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Context-driven expectations about focus alternatives

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Abstract

What is conveyed by a sentence frequently depends not only on the descriptive content carried by its words, but also on implicit alternatives determined by the context of use. Four visual world eye-tracking experiments examined how alternatives are generated based on aspects of the discourse context and used in interpreting sentences containing the focus operators *only* and *also*. Experiment 1 builds on previous reading time studies showing that the interpretations of *only* sentences are constrained by alternatives explicitly mentioned in the preceding discourse, providing fine-grained time course information about the expectations triggered by *only*. Experiments 2 and 3 show that, in the absence of explicitly mentioned alternatives, lexical and situation-based categories evoked by the context are possible sources of alternatives. While Experiments 1–3 all demonstrate the discourse dependence of alternatives, only explicit mention triggered expectations about alternatives that were specific to sentences with *only*. By comparing *only* with *also*, Experiment 4 begins to disentangle expectations linked to the meanings of specific operators from those generalizable to the class of focus-sensitive operators. Together, these findings show that the interpretation of sentences with focus operators draws on both dedicated mechanisms for introducing alternatives into the discourse context and general mechanisms associated with discourse processing.

Keywords

focus; discourse processing; Visual World eye-tracking; alternatives; context dependence; domain restriction

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1 Introduction

Language processing involves not only continuously integrating multiple information sources but also generating expectations about the upcoming discourse (Marslen-Wilson, 1973, 1975; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995; Altmann & Kamide, 1999). In this paper, we investigate the role of context-based expectations in the processing of sentences with alternative-triggering focus operators (or focus particles). Increasingly, the role of context-relevant alternatives has emerged as a central factor in both semantics and pragmatic interpretation. Consider the example in (1).

- (1) Jane only has some *apples*.

In addition to conveying what Jane does have, (1) crucially conveys that Jane does not have any other element from some contextually-determined set of *alternatives* to apples. Examining discourse expectations associated with alternative-triggering focus operators like *only* makes it possible to separate expectations about *contextually-determined alternatives*, from expectations about *explicit descriptive content*, which have been the primary focus of previous research. Studying how listeners use focus operators to access and construct alternatives thus provides a window into one of the fundamental puzzles in real-time language processing, namely how listeners construct the contextual domains that support rich incremental interpretation.

1.1. Incremental interpretation based on semantically indeterminate input

Linguistic input is highly structured: every element is interpreted relative to other elements. For example, relations hold between a main verb and its arguments, between a *wh*- element and its gap, between functional elements and their arguments, and between arguments and their modifiers. Linguistic dependencies give rise to expectations about their completions (Lewis, 1993; Gibson, 1998, 2000; Hale, 2003; Lewis & Vasishth, 2005; Levy, 2008). In expectation-based experimental paradigms like visual world eye-tracking (Cooper, 1974; Tanenhaus et al., 1995), eye movements not only respond in a time-locked manner to linguistic events in the auditory input, but are also *anticipatory*, reflecting expectations generated by the listener about how the sentence or discourse will resolve (Altmann & Kamide, 1999, 2007; Chambers, Tanenhaus, Eberhard, Filip & Carlson, 2002).

In typical visual world studies, the target sentence contains a definite description of the target referent (e.g. *the green triangle*) and the display of visually-presented objects establishes the initial referential domain. Given the uniqueness presupposition carried by *the*, listeners use the linguistic input (along with other cues) to determine the unique candidate matching the description, proceeding incrementally as descriptive content becomes available. We refer to reference resolution that is triggered by explicit descriptive input as *description-matching*.

In sentences like (2) description-matching and contextual restriction of the referential domain triggered by the functional element *the* are conflated. The identification task is to pick out the object that is green and triangular, excluding non-green and non-triangular candidates.

(2) Click on the green triangle.

Semantic and pragmatic constraints generate strong expectations about the likelihood of reference to objects in a scene, influenced by both linguistic factors (e.g. old/new status in the discourse) and non-linguistic information (e.g. knowledge about contingencies and likelihoods of eventualities in real world situations; Altmann & Kamide, 1999; Chambers, et al., 2002; Chambers, Tanenhaus & Magnuson, 2004). Moreover, pragmatically-driven expectations can lead to rapid reference resolution even before disambiguating descriptive content is encountered. For example, Sedivy, Tanenhaus, Chambers and Carlson (1999) examined processing of noun phrases with gradable prenominal adjectives as in (3) using visual displays where more than one item qualified as tall in the context (e.g. a tall cup and a tall pitcher).

(3) Click on the *tall* cup.

When *tall* is encountered, the property (tall) in the description could be mapped onto both the cup and the pitcher. However, if there is also a smaller cup in the display, then given a contrastive interpretation, only the taller cup is a plausible referent. Sedivy et al. (1999) found that contrast leads listeners to construe the adjective as a disambiguating modifier, effectively restricting the domain of reference to the contrastive referents (the two cups). This result demonstrates rapid use of contextually-coded contrast to achieve highly incremental semantic interpretation (Sedivy, 2003; Wolter, Gorman & Tanenhaus, 2011).

Description matching based on linguistic content and context-based domain restriction normally work together to enable highly incremental interpretation. However, in most visual world studies showing this, interpretive effects associated with contextual inference are obscured because these two sources of information are conflated. The current study uses the focus particle *only*, which allows these two interpretive components to be pulled apart.

1.2 Generating expectations without descriptive content

In contrast to gradable adjectives, focus particles do not have intrinsic descriptive content: a focus particle such as *only* does not circumscribe reference the way property-denoting elements such as *green* and *tall* do. In their lack of descriptive content, focus particles resemble function words like *the*. Unlike *the*, however, focus particles are generally not confined to the noun phrase either syntactically or semantically. Focus particles can typically co-occur with a variety of phrasal types, depending on what is in focus, and when a focus operator does associate with a noun phrase, such as *only* with *some apples* in (1), the operator need not be part of or even adjacent to that noun phrase.

We will be concerned with the focus operators *only* and *also*, both of which specify the relation of a focused element (object noun phrases in this study) to a set of alternatives (including the focused element) of the same semantic type. For example, the interpretation of (1), repeated below as (4a), is standardly assumed to have two meaning components (4b-c), where (4c) depends on a set of contextually-determined alternatives such as (4d) (Rooth, 1992).

(4) a. Jane *only* has some *apples*.

- b. Jane has some apples.
- c. Jane does not have anything in *A* besides apples.
- d. $A = \{\text{apples, oranges, tangerines, mangos, bananas...}\}$

While both (4a) and its counterpart without *only* both say something about apples, (4a) also conveys something about *non-apples*—specifically, that Jane has nothing in the set of non-apples. But not all non-apples are equally relevant. If they were, Jane would only need to have one non-apple in her possession to rule out the applicability of *only*—a book, say, or a toothpick, or in the more general domain of what an individual can “have,” a body, a sense of humor, or the trivial property of being self-identical. Instead, (4a) conveys that with respect to some constrained set of alternatives of which apples is one member, Jane has apples but lacks all of the other alternatives. The identity of these alternatives remains implicit in the *only* sentence. In (4a), description-matching suffices to identify what Jane has (apples), but no part of (4a) explicitly describes the non-apple alternatives she lacks. Thus, while the accuracy of (4a) as a whole rides on an appropriate determination of the alternative set, there is no clear point in the sentence where the explicit linguistic content is decisive with respect to alternatives.

Some prior studies have shown that the alternatives associated with *only* are available in online sentence comprehension. Ni, Crain and Shankweiler (1996) compared sentences with a temporary main verb/reduced relative clause ambiguity like (5), which contained either the determiner *the* or the particle *only*.

- (5) {*The, Only*} businessmen loaned money at low interest were told to record their expenses.

The alternative set evoked by *only* led comprehenders to expect modification on *businessmen* to distinguish the businessmen that the sentence was about from other businessmen. This encouraged comprehenders to construe *loaned* as introducing a reduced relative clause, weakening the garden path that normally results when the sentence begins with a definite description (but cf. Paterson, Liversedge & Underwood, 1999). Sedivy (2002) replicated Ni et al's *only* effect, and also showed that providing explicit alternatives in the prior discourse, which, by hypothesis, eliminates the expectation for modification, indeed strengthened the garden path. These results strongly suggest that the alternatives depend on the discourse context.

The examples in (6) suggest that the alternatives used to interpret a sentence like (4a) are dependent on elements made salient in some way by the prior discourse, whether this is by explicit mention or some other more indirect means. Context (6a) explicitly mentions two elements (apples and pears) which can then be understood as the alternatives to apples in (4a); this is comparable to the explicitly provided alternatives in Sedivy (2002).

- (6) a. Beth is asking Jane if she has any apples or pears.
- b. Beth wants to make a pie. She's asking her roommates if they have any ingredients to make one.

