Published in final edited form as:
J Exp Psychol Learn Mem Cogn. 2011 July ; 37(4): 966–978. doi:10.1037/a0023218.

Distinguishing the time-course of lexical and discourse processes through context, co-reference, and quantified expressions

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Abstract

How does prior context influence lexical- and discourse-level processing during real-time language comprehension? Experiment 1 examined whether the referential ambiguity introduced by a repeated, anaphoric expression had an immediate or delayed effect on lexical and discourse processing, using an eye-tracking while reading task. Eye-movements indicated facilitated recognition of repeated expressions, suggesting that prior context can rapidly influence lexical processing. However, context effects at the discourse level affected later processing, appearing in longer regression-path durations two words after the anaphor and in greater re-reading times of the antecedent expression. Experiments 2 and 3 explored the nature of this delay by examining the role of the preceding context in activating relevant representations. Off-line and on-line interpretations confirmed that relevant referents were activated following the critical context. Nevertheless, their initial unavailability during comprehension suggests a robust temporal division between lexical- and discourse-level processing.

Keywords

lexical; discourse; co-reference; quantifiers; anaphors

1. Introduction

The time-course of language comprehension has been a central topic in psycholinguistics. On the one hand, language processing is often characterized as incremental and opportunistic, rapidly incorporating various informational sources during sentence interpretation (MacDonald, Pearlmutter, & Seidenberg, 1994; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Elman, 2009; Sedivy, Tanenhaus, Chambers, & Carlson, 1999; Levy, 2008). Under this framework, prior linguistic and non-linguistic context is seamlessly incorporated into analysis of the current input, leading to a full and complete interpretation at the earliest moments of processing. On the other hand, alternative accounts have highlighted genuine inefficiencies in real-time comprehension (Sanford & Sturt, 2002; Ferreira & Patson, 2007; Daneman, Lennertz, Hannon, 2007). Readers often fail to

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appreciate the presence of anomalous content or only notice it relatively late in interpretation.

This dichotomy between immediate and delayed processing is also reflected in the equivocal nature of empirical evidence. For example, one recent and prominent line of research in the eye-tracking while reading literature examines the influence of prior linguistic context on sentence processing (Rayner, Warren, Juhasz, & Liversedge, 2004; Warren & McConnell, 2007; Staub, Rayner, Pollatsek, Hyona, & Majewski, 2007; Warren, McConnell, & Rayner, 2008; Joseph, Liversedge, Blythe, White, Gathercole, & Rayner, 2008; Filik, 2008). Rayner and colleagues (2004) compared reading times of a target theme (*carrots*) when it was preceded by one of three contexts. The control condition (1a) introduced an appropriate instrument and verb (*knife, chop*) acting on a theme while the implausible condition (1b) involved an inappropriate instrument but appropriate verb (*axe, chop*) and the anomalous condition (1c) involved both an inappropriate instrument and verb (*pump, inflate*).

(1)

a. John used a knife to chop the large carrots for dinner.

b. John used an axe to chop the large carrots for dinner

c. John used a pump to inflate the large carrots for dinner.

Gaze durations on the target word were longer in the anomalous condition compared to implausible and control ones, demonstrating that prior context can rapidly influence subsequent interpretation. In contrast, differences between the implausible and control conditions were evident in regression-path durations, a measure of later processing. This delayed effect suggests that not all incongruous information has immediate effects on comprehension.

Nevertheless, this line of work leaves open questions about how prior context influences later interpretation. In particular, while much of everyday language comprehension involves interpretations based on discourse models of events, the focus on anomalous sentences introduces the possibility that eye-movements were driven by more local processes. One possibility is that the patterns of fixation may reflect the relatedness of the lexical semantics of content words in the sentence or the degree to which the target word (*carrots*) could be predicted by the preceding material (*knife, chop, axe, pump, inflate*). This would be consistent with prior studies emphasizing the rapidity of priming across related lexical items (Meyer & Schvaneveldt, 1971; Seidenberg, Waters, Sanders, & Langer, 1984; Tanenhaus & Lucas, 1987; Duffy, Morris, & Rayner, 1988; Camblin, Gordon & Swaab, 2007). A second related possibility is that differences in the time-course of the anomalous versus implausible conditions reflect more strategic procedures such as the ease of detecting violations (see Staub and colleagues (2007) for an earlier discussion of this issue). Since the violations featured in these studies consistently varied the appropriateness of the instrument and the verb, participants could become sensitive to the likelihood of an up-coming violation shortly after the onset of the critical sentence ("*John used*") and could actively predict possible outcomes.

Critically, the failure to distinguish between discourse versus lexical processes in the recent studies (Rayner et al., 2004; Warren & McConnell, 2007; Joseph et al., 2008; Filik, 2008) leaves open the possibility that early temporal effects are limited to the interpretation of anomalous sentences and have limited generalization to the understanding of plausible events. The goal of the current paper is to examine the time-course of context effects by differentiating between those that occur at the discourse level from those that occur at the lexical level. This division between word-level and higher-level interpretation has been featured prominently in earlier empirical work (Seidenberg et al., 1984; Tanenhaus & Lucas, 1987; Morris, 1994; Hess, Foss, & Carroll, 1995; Garrod & Sanford, 1994; Gordon &

Hendrick, 1998) as well as in recent models of eye-movements while reading such as the EZ Reader (Pollatsek, Reichle, & Rayner, 2006; Reichle, Warren, McConnell, 2009). This perspective stands in contrast to current theoretical accounts which tend to characterize processes as uniformly immediate (MacDonald et al., 1994; Elman, 2009; Levy, 2008) or late (Sanford & Sturt, 2002; Ferreira & Patson, 2007). Yet by distinguishing between processing at various levels of representation, one may account for ways in which particular processes are rapid while others are more delayed.

Nevertheless, isolating the precise time-course of lexical and discourse processes has been particularly challenging for at least two reasons. First, as discussed above, critical manipulations of lexical and discourse representations often affect interpretations at both levels, making it difficult to discern the independent contributions of either (Rayner et al., 2004; Warren & McConnell, 2007; Warren et al., 2008; Joseph et al., 2008; Hess et al., 1995; Duffy, Henderson, & Morris, 1989; Morris, 1994). Attempts to tease apart discourse and lexical contexts have often relied on manipulations that hold constant the lexical content of critical sentences while varying qualities of the discourse representation. For example, Morris (1994) created congruent and incongruent discourse contexts by varying the syntactic configuration of the same content words. She found that reading times on the target word were shorter when it was embedded in a congruent context compared to an incongruent one. Similarly, Warren and colleagues (2008) varied the prior discourse by placing possible and impossible sentences into real-world versus fantasy contexts (see also Nieuwland & van Berkum (2006) and Filik (2008)). They found that regression-path durations on the target word in an impossible sentence were longer than those in a possible sentence when both were embedded in a real-world context, but these differences disappeared when sentences were placed in a fantasy context.

