with Just and Carpenter's (1992) theory, DLT assumes that both storage and integration draw on the same working-memory resources. Storage costs are incurred when more than one unbounded referent (i.e., an entity, usually introduced by a noun) must be stored in memory, retrieved, and attached to a verb. Integration costs occur when new discourse referents need to be integrated into the existing discourse structure and these costs will increase with the number of referents that intervene between elements that need to be integrated. For example, in an SRC like (12), there is an integration cost of 1 each for *the child*, *chased*, and *the babysitter*, but there are no extra integration or

(12) *The child that chased the babysitter squealed with delight.*

(13) *The child that the babysitter chased squealed with delight.*

storage costs since each is local to the element that it is to be integrated with. In other words, in (12) no new discourse entities are introduced between *the child* and the RC-verb *chased* which it is integrated with. Conversely, in the corresponding ORC in example (13), the same number of new discourse referents are introduced (i.e., *the child*, *chased*, and *the babysitter*), but in this instance integrating the head NP (*the child*) as the object of the RC-verb (*chased*) has a higher integration cost because two new discourse referents are introduced (i.e., *the babysitter* and *chased*) before integration can occur. Furthermore, in ORCs both the head NP and the RC-internal NP must be stored in memory as unattached referents temporarily before they can be syntactically or semantically integrated with a verb, which consumes further processing resources. By contrast, in SRCs, the head NP is attached to its thematic role (e.g., as the agent of the verb) within the relative clause before the NP of the relative clause is encountered. As such, the storage and retrieval demands of ORCs are greater than that for SRCs, and this contributes to the ORC processing difficulty (Gibson, 1998). Support for DLT comes from research that reports greater comprehension errors and longer reading times as the distance between constituents needing to be integrated increases (Grodner & Gibson, 2005; Jarvella, 1971; Just & Carpenter, 1992; Lesgold, Roth, & Curtis, 1979).

Another memory-based explanation, the similarity-interference (Gordon et al., 2001) approach, proposes that the ORC processing difficulty results from the unattached nouns interfering with each other in memory. For example, in the ORC above in (13), the two NPs (i.e., *the child* and *the babysitter*) are lexically similar, both being descriptions of individual humans introduced by a definite article and a role description, and the order in which the NPs need to be integrated with the verb can become difficult to sort out because their representations are similar. This approach is similar to the DLT because it suggests that processing difficulty is

associated with the increased difficulty of retrieving the NP from memory. However, these two approaches differ in that DLT argues that the processing costs associated with ORCs are due to the amount of time the two unattached referents need to be held in memory, while the similarity-interference approach argues that they are due to the similarity of the two unattached referents.

Evidence supporting a memory-based explanation for the ORC-SRC difference has come from research demonstrating that when the NP of a relative clause was an indexical pronoun (e.g. *you* or *I*), as illustrated below in (14) and (15), the ORC-SRC difference was reduced (Gordon,

(14) *The barber that you admired climbed the mountain.*

(15) *The barber that admired you climbed the mountain.*

Hendrick, & Johnson, 2001). Additionally, Warren and Gibson (2002) found that readers rated ORCs as less complex and more comprehensible when the NP of the relative clause was a indexical or second-person pronoun compared to when the NP was a third-person pronoun or a description. Warren and Gibson argued that pronouns such as *you* or *I* are implicit to a discourse and therefore are not considered "new" discourse referents. Thus, for these pronouns integration costs do not increase as a function of intervening discourse elements. By contrast, the similarity-interference approach argues that the reduced ORC-SRC difference reported by Gordon et al. (2001) and the increased comprehensibility of the ORCs used by Warren and Gibson (2002), is a result of the head NP and the NP of the relative clause being syntactically and lexically different from one another. This interpretation differs from the DLT in that it argues that the ORC difficulty is a result of the two unattached referents having similar lexical and semantic properties rather than the length of time the referents have to be held in memory.

To test the predictions of the similarity-interference approach, a series of reading-time experiments was conducted (Gordon et al., 2001) with descriptions, indexical pronouns, or

proper names used as the NPs in the relative clause. An example of Gordon et al.'s materials, along with illustrations of the manipulations, appears below in (16) and (17). If the ORC-SRC

(16) *The banker that praised **the barber / you / Ben** climbed the mountain.*

(17) *The banker that **the barber / you / Ben** praised climbed the mountain.*

difference is due to the similarity of the NPs' representations in memory, then the difference should be reduced when the NP of the relative clause is either an indexical pronoun (i.e., you) or a proper name. If the processing difference is due to the implicitness of the discourse referent, then the ORC-SRC difference should be reduced only when the NP of the relative clause is an indexical pronoun. The results supported the predictions of the similarity-interference approach. The ORC-SRC difference was reduced when the RC-internal verb was an indexical pronoun or a proper name. Gibson (1998) argued that names are not implicit to a discourse situation, and thus comprehending a name should involve an integration cost because it introduces a new discourse referent. By contrast, pronouns and proper names are lexically different from one another, creating less interference between the two representations, which subsequently makes the retrieval and integration of the proper NP with the correct verb easier. Furthermore, that the ORC-SRC difference is significantly reduced (and sometimes eliminated) by having an indexical pronoun or proper name as the subject of the ORC suggests that the syntactic parser may make immediate use of lexical and semantic information when making initial parsing decisions. In other words, under conditions where there is available non-syntactic information, the parser may make use of it to help determine the correct syntactic structure of the sentence. If this does in fact happen then it could be expected that ORCs would as easy, if not easier to process than SRCs. By contrast, the active-filler strategy argues that non-syntactic information only influences processing during re-analysis and therefore predicts that the ORC-SRC difference

would never be eliminated. In short, the results suggest that prior discourse context may be able to immediately influence parsing decisions.

Discourse-Based Models

Discourse-based models propose that sentence processing is influenced by non-syntactic contextual information that has been established in the preceding[4] discourse context (Altmann & Steedman, 1988, Mak et al. 2002, 2008), and research on syntactic ambiguity is one area in which contextual influences have shown to influence immediate parsing decisions (Altmann & Steedman, 1988; McKoon & Ratcliff, 2007; Mitchell, Corley, & Garnham, 1992; Spivey & Tanenhaus, 1998).

Battinich et al. (2012) argued that restrictive RCs play a referential role: they help to select which member of a category (i.e., the category named by the NP that is modified by the RC) is being referred to. When restrictive RCs are used out of context, they provide new information in a way that is syntactically and pragmatically odd. Thus, Battinich et al. argued that when restrictive RCs are presented in isolation, the information in the RC is not serving its intended function of reference and is therefore unlicensed. By contrast, a licensing context for a restrictive RC would be a context that introduces more than one member of a category (e.g., a group of children) such that reference to a subset of the category (e.g., one child) requires additional information. To test this hypothesis Battinich et al. performed two reading time experiments. In one experiment SRCs and ORCs were presented in isolation replicating the typical ORC-SRC difference. In a second experiment they presented participants with licensing contexts that supported both an SRC and ORC interpretation, as in (18). In this passage,

[4] Or in the immediate, surrounding context, in the case of references made to entities that are physically present.

(18) *The Smiths had two very active kids. They hired a babysitter every time they went out. The babysitter was fun and enjoyed playing games with the children. The children's favorite game involved one child chasing the babysitter around the room while the babysitter chased the other child.*

the context establishes two similar discourse referents (i.e., two children) and describes the actions of each with respect to the singleton (i.e., the babysitter). They hypothesized that when a reader encounters the relative pronoun *that*, the subsequent RC would not impose a differential storage and processing cost between the ORC and SRC, because in both cases the information in the RC is immediately useful for selecting the proper referent. That is, instead of providing new information about the head NP, which is what RCs do in isolation, the RC narrows the domain of reference. Thus, it was expected that contextualizing RCs in licensing context would reduce or eliminate the usual ORC-SRC difference. However, the results revealed that in a licensing context, not only was the ORC-SRC difference present, but the difference was slightly larger than when these RC-sentences were presented in isolation, as in Experiment 1. Moreover, Fedorenko et al. (2012) reported similar findings using similar contexts and materials. These results did not support the referential hypothesis, the DLT, or the active-filler strategy, all of which predicted a reduction in the ORC-SRC difference. Furthermore, the similarity-interference approach, proposed by Gordon, Hendrick, and colleagues (Gordon et al., 2001, 2002, 2004, 2006; see also Van Dyke & McElree, 2006 and Lewis, 1996), may also have trouble explaining these results. In one sense, if similarity is a function of the type of NPs that appear in the critical sentence and is unaffected by prior context, then the ORC-SRC difference can be readily explained by the similarity-interference approach. However, if the prior context, as in (18), enables the representation of the two NPs to be discriminable, the similarity-interference

approach would predict the ORC-SRC difference to be reduced by prior context. In other words, despite that the NPs of the critical RC-sentence are of the same type, they have been previously described somewhat differently. If this differential description leads to memory representations of these entities that are easier to distinguish than when they are presented in isolation, the interference seen due to similarity should be reduced in referentially-appropriate context. Nevertheless, the ORC-SRC difference persisted even with what should have been more highly discriminable NPs.

However, one criticism of Battinich et al's argument is that contexts which equally support multiple interpretations do not exist (Altmann & Steedman, 1988). Altman and Steedman argue that a context cannot make two competing structures equally plausible. Thus, the "neutral" contexts often used in sentence processing research are not really neutral. Instead a context will always favor one structure over another. Thus, in theory, the contexts used by Battinich et al., and Fedorenko et al. were intended such that no syntactic analysis is favored over another. The contexts used by Battinich et al. and Fedorenko et al. contained two similar referents that needed to be distinguished. Despite this, Altmann and Steedman's argument suggests that this does not necessarily mean that the context supported both an SRC and ORC interpretation equally. For instance, the licensing contexts used by Battinich et al. (see 18 above) included one subject-verb-object (SVO) segment (e.g., *one child chasing the babysitter*) and a second SVO segment (e.g., *the babysitter chased the other child*). Both segments are more syntactically similar to the SRC version of the critical sentence than to the ORC version, raising the possibility that the context syntactically primed the SRC, facilitating its processing (e.g., Branigan, Pickering, & McLean, 2005), thereby effectively canceling out any reduction of the ORC-SRC difference.