- c. Jane is alone in the kitchen at night when she hears a burglar trying to break in. She looks around for something she can pelt him with as he comes through the window.

- (4) a. Jane only has some *apples*.

Context (6b) is similar in content to (6a), but does not rely on explicit content to evoke the appropriate alternatives for (4a), namely kinds of fruit that might go into a pie. (6c) suggests that abstract aspects of the prior context such as goals can suggest as alternatives the more heterogeneous collection of objects suitable for hurling at intruders as in (7).

- (7) $A = \{\text{apple, baseball, soup can, orange, kitchen timer...}\}$

While these examples show that alternatives can be inferred from the context indirectly, it is unclear whether alternatives associated with such potentially open-ended categories have the same restrictive power as explicitly mentioned alternatives.

The current paper addresses two questions about the generation and use of expectations triggered by focus-sensitive operators:

- 1 What is the nature of the expectations triggered by focus-sensitive operators? Specifically, to what extent are alternatives calculated incrementally in the (initial) absence of descriptive content? Do alternatives evoked by indirect means have the same status as those introduced explicitly into the discourse, and do focus operators preferentially distinguish between direct and indirect mention?
- 2 Which parts of the expectations associated with the lexical items *only* and *also* can be generalized to the class of focus-sensitive operators, and which parts are attributable to particular operators?

We can frame possible answers to the first question in terms of two hypotheses, which we illustrate using sentence (4a) and its hypothetical alternative set (4d).

Lexical Associates Hypothesis—Comprehenders generate expectations about the upcoming *descriptive content* of the sentence based on lexical or conceptual similarity with prior discourse content. For (4a), this means that comprehenders generate expectations about the focus value *apples* based on prior discourse information, as in an analogous sentence without *only*. This is illustrated by the context in (6b), repeated below.

- (6) a. Beth wants to make a pie. She's asking her roommates if they have any ingredients to make one.
- (4) a. Jane only has some *apples*.
- d. $A = \{\text{apples, oranges, tangerines, mangos, bananas, ...}\}$

On this hypothesis, existing lexical representations and their conceptual relatedness do the work of determining which continuations are expected: there need not be any moment to moment calculation of the relative likelihoods of possible alternatives. The alternatives should always be linked to the lexical content of the focus value, and they should be

predictable only to the extent that prior lexical content increases the availability of conceptually similar lexical material.

Situation-driven Alternatives Hypothesis—Comprehenders generate expectations about alternatives based on the specific properties or goals of the situation being described. In a context like (6b), comprehenders will infer something like (4d) as the alternatives because the situation described in the prior context makes them salient as ingredients for making a pie; the same alternatives are expected under the Lexical Associates Hypothesis due to facilitation from prior lexical material. However, in a context like (6c), only the Situation-driven Alternatives Hypothesis predicts that comprehenders will infer that alternatives in (7) are more likely than other possible alternative sets such as (4d). In the absence of direct conceptual similarity between prior lexical content and focus alternatives, the alternatives in (7) would only be predicted if comprehenders anticipate alternatives that are salient to the particular situation described.

- (6) c Jane is alone in the kitchen at night when she hears a burglar trying to break in.

She looks around for something she can pelt him with as he comes through the window.

- (7) A = {apple, baseball, soup can, orange, kitchen timer...}

If aspects of the discourse situation influence the perceived likelihood of alternatives, existing models of sentence processing would have to be enriched; for example, expectation-based models would need to track probability distributions over candidate alternatives. We address these issues regarding time course and contextual cues in Experiments 2 and 3.

We can separate out the meaning contributions of different lexical items from general properties shared by all members of the class by comparing *only* with another alternative-triggering lexical item, *also*. Like *only*, *also* has two meaning components—when the direct object is focused, a sentence like (8a) conveys both of the meanings in (8b) and (8c). The value of the alternative set, *A*, is determined by the context, as with *only*. Given the particular alternative set in (8d) (=4d), (8a) ends up meaning that Jane has some apples, and that she has one or more of the other items in *A*.

- (8) a. Jane also has some *apples*.
 b. Jane has some apples.
 c. Jane has something in *A* besides apples.
 d. A = {apples, oranges, tangerines, mangos, bananas...}

The difference in meaning between (8a) and its counterpart with *only* (4a) reflects how the focus value (*apples*) relates to the focus alternatives in *A*. However, the mechanism that generates and predicts likely alternatives might be common to both lexical items, and more generally to the broader class of focus sensitive operators. Characterizing the meaning differences associated with these operators would allow us to identify the broader processes involved in predicting alternatives. To this end, Experiment 4 compares the expectations triggered by *only* and *also*.

Before addressing the two questions just described in Experiments 2-4, we replicate the basic result of Sedivy (2002) in Experiment 1 using the visual world paradigm. In addition to showing that the interpretations of sentences with *only* are influenced by prior discourse content, the current methodology allows us to more precisely examine the time course of this effect.

2 Experiment 1: Focus alternatives and discourse mention

Experiment 1 examines the focus particle *only* using sentences like (4a), where *only* precedes the focused material it associates with. Many examples from the semantics literature illustrate how focus alternatives can be restricted by recent mention. For example, the second clause of (9) is most naturally interpreted with Tom, Bill, and Harry as the alternatives to Bill—that is, it conveys that that John introduced Bill *but not Tom or Harry* to Sue.

- (9) John brought Tom, Bill, and Harry to the party, but he only introduced [Bill]_F to Sue. (Rooth 1996, example 24)

In a self-paced reading study, Sedivy (2002) used reduced relative clauses to demonstrate that mentioned contrastive sets are construed as focus alternatives when followed by a sentence with *only*, as in (10).

- (10) a. All of the secretaries and accountants were made to take a tough computing course. Only the secretaries prepared for the exam...
b. ...and earned significant pay raises.
c. ...passed and earned pay raises.

When the context did not establish contrast, the expectation for alternatives triggered by *only* made the verb *prepared* likely to be interpreted as introducing a reduced relative clause (10b), resulting in increased reading time when the sentence resolved with a main clause parse (10c). However, when the requirement for alternatives was obviated by contrast recently established in the discourse, main clause continuations were more expected, and reduced relative continuations were associated with longer reading times.

In Experiment 1, we compare processing of sentences with *only* (4a) to their counterparts lacking a focus operator (11) (*target sentences*).

- (4) a. Jane only has some *apples*.
(11) Jane has some *apples*.

Listeners viewed a four-item display as they heard the target sentence. They were instructed to click on the item Jane had (*apples*). Target sentences appeared in discourses that either did or did not mention the eventual focus (the *target word*, e.g. *apples*).

Based on Sedivy's findings, we expect recently mentioned items to be naturally interpretable as focus alternatives in sentences like (4a), with participants preferring mentioned items in the display. Secondly, comparison with sentences lacking *only* like (11) will show whether any such bias is a general preference, or a bias triggered specifically by the presence of the

operator, as suggested by Sedivy (2002). Finally, if the expectation for recently mentioned items is triggered by the operator, the bias in favor of mentioned items should emerge once *only* has been encountered, even before any auditory information about the target word is available. Such time course information would provide additional support for the discourse-dependence of alternative-triggering focus operators like *only*.

2.1 Method

2.1.1 Participants—Twenty-four undergraduate students from the University of Rochester, recruited from introductory Linguistics courses and flyers posted on campus, were paid \$7.50. Participants were native speakers of American English, with normal or corrected-to-normal vision.

2.1.2 Materials and design—Experimental materials consisted of twenty discourses. In each two-sentence discourse, the first (*context*) sentence mentioned two items, and the second (*target*) sentence mentioned a single item (the *target word*). Four versions of each item were constructed by crossing two factors: Mention (whether the target word had appeared in the context sentence) and *Only* (whether the target sentence contained *only*) (see Table 1). In Mention trials, the target word was equally likely to occur first or second in the context sentence.

Twenty displays corresponded to the twenty experimental items. Each display contained four 200×200 pixel images located at the corners of the 1024×768 pixel computer screen (with images flush with screen edges): the *target* referent, a *competitor*, and two unrelated distractors. The competitor was a picture whose name begins with the same syllable as the target word, making the target and competitor names phonological cohorts (Marslen-Wilson, 1987)—for example, a target *apples* might have the competitor *axes*. The reasoning behind using phonological cohort competitors is as follows: if listeners were identifying the target based solely on the auditory input, with the target and competitor in the same cohort, then they would have to hear enough of the target word to distinguish it from the competitor before being able to identify the target. If, however, we observe an increase in target looks relative to competitor looks before the auditory input would have provided sufficient information to distinguish between them, then we can infer that some other cue (here, previous mention of the target word) is being used to identify the target referent. The target and competitor were not semantically related. The distractor items were neither cohorts of the target and competitor, nor of each other. The visual context restricts the space of possible responses. Because only one of the previously mentioned items appeared in the display on Mention trials, if participants track discourse mention, they should be able to uniquely identify that item in the display. An example display for the discourses in Table 1 is shown in Figure 1.