However, while both sets of studies suggest that readers interpreted target words with respect to constructed discourse representations and not simply local processes, the reliance on comparisons across multiple sentences highlights another difficulty with mapping the presence of early versus late effects onto models of comprehension: Critical manipulations often introduce multiple dimensions to which time-course differences can be attributed. For example, the critical sentences in Morris (1994) varied in the type of discourse context they introduced but also varied in their syntactic complexity. Similarly, the comparisons between real-world and fantasy contexts (Nieuwland & van Berkum, 2006; Warren et al., 2008; Filik, 2008) raises the possibility that reader's awareness of the manipulations led to systematically different strategies for subsequent interpretation. In the real-world context, readers may favor a more stringent approach while in the fantasy context, they may adopt a more permissive one. These same potential problems are also common in language studies from the event-related potential (ERP) literature which largely rely on interpretations of anomalous content and comparisons across different sentences (Van Berkum, Zwitserlood, Brown, & Hagoort, 2003; Nieuwland & van Berkum, 2006; Van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005; Kuperberg, Sitnikova, Caplan, & Holcomb, 2003; Hagoort, Hald, Bastiaansen, & Petersson, 2004). Consequently, while these studies have often found that prior context rapidly influences subsequent interpretations, it remains unclear what these effects indicate.

The current experiments differentiate between lexical and discourse processing by (1) recruiting a test case where context influences both interpretations in a salient but plausible manner and (2) comparing the timing of these effects on comprehension within a single sentence. To address the first point, we turn to a literature which examines how quantification highlights referents in a discourse model (Moxey & Sanford, 1993, 2000; Sanford, Moxey, & Paterson, 1996; Moxey, 2006; Sanford, Dawydiak, & Moxey, 2007). Moxey, Sanford, and colleagues have found that while positive quantifiers like *a few*

highlight an asserted value (the reference set), negative ones like *few* draw attention to the shortfall from an expected value (the complement set). To demonstrate this, Sanford and colleagues (1996) presented participants with sentences that varied along this dimension and asked them to interpret ambiguous anaphors like those in (2).

(2) A few/few of the football fans went to the game. They…

They found that following *a few*, participants interpreted the anaphors as co-referential with the reference set (i.e., "*They* [the ones that went] *thought it would be a good game*") while following *few*, they interpreted them with respect to the complement set as well (i.e., "*They* [the ones that didn't go] *watched it on TV instead*").

The focusing properties of these quantified expressions allow us to examine contextual effects on discourse processing in a situation where interpretations are both salient and plausible. Furthermore, the fact that this discourse manipulation minimally differs across conditions reduces the possibility that readers would adopt distinct strategies for interpretation. In the current experiments, we examine the representations generated by the positive/negative pair *some* and *only some* (see Table 1). These terms are of particular interest since they are the subject of several well-developed analyses in both the theoretical and empirical literatures on quantification and pragmatic inference (Horn, 1989;Sperber & Wilson, 1995;Chierchia, 2004;Breheny, Katsos, & Williams, 2006;Huang & Snedeker, 2009,in press;Grodner, Klein, Carbary, & Tanenhaus, 2010). Consistent with prior experimental evidence (Sanford et al., 1996;Moxey, 2006;Sanford et al., 2007), traditional semantic analysis suggests that the meaning of *some* specifies any quantity greater than *none* while *only some* establishes a shortfall by also excluding *all* (Rooth, 1985;Horn, 1989;Krifka, 1995). Consequently, when these quantifiers are embedded in our context sentence, we would expect the positive form to highlight the reference set (i.e., the girls who met with the teacher) and the negative form to draw additional attention to the complement set (i.e., the girls that didn't meet with the teacher).

To establish an appropriate contrast for comparing the time-course of context effects, we take advantage of methods that have separated levels of interpretation in the comprehension of anaphoric expressions. Using an eye-tracking while reading paradigm, Ledoux, Gordon, Camblin, and Swaab (2007) presented participants with sentences like (3).

(3) In spite of the rain Jared/Damon enjoyed the concert at which Jared met the band.

They found that reading times following the second name (*Jared*) exhibited two distinct patterns. In measures of early processing, reading times on the name were shorter when it was preceded by the same name as compared to a new name (*Damon*). This first effect is an instance of repetition priming, whereby prior exposure to a word facilitates subsequent recognition of the same word (Traxler, Foss, Seely, Kaup, & Morris, 2000; Raney, Therriault & Minkoff, 2000; Liversedge, Pickering, Clayes, & Branigan, 2003). Previous research on memory and word recognition suggests that repetition priming reflects the retrieval of salient lexical properties including the phonological/orthographic features and word frequency (Scarborough, Cortese, & Scarborough, 1977; Forster & Davis, 1984; Holcomb & Grainger, 2007). In contrast, in measures of later processing, Ledoux and colleagues (2007) found that reading times during downstream regions following repeated names were longer than those following new ones. Prior work suggests that this second effect reflects the interference resulting from the pragmatic infelicity of using an over-informative, repeated expression to refer to a prominent discourse referent (Almor, 1999; Gordon & Hendrick, 1998). Together, this pattern of initial facilitation followed by later delay provides a model for examining lexical- and discourse-level effects in a within-sentence comparison.

In Experiment 1, we follow this logic by using repetition priming as a benchmark of lexical processing to which the timing of discourse processing can be compared. In the critical sentence, we vary the referring expression (*the girls* vs. *the boys*) and predict that word recognition should be facilitated following a repeated NP compared to a new one. However, it is possible that the reading of these expressions may also be influenced at the discourse level by the polarity of the quantified expression in the context sentence. In particular, when the reference set is in focus following the positive quantifier, the mention of a repeated NP can be directly mapped onto this single referent. In contrast, following the negative quantifier, both the reference and complement set are in focus. Consequently, the repeated NP could plausibly refer to both these entities. The presence of this referential ambiguity would have the opposite effect as repetition priming and lead to slower processing of a repeated expression compared to a new one (Ehrlich, 1980; Vonk, 1984; Garrod & Sanford, 1994; Gordon & Hendrick, 1998; Huang & Snedeker, 2009, in press). Notice that since prior context is predicted to generate both facilitation at the lexical level and delays at the discourse level within the same sentence, the current manipulations offer a stronger test of early and late effects than those previously used (Hess et al., 1995; Duffy et al., 1989; Morris, 1994; Rayner et al., 2004; Warren & McConnell, 2007; Warren et al., 2008; Joseph et al., 2008).

Critically, the effects of referential ambiguity at the discourse level could emerge either early or late in processing. If this ambiguity immediately affects co-referencing, then we might expect to see evidence of a delay in discourse processing in the same early reading-time measures and regions of text as repetition priming. On the other hand, if these interpretative processes only emerge after initial lexical analysis, then delays of this nature should be observed in later measures of reading and in downstream regions of text relative to repetition priming.

2. Experiment 1

2.1. Methods

2.1.1. Participants—Forty English-speaking undergraduates from the University of North Carolina at Chapel Hill participated in this study. They received either course credit or $10 for their participation.