In short, the differing theories of SRC and ORC processing attribute the ORC-SRC difference to different processes. Syntax-based theories, such as the active-filler strategy (Frazier & Clifton, 1989; Frazier & Flores D'Arcais, 1989), propose that the ORC-SRC difference is due to the initial misinterpretation of ORCs and that context only influences subsequent re-analysis which may reduce the ORC-SRC difference. Memory-based theories, such as the DLT (Gibson, 1998) and the similarity-interference approach (Gordon et al., 2001), propose that the ORC-SRC difference is due to the increased storage and computational demands of ORCs compared to SRCs. While discourse-based models such as the referential theory (Altmann & Steedman, 1988) propose that sentence processing is influenced by non-syntactic contextual information and that the ORC-SRC difference is due to ORCs not serving their intended discourse function of identifying the correct referent being referred to. Thus, each of these theories make differing predictions regard the processing of SRCs and ORCs in context.

Current Studies

I conducted two experiments to to examine the role of different types of prior context on the processing of SRCs and ORCs. In Experiment 1 I embedded SRCs and ORCs in licensing contexts like (19), which were adapted from the ones used by Battinich et al. (2012, Experiment 2). The expectation was that this experiment would replicate the findings of Battinich et al. and Federenko et al. (2012), both of which showed that the usual ORC-SRC difference persisted even in referentially-supportive contexts.

(19) *A babysitter was playing games with two children. One child was chased by the babysitter and the other child chased the babysitter.*

The child that chased the babysitter / the babysitter chased squealed with delight.

In Experiment 2 I further explored the role of context by embedding SRCs and ORCs in contexts that biased towards either an SRC interpretation, like (20) below, or an ORC interpretation, like (21) below. In a norming study of the materials, participants selected whether

(20) *A babysitter was playing games with two children. One of the children chased the babysitter and the other did not.*
The child that the babysitter chased / chased the babysitter squealed with delight.

(21) *A babysitter was playing games with two children. One of the children was chased by the babysitter and the other was not.*
The child that the babysitter chased / chased the babysitter squealed with delight.

they preferred an SRC or an ORC continuation after reading SRC-biasing and ORC-biasing contexts. Participants preferred an SRC 72% of the time when the context was SRC-biasing and preferred an ORC 72% of the time when the context was ORC biasing. Although ORCs and SRCs are syntactically unambiguous there is some ambiguity as to which referent is being referred to by the head-NP. The *expectancy hypothesis* attempts to explain why certain entities are more accessible than others when it comes to reference resolution (Arnold, 2001; Arnold, Brown-Schmidt & Trueswell, 2007). The expectancy hypothesis argues that referential resolution is facilitated when discourse entities are prominent in the discourse or are in positions that are syntactically parallel to that of the intended referent (Chambers & Smyth 1998). Thus, according to the expectancy hypothesis, for the SRC-biasing contexts when readers encounter the RC portion of an SRC there should be a referential expectation that the subject of the main clause is the intended referent because it is the most prominent referent in the context. For example, consider again the SRC-biasing context above in (20). In the second sentence the child

is the subject or agent of the action, and in a critical SRC the head NP has the same syntactic role (e.g., *The child that chased the babysitter*) Conversely, if an ORC follows an SRC-biasing context, the expectation that the prominent referent in the context is the intended referent will be wrong. For example, in an SRC-biasing context the most prominent referent is the child that chased the babysitter; however in an ORC (e.g., *The child that the babysitter chased*) the child is no longer the agent of the action being performed but is now the recipient. Thus, the correct referent of an ORC is the child who is the recipient of the verb chased. Therefore the expectancy hypothesis predicts that referential resolution will not be facilitated but instead reading will slow down. Thus, in the SRC-biasing context the ORCs should be read more slowly than SRCs.

Of specific interest is the ORC-biasing context (i.e., 21). In this instance, the prominent referent in the second sentence of the context is the child that the babysitter is chasing. Therefore, *the babysitter* is the agent of the action and *the child* the recipient. Therefore, upon encountering the head NP (e.g., the child) of the RC sentence, readers should expect that the child being referred to is the same one who is being chased by the babysitter. When an ORC follows and ORC-biasing context then referential resolution should be facilitated. By contrast, when an SRC follows an ORC-biasing context, referential resolution will not be facilitated because the most prominent referent in an ORC-biasing context is not the correct referent of the head-NP in an SRC. In short, the expectancy hypothesis predicts that in the ORC-biasing context a referential expectation will be produced which will be consistent with an ORC, thereby facilitating the time it takes to process the sentence. Thus, it is expected that the ORC-SRC difference will be reduced.

Experiment 1

In Experiment 1 subjects read ORCs and SRCs that were embedded in contexts that referentially licensed the use of the RC and answered a comprehension question about each. The presence of the restrictive RC was licensed by placing the RC-sentence after a short discourse that mentioned two members of the same category. For example, in the sample passage in Table 1, the critical sentence, *The child that chased the babysitter / the babysitter chased squealed with delight,* appeared following sentences that mentioned a babysitter and two children, one chasing the babysitter, and the other being chased by the babysitter. Thus, in the critical sentence the NP *the child* is referentially ambiguous, and the restrictive RC resolves this ambiguity. According to Gibson's (1998) DLT, the ORC-SRC difference should be reduced in such contexts because the RC in the critical sentence does not provide new information and therefore the storage and processing demands that occur in isolation – especially in ORCs – should be reduced. However, consistent with earlier findings using similar contexts (Battinich et al. 2012; Fedorenko et al. 2012) it was expected that the referentially licensed contexts will not reduce the ORC-SRC difference. This experiment also served to ensure that the methods and materials used would produce the usual ORC-SRC difference.

Method

Subjects: Forty-six native-English-speaking students who were enrolled in General Psychology courses at the University of Arkansas participated to partially fulfill a course research-participation requirement.

Materials: 40 experimental RC sentences (see Table 1 for example materials and appendix for all critical RC sentences) were adapted from Traxler, Morris, and Seely's (2002, Experiment 1) materials. Each RC was a single sentence (*M* length = 11.2 words, *SD* = 1.5) that

appeared either as an SRC or as an ORC. The SRC and ORC versions had the same words, but the order of the words within the RC was changed. As in Traxler et al.'s materials, in the experimental sentences the sentence subject and the entity in the RC were both human and were referred to using work and social role descriptions (e.g., *the babysitter*). Additionally for each of the experimental sentences, I wrote a three-or-four sentence context. The contexts described a situation in which one individual, the singleton (e.g., a babysitter), interacted with two individuals, the pair, with both members of the pair being from the same category and being referred to with the same label (e.g., child). The members of the pair were described such that one member of the pair was the subject of an action being performed with the singleton as the object (e.g., one child chased the babysitter) and the other member of the pair was the object of the same action with the singleton as the subject of the action (e.g., the babysitter chased the other child); the descriptions always appeared in this order. Following this context the critical ORC or SRC sentence appeared with the category label (e.g., the child) serving as the head noun of the RC-sentence and the RC itself serving to determine which member of the pair was the subject. Each passage was associated with a yes-no comprehension question, all of which queried who did what to whom within the RC.

In addition to the experimental contexts and passages, there were 58 filler passages. Each filler was three sentences in length, but none included non-reduced RCs. All fillers had an associated yes-no comprehension question. Across experimental items and fillers, half of all comprehension questions required a yes answer.

Design. Two lists were created such that half of the critical RCs in a list appeared as an SRC and the other half appeared as an ORC; each of the critical RCs switched roles in the other

list. Subjects were randomly assigned to a list. The design was a one-factor (clause type: SRC, ORC) within-subjects design.

Procedure. Subjects were tested individually. Each subject was seated comfortably at the eye-tracker with the eyes 36" from the computer monitor. The subject's chin was on a chin-rest and forehead against a forehead-rest to minimize head-movements. After the subject read on-screen instructions, the eye-tracker was calibrated using a 9-point on-screen grid, and calibration was repeated as necessary to ensure that the mean error of tracking was less than 0.5 degrees of visual arc, and the maximum error was less than 1 degree. Once calibration was completed, the subject began reading passages.

Each passage trial in the experiment began with a fixation point appearing on-screen where the first word of a passage was to appear (i.e., near the left side of the screen). While fixating this point, the subject pressed a button on a game controller, at which point the passage appeared on the screen. The subject read the passage and indicated being done by pressing the same button on the controller. Immediately following this button-press, a comprehension question appeared on screen along with two answer options, one to the left and one to the right. The subject pressed one of two buttons on the controller to answer the question, which also triggered the beginning of the next trial. One break occurred during the experiment, halfway through all of the passages. The eye-tracker was recalibrated following the break if necessary.

Results and Discussion

Analysis: My analyses focused on one region of interest: the RC minus the relative pronoun plus the main verb (e.g., chased the babysitter squealed / the babysitter chased squealed). The relative pronoun was not included because subjects typically do not fixate on it

(Traxler et al., 2005). I analyzed this as a region rather than individual words because for both SRCs and ORCs the words of the critical region are the same, just in a different order.

I report three standard eye-movement measures. *Gaze duration* is the sum of all fixation durations beginning with the first fixation in a region until the reader's gaze leaves the region, left or right. Gaze duration is usually taken as a measure of initial processing. *First-pass regressions* are the ratio/probability of eye-movements that crossed a region's left-hand boundary immediately following a first-pass fixation. First pass regressions are usually taken as a measure of early processing difficulties. *Total duration* is the sum of all fixation durations in a region regardless of order. Total duration is usually taken as a measure of late processing difficulties.