Four lists were created using a Latin square design, with Mention and *Only* counterbalanced across lists. Each participant was assigned to one list and saw one version of each item. Experimental trials were interspersed with 60 filler trials. The position of objects in each display was randomized, and a random trial order was generated for each run of the experiment.

For all experiments, filler trials had the same format as experimental trials (here, one context sentence followed by the target sentence). Certain properties were distributed across filler items to minimize statistical regularities across the materials. First, trials featuring displays with cohort pairs were equally frequent across the entire set of materials as those without cohort pairs; in displays with cohort pairs, the eventual target was equally likely to be a cohort member or one of the other two referents. Fillers were also constructed to minimize the salience of alternative readings of sentences with *only*, which could have interfered with the intended exclusive reading. For example, *only* has a scalar reading under which the example in Table 1 can be paraphrased as “Neil has a valuable item, while Jane has a less valuable item,” or “Neil has two items, while Jane has one item.”¹ To make the latter reading less salient, target sentences were equally likely to contain two target words (“Jane has some apples and some crayons”) as they were to contain one target word. Care was taken to select competitor and distractor referents for the visual displays which did not obviously differ in inherent value. No filler items contained *only*.

Sentences were recorded by a native speaker of American English. In all experiments, the same context sentence recordings were used across trials sharing the same context sentence. The sentences were pronounced with prominence on the final noun of the object noun phrase in both *only* and non-*only* sentences, a pattern consistent with either direct object focus or unmarked whole-sentence focus (Ladd, 1996). Readers might be concerned that any differences in timing could be due to prosodic characteristics of the *Only* and No *only* stimuli. We include files with the stimuli as supplemental materials for interested readers. In the Appendix we present a discussion of the prosody issues, including details of acoustic analyses that we conducted, and a discussion of how these analyses address concerns about the interpretation of the eye-movement data that we report in the results section.

Trials were presented in a random order generated on each run of the experiment. Four practice trials—none containing *only* or an image that appeared as a target referent in an experimental trial—preceded the 80 trials.

2.1.3 Procedure—Each trial began with the participant fixating and clicking on a crosshair in the center of the screen. Participants listened to the context and target sentences over headphones. The display appeared on the computer screen at the onset of the target sentence; there was no preview. Participants were instructed to click on the items that the second mentioned character had, corresponding to the focused element in the target sentence. The trial ended when the participant clicked on a picture. Eye movements were recorded from the onset of the target sentence to the end of the trial, using a head-mounted SR EyeLink II eye-tracking system sampling at 250Hz.

2.1.4 Modeling—The data were analyzed using mixed-effect logistic regression models with Participant and Item as random effects (Jaeger, 2008; Barr, 2008)². The models predicted fixations to the target referent, and included the following fixed effects: (1) the

¹The scalar reading of *only* is particularly salient since sentence-final prominence is compatible with both scalar *only* and the (intended) exclusive reading. A potential concern is that prominence on *only* may highlight the exclusive reading, while final prominence highlights the scalar reading. While this may be the case, our target sentences all have final prominence, therefore any differences observed cannot be attributed to the relative availability of the exclusive and scalar readings.

presence/absence of *only*, (2) whether or not the target was mentioned in the preceding sentence, and (3) time (in seconds, with one data point sampled every 4 ms). Data was unaggregated in all the regression models reported. In addition, we included the state of the previous fixation (on or off the target) as a predictor to deal with the oversampling problem that arises in analyses of visual world fixation data.³

All analyses began with the full model, which included all interactions among Mention, *Only* and Time. The State term was left in the model, regardless of significance. All predictors were centered. Redundant terms were removed by eliminating one predictor at a time for all terms correlated with one or more other terms in the model, starting with the highest order term. Model comparison using the likelihood ratio test determined whether the model including the predictor increased the likelihood of the data relative to the model excluding that term. All analyses followed the procedure in Barr, Levy, Scheepers, & Tily (2013) to determine the maximal random effects structure supported by the data. For each model with a given fixed effects structure, we started with the model containing the maximal random effects structure for Participant and Item, and iteratively removed random effects from the model if the model failed to converge. The final model is given in the table of model coefficients. When interaction terms in the regression models were significant, we assessed the simple slopes associated with each level of the relevant predictor by fitting the regression model separately for each level (Aiken & West, 1991).

Two analysis windows were delimited by salient linguistic events in the stimuli. The *early window* started at the onset of the particle *only* for *Only* conditions and the onset of the main verb for No *only* conditions, and ended at the onset of the target word (spanning on average 573 ms). The *late window* started at the onset of the target word, and ended 500 ms after the onset of the target word.

2.2 Results

We present graphs of proportions of fixations to potential referents (Figure 2), planned comparisons of target and competitor fixations over 100 ms intervals, and logistic regression models predicting target fixations in two time windows (Tables 2-5).

Figure 2 shows the mean proportion of fixations to the target and competitor, and the averaged fixations to the two distractors, for the four experimental conditions (aggregated over 100 ms bins in proportion of fixation plots). Data are aligned to the onset of the target word. In both No Mention conditions and the Mention-No *Only* condition, fixations to the target did not exceed competitor and distractor fixations until well after 200 ms after target word onset. In contrast, target fixations in the Mention-*Only* condition began to increase relative to fixations to the other scene referents approximately 200 ms after word onset.

²See Brown-Schmidt (2009); Brouwer, Mitterer and Huettig (2012); Mack, Ji and Thompson (2013) for similar logistic regression analyses of Visual World eye-tracking data.

³Looks to objects in a display arise as a result to saccadic eye movements which shift the listeners gaze to attended regions; however, eye movements take about 150-200 ms to plan and execute. Thus, at the moment in time sampled by the eye-tracker, the best predictor of whether or not a participant is looking at the target is whether she was looking at the target on the previous sample. In the absence of using event-based analyses, which predict the onset of a saccade to a location, using State as a predictor is a principled, hypothesis-neutral way of dealing with the oversampling problem. We do not include interactions with State. There is no clear theoretical reason for State to interact with the variables of interest, and any such interactions would not be interpretable.

Signal-driven eye movements in action-based visual world experiments with four-picture displays occur with a minimal lag of about 200 ms (Allopenna, Magnuson, & Tanenhaus, 1998; Salverda, Kleinschmidt & Tanenhaus, 2014; but cf. Altmann, 2011). Therefore, fixations begin to converge on the target in the context of *only* before the point in time when fixations could reflect a change due to the auditory information of the target word.

To assess the extent to which the competitor competed with the target referent, we determined when target and competitor fixations diverged in each condition by conducting planned comparisons over 100 ms intervals beginning at the onset of the target word. All planned comparisons were performed on log-odds transformed proportions of fixations. Target fixations reliably exceeded competitor fixations in the 200-300 ms window for the *Only-Mention* condition, $t(46)=2.27$, $p<0.05$ (100-200 ms window, $t(46)=0.85$, *n.s.*), but not until the 400-500 ms window for the *No only-Mention* condition, $t(46)=3.05$, $p<0.005$ (300-400 ms window, $t(46)=0.76$, *n.s.*), and the 600-700 ms window for both *Only-No mention*, $t(46)=3.50$, $p<0.005$, and *No only-No mention*, $t(46)=2.75$, $p<0.01$ (500-600 ms window, $t(46)=0.34$, *n.s.* and $t(46)=1.08$, *n.s.*, respectively).

Estimates of the coefficients corresponding to fixed effects in the regression models, and the correlations among fixed effects, are given in Tables 2-3 for the early analysis window, and in Tables 4-5 for the late window. In the early window, there were main effects of Time and State. Participants were more likely to fixate the target later in the trial and fixation on the target at the previous time point was highly predictive of fixation on the target at the current time point (these effects will be significant in general for all the models presented, so we will not discuss them further). There was a main effect of Mention: when the target word had been mentioned in the previous sentence, participants were more likely to fixate that referent. There was no significant effect of *only*, and none of the interactions among *Only*, *Mention*, and *Time* survived model comparison.