2.1.2. Procedure—Participants sat in front of a computer screen which presented sentences and their eye movements to these sentences were measured using an *Eyelink 1000* system (SR Research). This desktop eye-tracker measured pupil location at the rate of 1000Hz and analyzed these samples with respect to fixations and saccades. Throughout the study, the experimenter monitored the location of participants' gaze to the items on the screen using a second computer and ensured that the location of pupil was consistently calibrated. Each trial began with the appearance of a fixation point, marking the location of the first word of the up-coming passage. Once participants held a steady gaze to this point, the experimenter initiated the appearance of these sentences. Participants were instructed to read the passage at a natural pace and to press the space bar once they were finished. They then saw a true/false comprehension question and made their responses by pressing the corresponding buttons on a consol. All studies began with a short block of three practice trials, followed by the presentation of the critical trials.

2.1.3. Materials—The critical conditions represented the four cells of 2 × 2 design. The first factor, polarity, contrasted the positive and negative forms of the quantifier in the context sentence (*some* vs. *only some*). The second factor, repetition, contrasted the repetition of a previously mentioned referent with the introduction of a new referent in the critical sentence (*girls* vs. *boys*).

Table 1 illustrates an example of one of the 32 three-sentence critical passages.1 The first introductory sentence provided background for the up-coming events. The second context sentence began with a locative expression followed by a definite noun phrase in the subject position. This NP was always embedded in a quantified expression but the polarity of this expression varied across positive ("*some of the girls*") and negative ("*only some of the girls*") conditions. The predicate of the context sentence remained identical across conditions ("*met with the teacher*"). The final critical sentence began with a referring expression but varied whether it repeated the preceding NP or introduced a new referent. In the repeated condition, these expressions were embedded in a five- to nine-word sentence frame that was initially ambiguous between the reference and complement set ("*The girls were studying for the test*…"). Nevertheless, to avoid explicit mention of the complement set, the final phrase always disambiguated these sentences in favor of the reference set ("… *and wanted to ask questions*"). In the new condition, referring expressions were derived from similar categories as the repeated condition and were embedded in the same initial sentence frame as the repeated condition ("*The boys were studying for the test*…"). However, in order to maintain the felicity of introducing a completely different set, the final phrase contrasted the actions of the new set with those of mentioned in the context sentence ("…*but didn't want help*").

Potential main effects of nouns (*girl* vs. *boys*) were eliminated in two ways. First, the new referents also served as repeated referents across counterbalancing lists. Four versions of each base item were used to create eight presentation lists such that each list contained eight items in each condition and that each base item appeared just once in every list. Second, within each counterbalancing list, new and repeated referents were matched in average length (M = 7.37 and M = 7.40 characters respectively, *p's* > .90) and written frequency (Kucera & Francis, 1967; M = 1.36 and M = 1.54 log frequency respectively, *p's* > .40). Across all experiments, critical trials were randomized within four experimental blocks and intermixed with 16 three-sentence filler passages which did not include quantifiers. Lists of sample items are provided in the Appendix.

2.2. Results

Eye movements were analyzed using four measures of reading time (see Liversedge, Paterson, & Pickering, 1998; Rayner, 1998): (1) *gaze duration* (the sum of fixation durations on a region of interest from the first time that region is fixated until a region outside the target region is fixated provided that the eyes have not yet gone beyond that region); (2) *regression-path duration* (the sum of all fixation durations from the first fixation in a region until there is a fixation to the right of that target region); (3) *likelihood of regression into a region* (the proportion of saccades to a previous region following a first fixation to a subsequent region); and (4) *re-reading duration* (the difference between total reading time and gaze duration). Gaze durations are typically associated with earlier aspects of language processing while the remaining three measures are typically associated with later ones (Rayner, 1998).

2.2.1. Initial reading of quantifier region—To determine whether there were any differences in the processing of the quantified expressions, we first examined gaze and regression-path durations in the four-word region from the quantifier to the NP in the context sentence ("*some of the girls*"). There were no effects of polarity, repetition, or interaction between the two (all *p's* > .30), demonstrating that initial processing of the quantified expressions was well matched across conditions. This congruity reduces the

[1]One item was excluded from analysis due to experimenter error.

possibility that subsequent effects of polarity or interactions with polarity are driven by overt strategies or awareness of the manipulation.

2.2.2. Critical expression region—Next we examined the effects of lexical processing on repeated versus new expressions at the onset of the critical sentence. Following earlier studies (Ledoux et al., 2007; Traxler et al., 2000; Liversedge et al., 2003; Raney et al., 2000), we focused on evidence of repetition priming in two measures of reading time on the critical noun ("*girls/boys*") and the following word ("*were*"). Figure 1 shows that gaze durations on the critical expression were marginally shorter following a repeated referent than a new one (257ms vs. 269ms, $F_1(1,39) = 3.42$, $p = .07$; $F_2(1,30) = 3.14$, $p = .09$).2 This difference became significant on the following word (226ms vs. 253ms, $F_1(1,39) = 9.73$, $p < .01$; $F_2(1,30) = 15.91$, $p < .001$). Similarly, Figure 2 shows that regression-path durations on the critical expression were significantly shorter in the repeated than new condition (334ms vs. 430ms, $F_1(1,39) = 8.07$, $p < .01$; $F_2(1,30) = 10.80$, $p < .01$) though this difference diminished in the following word (337ms vs. 371ms, *p's* > .20).

Importantly, during both the critical expression and the following word, there were no significant effects of polarity and no interactions between polarity and repetition on gaze and regression-path durations (all *p's* > .30). In fact, contrary to the predicted discourse effects, reading times following repetition were slightly greater in the positive condition compared to the negative condition (gaze: 258ms vs. 255ms; regression-path: 360ms vs. 307ms), though these differences were not significant (all *p's* > .15). Altogether these results suggest that while prior context can rapidly influence lexical processing, it had no impact on early processing at the discourse level.

2.2.3. Post-critical expression region—We then focused on whether the polarity of the quantified expression had any measureable influence on the reading of the passage. In particular, we had predicted that when the repeated expression was preceded by the negative quantifier, activation of both the reference and complement sets would lead to referential ambiguity and corresponding delays in processing. We found evidence of this referential ambiguity in measures of later processing during two regions of interest. First, Figure 2 shows that two words after the critical noun, regression-path durations in the negative-repetition condition began to exceed those in other conditions. We averaged regression-path durations during a four-word region corresponding to this delay ("*studying for the test*") and found no main effects of polarity or subsequent reference (all *p's* > .20). Critically however, these two variables did exhibit a significant interaction during this region ($F_1(1,39) = 4.34$, $p < .05$; $F_2(1,30) = 3.06$, $p = .09$). Comparisons within levels of polarity showed no reliable differences between new and repeated expressions following a positive quantifier (759ms vs. 806ms, $F_1(1,39) = 0.64$, $p > .40$; $F_2(1,30) = 0.28$, $p > .60$). In contrast, when the quantifier had been negative, times were significantly longer with repeated referents than with new ones (863ms vs. 696ms, $F_1(1,39) = 4.01$, $p = .05$; $F_2(1,30) = 4.33$, $p < .05$).3

However, these increases in regression-path durations coincided with the linguistic disambiguation of the reference and complement sets among eight critical items. This

[2]Careful readers (and our Editor) have noticed the gaze duration in the positive-repetition condition was unusually high on the first word of the critical sentence ("*the*"). This may have contributed to marginal effects of repetition priming on the critical expression ("*girls/boys*"). Closer inspection of the data revealed that gaze durations on the article led to an interaction between repetition and polarity that was marginal by subjects ($F_1(1,39) = 3.28$, $p = .08$) but nowhere near significant by items ($F_2(1,30) = 0.39$, $p > .50$). We noticed that while participants typically skipped this short word, two subjects inexplicably exhibited very long gaze durations (> 450ms) in this condition. When their data were excluded from analyses on this region, differences across conditions disappeared (all *p's* > .60).