Four of the forty-six subjects answered < 70% of the comprehension questions correctly and were excluded from the analyses. Following Traxler, William, Blozis, and Morris (2005), for the critical region, fixation times less than 120 ms and greater than 3000 ms were also excluded. This outlier treatment procedure resulted in additional 7% of the data being excluded from further analysis. Effect sizes reported below are based on the by-subjects analyses.

For *gaze duration* in the licensed context the paired t-test revealed no significant differences between ORCs and SRCs by subjects $t_1(41) = 0.32$, $p > .05$, or by items $t_2(39) = 0.389$, $p = .69$. Gaze duration was longer in the ORC than in the SRC, but this difference was not significant (see Table 2).

For first pass regressions, paired t-tests revealed significantly more regressive eye-movements for ORCs ($M = .540$, $SD = .197$) compared to SRCs ($M = .389$, $SD = .197$) by subjects, $t_1(41) = 4.83$, $p = .001$, and by items, $t_2(39) = 5.59$, $p = .001$. These results indicate that

in the licensed context readers regressed to earlier portions of the text significantly more often for ORCs compared to SRCs.

For *total duration*, the paired t-test revealed that readers spent significantly longer in the critical region for ORCs ($M = 1634.5$, $SD = 551.0$) compared to SRCs ($M = 1363.9$, $SD = 476.7$) $t_1(41) = 6.28$, $p = .001$, $t_2(39) = 8.82$, $p < .001$. This result indicates that for the licensed context readers spent significantly more time reading the critical region for ORCs compared to SRCs.

Discussion

The results revealed a significant ORC-SRC difference in total time and first pass regressions. Although the results for gaze duration were not significant, the means were in the expected direction with the critical region of ORCs showing longer gaze durations than SRCs.

The significant effect for first pass regression ratios indicates that for the critical region readers made significantly more regressive eye-movements to earlier portions of the context for ORCs compared to SRCs. However, it is interesting to note that the typical rate of regressive eye-movements is 10-15% (Rayner, 1998) and the regression ratios in Experiment 1 are much higher than would be expected. There are a couple of possible explanations for this. First, non-reduced relative clauses are complex sentences and are typically more difficult to process than other types of sentences. Thus, the higher regression ratios may reflect the complexity of ORCs and SRCs compared to other types of sentences. A second possible explanation for the high regression ratios is that the critical region contained multiple words. First pass regression ratios reflect the probability that the reader will make a backwards regression for a given word. Therefore, combining multiple words into a single region may have also increased this statistic.

Finally, the significant effect for total duration clearly demonstrates the expected ORC-SRC difference. Total duration reflects the total time readers fixated on the critical region and

the results demonstrate that readers took significantly longer processing the critical region when it was an ORC compared to an SRC. In short, the results demonstrate that participants had more difficulty processing ORCs compared to SRCs.

Experiment 2

In Experiment 2, subjects read the same RC-sentences as in Experiment 1, but in this experiment the RC-sentences appeared in discourse contexts that biased towards an SRC interpretation or an ORC interpretation (see Table 1). As in Experiment 1, the presence of the restrictive RC was appropriate because the RC sentence appeared after a short discourse that mentioned two members of the same category. For example, in the sample passage in Table 1, the critical sentence, *The child that chased the babysitter / the babysitter chased squealed with delight*, appeared following contexts that biased towards an SRC interpretation or an ORC interpretation. The first sentence of both contexts introduced one babysitter and two children. The second sentence of the context described the action. For the SRC-biasing contexts the action was described such that *one of the children chased the babysitter and other did not*. For the ORC-biasing contexts the action was described such that *one of the children was chased by the babysitter and the other was not*. The third and final sentence was the critical RC. Thus in the critical sentence, the NP *the child* is referentially ambiguous, as in Experiment 1, and the restrictive RC resolves this ambiguity. Following Altmann and Steedman (1988), the contexts were constructed such that they were minimally different from one another; only the second sentence in which the action was described was different between the two types of contexts, and the effect was to change the principal meaning of the sentence. When the critical sentence is an SRC, the RC portion of the sentence refers to the member of the pair (e.g., *the child*) that is the agent of the action, which is consistent with the action described in the preceding sentence, and

therefore an SRC interpretation should be the most plausible. Conversely, in the ORC-biasing contexts the action describes the one member of the pair as the object of the action (i.e., the child that is being chased). When the critical sentence is an ORC the RC portion of the sentence refers to the member of the pair that is the object of the action and therefore an ORC interpretation should be most plausible. The SRC-biasing contexts made one of the pair much more likely to be the subject of the RC because the description in the second sentence of the context should make *the child* who is chasing *the babysitter* the most prominent referent (Lambrecht, 1994). The ORC-biasing contexts also made one of the pair much more likely to be the object of the RC. In this instance the ORC-biasing contexts *the child* who is the recipient of the action should be the most prominent referent. Thus, the expectancy hypothesis (Loncke et al. 2011) predicts that with ORC-biasing contexts the typical ORC-SRC difference seen both in isolation and in licensed contexts should be reduced. The expectancy hypothesis also predicts that for SRC-biasing contexts the ORC-SRC difference should be present. This is because readers that encounter an ORC following a SRC-biasing context will have a more difficult time determining the correct referent of the RC sentence. Finally, the expectancy hypothesis that processing ORCs following ORC-biasing contexts will be easier to process than ORCs following SRC-biasing contexts and SRCs following SRC-biasing contexts will be easier to process than SRCs following ORC-biasing contexts.

Method

Subjects: Forty-nine native-English-speaking students who were enrolled in General Psychology courses at the University of Arkansas participated to partially fulfill a course research-participation requirement.

Materials: For each of the forty critical RC sentences from Experiment 1 I wrote two contexts, one biasing towards an SRC interpretation and one biasing towards an ORC interpretation. All the contexts were two sentences in length. For example, the contexts in Experiment 1 introduced two children, one chasing the babysitter and the other being chased by the same babysitter. Thus, the actions of both children were described in which one member of the pair was the agent of the action and the other member of the pair the patient or theme of the action. By contrast, in the current experiment the first sentence of the contexts also described a singleton (e.g., *a babysitter*) interacting with a pair (e.g., *children*); however, the action described in the second sentence differed for the SRC-biasing and ORC-biasing contexts. For example, in the SRC-biasing contexts the action of only one member of the pair was described (e.g., *one of the children chased the babysitter*) and the second member of the pair was mentioned only as not taking part in the action (e.g., *and the other did not.*) Moreover, in the SRC-biasing contexts the agent of the action was always one of the pair (e.g., the child) and the patient of the action was always the singleton (e.g., the babysitter).

The ORC-biasing contexts also described only one action. However, in this instance the action described one member of the pair as the patient of the action (e.g., *One of the children was chased by the babysitter*) and the second member of the pair being described as not the patient of the action (e.g., *and the other was not.*). Thus, for ORC-biasing contexts the agent of the action was always the singleton (e.g., the babysitter) and the patient of the action was always one member of the pair (e.g., the child).

As in Experiment 1, the RC is still necessary because in the critical sentence the NP *the child* is still referentially ambiguous, and the RC resolves this ambiguity. In SRC-biasing contexts both members of the pair are mentioned but only one member of the pair is described as

being involved in the action (i.e., the child that performs the action). The same 58 filler passages from Experiment 1 were used in this experiment. A yes-no comprehension question followed each experimental and filler passage.

Design. Four lists were created such that in each list one-fourth of the critical SRCs followed SRC-biasing contexts and one-fourth followed ORC-biasing contexts. Additionally, one-fourth of the critical ORCs followed ORC-biasing contexts and one-fourth followed SRC-biasing contexts. Moreover, each critical RC switched roles in the other lists. Thus, the design was a 2 (context: SRC bias, ORC bias) x 2 (RC: SRC, ORC) x 4 (list) mixed design, with clause type being manipulated as within subjects and list between subjects. However, the last factor is of no theoretical interest.

Procedure. The procedure was the same as in Experiment 1.

Results & Discussion.

Data cleaning and analysis. For comprehension accuracy in Experiment 2 I used a cut-off of 75% rather than 70% as in Experiment 1. This cut-off was chosen because overall accuracy was clearly lower in the biased condition. Including all subjects accuracy in the biased condition is 78.2%. In the licensed condition in Experiment 1 it was 84%. Four of the 49 subjects answered < 75% of the comprehension questions correctly. I also excluded short and long fixation times according to the criteria described in Experiment 1, which resulted in additional 7% of the data being excluded from further analysis. Additionally two other subjects were removed from the analysis due to faulty tracking.

Analyses were carried out as in Experiment 1.

Reading times in region of interest. The same region of interest in Experiment 1 was examined in Experiment 2.

Gaze duration: For the critical region there was a main effect of clause type. ORCs (M = 792.9 ms, SE = 31.3) were read significantly slower than SRCs (M = 730.1 ms, SE = 30.1), $F_1(1,42) = 5.45, p = .024$, $F_2(1,39) = 4.23, p = .04$, $\eta^2_p = .09$. There was no significant effect of context or interaction between the two factors (Fs < 1) (see Figure 1). Planned comparisons for the ORC-biasing context on the ORC-SRC difference was not significant, $t_1(42) = 1.409, p = .16$, $t_2(39) = 1.226, p = .22$. In the SRC-biasing context the ORC-SRC difference was significant by subjects $t_1(42) = 2.36, p = .02$, and nearly so by items $t_2(39) = 1.99, p = .053$, with ORCs (M = 806.4 ms, SE = 29.28) being more difficult to process in the SRC-biasing context than SRCs (M = 731.8 ms, SE = 29.9).

First pass regressions: The analysis of first-pass regressions revealed a main effect for clause type that was significant by subjects, $F_1(1,42) = 4.29, p = .04$, but not quite so by items $F_2(1, 39) = 2.37, p = .13$, $\eta^2_p = .05$. There were no other significant main effects or interaction (all Fs < 1) (see Figure 2). Readers made significantly more regressions out of the critical region for ORCs (M = .407, SE = .02) compared to SRCs (M = .355, SE = .03). Planned comparisons for first-pass regressions in the ORC-biasing context revealed no significant difference between ORCs and SRCs, $t_1(42) = 1.37, p = .17$, $t_2(39) = 1.03, p = .30$. For the SRC-biasing context there was also no significant difference, $t_1(42) = 1.69, p = .09$, $t_2(39) = 1.41, p = .16$.