In the late window, the main effect of *Mention* is no longer reliable. There was also a two-way interaction between presence of *only* and *Mention*. Analysis of simple slopes revealed a significant facilitative effect due to *Mention* when *only* was present ($\beta=0.95$, $z=4.32$, $p<0.0001$), but not in sentences without *only* ($\beta=0.29$, $z=1.36$, $p>0.1$).⁴

2.3 Discussion

The main effect of *Mention* in the early window raises the possibility that listeners generally have a higher expectation for previously mentioned material in upcoming discourse than for

⁴We also conducted ANOVAs over log-odds transformed proportions of target fixations (Jaeger, 2008), using the same two analysis windows as for the regression models. The results were comparable to the regression analyses. In the early window, the advantage due to *Mention* was significant in the by-Subjects ($F(1,120)=16.2$, $MSE=1243.5$, $p<0.0001$) and by-Items ($F(2,1,16)=4.3$, $MSE=250.5$, $p<0.05$) analyses; there was an advantage for *No only* sentences which was marginal by Subjects ($F(1,120)=3.3$, $MSE=255.8$, $p=.07$) and significant by Items ($F(2,1,16)=4.2$, $MSE=247.4$, $p<0.05$); the *Mention-Only* interaction was only marginal by Items ($F(1,120)=.85$, $MSE=64.8$, *n.s.*; $F(2,1,16)=3.3$, $MSE=192.8$, $p=.07$). In the late window, the *Mention* advantage remained reliable ($F(1,120)=72.6$, $MSE=5332.0$, $p<0.0001$; $F(2,1,16)=86.5$, $MSE=4718.0$, $p<0.0001$); there was an *Only* advantage, reliable only by Subjects ($F(1,120)=7.4$, $MSE=543$, $p<0.01$; $F(2,1,16)=2.9$, $MSE=157$, $p=.09$); importantly, the *Mention-Only* interaction was significant ($F(1,120)=6.8$, $MSE=498$, $p<0.01$; $F(2,1,16)=8.9$, $MSE=487$, $p<0.005$). Post hoc comparisons revealed that the *Mention* advantage was highly reliable by Subjects and Items when the target sentence contained *only*, $t(766)=5.1$, $p<0.00001$; $t(638)=5.3$, $p<0.00001$, but reliable only by Subjects when it did not, $t(443)=1.9$, $p=.05$; $t(335)=1.4$, *n.s.* The primary effects of interest are the same in both regression and ANOVA analyses: (i) there is facilitation due to *Mention* in the early window, and (ii) the *Mention-Only* interaction is reliable only in late window.

discourse-new material. We note, however, that the materials used in Experiment 1 leave open the possibility that the Mention effect might be subsumed by a more general bias for discourses to remain on topic. We will address this possibility in Experiments 2 and 3 by using materials that distinguish between alternatives introduced by explicit mention and those introduced more indirectly. This will also allow us to evaluate the hypothesis that *only* might have a specific preference for explicitly mentioned alternatives.

The Mention-*Only* interaction that emerges in the late window replicates Sedivy's (2002) finding that, specifically in sentences with *only*, discourse-given alternatives affect how subsequent sentences are interpreted. Since primary prominence is on the direct object for both *Only* and No *only* sentences, and both sentence types are consistent with direct object focus, the finding that *only* modulated the Mention bias suggests that the presence of an overt operator makes the crucial difference in restricting alternatives for subsequent interpretation.

When the operator was present, the effects of the Mention bias preceded acoustic phonetic input about the target word. The visual context is a powerful constraint on the space of possible interpretations (for review see Altmann & Mirkovi, 2009). Given the already restricted referential domain specified by the visual context, participants were able to identify a probable target referent based on the presence of *only* alone, even before any information about the target word itself was available. Taken together, the results show that interpretation is incremental even in the face of radical indeterminacy with respect to descriptive content. The sensitivity of focus-sensitive operators to explicit mention is consistent with previous studies that have shown that listeners keep track of old/new status (e.g., Kaiser & Trueswell, 2004; Arnold, Fagnano & Tanenhaus, 2003; Arnold, Altmann, Fagnano & Tanenhaus, 2004; Wolter et al., 2011).

3 Experiments 2 and 3: Sources of focus alternatives

Experiments 2 and 3 examine how alternatives are constructed when they are not introduced explicitly, focusing on predictions made by the Lexical Associates and Situation-driven Alternatives Hypotheses. In addition, use of potential alternatives that are not explicitly mentioned allows us to evaluate whether or not there is a general mention bias and whether *only* is biased towards focus alternatives that have been explicitly mentioned.

According to the Lexical Associates Hypothesis, the ongoing retrieval and activation of lexical-conceptual representations during discourse processing supplies focus alternatives when required by a focus operator. Mechanistically, retrieving the meaning of a concept “activates” semantic neighbors in a gradient manner (Collins & Loftus, 1975; Cree, McRae, & McNorgan, 1999). When alternatives are not explicitly supplied by the discourse context, the processor may use this existing mechanism as a source of alternatives. According to this hypothesis, alternatives inferred from prior discourse are always linked to specific lexical items; they should be more predictable when they are closer lexical neighbors to mentioned elements.

Such a system, with focus operators piggybacking on existing lexical retrieval mechanisms, is compatible with the formal account of alternative generation proposed by Blok and Eberle

(1999), where alternatives are identified with elements in a sort hierarchy that combines syntactic and conceptual information. Crucially, alternatives are determined relative to a specific lexical item. Using the example in (4a), the focused element *apples* is immediately dominated in the sort hierarchy by the sort APPLES, which is classified both in terms of its syntactic properties (e.g. plural, count noun) and its conceptual properties (e.g. subtype of the conceptual class FRUIT). The alternatives to *apples* are dependents of the category FRUIT for which the language has a lexical item, in other words, something approximated by (4d).

- (4) **d** $A = \{\text{apples, oranges, tangerines, mangos, bananas...}\}$

Blok and Eberle's proposal assumes that the focused element is the input to computing alternatives, but this could be adapted to take as input lexical items appearing in the preceding discourse. A context mentioning *oranges* and *mangos* would generate the alternatives in (4d), and explain why members of the category FRUIT are readily interpreted as alternatives to *apples*. However, because the conceptual component of Blok and Eberle's hierarchy is meant to be constant across languages and speakers, there is no room for individual experience to alter category structure in that framework.

By contrast, the Situation-driven Alternatives Hypothesis states that focus alternatives are restricted based on a composite representation of the situation described, rather than associations with individual lexical items. According to this hypothesis, understanding discourse involves constructing a mental representation of situations or events (see Zwaan & Radvansky, 1998 for a review); concepts are selectively activated according to their relevance to a specific situation. Often, both Situation-driven and Lexical Hypotheses will make the same predictions: a context like (6b) (repeated below) could make *apples* more expected as an alternative because it is lexically related to words like *pie*, or because it is relevant to a situation where someone is looking for potential pie ingredients. However, only the Situation-driven Hypothesis predicts that alternatives will be expected based on their situation relevance even when they lack inherent similarity with prior lexical content, as in (6c).

- (6) **b** Beth wants to make a pie. She's asking her roommates if they have any ingredients to make one.
- c** Jane is alone in the kitchen at night when she hears a burglar trying to break in.

She looks around for something she can pelt him with as he comes through the window.

Experiments 2 and 3 ask whether sharing a conceptual category with a mentioned item facilitates target identification, independent of discourse old-new status. Experiment 2 uses lexically-based categories, whose members share a set of properties (e.g. *apple*, *orange*, *mango* are members of the category *fruit*). Experiment 3 uses *ad hoc* categories associated with specific situations (e.g. *hot dogs*, *nachos*, *Coke* are items one might buy at a *baseball game*). The Lexical Associates Hypothesis predicts the lexically-anchored alternatives in Experiment 2, but not the situation-specific alternatives in Experiment 3. The Situation-driven Alternatives Hypothesis predicts expectations about situation-relevant alternatives in both Experiments 2 and 3 (including lexically associated ones). In both cases, we also ask

whether category effects are limited to sentences with *only*, like the mention effect from Experiment 1, or whether it is observed across the board, as would be expected if such effects reflect general-purpose processes that occur regardless of the presence of a focus operator.

3.1 Experiment 2: Lexically-anchored alternatives

3.1.1 Method

Participants: Twenty-four undergraduate students from the University of Rochester were recruited from introductory Linguistics courses and flyers posted on the university campus, and were paid \$7.50. All participants were native speakers of American English, with normal or corrected-to-normal vision. For all experiments presented, participants were not excluded for previous participation in another of the experiments as long as the sessions were separated by at least one academic semester.

Materials and design: Experimental materials were 24 discourses, each with a context sentence followed by a target sentence. Six lists were created according to a Latin square design, counterbalancing ContextType (whether the context sentence *explicitly mentioned* the target word, mentioned members of the *same conceptual category* as the target word, or mentioned members of a *different conceptual category*) and *Only* (whether the target sentence contained *only*) (see Table 6). We refer to the two conditions without explicit mention as Same Category Novel and Different Category Novel, respectively. The Explicit mention and Different category conditions correspond to the Mention and No mention condition from Experiment 1.

The display for each test item had a target referent corresponding to the target word, a competitor in the same phonological cohort as the target, and two unrelated distractors.