[3]Power analyses within the negative condition revealed a moderate-sized discourse effect (mean difference = 167ms, λ =.78). Thus if an effect of this magnitude were present at the onset of the critical expression, it would have been detected with virtual certainty (λ =. 95). This suggests that discourse effects were not simply weaker than lexical effects but were genuinely delayed.

introduced the possibility that differences in the negative-repetition condition were in fact driven by readers' sensitivity to linguistic cues that were consistent with the reference set among a subset of items. To evaluate this hypothesis, we performed the same analyses excluding these short ambiguous-frame items. We found that regression-path durations continued to be higher in the negative-repetition condition (850ms) compared to all other conditions (negative-new: 656ms, positive-repeated: 689ms, positive-new: 815ms). This led to a significant interaction between polarity and subsequent reference ($F_1(1,39) = 5.12$, $p < .05$; $F_2(1,22) = 5.85$, $p < .05$), with no additional main effects (all p's $> .50$). This suggests that delays in the discourse processing of referential ambiguity occurred after facilitation in the lexical processing of repeated expressions.

2.2.4. Re-reading of quantifier region—Finally, re-reading of the region around the quantified expression was used to further test the possibility that interpretation of the repeated noun following the negative quantifier reflected reprocessing of the complement and referent sets. We focused on regressions back to a two-word region around the quantifier in the context sentence ("*lecture…some*") that were triggered by reading of the region two words following the critical noun (i.e., the earliest point at which polarity effects emerged in the critical sentence). Figure 3a reveals that the likelihood of regression into a positive quantifier trended toward being lower following a repeated referent than a new one (32% vs. 40%), but the likelihood of regression into a negative quantifier was no different following repeated and new referents (39% vs. 37%). These differences led to a marginal interaction between polarity and subsequent reference ($F_1(1,39) = 3.50$, $p = .06$; $F_2(1,30) = 2.27$, $p < .15$) but no individual main effects (all p's $> .40$).

A similar pattern emerged in the corresponding re-reading durations during this two-word region around the quantifier. Figure 3b reveals that re-reading times around the positive quantifier were significantly shorter following a repeated referent than the new one (139ms vs. 184ms, $F_1(1,39) = 6.22$, $p < .05$; $F_2(1,30) = 3.30$, $p = .08$). This again indicates that the mention of repeated referents led to easier re-processing of the quantified expression than the introduction of new referents. In contrast, re-reading times in the region around the negative quantifier were longer following the repeated referent than a new one (190ms vs. 138ms, $F_1(1,39) = 4.92$, $p < .05$; $F_2(1,30) = 2.68$, $p = .11$). This is consistent with the notion that there is greater referential ambiguity in these trials. Altogether these differences in re-reading durations led to critical interaction between polarity and subsequent reference ($F_1(1,39) = 8.81$, $p < .01$; $F_2(1,30) = 5.90$, $p < .05$) but no individual main effects (all p's $> .70$).

2.3. Discussion

In Experiment 1, we examined the influence of a quantified context on subsequent lexical- and discourse-level processing during real-time language comprehension. Replicating previous studies (Ledoux et al., 2007; Traxler et al., 2000; Liversedge et al., 2003; Raney et al., 2000), we found faster reading times for repeated expressions compared to new ones. The presence of repetition priming at the onset of the repeated word demonstrates that prior context can rapidly influence lexical processing. However, relative to this benchmark, the influence of context on discourse processing was very slow, appearing in measures of regression-path durations two words after the repeated expression and in re-reading of the quantifier. This pattern supports the distinction between lexical and discourse processing and suggests that context effects on each of these levels of interpretation unfolds across discrete moments in time.

Nevertheless, while we interpret the delays in the negative-repetition trials as reflecting the processing of referential ambiguity triggered by the repeated expression, it is possible that

they were caused by other sources. One possibility is that *only some* activated both the reference- and complement-set representations and that this in turn generated expectations that the repeated, definite expression would be followed by a postnominal modifier to distinguish between these two sets (e.g., "*the girls that didn't meet with the teacher*"). Thus the presence of a repeated NP did not itself trigger the processing of the referential ambiguity; rather it was the absence of a disambiguating modifier two words later. However, while this is an intriguing hypothesis, it is at odds with a dominant finding in the literature which consistently shows that definite expressions immediately trigger processing of referential ambiguity (Sedivy et al, 1999; Grodner et al., 2010; Tanenhaus et al., 1995). For example, Huang and Snedeker (2009, in press) found that when asked to "*Point to the girl that has some of the socks*," listeners' eye-movements following the onset of the gender cue ("*the girls*") demonstrated immediate competition between two girls in the scene (a girl with socks and a girl with soccer balls). This occurred even though the definite expression was followed by a modifier which unambiguously distinguished between the two referents. These findings suggest that the repeated expressions in Experiment 1 should have been sufficient to trigger referential processing. Nevertheless, we will return to this possibility in our analysis of the results from Experiment 2.

A second alternative explanation for the delayed discourse effects is that *only some* strongly evokes the complement set and is only weakly associated with the reference set. Indeed prior work has found variability in the proportion of set interpretations generated across different quantifiers (Sanford et al., 1996; Sanford et al., 2007). Consequently, when participants in the negative condition reached the region two words after the repeated expression ("*studying for the test*"), they may have interpreted this phrase as referring to the reference set and were boggled by the mismatch between what was highlighted by the context sentence and what was specified by the critical sentence. This suggests that rather than reflecting delays in global discourse processing, reading times during this region indicated readers' immediate sensitivity to an anomalous reference at the local level. Thus like the context effects on lexical processing, this detection of a mismatch is incrementally time-locked to the onset of the relevant input. However unlike lexical processing, this input appears two words after the repeated expression rather than on the expression itself, accounting for its later emergence in processing.

Yet this account fails to capture other features of the current data. First, if evidence of discourse processing was triggered by mismatching input, it is unclear why this pattern should have emerged during a region that was ambiguous between the reference and complement sets. Recall that the final portion of the critical sentence disambiguated the referring expression in favor of the reference set but that these later regions were excluded in a follow-up analysis. Thus there is no evidence that strongly links temporal delays at the discourse level with any kind of triggering input. Second, re-reading times around the quantifier provides indirect evidence that *only some* was not exclusively associated with the complement set. While new expressions led to longer durations for the positive quantifier, they actually led to shorter durations for the negative quantifier. It is possible that *only some* facilitated processing of new expression by triggering representations of contrast across various sets, including to other basic level categories (e.g., girls, boys). This is consistent with linguistic accounts arguing that the presence of the *only* focus operator highlights contrast across relevant alternatives (Rooth, 1985; Krifka, 1995).