Total duration: Analysis of total duration revealed a main effect for clause type such that readers spent significantly longer reading ORCs (M = 1567.7 ms, SE = 75.8) compared to SRCs (M = 1297.4 ms, SE = 58.4), $F_1(1, 42) = 35.94, p < .001$, $F_2(1, 39) = 28.86, p < .001$, $\eta^2_p = .42$. This effect is qualified by a significant clause-by-context interaction, $F_1(1, 42) = 22.82, p < .001$, $F_2(1, 39) = 19.09, p < .001$, $\eta^2_p = .32$ (Figure 3). Thus, the interaction revealed that when the context was ORC-biasing, ORCs (M = 1491.3 ms, SE = 79.0) were not significantly more

difficult to process than SRCs (M = 1415.9 ms, SE = 73.2). Conversely, when the context was SRC-biasing, ORCs (M = 1644.1 ms, SE = 87.0) were significantly more difficult to process than SRCs (M = 1179.0 ms, SE = 52.3). Planned comparisons revealed that for the ORC-biasing context there were no significant differences between ORCs and SRCs by both subjects and items, $t_1(42) = 1.26$, p =.21, $t_2(39) = 1.06$, p = .29. In the SRC-biasing context the ORC-SRC difference was significant by both subjects and items, $t_1(42) = 7.50$, p =.001, $t_2(39) = 7.20$, p = .001, with ORCs (M = 1644.1 ms, SE = 87.0) showing significantly longer total durations in the SRC-biasing context compared to SRCs (M = 1179.0 ms, SE = 52.3).

Discussion

For gaze duration, the results demonstrate that the different biasing contexts did not differentially influence the processing of ORCs and SRCs. ORCs showed significantly longer gaze durations than SRCs regardless of context. Thus, subjects took longer to read the RCs on their first pass through for ORCs compared to SRCs. Although the difference was not significant, SRCs did show slightly longer gaze durations in the ORC-biasing context (M = 742.1 ms, SE = 31.6) compared SRC-biasing contexts (M = 718.2 ms, SE = 33.4).

Context also did not have a differential influence on first pass regressions. The probability that readers would regress out of the critical region to earlier portions of the context was significantly greater for ORCs than for SRCs regardless of context. However, the paired t-tests revealed that when the context biased towards an ORC interpretation the ORC-SRC difference was reduced. Thus, the probability that readers would regress out of the critical region was significantly less for ORCs in the ORC-biasing context. For the SRC-biasing contexts the t-test demonstrated significant differences in first pass regressions. Thus, the

probability that readers would regress out of the critical region was significantly greater for ORCs compared to SRCs.

For total duration, the results demonstrated that context did differentially influence the total amount of time readers spent in the critical region as indicated by the significant clause-by-context interaction. When the context biased towards an ORC interpretation, ORCs were no more difficult to process than SRCs. Thus, readers did not spend significantly more amount of time in the critical region for ORCs compared to SRCs in the ORC-biasing context. By contrast, when the context biased towards an SRC interpretation readers spent a significantly longer amount of time in the critical region when processing ORCs compared to SRCs. Total duration reflects the total time a reader fixated on the critical region including the reader's first fixation and any subsequent fixations that followed due to re-reading. Thus, when the context was SRC-biasing readers spend more time re-reading the critical region of ORCs compared to SRCs. Finding a significant clause-by-context interaction for total duration and not in the early measures of gaze duration and first-pass regressions suggests that the biased contexts were not able to fully reduce the complexity issues of ORCs. Although both gaze duration and first-pass regressions for ORCs were slightly lower in the ORC-biasing contexts compared to the SRC-biasing contexts this difference was non-significant. Thus, context appears to have a greater influence on late processing rather than early processing. The results of the paired t-tests demonstrate that when the context was ORC-biasing there were no significant differences between ORCs and SRCs in the total time readers spent in the critical region. However, when the context was SRC-biasing readers spent a significantly longer time in the critical region for ORCs compared to SRCs. Thus, ORCs showed more re-reading of the critical region when the context was biased towards and SRC interpretation.

Cross-experiment comparisons

Besides theoretical interest cross-experiment comparisons are justified because the samples from the two experiments came from the same population, the same critical sentences appeared in both experiments, and the two experiments were run partially contemporaneously.

I first compared whether the licensed contexts from Experiment 1 and the biased contexts from Experiment 2 had differing influences on the three dependent measures of gaze duration, first pass regression ratios and total duration for ORCs and SRCs. Secondly, I examined whether the licensed contexts from Experiment 1 and the biased contexts from Experiment 2 differentially influenced the ORC-SRC difference.

For each subject and item ORCs in licensed context and ORCs in the two biasing contexts were subjected to independent measures t-test's respectively. SRCs in licensed contexts were compared to SRCs in the two biasing contexts as well using the same analysis.

For gaze duration there were no significant difference between ORCs in the licesened context (M = 737.9, SD = 220.7) and ORCs in ORC-biasing contexts (M = 787.8, SD = 228.1), $t_1(83) = -1.03$, $p = .31$, $t_2(78) = -1.09$, $p = .28$. For ORCs in SRC-biasing (M = 798.1, SD = 220.7) contexts and ORCs in licensing contexts there were also no significant differences $t_1(83) = -1.25$, $p = .22$, $t_2(78) = -1.44$, $p = .16$.

For SRCs in licensing context (M = 729.6, SD 177.0) and SRCs in ORC-biasing contexts (M = 742.1, SD = 207.5) there were no significant differences $t_1(83) = -0.30$, $p = .77$, $t_2(78) = -0.52$, $p = .60$. For SRCs in SRC-biasing contexts (M =718.22) and SRCs in licensing contexts there were also no significant differences $t_1(83) = 0.26$, $p = .79$, $t_2(78) = 0.13$, $p = .90$

For first pass regressions for ORCs in licensing contexts (M = .540, SD = .197) and ORCs in ORC-biasing contexts (M = .396, SD = .194) the results revealed that readers made

significantly more regressive eye-movements for ORCs in licensing contexts compare to ORCs in ORC-biasing contexts $t_1(83) = 3.05$, $p = .001$, $t_2(78) = 3.68$, $p = .001$. For ORCs in SRC-biasing contexts ($M = .413$, $SD = .197$) and ORCs in licensing contexts the results revealed that readers made significantly more regressions when the context was licensing compared to SRC-biasing there were also significant differences $t_1(83) = 2.78$, $p = .01$, $t_2(78) = 3.47$, $p = .001$.

For SRCs in licensing contexts ($M = .389$, $SD = .197$) and SRCs in ORC-biasing contexts ($M = .358$, $SD = .226$) there were no significant differences $t_1(83) = .687$, $p = .49$, $t_2(78) = 1.07$, $p = .29$. For SRCs in SRC-biasing contexts ($M = .352$, $SD = .197$) and SRCs in licensing contexts there were also no significant differences $t_1(83) = .795$, $p = .43$, $t_2(78) = .975$, $p = .33$.

Total duration for ORCs in licensing contexts and ORCs in ORC-biasing contexts demonstrated that the difference was not significant by subjects $t_1(83) = 1.23$, $p = .22$, but was significant by items $t_2(78) = 2.13$, $p = .04$ (ORC-biasing: $M = 1492.57$, $SD = 337.40$; Licensing: $M = 1646.02$, $SD = 307.02$). Thus, for ORCs readers spent a significantly longer total amount of time in the critical region for licensing contexts compared to ORC-biasing contexts. For ORCs in SRC-biasing ($M = 1644.1$, $SD = 570.8$) contexts and ORCs in licesening contexts ($M = 1634.5$, $SD = 551.1$) there were no significant differences $t_1(83) = .-0.07$, $p = .94$, $t_2(78) = -.04$, $p = .97$.

For SRCs in ORC-biasing contexts (M = 1415.9, SD = 480.4) and SRCs in licensing contexts (M = 1363.9, SD = 476.8) the results revealed no significant differences $t_1(83) = -0.50$, $p = .62$, $t_2(78) = -0.56$, $p = .58$. For SRCs in SRC-biasing context and SRCs in licensing contexts the results revealed that readers spent a significantly longer total amount of time reading SRCs in licensing contexts ($M = 1373.5$, $SD = 282.4$) compared to reading SRCs in SRC-biasing contexts ($M = 1179.0$, $SD = 343.3$), $t_1(83) = 2.06$, $p = .04$, $t_2(78) = 2.56$, $p = .01$.

To examine the ORC-SRC difference between Experiment 1 and Experiment 2 for each subject and item in Experiments 1 and 2, an ORC-SRC effect was computed by subtracting mean SRC reading time from mean ORC reading time; positive scores indicate longer reading time on ORCs. Thus, I compared the ORC-SRC difference in the ORC-biasing context (in Experiment 2) to the ORC-SRC difference in the licensing context (in Experiment 1) and then I did the same for the ORC-SRC difference in the SRC-biasing context (in Experiment 2).

For gaze duration the t-tests revealed no significant differences in the ORC-SRC difference between ORC-biasing contexts and licensed contexts either by subjects or items, $t_1(83) = -0.91, p = .36, t_2(78) = -0.56, p = .57$. Comparing the ORC-SRC difference in the SRC-biasing context with the ORC-SRC difference in the licensed context the t-test also revealed no significant differences by both subjects and items, $t_1(83) = -1.69, p = .09, t_2(78) = -1.26, p = .21$.