Participants heard each experimental item in one of six conditions (Table 6). Experimental trials were interspersed with 48 filler trials designed to eliminate statistical regularities in the materials. Trials featuring displays with cohort pairs were equally frequent as those without cohort pairs; in displays with cohort pairs, the target was equally likely to be a cohort member or one of the other referents. Across the entire set of materials, 42% of target sentences contained two target words, and 29% of trials had displays with cohort pairs. A native speaker of American English recorded the discourses. The experiment began with four practice trials. The procedure was the same as in Experiment 1.

Modeling: Three time windows were analyzed: (i) the *pre-particle window*, the 500 ms window ending at the particle onset for *Only* conditions and at the onset of the main verb for No-*Only* conditions (the earliest segment of the trial, when the visual display and the initial word in the auditory stimulus are available), (ii) the *pre-target window*, starting at particle or main verb onset and ending at target word onset (spanning on average 551 ms), and (iii) the *post-target window*, starting at target word onset and ending 500 ms after target onset. To more directly compare looks to same category targets relative to mentioned and different category targets, we show the mean proportion of fixations to only the target referents across

conditions. These are shown in Figure 3 for the three *No-Only* conditions and the three *Only* conditions. Time is aligned to the onset of the target word.

Results were assessed by fitting target fixations from the experimental conditions with mixed-effect logistic regression models, using the three analysis windows. Models included fixed effects of *Only*, Target Type, Time and State. Target Type was Helmert-coded (the first contrast compares Same category Novel with Different category Novel; the second contrast compares Mentioned with both Same category and Different category Novel). *Only* and State were contrast-coded. Fixed and random effects structures were determined as described above.

3.1.2 Results—We present regression models predicting target fixations in the pre-particle, pre-target and post-target analysis windows (Tables 7-9). Graphs of the proportions of target fixations are given in Figure 3.

In the pre-particle window (Table 7), there is already a main effect of Category status—when only visual information about the display referents is available early in the target sentence, listeners prefer referents sharing a conceptual category with recently mentioned elements (this is indicated by the significance of the second Helmert contrast for the TargetType variable, which compares Same vs. Different Category targets). This effect increases over Time, as Different category referents become increasingly dispreferred ($\beta = -3.07$, $z = -3.06$, $p < 0.005$). There is also a main effect of Mention: fixations to explicitly mentioned targets are facilitated relative to (Same or Different category) novel target fixations. Interestingly, there is a negative effect of *Only*, which decreases over Time, as indicated by the negative *Only*:Time interaction in the model. To the extent that participants were able to pick up on prosodic cues to the presence of *only* this briefly decreased fixations to the target referent. There is also a negative interaction between Mention and the presence of *Only*, in the opposite direction from the Mention-*Only* interaction in the late window in Experiment 1: Mention had a facilitative effect in sentences *without only* ($\beta = 0.72$, $z = 1.97$, $p < 0.05$), and decreased target looks in sentences *with only* ($\beta = -0.74$, $z = -2.30$, $p < 0.01$).

The Same category advantage persists in the pre-target analysis window (particle onset to target word onset), suggesting that listeners expect continuations that share a conceptual category with recently mentioned content. None of the remaining fixed effects except for State were reliable predictors of target fixations (Table 8).

The Same category effect remains reliable in the post-target window (beginning at the onset of the target word). In addition, a Mention-*Only* interaction emerges: previous mention facilitates target identification relative to no-mention in discourses with *only* ($\beta = 0.31$, $z = 3.05$, $p < 0.005$), but not in those without *only* ($\beta = 0.014$, $z = 0.12$, $p > 0.1$). This replicates the Mention-*Only* interaction in the late window in Experiment 1. The negative Same category-Time and Mention-*Only*-Time interactions indicate that the strength of the Category and Mention-*Only* effects decrease with Time, as fixations converge on the target across conditions late in the trial (Table 9).

3.1.3 Discussion—The results of Experiment 2 suggest that conceptual associates of recently retrieved lexical items are interpreted as focus alternatives when required by the presence of a focus operator. This result is predicted by the Lexical Associates Hypothesis. However, as discussed earlier, these lexical effects would also be predicted by the Situation-driven Alternatives Hypothesis.

The Mention and Same category effects have clearly different profiles. Explicit mention (Experiments 1 and 2) selectively facilitates alternatives when *only* is present, whereas category status influences expectations about the target referent irrespective of the presence of *only*. In fact, listeners prefer same category referents in the earliest window, when visual context and discourse context from the preceding sentence are available, but it is not yet known whether the target sentence will contain a focus particle. This suggests that the mechanism underlying the category effect is not dedicated to generating focus alternatives, but is more general. For example, the category effect may reflect listeners' expectations that a discourse will generally stay "on topic" irrespective of discourse-old/new status (Ochs, 1979; Segal, Duchan, & Scott, 1991), in the absence of a clear indication of topic shift.

We remain agnostic about whether the facilitation for same category items can be explained by a general phenomenon such as lexically-based semantic priming (Yee & Sedivy 2006)—this would be consistent with the Lexical Associates Hypothesis. However, an explanation that only appeals to priming would not explain the interactions with *only* in the case of explicit mention. In Experiment 3, we turn to *ad hoc* categories, which are not expected to be facilitated under the Lexical Hypothesis, and cannot be explained by semantic priming.

3.2 Experiment 3: Ad hoc categories and situation-relevant alternatives

Experiment 3 addresses effects of prior mention of instances of a conceptual category on subsequent processing of same category material, using *ad hoc* categories evoked by the goals or expectations associated with a situation in the world. For instance, items like hot dogs or nachos could become salient alternatives in a situation where something is being purchased at a baseball game—not because they inherently share features with baseball, but because our cumulative experience with baseball games tells us that hot dogs and nachos are likely to be sold there. The current experiment asks whether, in a baseball game scenario, hot dogs and nachos become salient alternatives, despite having little inherent conceptual similarity with mentioned items. If category effects resembling those in Experiment 2 are observed, their explanation must involve experience-based inference about likely situations in the world—as expected on the Situation-driven Alternatives Hypothesis—in addition to any lexically-based semantic priming.

We created pairs of scenarios, where one scenario was compatible with a narrow set of situations (*Biasing context*), and the other with a wider range of situations (*Neutral context*). The biasing contexts are analogous to the Same category conditions in Experiment 2—here, rather than evoking lexically-anchored categories, contextual bias evoked highly constrained situations which should support formation of goal-related categories.

3.2.1. Method

Participants: Thirty-eight undergraduates from the University of Rochester, recruited from introductory Linguistics courses and flyers posted on campus, were paid \$7.50. All participants were native speakers of American English with normal or corrected-to-normal vision.

Materials and design: Experimental materials were 32 three-sentence discourses. Each discourse had an initial context sentence describing a setting, a second context sentence, and a target sentence describing what two individuals want to buy. The design crosses *Mention* (whether the target word appeared in the second context sentence), *Bias* (whether the initial sentence described a biasing scenario consistent with a narrow set of outcomes, or a relatively neutral scenario), and *Only* (whether *only* appeared in the target sentence). Eight lists were created using a Latin square design; Table 10 shows an example item.

Displays were constructed for each test item. Each display had a referent corresponding to the target word, a competitor in the same phonological cohort as the target, and two distractors. Displays for neutral conditions had four referents compatible with the scenario; in biasing contexts only one referent was compatible with the scenario.

Participants heard each experimental item in one of the eight conditions shown in Table 10. Experimental trials were interspersed with 53 filler trials to minimize statistical regularities in the materials. Trials featuring displays with cohort pairs were equally frequent as those without cohort pairs; in displays with cohort pairs, the target was equally likely to be a cohort member or one of the other referents. In addition, half of the target sentences contained two target words, and half contained one. A native speaker of American English recorded the discourses. The experiment began with four practice trials. The procedure was as in Experiment 1.

Modeling: We analyzed fixations in three time windows: (i) the *pre-particle window*, spanning the 500 ms before particle onset for *Only* conditions and before main verb onset for *No-Only* conditions, (ii) the *pre-target window*, starting at particle or main verb onset and ending at target word onset (spanning on average 918 ms), and (iii) the *post-target window*, the 500 ms window starting at the target word onset. For each analysis window, results were assessed by fitting target fixations from the eight experimental conditions using mixed-effect logistic regression models. Models included fixed effects of *Only*, *Mention*, *Bias*, *Time* and *State*. All predictors were contrast-coded.

3.2.2 Results—We present regression models predicting target fixations in the three analysis windows (Tables 11-13). Graphs of the proportions of target fixations are shown in Figure 4. The top two panels of Figure 4 show the proportion of target fixations for the Neutral context conditions. The bottom panels show the corresponding Biasing context conditions. Time is aligned to the onset of the target word.