Nevertheless, our current data does not offer direct insight into whether the activated contrast includes both the reference- and complement-set representations. Thus in order to properly interpret the delays found in Experiment 1, we need better evidence about how the polarity of the expressions of interest focuses elements within the discourse representation. In Experiment 2, we explicitly test the hypothesis that *only some* - unlike *some* - is

ambiguous between both the reference and complement sets. We did so by modifying the sentence completion task used by Sanford and colleagues (1996) and presenting participants with the context sentences from Experiment 1 (Table 2). Our critical dependent measure examined completion of an anaphoric expression which repeated the definite NP in the preceding quantified expression. If *only some* is solely associated with the complement set, then we should expect the majority of continuations to refer to this quantity. However, if *only some* is ambiguous between both the reference and complement sets, then we should expect continuations to refer to both.

3. Experiment 2

3.1. Methods

3.1.1. Participants—Thirty-six English-speaking undergraduates from the University of North Carolina at Chapel Hill participated in this study. They received course credit for their participation.

3.1.2. Procedure and Materials—Participants sat in front of a computer and saw two-sentence passages presented using the software program *Linger* (http://tedlab.mit.edu/~dr/Linger/). Each trial began with the entire passage and repeated expression and participants were instructed to "finish this sentence in a way that made sense given the situation." A blank space was available under each passage so that participants could type in their answers.

Table 2 illustrates an example of one of the 32 critical passages which were based directly on the materials used in Experiment 1. The context sentence varied in the polarity of the quantified expression while the critical sentence always repeated the definite NP in the prior expression. Two versions of each base item were used to create two presentation lists such that each list contained 16 items in each condition and that each base item appeared just once in every list. The same 16 filler passages used in Experiment 1 were also modified for the purposes of this task and were randomly intermixed with the critical passages.

3.2. Results

Participants' continuations were coded as referring to either (1) the reference set (i.e., "…*had questions about the up-coming test*"), (2) the complement set (i.e., "…*wanted to study on their own*"), or (3) an ambiguous set (i.e., "…*loved to go to school*"). Responses of the last type often involved the total set of girls or an irrelevant generic statement. However, since they were rare (< 3% of all responses) and did not vary across the two polarities, they were excluded from remaining analyses. Table 3 shows that there were more complement-set responses following the negative polarity compared to the positive polarity. However, participants' responses also indicate that there was a robust preference for the reference set across both polarities.

To directly compare the ratio of reference- and complement-set responses, we calculated the preference for the reference set as a difference score of reference-set responses minus complement-set ones. Comparisons across polarity revealed a greater preference for the reference set following the positive expression compared to the negative one ($F_1(1,35) = 119.34$, $p < .001$; $F_2(1,31) = 45.80$, $p < .001$). We also compared the preference for the reference set against what would be predicted by chance (in this case, zero). These analyses confirmed that preference for the reference set exceeded chance following both the positive ($t_1(35) = 13.35$, $p < .01$; $t_2(31) = 11.76$, $p < .01$) and negative polarities ($t_1(35) = 4.15$, $p < .01$; $t_2(31) = 2.61$, $p < .05$).

Finally, we also coded participants' responses to examine how often the repeated expression was continued with a postnominal modifier (e.g., *that, which, who*). Recall that in our discussion of Experiment 1, we had introduced the possibility that a preference for this construction might have led readers to ignore the referential ambiguity at the onset of the definite NP. Comparisons across polarity revealed more frequent postnominal modification following the negative quantifier compared to the positive one (M = 38% (SD = 17%) vs. M = 23% (SD = 17%); $F_1(1,35) = 56.54$, $p < .001$; $F_2(1,31) = 34.89$, $p < .001$). This suggests that participants were aware of the ambiguity following "*only some*" and made efforts to explicitly distinguish between the two sets. However, while participants produced more postnominal modifiers following the negative polarity, this was certainly not the dominant response. On the remaining 62% of trials, sentences were completed with disambiguating predicates that were true of either the reference or complement set. This provides additional evidence against an account where delays in discourse processing were driven by an initial failure to detect referential ambiguity.

3.3. Discussion

Altogether these results are consistent with prior research demonstrating that negative polarity expressions highlight the complement set to a greater degree (Sanford et al., 1996; Moxey, 2006). Sanford and colleagues (1996) found that positive quantifiers were almost always finished with reference set completions (93% of the time) and never with complement set completions while negative quantifiers were often finished with complement set completions (71%) and sometimes with reference set completions (15%). Our results demonstrate a similar asymmetry where the positive form unequivocally highlights the reference set while the negative form is more ambiguous between the reference and complement sets. Furthermore, relative to the other negative quantifiers examined by Sanford and colleagues (*not quite all*, *not all*, *less than half*, *not many*, *few*), we found that *only some* was much more likely to generate both types of responses.4 Critically, with respect to the findings in Experiment 1, these results suggest that following *only some*, representations of both the reference set and complement set were available at the onset of a repeated NP. This suggests that delays in the context effects on discourse processing were not due to a failure to access these robust representations.

Nevertheless, it is possible that off-line sentence completion measures conflate several distinct processes including the interpretation of the preceding passage and the production of the subsequent continuation (Arnold, 2001; Rohde, 2008). Consequently, participants' responses may provide an accurate assessment of the range of interpretations that are possible following the quantified expression but a less accurate indication of the ones that are actually available during online comprehension. In Experiment 3, we the turn to a self-paced reading task to isolate the discourse representations triggered by the comprehension of positive and negative quantifiers. We do so by examining how *some* and *only some* influence the reading of congruent and incongruent anaphoric expressions (see Table 4).

Prior evidence has shown that reading times of a complement-set anaphor (*the rest*) are shorter following *only some* compared to *some* (Breheney et al., 2006). This suggests that negative polarity highlights representations of the complement set which in turn facilitates subsequent reading of an anaphor with a matching meaning. Critically, it is unknown how polarity might influence the processing of a reference-set anaphor (*they*). One possibility is that *only some* highlights the complement set to the exclusion of the reference set. If this

[4]Because of the goals of our experiment, our materials differed slightly from that of Sanford and colleagues (1996). These modifications likely account for the larger differences between positive and negative quantifiers in the previous study. Sanford and colleagues elicited continuations from five sets of positive/negative pairs (rather than focusing on one) and asked for continuations using "*They*…" (rather than the repetition of the antecedent NP).

were the case, then we would expect that following *only some* compared to *some*, there would be faster reading of a congruent complement-set anaphor but slower reading of an incongruent reference-set anaphor. Another possibility is that *only some* is truly ambiguous between the reference and complement set. If this were the case, then we would expect the same pattern of facilitation following a congruent complement-set anaphor but no difference across polarities following an equally congruent reference-set anaphor.

4. Experiment 3

4.1. Methods

4.1.1. Participants—Thirty-six English-speaking undergraduates from the University of North Carolina at Chapel Hill participated in this study. They received course credit for their participation.