For first pass regressions the t-tests revealed that the ORC-SRC difference in the ORC-biasing context was significantly different from the ORC-SRC difference in the licensed context by both subjects and items, $t_1(83) = 2.48, p = .01, t_2(78) = 2.46, p = .01$. Thus, the ORC-SRC difference was significantly greater in the licensed context ($M = .148$, $SE = .02$) compared to the ORC-biasing context ($M = .037$, $SE = .03$). Comparing the ORC-SRC difference in the SRC-biasing context with the ORC-SRC difference in the licensed context, the t-test revealed that the difference was marginally significant by subjects and significant by items, $t_1(83) = 1.89, p = .06$, $t_2(78) = 2.13, p = .03$. Thus, the ORC-SRC difference was also significantly greater in the licensing context ($M = .151$, $SE = .03$) compared to the SRC-biasing contexts ($M = .060$, $SE = .03$).

For total duration the t-tests revealed that the ORC-SRC difference in the ORC-biasing context was significantly different from the ORC-SRC difference in the licensed context by both

subjects and items, $t_1(83) = 2.64, p = .01$, $t_2(78) = 2.68$, $p = .00$. Thus, the ORC-SRC difference was significantly greater in the licensed context ($M = 270.5$ ms, $SE = 43.0$) compared to when the context was ORC-biasing ($M = 75.4$ ms, $SE = 59.9$). Comparing the ORC-SRC difference in the SRC-biasing context with the ORC-SRC difference in the licensed context the t-test also revealed significant differences by both subjects and items, $t_1(83) = -2.56, p = .01$, $t_2(78) = -2.57$, $p = .01$. However, this time the results indicate that the ORC-SRC difference was significantly greater for the SRC-biasing context ($M = 465.1$ ms, $SE = 61.9$) compared to the licensing context ($M = 270.5$ ms, $SE = 43.0$).

Discussion

The results of the cross experiment analyses demonstrated that the licensed and biased contexts had different influences on first pass regression ratios and total duration. It was revealed that licensing and biasing contexts did not have a differential influence on gaze duration for both SRCs and ORCs.

For first-pass regressions the results demonstrated that for ORCs readers made significantly fewer regressive eye-movements when the contexts were ORC-biasing or SRC-biasing compared to when the context was licensing. For SRCs there were no significant differences between licensing contexts and the two biasing contexts.

For total duration the results revealed that for ORCs readers spent significantly less time in the critical region when the context was ORC-biasing compared to when the context was licensing. However, this effect was significant only by items. When the context was SRC-biasing readers did not spend a significantly longer amount of time in the critical region compared to licensing context when processing ORCs.

For SRCs the results revealed that in ORC-biasing contexts there was not a significant difference in the total amount of the time readers spent in the critical region compared to licensing contexts. When the context was SRC-biasing readers spent significantly less amount of total time in the critical region compared to licensing contexts.

With regards to the ORC-SRC difference it was revealed that for biasing contexts, both SRC-biasing and ORC-biasing, the ORC-SRC difference was significantly smaller than in the licensing context for first-pass regression ratios. This was significant for the ORC-biasing contexts but only marginally so for the SRC-biasing contexts. This indicates that the critical ORCs and SRCs were more comprehensible when they appeared in biasing contexts compared to when they appear in licensed contexts.

For total duration the results demonstrated that the ORC-SRC difference was significantly less for the ORC-biasing context compared to the licensed context. Thus, when the context was ORC-biasing the ORC-SRC difference was significantly less than in licensing contexts. However, the opposite pattern was found for SRC-biasing contexts. When the context was SRC-biasing to the ORC-SRC difference was significantly greater than when the context was licensing. One explanation for this is that the SRC-biasing context made ORCs much more difficult to comprehend. By contrast, in the ORC-biasing contexts SRCs were only slightly more difficult.

General Discussion

The purpose of these experiments was to investigate how biased contexts would influence the processing of SRCs and ORCs. Experiment 1 was designed to first examine the processing of these RC-sentences in nominally-unbiased contexts, and replicated two recent findings (Battinich et al., 2012; Fedorenko et al., 2012) that demonstrated the ORC-SRC difference was

still significant in contexts that licensed the use of both SRCs and ORCs. It also provided comparison conditions for the biased contexts in Experiment 2. Experiment 2 revealed that the biased context differentially influenced the processing of restrictive-RCs with the ORC-SRC difference being significantly reduced in the ORC-biasing contexts for total duration.

With respect to the results of Experiment 1, the active-filler strategy (Frazier & Flores D'Arcais, 1989) and DLT (Gibson, 1998; Warren & Gibson, 2002) both predict a reduction in the ORC-SRC difference when embedded in referentially-appropriate contexts. Because all the discourse referents and their actions were established prior to encountering the critical RC, DLT predicted that the increased processing costs associated with ORCs should be reduced, reducing the ORC-SRC difference. Conversely, the active-filler strategy predicted that the prior context would facilitate re-analysis of ORCs thereby reducing the ORC-SRC difference. With regard to the similarity-interference approach (Gordon et al., 2001), if similarity is strictly a function of the type of NPs that appear in the critical sentence and is unaffected by prior context, then the ORC-SRC difference can be readily explained. However, if the prior context enables the representation of the two NPs to be discriminable, the similarity-interference approach would also predict the ORC-SRC difference to be reduced by prior context. Thus, these theories are unable to explain the results of Experiment 1 (but see Fedorenko et al., 2012 for a modification of DLT that might explain these results).

One additional possible explanation for why the licensing contexts did not reduce the ORC-SRC difference is that the contexts may have primed an SRC construction. Branigan, Pickering, and McLean (2005), among others, have shown that when a syntactic structure is repeated, the second encounter with that structure is facilitated. In the licensing contexts I used (see Table 1), the last sentence prior to the critical RC described the actions. The first action

described is a passive construction (e.g., *the child was chased by the babysitter*) which is consistent with the meaning of an ORC, but also has a subject-verb-object (SVO) ordering to its constituents. The second action described was an active construction also with an SVO order (e.g., *the other child chased the babysitter*), which is more similar to an SRC construction, which has an SVO ordering (e.g., *that chased the babysitter*), whereas an ORC has an OSV ordering (e.g., *that the babysitter chased*). Moreover, the order of these actions was the same for all the contexts. Thus, it is possible that because the repetition of SVO structures in the context, the context syntactically primed the SRC construction.

Experiment 2 was intended to further investigate the role of context in the processing of restricted-RCs. To do this, I embedded the critical RC sentences in contexts that biased towards either an ORC or SRC construction (see Table 1). For the ORC-biasing contexts the second sentence describes the action and is in the passive voice (e.g., *One child was chased by the babysitter*) which is to how ORCs are interpreted, although still similar structurally to an SRC (i.e., it has an SVO ordering). For example, in both the ORC-biasing context and ORC critical sentences it is the babysitter who is chasing the child. Thus, the ORC-biasing context makes one of the pair more prominent and much more likely to be the referent of the critical RC. By contrast, the SRC-biasing context describes the action in the active voice following a SVO ordering, and is similar to an SRC construction because SRCs follow the same SVO structure (e.g., *One child chased the babysitter*). Moreover, the SRC-biasing contexts also make one of the pair more prominent (e.g., *the child that chased the babysitter*). Thus, the expectancy hypothesis would predict that ORC-biasing contexts would facilitate the processing of ORCs and that SRC-biasing contexts would facilitate the processing of SRCs. The results of Experiment 2 demonstrate that the biasing contexts had a differential influence on the ORC-SRC difference. It

was revealed that in general ORCs were more difficult to process than SRCs regardless of context. However, the context did have a differential influence on the ORC-SRC difference. In the ORC-biasing context the ORC-SRC difference was non-significant for all measures. By contrast, in the SRC-biasing context the ORC-SRC difference was significant. Gibson's (1998, Warren & Gibson, 2002) DLT posits that the difficulty with ORCs in isolation is a result of increased storage and computational demands. However, both the SRC- and ORC-biasing contexts introduce all the discourse referents and their actions prior to encountering the critical RC-sentence. Thus, DLT would predict that the ORC-SRC difference should be reduced for both types of contexts because the processing and storage costs typically associated with ORCs should have been reduced. DLT argues that introducing new discourse referents comes with a processing cost in terms of integration and these costs will increase with the number of referents that intervene between elements that need to be integrated. Both SRCs and ORCs introduce the same number of discourse referents however, in isolation integration and storage costs are higher for ORCs than for SRCs. For example, consider the SRC in (22) and ORC in (23). For SRCs

(22) *The child that chased the babysitter squealed with delight.*

(23) *The child that the babysitter chased squealed with delight.*

the child, *chased*, and *the babysitter*, all have an integration cost of 1 but there are no extra integration or storage costs since no other discourse referents intervene between the elements that need to be integrated. Conversely, in the ORC in (23), the same number of new discourse referents are introduced, but in this instance integrating the head NP (*the child*) as the object of the RC-internal verb (*chased*) has a higher integration cost because two new discourse referents are introduced (i.e., *the babysitter* and *chased*) before integration can occur. Therefore,

embedding the critical RCs in a prior context that introduces all the discourse referents and their actions should reduce integration costs for ORCs because the referents in the critical RC sentence are not new and thus should no impose an additional cost. As such the ORC-SRC difference should be reduced.

A second memory-based explanation, the similarity interference approach (Gordon et al. 2001), also cannot explain the results from Experiment 2. This approach argues that the processing difficulty with ORCs is due to readers having to maintain in memory two NPs that are similar lexically and semantically for a period of time until they can be integrated with the proper verb, resulting in the ORC-SRC difference. On one hand, if similarity is simply a function of lexical and semantic properties and is not influenced by context, then the similarity-interference approach would predict the ORC-SRC difference to be significant regardless of context. By contrast, if a reader's representation is influenced by context, then the differing descriptions of the NPs in the biased contexts should have made the two NPs discriminable from one another thereby reducing the ORC-SRC difference for both SRC biasing and ORC-biasing contexts.