In the pre-particle window (Table 11), none of the predictors reach significance (except *State*). Effects of *Mention* and *Bias* emerge in the pre-target window (Table 12; particle or main verb onset to target word onset). As in Experiments 1 and 2, there is a *Mention-Only*

interaction: prior mention facilitates target identification to a greater extent when *only* is present ($\beta=0.59$, $z=8.25$, $p<0.0001$), and has the reverse effect, decreasing the likelihood of target fixations, when it is not ($\beta=-0.26$, $z=-3.58$, $p<0.001$). The Mention-*Only* interaction strengthens over the early window, as indicated by the Mention-*Only*-Time interaction. In addition, there is a main effect of Bias. Fixations converge on the target earlier in biasing contexts than in neutral contexts. Like lexical category in Experiment 2, the contextual bias effect does not interact with the presence of *only*.

The main effect of Bias persists in the post-target window (Table 13; beginning at the onset of the target word). None of the Mention or *Only* terms from the early window remain significant as all fixations converge on the target referent toward the end of the trial.

3.2.3 Discussion—*Ad hoc* categories evoked by particular situation types (represented by contextual bias) pattern like the lexical categories in Experiment 2: category information influences expectations about upcoming discourse across the board, rather than specifically when required by particles like *only*. However, since *ad hoc* categories are made up of elements that lack inherent conceptual similarity, the bias effect in Experiment 3 cannot be explained entirely by lexically-based priming, or as a by-product of lexical access (the Lexical Associates Hypothesis). Rather, expectations based on these categories require situation-specific reasoning about likely outcomes, as predicted by the Situation-driven Alternatives Hypothesis.

Together, the results of Experiments 2 and 3 show that listeners generate expectations about upcoming discourse content based in part on conceptual properties of recently mentioned material. Although the (lexical and *ad hoc*) categories evoked by prior discourse *can* serve as a source of alternatives when this is required by the presence of a focus operator, the generality of the category effects suggests they reflect mechanisms involved in general discourse processing. Indeed, since Same Category (Experiment 2) and Biasing Context (Experiment 3) target words were always discourse-new, the bias toward same category referents cannot be a result of listeners keeping track of previously mentioned discourse referents. By contrast, the mention bias is modulated by the presence of *only*, suggesting that introducing alternatives into a discourse by explicit mention is qualitatively different from increasing the salience of certain elements by other, indirect means such as naming a superordinate category.

4 Experiment 4: The lexical contribution of the focus operator

We now turn to the second question introduced in Section 1: Which parts of the expectations associated with the lexical items *only* and *also* can be generalized to the class of focus-sensitive operators, and which parts are attributable to particular operators? By looking at other alternative-triggering lexical items, we can begin to separate out the meaning contributions of different focus operators from general properties shared by all members of the class.

Based on Experiment 1, listeners seem to readily interpret the set of recently mentioned items as a restriction on the set of potential alternatives. The restricted alternatives together

with the meaning of *only* gave rise to the expectation that the upcoming focus would be one of the mentioned items—that is, a subset of the restricted alternatives. In order to tease apart the contributions of general focus processing and lexical content, Experiment 4 compares *only* with discourses like (12), featuring *also*, another alternative-triggering focus operator.

(12) Jane also has some *apples*.

We restrict ourselves to cases where *also* associates with the direct object of the sentence, as opposed to the subject. For a sentence with *also*, VP or direct object focus is indicated by prominence on the focus value, and lack of prominence on the particle. Based on Experiment 1, we assume that the set of items mentioned in the context sentence is interpreted as the alternative set for interpreting the target sentence. The presupposition of *also* together with the focus on the direct object should then lead listeners to expect the upcoming focus to be a discourse *new* item, where the proposition expressed by the target sentence is true for the focus value and the set of recently mentioned alternatives. Given a context sentence like (13a), we would expect (13b) (=12) to convey something like (13c).

- (13) a. Neil has some pears and some oranges.
 b. Jane also has some *apples*.
 c. Jane has some pears, some oranges, and some apples.

By contrast, the counterpart to (12) with *only* (4a) gives rise to an expectation that the focus will be a subset of the mentioned items. Thus, we predict that discourses with *only* and *also* will lead to opposite expectations about the discourse-old/new status of upcoming focused referents. Because this information is carried by the focus operator, we predict that patterns of fixations for *only* and *also* trials will diverge early in the target sentence. Finally, convergence on a display referent should be facilitated when the target sentence is consistent with expectations based on the focus operator: fixations on the referent should converge earlier in Mention than Novel conditions for *Only* trials, and earlier in Novel than Mention conditions for *Also* trials.

4.1 Method

4.1.1 Participants—Twenty-six undergraduate students recruited from introductory Linguistics courses and flyers posted on the University of Rochester campus, were paid \$7.50. Participants were native speakers of American English, with normal or corrected-to-normal vision.

4.1.2. Materials and design—Experimental materials were 24 discourses with a context sentence followed by a target sentence. In half of the test items, the target word was explicitly mentioned in the context sentence; in the other half the target word had not been mentioned. Half of the target sentences included *only*, and half, *also*. Each participant saw six tokens of each condition (see Table 14).

Displays were constructed for each test item. Each display had a referent corresponding to the target word. However, due to the presupposition of *also* (here, that Jane has something in the alternative set other than apples), some of the target sentences required targets that included multiple objects. For example, given the context sentence “Neil has some pears and

some oranges,” the target sentence “Jane also has some apples” conveys that Jane has not only apples, but pears and oranges as well. To minimize differences among conditions, and maintain roughly equal visual complexity among the four display quadrants, we constructed displays with four *sets* of referents, as illustrated in Figure 5. The status of the display referents differed by condition. The four sets were: a *subset* of the mentioned items (*apples* in the *Only* condition example in Figure 5), a *superset* of the mentioned items (*apples, pears, oranges*), the mentioned items (*apples, pears*), and a novel item without either mentioned item (*oranges*).

Participants heard each experimental item in one of the four conditions shown in Table 14. Experimental trials were interspersed with 84 filler trials designed to minimize statistical regularities in the materials. Half of the target sentences contained two target words, and half contained one. The discourses were recorded by a native speaker of American English. Trials were presented in random order, after four practice trials.

4.1.3. Procedure—As in Experiments 1-3, participants were instructed to click on the items that Jane had, rather than items mentioned in the target sentence. Sentences with the same target words could correspond to different referents depending on the focus particle: for *Only* trials, the target corresponded to either the subset or the novel referent, while for *Also* trials, the target was either the superset or the same set referent.

4.1.4. Modeling—Three analysis windows were designated: (i) the *pre-particle window*, the 500 ms window ending at the onset of the focus particle, (ii) the *pre-target window*, starting at particle onset and ending at target word onset, and (iii) the *post-target window*, the 500 ms starting at target onset. Onsets used to delimit analysis windows were determined on a trial-by-trial basis.

To assess the influence of the focus operator, we fit fixations to the Novel/Superset referent using a mixed-effect logistic regression model in the pre-particle analysis window. The model predicted fixations to the novel referent for *Only* conditions, and fixations to the superset referent for *Also*. In order to compare the two focus particles despite their presuppositional differences, we created a binary variable whose value was 1 if either the Novel or the Superset referent had a value of 1, and 0 otherwise. This was used as the dependent variable. The random effects structure was determined as previously described. State was included as a fixed effect.

Because the time courses of effects associated with the focus particle diverged in the later analysis windows, Mention effects were analyzed separately for *Only* and *Also*. For each particle, we asked whether prior mention influenced identification of the referent. We fit fixations to the target referent (defined by trial as the referent clicked on in that trial) using logistic regression models, for the pre-target and post-target analysis windows. Mention, Time, and State were included as fixed effects, and Participant and Item as random effects.

4.2 Results

The predicted target referent varies by condition as follows: *subset* for *Only*-Mention, *novel* for *Only*-Novel, *superset* for *Also*-Novel, and *same set* for *Also*-Mention. Two types of

analyses were performed. First, we asked whether the choice of focus operator predicted fixations to novel scene referents. This analysis assesses differences in novelty biases based on the operator in a region where information about the target is not yet available. Next, we analyzed looks to the target referent separately for *Only* and *Also* conditions, assessing differences in how quickly fixations converged on the target referent for mentioned and novel targets. Proportions of fixations to scene referents are presented in Figure 6 for *Also* conditions, and Figure 7 for *Only*.

For the *Also*-Mention condition, the direct-object focus leads to a conflict between the presupposition of *also* and the expectation of a novel object. Therefore, none of the displayed referents is a perfectly felicitous interpretation of the target sentence. This infelicity is reflected in both the variability in responses and later response times in this condition (Figure 6). There were two main response types in the *Also*-Mention condition: in the majority of trials, participants chose the Subset referent, which is consistent with the form of the target word, but violates the presupposition associated with *also* (that Jane has items other than the referent corresponding to the target word). In most of the remaining trials, participants chose the Same set referent, which satisfies the presupposition of *also* (but, like the Subset referent, violates the expectation that the target will be discourse-novel).⁵ Figure 8 shows the distribution of response types by condition.