4.1.2. Procedure and Materials—Participants sat in front of a computer and saw phrase-by-phrase intervals of passages presented using *Linger*. Each trial began with a series of hash marks, indicating the location of the words in the passage. Participants were instructed to press the space bar to change the hash marks into words for the current phrasal unit. To prevent re-reading of previous content, the current segment reverted back to hash marks when the space bar was pressed again and only the words for the next unit segment were visible. Participants were told to read the sentence at a natural pace. After each passage, they were presented with a true-false comprehension question and responded by pressing the appropriate keys.

Table 4 illustrates an example of one of the 32 critical passages which were based directly on the materials used in Experiment 1. The context sentence again varied in the polarity of the quantified expression while the critical sentence varied the type of referring expression. In the reference set condition, a reference-set anaphor was embedded in the same frame as the critical sentences in the repeated condition of Experiment 1 (“*They were studying for the test | and wanted to ask questions* ”). In the complement set condition, a complement-set anaphor was embedded in the same frame as the critical sentences in the new condition (“*The others were studying for the test | and didn’t want help* ”). These sentences were divided into two regions of interest, one containing the anaphoric expression and a following region which disambiguated the sets in a way that was consistent with the anaphors. The preceding content was divided into five phrasal segments, making each passage seven units long. Four versions of each base item were used to create four presentation lists such that each list contained eight items in each condition and that each base item appeared just once in every list. The same 16 filler passages used in Experiment 1 were also divided into phrasal segments and were randomly intermixed with the critical passages.

4.2. Results and Discussion

Our primary analyses focused on reading times within the sixth region of the passage which contained the critical anaphoric expressions (“*They/The others were studying for the test*”). Additional analyses confirmed that were no main effects or interactions during intervals immediately prior to and following this critical region (all p’s > .60). Figure 4 illustrates that the complement-set anaphor was in general read slower than the reference-set anaphor, leading to a main effect of referring expression ($F_1(1,35) = 55.42$, $p < .001$; $F_2(1,31) = 34.15$, $p < .001$). This pattern is consistent with previous studies (Sanford et al., 1996; Paterson et al., 1998) and suggests that the complement-set expression may be more complex to interpret relative the referent-set expression; it also may reflect the presence of an additional word in the complement-set expression as compared to the referent-set expression. Reading times in the negative condition were also faster during this region

compared to in the positive condition, leading to a marginal main effect of polarity ($F_1(1,35) = 3.06$, $p = .09$; $F_2(1,31) = 4.63$, $p < .05$).

Critically, these main effects were modulated by the presence of the predicted interaction between the polarity of the quantified expression and type of subsequent referring expression ($F_1(1,35) = 4.68$, $p < .05$; $F_2(1,31) = 5.83$, $p < .05$). Reading times of the complement-set anaphor were faster when preceded by a negative quantifier compared to a positive one (1354ms vs. 1475ms, $F_1(1,35) = 5.30$, $p < .05$; $F_2(1,31) = 6.34$, $p < .05$). This is consistent with patterns in prior studies (Sanford et al., 1996; Paterson et al., 1998; Breheney et al., 2006) and suggests that complement-set representations were invoked following *only some* but not *some*. In contrast, reading times in the reference-set anaphor were no different across the two polarities (1144ms vs. 1155ms, $F_1(1,35) = 0.04$, $p > .80$; $F_2(1,31) = 0.01$, $p > .90$), suggesting that reference-set representations were invoked equally by *some* and *only some*. Furthermore, the fact that these patterns emerged in this region suggests that these discourse representations were available to guide online interpretation at the onset of the anaphoric expressions.

Altogether the results from Experiments 2 and 3 are consistent with a discourse model where positive polarity activates only reference-set representations, while negative polarity activates both reference- and complement-set representations. This asymmetry in the effects of polarity on discourse representations sheds light on our interpretations of the results from Experiment 1. In particular, they suggest that the discourse processing of the repeated expression following a negative context reflects the ambiguous co-reference of multiple salient sets. This procedure involves the matching of the linguistically-specified content with the mental model of the language processor (Gordon & Hendrick, 1998). Critically, the lateness of these context effects relative to those at the lexical level suggests a genuine temporal division between processing across these representations.

5. General Discussion

This study examined the influence of context on lexical- and discourse-level processing during real-time language comprehension. Consistent with previous work, we found that prior recognition of a word facilitates subsequent recognition of that same word later in the passage (Ledoux et al., 2007; Traxler et al., 2000; Raney et al., 2000; Liversedge et al., 2003). The overall rapidity of these effects suggests that context can immediately influence lexical processing. In contrast, the influence of context on discourse processing was very slow, appearing in measures of regression-path durations two words after the repeated expression and in re-reading of the quantifier. Altogether our results suggest a robust temporal division between language processing across these levels of representation.

Methodologically, our study highlights two effective ways to examine the interaction between lower-level and higher-level representations. First, the presence of repetition priming provides an informative benchmark for understanding time-course of context effects. Establishing the onset of lexical processing provides a meaningful lower-bound for which to compare the onset of discourse processing. Second, the combined use of quantification and co-reference provides a useful tool for studying discourse representations since they highlight entities that are sufficiently abstract and not directly tied to the linguistic input (Moxey & Sanford, 1993, 2000; Sanford et al., 1996; Moxey, 2006; Sanford et al., 2007; Breheney et al., 2006). This ensures that processing indeed reflects procedures related to the matching of the linguistically-specified content with the mental model of the language processor rather than those that could be possibly attributed to lower-level processes.

Theoretically, our results speak to current debates about the timing of language processing. On one side are accounts that highlight the rapidity and interactivity of various informational sources during real-time comprehension (MacDonald et al., 1994; Elman, 2009; Levy, 2008) while on the other are those that focus on the relative inefficiencies of these processes (Sanford & Sturt, 2002; Ferreira & Patson, 2007). Our findings suggest a possible solution for this paradox: While linguistic input is incrementally mapped onto various linked representations (orthographic/phonological, syntactic/semantic, discourse), these representations are partially ordered such that processing at one level constrains processing at other levels. Consequently, we can find evidence of both rapid effects of lower-level lexical representations in early measures of reading as well as delayed effects of higher-level discourse representations in later measures. The presence of a robust temporal division between these procedures is also consistent with prominent models of eye-movement control during reading such as the EZ reader (Pollatsek et al., 2006). This approach has traditionally emphasized effects at the lexical level; however, recent attempts have expanded this framework to account for influences from high-level, post-lexical processes (see Reichle and colleagues (2009), pg. 5–6 for details on the mechanisms underlying post-lexical integration during the “I stage” in EZ Reader 10).

The division between processing at the lexical and discourse levels also has important implications for the interpretation of current empirical data. First, it suggests that context effects may not always reflect interference from the construction of a fully-developed global discourse model. With respect to studies that use anomalous sentences (Rayner et al., 2004; Warren & McConnell, 2007; Warren et al., 2008; Joseph et al., 2008; Filik, 2008), our results suggest the possibility that rapid context effects instead reveal early sensitivity at a much lower-level such as the local processing of unexpected lexical items. This alternative presents challenges for interpreting findings from studies which make inferences about linguistic architecture based on the reading of anomalous sentences, including those from the ERP literature (Van Berkum et al., 2003; Van Berkum et al., 2005; Kuperberg et al., 2003; Hagoort et al., 2004; Nieuwland & van Berkum, 2006).