Of the syntax-based theories, the active-filler strategy (Frazier & Flores D'Arcais, 1989) also has a difficult time accounting for the full range of results seen in Experiment 2. The active-filler strategy posits that the initial structure of the sentence is determined solely by syntactic information and that the default structure follows an SRC interpretation. Any non-syntactic information, such as context, is only accessed and used during re-analysis. In other words, according to the active-filler strategy, if the initial structure created is determined to be wrong the parser then accesses any available non-syntactic information to help facilitate the process of re-analysis. For ORC-biasing contexts the active-filler strategy correctly predicts a reduction in the ORC-SRC difference. When ORCs are embedded in ORC-biasing contexts, the information in

the context should speed up re-analysis because the actions described are consistent with an ORC interpretation (i.e., it is the child being chased by the babysitter). However, the active-filler strategy does not predict the increased processing time for SRCs when they are embedded in an ORC-biasing context. According to the active-filler strategy the parser is impervious to contextual information during its initial construction of the syntactic structure of the sentence, with SRCs being the default argument form. Thus, if contextual information does not influence the initial parse of the sentence then processing an SRC in an ORC-biasing context should proceed smoothly. However, the results reveal a non-significant increase in processing time for SRCs in ORC-biasing contexts for both gaze duration and first-pass regressions compared to SRCs in SRC-biasing contexts, suggesting that the context may have had an influence on initial parsing decisions.

In the SRC-biasing context the results revealed increased processing time for ORCs and decreased processing time for SRCs. The active-filler strategy can account for the former but not the latter. For SRC-biasing contexts, when readers' encounter an ORC, re-analysis should be initiated at the word following the relative pronoun and contextual information should then be accessed and used. However, the information in the SRC-biasing context is dissimilar to an ORC interpretation and should therefore not help with re-analysis. For example, consider the SRC-biasing context with an ORC like in (24). The second sentence of the context describes the

(24) *A babysitter was playing games with two children. One of the children chased the babysitter and the other did not.*

The child that the babysitter chased squealed with delight.

action such that *the child* is the agent of the verb *chased* and *the babysitter* is the theme. In the critical ORC, however, it is *the babysitter* who is the agent of the verb *chased* and *the child* is the

recipient. Thus, the contextual information of an SRC-biasing context should not facilitate the re-analysis of an ORC. Rather the contextual information should make re-analysis more difficult because the information in the context does not correspond to an ORC interpretation, and the results demonstrate this. By contrast, the active-filler strategy does not predict a speed up in processing for SRCs in SRC-biasing contexts. Again, if the parser is informationally-encapsulated from non-syntactic information, then processing SRCs in context, biasing or otherwise, should not be different from processing SRCs in isolation. Rather, the SRC-biasing context made SRCs easier to process than the ORC-biasing contexts. This difference was non-significant in the early measures of gaze duration and first-pass regressions but it was significant in the total duration measure. This suggests that the context may have had an impact on parsing decisions.

Of the proposed theories, the expectancy hypothesis (Arnold, 2001; Arnold et al., 2006)) best accounts for the results in Experiment 2. This hypothesis proposes that referential resolution is facilitated when discourse entities are prominent in the discourse or are in positions that are syntactically parallel to that of the intended referent (Chambers & Smyth 1998). Experiment 1 demonstrated that licensing contexts did not reduce the ORC-SRC difference replicating earlier findings (Battinich et al., 2012; Fedorenko et al., 2012). One possible explanation is that even though the licensing contexts introduced all the discourse referents and their actions, it did not make one of the referents more prominent than the other. For example consider the licensed context in (25). In this instance the second sentence of the context

(25) *A babysitter was playing games with two children. One child was chased by the babysitter and the other child chased the babysitter.*

The child that chased the babysitter /the babysitter chased squealed with delight.

describes the action in such a way that one of the pair (e.g., two children) is the recipient of action (e.g., *was chased by the babysitter*) and the other is the agent of the action (e.g., *chased the babysitter*). However, the context does not seem to make one of the referents stand out more than the other, thereby failing to reduce the ORC-SRC difference.

By contrast, in Experiment 2 the biasing contexts may have helped the parser determine which of the pair the intended referent was. For example, in the ORC-biasing context the action (e.g., *One child was chased by the babysitter and the other was not.*) describes the pair very differently, making one of pair seemingly more important to the discourse and the SRC-biasing context did the same (e.g., *One child chased the babysitter and the other did not*). Moreover, research has shown that referent prominence can influence referent identification (Lambrecht, 1994; Song & Fisher, 2005). Thus, when readers encounter the RC portion of the critical sentence, they must determine which referent is being referred to, and the contexts may have helped with this process. In the case of ORCs, when the context is ORC-biasing, the information provided by the context should make one of the pair (e.g., the child that was chased by the babysitter) more likely to be the intended referent. In other words, of the possible referents the one who is the most prominent or salient should be selected as the referent of the head-NP. Thus, when the context matches the critical RC, processing should be facilitated because the referent being referred to in the RC is the most salient referent in the context. Conversely, when there is a mismatch between the context and the critical RC-sentence, processing should slow down. For example, when readers encounter the RC of an ORC that is embedded in an SRC-biasing context as in (26), determining the correct referent of the RC should be more difficult

(26) *A babysitter was playing games with two children. One of the children {chased the babysitter} and the other did not.*

The child that {the babysitter chased} squealed with delight.

because the salient entity in the context is not the entity being referred to in the RC portion of the sentence. Therefore, processing time should increase. In other words, the biased contexts helped make one of the referents more likely to be the correct referent of the RC and when the context matched the RC type this facilitated the selection of the correct referent. By contrast, when there was a mismatch between context and the RC type the reduction in ambiguity did not help with the selection of the correct referent. In the case of ORCs this mismatch was found to significantly increase processing time for total duration. With total duration being a measure of later processing this may suggest that readers had trouble determining the correct referent of the RC in an ORC that is embedded in a SRC-biasing context. Also, it is possible that because the biasing contexts made one of the referents more likely to be the correct referent of the critical RC readers may have partially interpreted the head NP before they even encountered the relative pronoun. Thus, when the context mismatched the critical RC readers may have had to initiate re-analysis.

However, there is another alternative explanation: syntactic priming. Research has shown that syntactic structures can be primed (Branigan, Pickering, McLean, & Cleland, 2007; Loncke, Van Laere, & Desmet, 2011; Tooley, & Traxler, 2010). Syntactic priming refers to the finding that processing a syntactic structure is easier if it has been encountered recently. Therefore it is possible that the syntactic structures for SRCs and ORCs could have been primed due to how the contexts were constructed. In the SRC-biasing contexts the actions described followed the typical subject-verb-object order that is consistent with an SRC interpretation. For example, consider the second sentence in an SRC-biasing context seen in (27). *The child* is the

subject, *chased* is the verb, and *the babysitter* is the object and this SVO order is the same for the critical

(27) *A babysitter was playing games with two children. One of the children chased the babysitter and the other did not.*

The child that chased the babysitter squealed with delight.

SRC.

For the ORC-biasing contexts, despite that the actions described did not have a corresponding object-subject-verb order; it was described in the passive voice which is consistent with how ORCs are interpreted. For example, consider the second sentence in following ORC-biasing context in (28). Although the structure of the information in the second sentence of the

(28) *A babysitter was playing games with two children. One of the children was chased by the babysitter and the other was not.*

The child that the babysitter chased squealed with delight.

context follows an SVO order, the intended meaning of the sentence is that *the babysitter* is the one who is chasing *the child* and this is consistent with how ORCs are intended to be interpreted. Thus, when readers encounter the head NP and the relative pronoun (e.g., *The child that*) it is possible that the prior context may have primed an RC construction that is consistent with biasing context. Therefore, if syntactic priming did occur this could also possibly explain the results of Experiment 2. If ORC-biasing contexts syntactically primed an ORC interpretation and SRC-biasing contexts syntactically primed an SRC interpretation then it could be expected that processing would be facilitated when the context matched the RC type. Conversely, when there is a mismatch between context and RC type it could be expected that processing would slow down and this precisely what the results revealed.

With respect to the context-by-clause interaction the results revealed that it was only significant for total duration and not gaze duration or first-pass regressions. In other words, the biasing contexts had less of an impact on the early measures of processing compared to later measures. For example, gaze duration is a measure of early processing and is usually interpreted to reflect both lexical access as well as text integration processes. It is further affected by both word frequency and the predictability of the word in the context (Rayner, 1998). Thus, the biasing contexts did not have a great impact on readers' ability to access the lexical meaning of a given word or their ability to predict upcoming words. In fact, for gaze duration processing ORCs in ORC-biasing contexts only facilitated processing by 10.2 ms compared to processing ORCs in SRC-biasing contexts. In short, the biasing contexts had little influence on the early processing of SRCs and ORCs. The same can be said for first-pass regressions, which are interpreted to be the probability that a reader will regress for a given word. As with gaze duration, the biasing contexts did not significantly reduce the ORC-SRC difference in first-pass regressions. In short, the results early measures of sentence processing were not greatly affected by context in the two experiments reported here. By contrast, total duration is measure of late processing and is interpreted to reflect late processing difficulties. Specifically, total duration is the total amount of time readers fixated on the words in a region, both the reader's first fixations of the words and all subsequent fixations that are a result of re-reading. When ORCs were embedded in ORC-biasing contexts, the total amount of time readers spent in the critical region was significantly less than when ORCs were embedded in SRC-biasing contexts (see Figure 3).

The results of the cross-experiment analyses are also potentially interesting. It was revealed that the licensing and biasing contexts had differential influences on readers' first-pass regressions and total durations. For ORCs, the results demonstrated that when an ORC-biasing

or SRC-biasing context preceded the critical ORC readers made significantly fewer regressive eye-movements compared to when a licensing context preceded the critical sentence. Conversely, for SRCs the results revealed that there were no significant differences between the biasing and licensing contexts for regressive eye-movements. Gibson's (1998) memory-based explanation DLT would predict no significant differences between the licensing and biasing contexts for both ORCs and SRC since all the relevant discourse entities and actions were introduced prior to the critical sentence. Thus, DLT would argue that the critical-RC did not introduce new discourse referents and therefore costs to storage and integration should be reduced for the contexts used in Experiment 1 and Experiment 2. This appears to be true for SRCs but not ORCs.