Responses from the *Also*-Novel condition are plotted in the top left panel of Figure 6, and the two main response types in the *Also*-Mention condition are shown in the two right panels.

4.2.1 Novelty bias predicted by focus operator—We predicted that *also* would lead to expectations for a superset referent, while *only* would lead to expectations for a subset referent. Because this difference is tied to the information carried by the focus operator, we expect it to emerge early in the utterance, in principle as soon as the focus particle has been processed.

Table 15 shows estimated coefficients from the regression model for the pre-particle window. The pre-particle window shows a main effect of focus operator, with fewer fixations to the Novel/Superset referent when the target sentence contained *only* than when it contained *also*. This is apparent in the early increase in fixations to the Superset referent in *Also* conditions (Figure 7), compared to *Only* conditions (Figure 8). The effect is carried by a novelty bias associated with *also*: planned comparisons over 100 ms intervals showed no advantage due to Mention in *Only* conditions in the pre-particle window, $t(50)=1.08$, *n.s.* (100 ms preceding target word onset). However, for sentences with *also*, fixations converged on the superset referent in the 100 ms window preceding the onset of the particle, $t(50)=2.83$, $p<0.01$ (in the 200-100 ms preceding particle onset, $t(50)=1.22$, *n.s.*). The effect of focus operator interacts with Time: the advantage for Novel/Superset fixations associated with *also* weakens over the pre-particle analysis window. We return to this point shortly.

⁵Twenty of the 26 participants responded consistently throughout. Within the 6 inconsistent responders, 2 converged on Subset responses in late trials, 1 converged on Same set responses, and 3 responded variably throughout the experiment. The convergence on response types in the *Also*-Mention condition did not affect responses in the other conditions, which received consistent responses throughout the experiment.

While the focus operator effect is in the direction we predicted, it is surprising that it is already present before the onset of the focus particle.

What might account for these early effects? We hypothesized that participants were sensitive to acoustic differences between the initial segments of sentences containing *only* and *also*—differences that reflect the prosody associated with their respective focus structures. To test this hypothesis, we first measured minimum and maximum F_0 , and duration for the subject argument in *only* and *also* target sentences (Table 16). Indeed the subject in *also* sentences had a higher maximum F_0 , $t(23)=2.2$, $p<0.05$, and larger pitch excursion, $t(23)=2.97$, $p<0.001$, than subjects in *only* sentences, likely serving as cues to the identity of the focus operator before it became available in the auditory input. (Note that the magnitude of the *Only/Also* differences is considerably larger than the differences between *Only* and *No only* sentences in Experiment 1.)

To examine whether prosody was responsible for the particle effects in the pre-particle window, we re-ran the analyses with four additional fixed effects included in the model: (i) the maximum F_0 in the pre-particle window, (ii) the F_0 range in the pre-particle window, (iii) the rate of F_0 change between the minimum and maximum F_0 values, and (iv) the duration of the segment between the minimum and maximum F_0 points. Duration and F_0 rate remained in the model after model comparison. The main effect of Particle is no longer significant in the resulting model (Table 17), suggesting that prosodic cues in the pre-particle window were responsible for the early divergence between *Only* and *Also* sentences. We return below to the differences in contextual support required by *only* and *also*, and their consequences for prosody.

The negative interaction between focus operator and Time appears in both models for the pre-particle window. The decrease in the focus operator effect after an early advantage for *also* suggests that Novel/Superset fixations do not increase monotonically, as is typically found for target fixations. In addition, Figures 7 and 8 show that the time course of target fixations differs substantially by focus operator, with effects emerging later for *only* than for *also*. We therefore performed separate analyses for each particle for the pre-target and post-target analysis windows.

4.2.2 Time course of mention/novelty biases—Estimated model coefficients are shown in Tables 18-19 for the *Only* conditions, and in Tables 20-21 for *Also*.

For the *Only* conditions, there is no significant effect of Mention in the pre-target window (Table 18). In the post-target window, a Mention advantage emerges (Table 19). Thus, the *Only* conditions showed more target fixations when the target had been mentioned than when it was discourse-new, replicating the Mention-*Only* effect from Experiment 1. Planned comparisons over 100 ms intervals revealed that fixations converged on the target referent in the 0-100 ms window after target word onset for the *Only*-Mention condition, $t(50)=2.47$, $p<0.05$ (-100-0 ms window, $t(50)=1.08$, *n.s.*) and in the 400-500 ms window for the *Only*-No Mention condition, $t(50)=3.08$, $p<0.01$ (300-400 ms window, $t(50)=0.86$, *n.s.*).

The *Also* conditions (Tables 20-21) show a different time course. In the *Also-Mention* condition, the novelty bias that emerged in the pre-particle window persists in the pre-target window until the 200-100 ms window preceding the onset of the target word, $t(50)=2.31$, $p<0.05$. The novelty bias reemerges in the pre-target window in the 200-300 ms following target word onset, $t(50)=3.12$, $p<0.01$. The early emergence of this effect, even before the onset of the particle, may suggest a confluence of early prosodic cues consistent with *also* rather than *only*, and the resulting novelty bias being boosted by a general preference for discourse-new material. In the *Also-Mention* condition, fixations do not converge on the target referent even 800-900 ms after target onset, $t(50)=0.13$, *n.s.*, well after the target word.

4.3 Discussion

Based on the meaning difference between *only* and *also*, we expected *also* to give rise to expectations for a superset referent (mentioned referents plus a novel target), and *only*, to expectations for a subset referent (one of two mentioned referents). This is indeed what we observed in Experiment 4. In addition, the patterns of eye movements for *only* and *also* sentences diverged early, as expected if the difference in expectations was linked to information carried by the focus operator. This pattern of time courses is consistent with Romoli, Khan, Sudo and Snedeker (2015), who also found earlier target fixations with *also* relative to *only* conditions.

The different time courses associated with the mention and novelty biases might be explained in part by a general novelty preference. The novelty bias associated with *also* would be boosted by such an underlying preference, while the mention bias associated with *only* would be working against it, explaining the early novelty preference in *also* sentences. Such a bias would seem to be at odds with the main effect of Mention observed in Experiment 1. However, Experiment 1 did not include a Same/Different category manipulation, and as such, the general Mention preference (in contrast to the Mention-Only interaction) might actually reflect a Same category bias, as in Experiments 2-3. To substantiate this idea, we conducted a sentence completion study using the online crowdsourcing platform Amazon Mechanical Turk, asking whether discourse-new continuations are preferred after the diverging mention biases associated with *only* and *also* have been taken into account. We presented 24 participants with 24 pairs of sentences like (14)-(15). The first sentence mentioned two same category referents; the second sentence either contained *only*, *also*, or no particle. The sentence pairs were based on the test items used in Experiment 2.

(14) Neil has some apples and some pears.

(15) Jane {only,also,Ø} has ____.

98.8% of all responses were same category completions.⁶ Consistent with Experiment 4, *only* and *also* gave rise to different tendencies for completions containing explicitly mentioned content (Figure 9). However, all conditions showed a preference for continuations that contained novel lexical material which nevertheless stayed within the conceptual category introduced in the prior discourse, consistent with the Same category bias observed in Experiment 2.

Returning to the results of Experiment 4, the novelty bias associated with *also* is superimposed on the underlying general novelty bias: together with the early prosodic cues, this yields an early, very prominent novelty bias in *also* sentences. However, the same general novelty bias works against the mention bias associated with *only*. A consequence of these conflicting pressures may be the relatively late emergence of the mention bias in *only* sentences.

The early divergence of the patterns of eye movements in *only* and *also* sentences suggests listeners were able to discern the difference between these sentence types based on prosodic cues in the pre-particle window. Why would the target sentences with *only* and *also* have perceptible prosodic differences? The sentences have identical syntactic structures, with the focus particle syntactically attaching to and taking scope over the verb phrase. We suspect the difference lies in how differences in focus structure are encoded for each sentence type. In Experiment 2, we restricted ourselves to cases of VP-focus, setting aside subject-focus sentences like the ones exemplified in (16) and (17); paraphrases in terms of alternative sets are given in (16c) and (17c). (18) and (19) give VP-focus sentences for comparison. Italics represent the focused argument, and capitals represent (primary) prosodic prominence.

- (16) a. Neil and Jane have some pears.
- b. Only *JANE* has some apples.
- c. No one in the alternative set has apples except Jane.
- (17) a. Neil and Jane have some apples.
- b. *Jane* ALSO has some apples.
- c. There is a set of alternative individuals who have apples; Jane has apples.
- (18) Jane only has some *APPLES*.
- (19) Jane also has some *APPLES*.

For *only*, the focal difference between (16b) and (18) is encoded by word order: the particle precedes the subject when the subject argument is in focus. Because focus structure is signaled unambiguously by word order, prosodic prominence is, by comparison, a relatively unreliable cue to focus structure.