Second, our results also suggest that by situating representations across multiple levels, one can make distinctions between effects of language processing that emerge primarily from top-down prediction of up-coming words and those that result directly from bottom-up integration of past and current input (Kintch, 2005; Huang & Snedeker, in press). There has been considerable evidence demonstrating that listeners and readers can reliably anticipate up-coming linguistic input based on the predictability of previous content or salient features in the context (Tanenhaus et al., 1995; Altmann & Kamide, 2007; Van Berkum et al., 2005; Kamide, Altmann, & Haywood, 2003; Pickering & Garrod, 2007; Lau, Stroud, Plesch, & Phillips, 2006). Very salient entities can enter the discourse model through inference and may even be implicitly labeled prior to being explicitly mentioned in the linguistic context (Sharkey & Sharkey, 1987; Huang & Snedeker, in prep). This mapping between an inferred entity and implicit label may facilitate subsequent processing once the linguistic input is encountered and result in rapid context effects via discourse representations.

Nevertheless, while top-down procedures may play a critical role during language comprehension, our current work highlights the importance of bottom-up procedures as well. In particular, if the previous input does not make obvious a single interpretation, the relevant discourse entities cannot be represented prior to their linguistic mention. Thus in order for language comprehension to proceed, the reader must rely on integration of past and current context to access the meanings of the expressions and build a discourse model of the event (Garrod & Sanford, 1994; Gordon & Hendrick, 1998). Since these bottom-up processes are constrained by the ordering of these representations within the linguistic architecture, aspects of higher-level interpretation in these cases may be delayed relative to

lower-level ones (Tanenhuas & Lucas, 1987; Morris, 1994; Hess et al., 1995; Warren et al., 2008; Huang & Snedeker, 2009, in press; Ledoux et al., 2007). Our results suggest that these distinctions – between lexical versus discourse processes and top-down versus bottom-up processing – play a crucial role to understanding effects of context during reading.

Acknowledgments

We thank the members of the Language, Cognition, and Brain group for their help with this project. We are grateful to Josh Hartshorne, Matt Lowder, Tessa Warren, and an anonymous reviewer for invaluable comments on an earlier draft of this paper. This research is supported by a grant from NSF to PCG (BCS-074994) and a National Research Service Award from NICHD to YH (HD061173).

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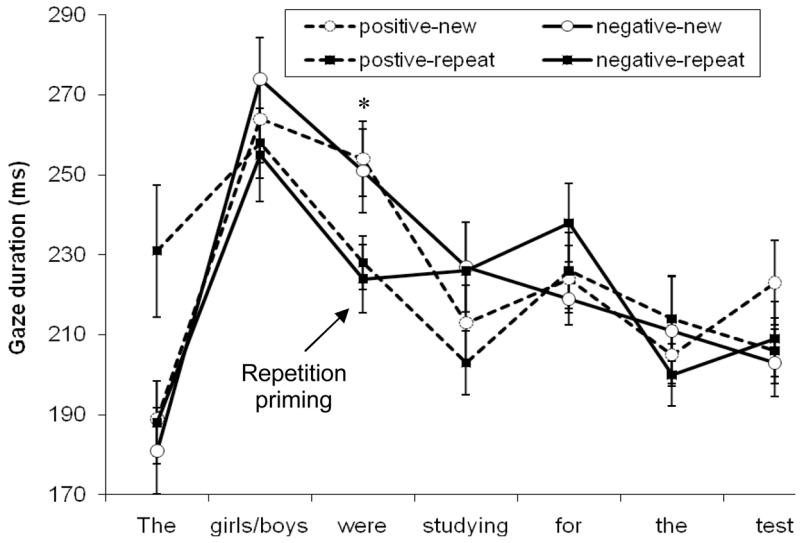

Figure 1.
Gaze duration during the ambiguous region of the critical sentence. Bars indicate standard error of the mean. Asterisks indicate the presence of significant effects.

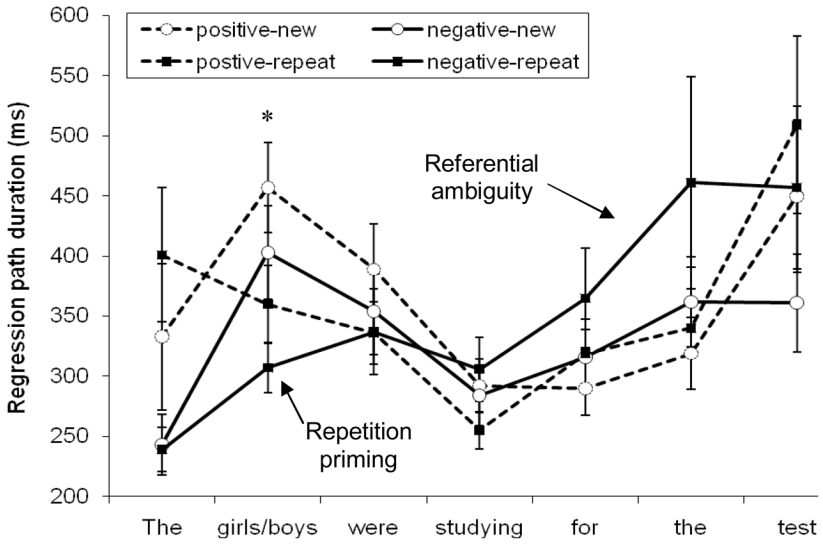

Figure 2.
Regression-path duration during the ambiguous region of the critical sentence. Bars indicate standard error of the mean. Asterisks indicate the presence of significant effects.