The similarity-interference approach (Gordon et al., 2001) also has trouble explaining the different pattern of results for ORCs and SRCs. If processing difficulty is a function of the two NP's having similar semantic and lexical properties it could be expected that processing should be easier in the biasing contexts compared to the licensing contexts. This is because in the biasing contexts the two similar NPs were described differently. One of the NP's was described as a child while the second child was simply referred to as 'the other'. Thus, according to the similarity interference approach describing the pair differently should have led to different mental representations making it easier for readers to discriminate which of the pair is being referred to in the critical-RC and integrating the correct NP with the proper verb. For ORCs this seems to be the case. ORCs showed significantly fewer regressive eye-movements for both types of biasing contexts compared to licensing contexts. This could possibly suggest that the differing descriptions of the similar referents described in the context reduced the complexity of the reader's mental representations making it easier for readers to integrate the correct referent

with the correct verb in the critical-RC. Furthermore, this should have been true for SRCs as well. However, the results demonstrate that readers did not make significantly fewer regressive eye-movements when SRCs followed either of the biasing contexts compared to the licensing contexts as would be predicted by the similarity-interference approach. Thus, having the two similar referents described differently in the biasing contexts did not seem to help readers select the correct referent of the RC-internal verb for SRCs.

The active-filler strategy (Frazier & Flores D'Arcais, 1989) on the other hand may be able to account for the pattern of regressive eye-movements. According to this strategy contextual information is used only after the initial analysis of the sentence has been shown to be wrong. It is at this point that contextual information is accessed and used to help facilitate re-analysis. The active-filler strategy argues that SRCs are the default structure preferred by the parsing mechanism thus SRCs should not require re-analysis and therefore the contextual information would not be necessary. By this account SRCs should not be any more difficult or easier to process in either of the biasing contexts compared to licensing contexts and the results support this. By contrast, according to the active-filler strategy ORCs require re-analysis and therefore contextual information should be useful for facilitating this process. One possible reason why re-analysis should be faster in the biasing contexts compared the licensing context is that the descriptions used in the licensing contexts may be more confusable than the biasing contexts. For example, consider the licensing context in (29) and the ORC-biasing context in (30). In the

(29) *A babysitter was playing games with two children. One child was chased by the babysitter and the other child chased the babysitter.*

(30) *A babysitter was playing games with two children. One of the children was chased by the babysitter and the other was not.*

licensing context such as in (29) the descriptions of the two children are similar to one another and use the same role-description to describe the pair. Thus, when the parser accesses the contextual information to help with re-analysis it may take the parser longer to select which referent the critical-RC is referring to. Conversely, in the biasing contexts such as in (30) the descriptions of the two children are not similar. Therefore, when the parser accesses the contextual information of the biasing contexts during re-analysis the differing descriptions should make it easier to select the correct referent thereby facilitating re-analysis for ORCs.

For total duration the results revealed that ORCs were easier to process in ORC-biasing contexts and SRCs were easier to process in SRC-biasing contexts compared to licensing contexts. Again both DLT (Gibson, 1998) and the similarity-interference approach are unable to account for this pattern of results. DLT predicts that ORCs and SRCs should not be anymore easier or difficult to process in biasing contexts compared to licensing contexts due to all the discourse referents and actions being established in the prior context. By contrast the similarity interference approach predicts that ORCs and SRCs should be easier to process in biasing contexts, ORC-biasing and SRC-biasing, compared to licensing contexts.

The active-filler strategy (Frazier & Flores D'Arcais, 1989) may also have difficulty explaining the pattern of results for total duration. This strategy predicts that contextual information is only used during the process of re-analysis and that SRCs are the default structure chosen by parsing mechanism. The, the active-filler strategy successfully predicts that ORCs should be easier to process in ORC-biasing contexts compared to SRC-biasing contexts and licensing contexts but it does not predict that SRCs should be easier in SRC-biasing contexts compared to ORC-biasing contexts or licensing contexts as the results demonstrate. Rather for SRCs the active-filler strategy predicts no differences regardless of context.

For total duration the expectancy hypothesis (Chambers & Smyth 1998) may best account for the pattern of results. This hypothesis attempts to explain why certain entities are more accessible than others when it comes to reference resolution (Arnold, 2001; Arnold, Brown-Schmidt & Trueswell, 2007) and argues that referential resolution is facilitated when discourse entities are prominent in the discourse or are in positions that are syntactically parallel to that of the intended referent. The two biasing contexts used in Experiment 2 did make one of the referents more prominent than the other. By contrast the licensing contexts did not make one of the referents more prominent over the other. For ORCs in ORC-biasing contexts (i.e., 30) the prominent referent in the second sentence of the context is the child that the babysitter is chasing. Therefore, upon encountering the head NP (e.g., the child) of the RC sentence, readers should expect that the child being referred to is the same one who is being chased by the babysitter. Thus, when an ORC follows an ORC-biasing context then referential resolution should be facilitated compared to when ORCs follow licensing contexts. Conversely, when an ORC follows and SRC-biasing context referential resolution should not be easier compared to when ORCs follow licensing contexts because the prominent referent in SRC-biasing contexts is not the correct referent of the head-NP and the results support this. ORCs were significantly easier to process following ORC-biasing contexts compared to licensing contexts but not when they follow SRC-biasing contexts. By contrast, when an SRC follows an ORC-biasing context, referential resolution will not be facilitated because the most prominent referent in an ORC-biasing context is not the correct referent of the head-NP in an SRC. Thus, SRCs should not be easier to process in ORC-biasing contexts compared to licensing contexts. Conversely, when SRCs follow SRC-biasing contexts there should be a referential expectation that the subject of

the main clause is the intended referent because it is the most prominent referent in the context and therefore processing should be facilitated

In short, taken together the patter of results for first pass-regressions and total duration cannot be accounted for by a single theory. The active-filler strategy seems best able to account for the results for firs-pass regressions and the expectancy hypothesis appears to account best for the results of total duration.

With regard to the ORC-SRC difference between Experiments 1 and 2 it was revealed that for early measures of processing, such as gaze duration and first-pass regressions, that the ORC-SRC difference in the licensing context was significantly greater than when the context was ORC-biasing or SRC-biasing. Battinich et al. (2012) found that readers spent a longer time in the RC portion of the critical sentence when it was embedded in a licensed context compared to being read in isolation. This led to the speculation that the licensing contexts may have increased the complexity of the relative clause. The contexts I used in Experiment 1 were adapted from Battinich et al. and the difference in pattern for the ORC-SRC difference for licensing context and biasing contexts tend to support this.

However, for total duration the results revealed that the ORC-SRC difference was significantly smaller in ORC-biasing contexts compared to licensed contexts. The opposite was true for SRC-biasing contexts, with the ORC-SRC difference being significantly greater for the SRC-biasing contexts compared to the licensing contexts. By looking at Figure 3 it can be seen that in ORC-biasing contexts the ORC-SRC difference was reduced. ORCs are easier to process in ORC-biasing contexts and SRCs are only slightly more difficult to process in ORC-biasing contexts compared to SRC-biasing contexts. Conversely, the ORC-SRC difference is exacerbated in SRC-biasing contexts. In SRC-biasing contexts SRCs are non-significantly easier

to process while ORCs are significantly harder to process. In other words, the increase in processing difficulty is less for SRCs in ORC-biasing contexts compared to ORCs in SRC-biasing contexts. Therefore, the different results between experiments 1 and 2 may be a result of the prominence of the referents described in the context. In Experiment 1 the licensing contexts did not make one of the discourse referents more salient than the other. Thus the context may have failed to facilitate referent resolution. By contrast, the biasing contexts used in Experiment 2 did make one of the referents in the context more prominent than the other. Thus, referent resolution may have been facilitated when the context matched the RC (i.e., ORC biasing – ORC, SRC biasing – SRC) and referent resolution may have been hindered when the context and critical RC mismatched (i.e., ORC biasing – SRC, SRC biasing – ORC).

In conclusion, the results of the two experiments indicate that the contexts differentially influence the processing of restricted-RCs. The ORC-SRC difference was significantly reduced in ORC-biasing contexts compared to SRC-biasing contexts and licensing contexts. Furthermore, the results suggest that context may influence early parsing decisions. Specifically, the findings lend further support to the referential hypothesis, in particular the idea that the biasing contexts may have helped to restrict which referent is being referred to in the relative clause. More generally, the results suggest that is important to further examine how and when context influences the processing of restrictive-RCs.

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Appendix: RC-sentences used in Experiments 1 and 2

The co-worker that welcomed the secretary/ the secretary welcomed brought snacks to the office.

The child that chased the babysitter / the babysitter chased squealed with delight.

The assistant that offended the instructor / the instructor offended regretted the talk.

The actor that visited the director / the director visited demanded the starring role.

The inventor that commended the researcher / the researcher commended patented several inventions.

The maid that thanked the guest / the guest thanked hustled away down the hall.

The ambassador that summoned the interpreter / the interpreter summoned lived in Africa.

The judge that inspired the probation officer / the probation officer inspired locked many people up.

The prisoner that attacked the guard / the guard attacked started a riot.

The carpenter that impeded the bricklayer / the bricklayer impeded did not finish on time.

The caterer that frustrated the chef / the chef frustrated made an excellent soup.

The hunter that spotted the game warden / the game warden spotted ran off into the forest.

The pupil that greeted the teacher / the teacher greeted was well liked.

The gambler that distrusted the security officer / the security officer distrusted was known to cheat.

The employee that punched the trainee / the trainee punched had a bad temper.

The historian that criticized the graduate student / the graduate student criticized continued with the day's lecture.

The analyst that consulted the manufacturer / the manufacturer consulted implemented the deal.