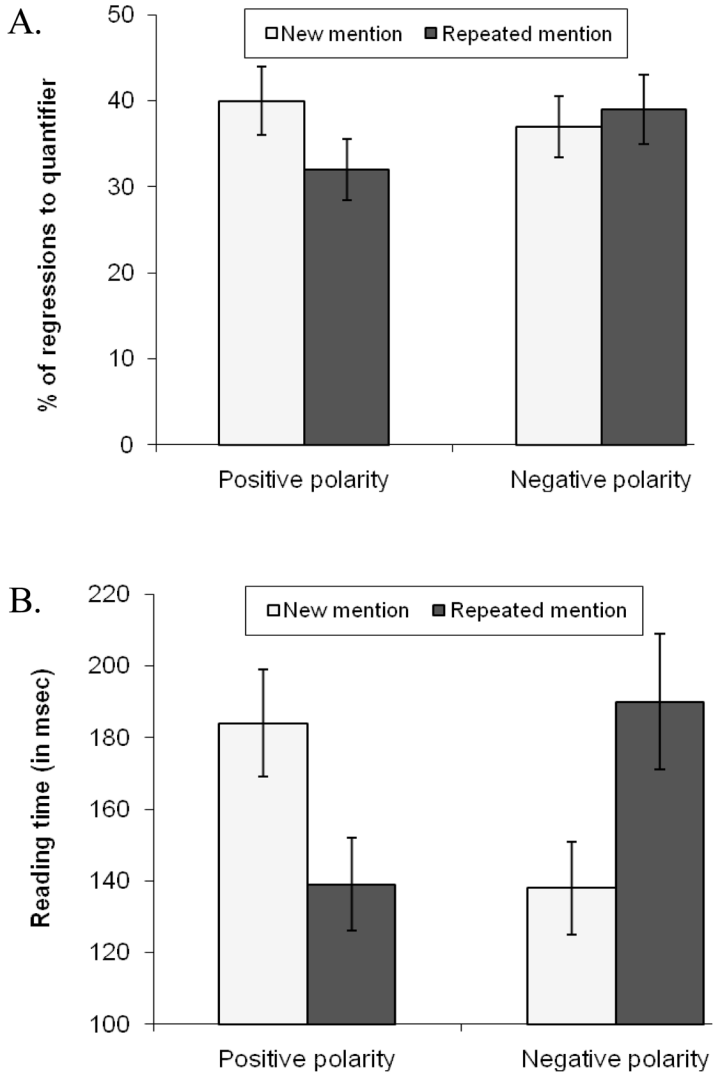

Figure 3.
(A) The likelihood of regressions into the quantifier and (B) re-reading durations of the quantifier. Bars indicate standard error of the mean.

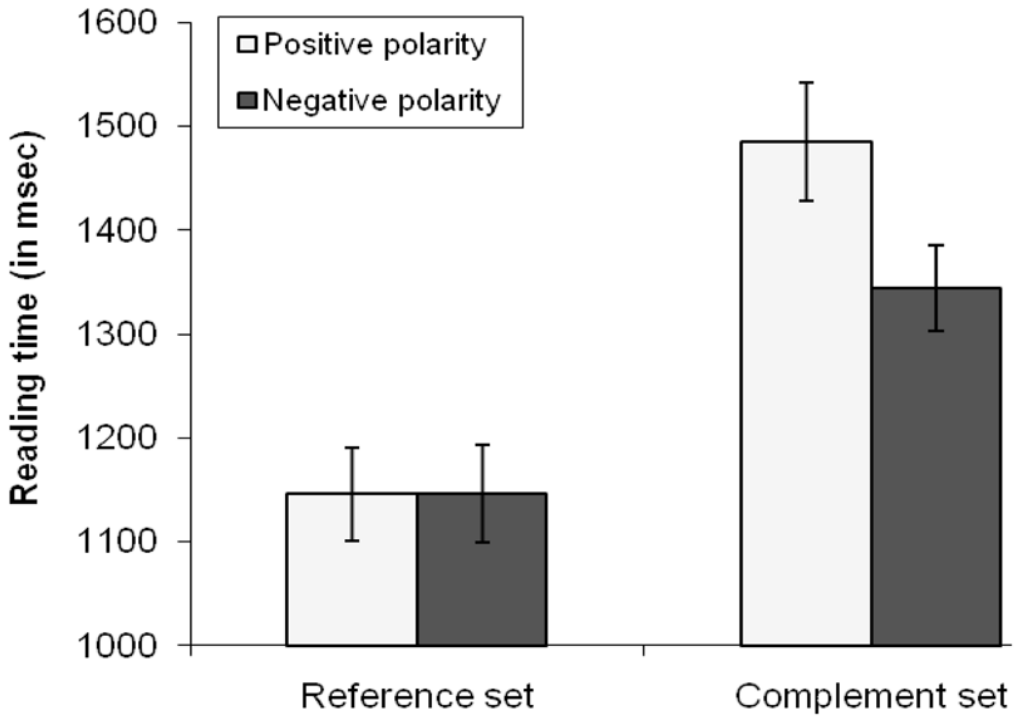

Figure 4.
Reading times during the reference-set and complement-set anaphor region. Bars indicate standard error of the mean.

Table 1

Example of a critical passage in Experiment 1

Introduction sentence		**There were forty days until the test.**
Context sentence	**Positive**	After the lecture, some of the girls met with the teacher.
	Negative	After the lecture, only some of the girls met with the teacher.
Critical sentence	**Repeated**	The girls were studying for the test and wanted to ask questions.
	New	The boys were studying for the test but didn't want help.
Question		True or False: No one bothered to prepare for the test.

Table 2

Example of a critical passage in Experiment 2

Introduction sentence		**There were forty days until the test.**
Context sentence	**Positive**	After the lecture, some of the girls met with the teacher.
	Negative	After the lecture, only some of the girls met with the teacher.
Critical sentence		The girls …

Table 3

Continuations of the repeated expression across positive and negative polarities

	Type of continuation		
	Reference set	**Complement set**	**Difference score**
Positive polarity	81% (15%)	16% (14%)	64% (29%)
Negative polarity	57% (13%)	40% (13%)	18% (26%)

Note. Parentheses indicate SDs of the means.

Table 4

Example of a critical passage in Experiment 3

Introduction sentence		**There were forty days | until the test.**
Context sentence	**Positive**	After the lecture, | some of the girls | met with the teacher.
	Negative	After the lecture, | only some of the girls | met with the teacher.
Critical sentence	**Reference**	They were studying for the test | and wanted to ask questions.
	Complement	The others were studying for the test | but didn't want help.
Question		True or False: No one bothered to prepare for the test.

Note. The dividing lines indicate the word segments that were presented together.

Appendix

Sample items for Experiments 1, 2, and 3

1. The meeting involving the entire office was going to be three hours long. Prior to the scheduled time, some (only some) of the secretaries ate lunch.		
Exp 1	*Repeated*:	The secretaries went to a nearby restaurant so they would not be late.
	New:	The accountants went to a nearby restaurant but it too crowded to get a seat.
Exp 2		The secretaries …
Exp 3	*Reference*:	They went to a nearby restaurant | so they would not be late.
	Complement:	The others went to a nearby restaurant | but it was too crowded to get a seat.
2. The veterinarian had a busy schedule during the beginning of the week. On that Monday some (only some) of the cats could be seen.		
Exp 1	*Repeated*:	The cats waited patiently in the lobby until their owners were called.
	New:	The dogs waited patiently in the lobby but their owners were asked to bring them back another day.
Exp 2		The cats …
Exp 3	*Reference*:	They waited patiently in the lobby | until their owners were called.
	Complement:	The others waited patiently in the lobby | but their owners were asked to bring them back another day.
3. The school was planning a fund raiser on a Saturday night. Because it was the weekend some (only some) of the teachers could find the time to go.		
Exp 1	*Repeated*:	The teachers showed their support by providing free child care during the event.
	New:	The parents showed their support by donating their money.
Exp 2		The teachers …
Exp 3	*Reference*:	They showed their support by | providing free child care during the event.
	Complement:	The others showed their support by | donating their money.
4. It was three weeks before the annual cross disciplinary debates. Because of their schedules some (only some) of the scientists could attend..		
Exp 1	*Repeated*:	The scientists had prepared intensely but lost the debate.
	New:	The philosophers had prepared intensely for the next debate.
Exp 2		The scientists …
Exp 3	*Reference*:	They had prepared intensely | but lost the debate.
	Complement:	The others had prepared intensely | for the next debate.