The hiker that waved at the fisherman / the fisherman waved to fell badly and had to be rescued.

The doctor that ignored the nurse / the nurse ignored supervised the younger surgeons.

The professor that berated the student / the student berated felt embarrassed.

The chemist that revered the technician / the technician revered recognized his talent.

The soldier that assisted the civilian / the civilian assisted died in later combat.

The parent that charmed the therapist / the therapist charmed enjoyed the sessions.

The musician that insulted the newscaster / the newscaster insulted exited the building.

The neurologist that encouraged the physician / the physician encouraged was new to the hospital.

The engineer that impressed the mathematician / the mathematician impressed received an award.

The customer that thanked the cashier / the cashier thanked supported local business.

The governor that antagonized the congressman / the congressman antagonized apologized for his rudeness.

The wrestler that observed the gymnast / the gymnast observed performed well.

The realtor that questioned the broker / the broker questioned lost a lot of money.

The mime that amused the fire eater / the fire eater amused performed at the world's fair.

The banker that irritated the lawyer / the lawyer irritated played tennis every Saturday

The academic that surprised the statistician / the statistician surprised developed a new formula.

The critic that harassed the author / the author harassed had strong opinions.

The plumber that helped the electrician / the electrician helped retired after the job was done.

The cartoonist that avoided the prosecutor / the prosecutor avoided was very upset.

The quarterback that disliked the linebacker / the linebacker disliked threw the winning pass.

The announcer that idolized the baseball player / the baseball player idolized was very famous.

The editor that angered the screenwriter / the screenwriter angered fired half the staff.

The pediatrician that contacted the dentist / the dentist contacted left a message.

Table 1. Sample experimental passage

Licensing context (seen only in Experiment 1)

A babysitter was playing games with two children. One child was chased by the babysitter and the other child chased the babysitter.

Biasing contexts (seen only in Experiment 2)

SRC-biasing: A babysitter was playing games with two children. One of the children chased the babysitter and the other did not.

ORC-biasing: A babysitter was playing games with two children. One of thechildren was chased by the babysitter and the other was not.

Table 2. Mean reading times (standard error) in milliseconds for ORs and SRs as a function of condition in Experiment 1.

	Measure		
Condition	Gaze duration	First pass regression	Total duration
lcor	737.8 (220.6)	.540 (.197)	1634.5 (551.0)
lcsr	729.6 (176.9)	.389 (.197)	1363.9 (476.7)

Table 3. Mean reading times (standard error) in milliseconds for ORs and SRs as a function of context in Experiment 2.

	Measure		
Condition	Gaze duration	First pass regression	Total duration
oror	787.8 (228.1)	.440(.20)	1491.3 (518.1)
orsr	742.1 (207.4)	.357 (.22)	1415.9 (480.4
srsr	718.2 (219.5	.352 (.23)	1179.0 (343.3)
sror	798.0 (224.2)	.412 (.22)	1644.1 (570.7)

Figure 1. Experiment 2: Mean gaze duration context by clause-type

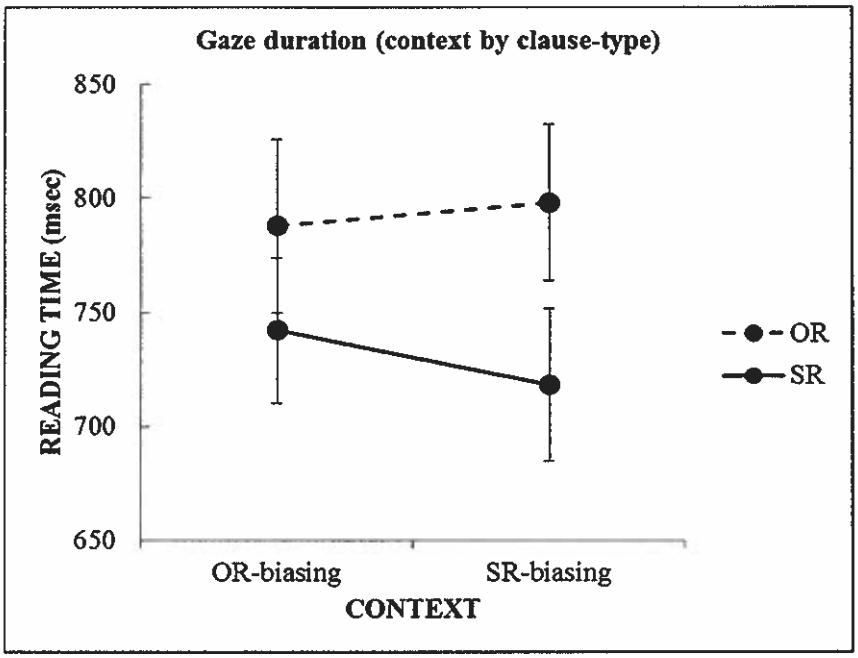


Figure 2. Experiment 2: Mean first-pass regression ratios context by clause-type.

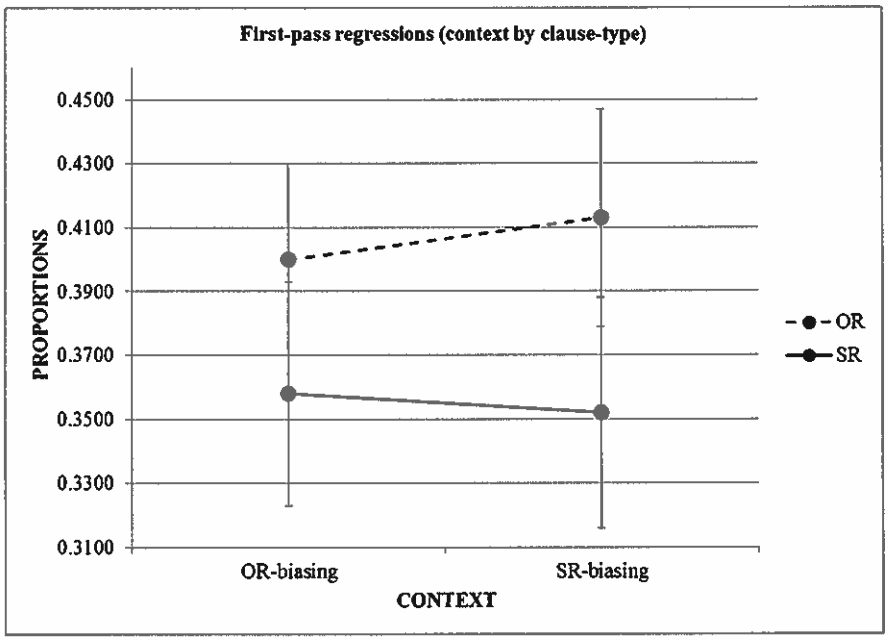
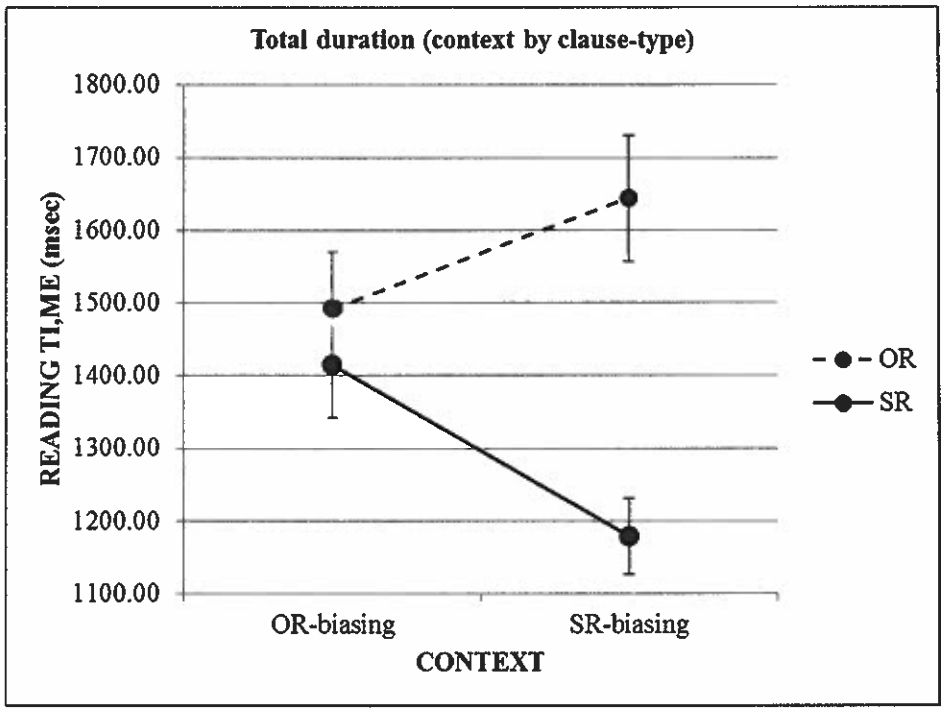


Figure 3. Experiment 2: Mean total duration context by clause-type



May 23, 2012

MEMORANDUM

TO:	William Battinich William Levine
FROM:	Ro Windwalker IRB Coordinator
RE:	PROJECT CONTINUATION
IRB Protocol #:	11-05-661
Protocol Title:	*The Influence of Context on the Comprehension of Relative Clauses*
Review Type:	☒ EXEMPT ☐ EXPEDITED ☐ FULL IRB
Previous Approval Period:	Start Date: 06/03/2011 Expiration Date: 06/02/2012
New Expiration Date:	06/02/2013

Your request to extend the referenced protocol has been approved by the IRB. If at the end of this period you wish to continue the project, you must submit a request using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. Failure to obtain approval for a continuation on or prior to this new expiration date will result in termination of the protocol and you will be required to submit a new protocol to the IRB before continuing the project. Data collected past the protocol expiration date may need to be eliminated from the dataset should you wish to publish. Only data collected under a currently approved protocol can be certified by the IRB for any purpose.

This protocol has been approved for 200 total participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or irb@uark.edu.