By contrast, the subject-focus and VP-focus *also* sentences in (17b) and (19) have identical word orders. Instead, the focus structure difference is encoded prosodically (König, 1991; Rullman, 2003; Beaver & Clark, 2008; Kripke, 2009). In both cases, the subject argument bears (secondary) prominence; however, while *also* is non-prominent when focus is in the VP as in (19), it bears primary prominence when the subject is focused, as in (17b). Since we wanted to signal VP-focus readings rather than subject-focus, we avoided prominence on

⁶We assigned each discourse a basic level category prior to analyzing the responses; where there was a salient subordinate category (e.g. *writing implement* instead of *office supplies* for *pen* and *pencil*), we used the more general category. We classified responses as Mentioned if the exact form of a mentioned item was used, not counting differences in determiners or plurality. For the remainder of responses, responses falling in the pre-assigned categories were counted as Same category. In most cases, Same category responses were consistent with the more specific category (e.g. the completion *marker* after *pen* and *pencil*). Most Different category responses involved a salient relation between the completion and mentioned items, despite not falling into the pre-assigned categories (e.g. the completion *flowers* after *candy canes* and *chocolate*).

also in our materials. This may have had the side effect of rendering the subject more prominent, thereby distinguishing it from subjects in the analogous *only* sentences. The early effects in Experiment 2 suggest that comprehenders are sensitive to these prosodic cues and can use them to anticipate the upcoming focus structure. Detecting a tendency for more prominence on subjects in the *also* sentences would have allowed subjects to infer the type of particle (*also*), with eye movements reflecting the novelty bias associated with that particle.

In summary, *only* and *also* lead to different expectations with respect to prior mention: while *only* facilitated identification of mentioned targets (corresponding to a subset of the mentioned items), *also* gave rise to an expectation for discourse-new targets (corresponding to a superset of the mentioned items). Listeners were also sensitive to differences in prosodic prominence between *only* and *also* sentences. Prosodic differences before the onset of the focus operator shaped expectations about the identity of the operator itself. These results, together with the results of Experiments 2-3, suggest that the interpretation of sentences with focus operators like *only* and *also* draw on both general mechanisms that are ongoing during discourse processing (giving rise to lexical and *ad hoc* category effects), and dedicated mechanisms for introducing alternatives into the discourse context (explicit mention), which are triggered when a focus operator requires that the context supply a set of alternatives.

5 General Discussion

The experiments presented allow us to at least partially answer the questions posed in the Introduction about the processing of context-relevant alternatives triggered by focus particles. The first question was about how to characterize the contextual information that shapes expectations about focus alternatives. The second question was about the division of labor between the lexical content of individual focus operators and the class of alternative-sensitive operators. We revisit these questions, spelling out the implications of our findings for existing models of language processing, and discussing areas for future research.

5.1 Incremental inference about abstract alternatives

We demonstrated that interpretation proceeds incrementally even when it involves restricting abstract alternatives. Because focus particles like *only* or *also* do not provide information about descriptive content, we can infer that the expectations listeners generate when they encounter such particles are shaped by the prior discourse context. In the absence of explicitly given alternatives, the processor uses alternatives made salient by general-purpose mechanisms involved in discourse processing. Moreover, the calculation of context-relevant alternatives appears to be separable from the requirements of specific lexical items; in the case of *only* and *also*, the choice of focus operator determined how the focus related to its alternatives, thereby generating expectations about whether the focus was given or new.

Issues related to the processing of abstract alternatives have not been directly investigated by much previous real-time processing research, which has tended to focus on how listeners use context to resolve local indeterminacy rather than on how listeners create context. Existing models of sentence comprehension are not explicit about whether and how expectations about implicit alternatives influence incremental sentence processing. For instance, cue-

based retrieval models (Lewis, 2000; van Dyke & Lewis, 2003; Lewis & Vasishth, 2005) only generate predictions about syntactic category. However, to accommodate the Situation-driven Alternatives Hypothesis, existing theories need to be scaled up to account for how abstract domain representations are constructed.

Referential Theory (Altmann & Steedman, 1988) and the broader family of constraint satisfaction models (MacDonald, Seidenberg & Pearlmutter, 1994; Spivey & Tanenhaus, 1998; McRae, Spivey-Knowlton & Tanenhaus, 1998) claim that discourse factors—for example, the presence of contrast—influence expectations about likely parses; but as with other models originally designed to account for syntactic ambiguity resolution, the expectations generated are about likely parses, not about likely representations of the context. Predictions of surprisal-based models (Hale, 2001; Levy, 2008) are similarly restricted to syntactic parses. Explaining the findings presented here will require scaling up such models to include tracking probability distributions over sets of alternatives—ultimately over common ground representations.

5.2 The nature of expectations about alternatives

In addition to tracking discourse mention, listeners generate expectations about candidate alternatives based on properties such as category membership. The category effects observed in Experiment 2 may be explained in part by general processes of lexical retrieval and conceptual activation required in processing a sentence (Collins & Loftus, 1975; Tversky & Hemenway, 1984; Srinivas & Roediger, 1990; Cree, et al, 1999), or by semantic priming (Yee & Sedivy, 2006). However, the situation-driven effects observed in Experiment 3 suggest that comprehenders also generate alternatives on the fly, which may involve novel *ad hoc* categories that are determined by the constraints or goals associated with a particular discourse (see Ballard & Hayhoe, 2009 for a discussion of task effects on gaze control; also Salverda, Brown & Tanenhaus, 2011). Arguments for communicative goals or relevance as organizing principles of linguistic behavior have been presented by theorists from different perspectives (Roberts, 1996; Clark, 1992, 1996; Sperber & Wilson, 1987; among others; see also the discussion of *conceptual covers* in Aloni, 2000). In future research it will be important to explore how listeners generate goal-oriented alternatives. It will also be important to examine how expectations about alternatives interact with structural properties of the discourse, such as discourse coherence relations (Kehler, 2002), which have independently been shown to influence discourse-level dependencies.

To conclude, the experiments presented support a processor that generates incremental predictions with respect to both upcoming discourse content and implicit alternatives required for focus interpretation. For the two focus operators investigated here (*only* and *also*), it does so by tracking mention within the local discourse. In addition, alternatives are generated on the basis of *ad hoc* categories, and therefore must be generated in a manner that is sensitive to features of particular contexts of use. Most generally, then, the current results provide an empirical foundation for future research that uses insights from linguistic operators such as focus particles to explore the representations and processes that underlie discourse comprehension, and for enriching current processing models to include the

machinery necessary to explain the behavior of constructions that require contextually-determined alternatives.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Appendix

Experiment 1: analysis of prosodic cues

One of the objectives of Experiment 1 was to assess the time course of interpretive effects associated with the focus operator. Specifically, we were interested in whether listeners anticipate the identity of the target referent based on contextual information (the content of the preceding sentence) and the presence of the operator alone, at a point when auditory input from the target word is not yet available. We found that in the early window (starting at the onset of the particle in *Only* conditions and the main verb in *No only* conditions, and ending at the onset of the target word), there was a main effect of Mention which did not interact with the presence of *only*. In the late window starting at the onset of the target word, a Mention-*Only* interaction emerged: in sentences with *only*, mentioned referents were more likely to be considered as targets. Since the Mention-*Only* advantage emerges 200-300 ms after target word onset, and signal-driven eye movements in this type of experiment occur at a 200 ms delay, we argue that this advantage preceded any acoustic phonetic input about the target word. This would show that the presence of *only* restricted the set of candidate alternatives to just the mentioned ones.

Such a conclusion assumes that prosodic information from earlier in the sentence was not responsible for the Mention-*Only* effect. In creating the materials, we ensured that primary prominence was on the direct object for both *only* and non-*only* sentences, since this pattern is consistent with either direct object focus or unmarked whole-sentence focus. Because all target sentences (including fillers) had sentence-final prominence, with secondary prominence on the subject, participants were unlikely to expect alternative prosodic realizations of the target sentence over the session. However, the possibility remains that small prosodic differences early in the sentence were used by participants to distinguish between conditions. In particular, we were concerned that systematic increased prominence on the subject argument might signal an *only* target sentence to participants, since such a pattern may suggest that the sentence will resolve with contrastive prominence on the direct object. This would provide an alternative explanation for our the Mention-*Only* effect, in terms of prosodic patterns rather than the presence or absence of the focus particle.

To assess whether participants could have used prominence on the subject to anticipate whether they were in an *only* sentence, we measured minimum, maximum and mean F_0 , pitch excursion, and duration for the subject argument in the target sentence (Table A1).

Only sentences had a lower maximum F_0 ($t(38)=-0.33$, *n.s.*), a smaller pitch excursion ($t(38)=-3.65$, $p<0.001$), lower mean F_0 ($t(38)=-2.14$, $p<0.05$) and shorter duration ($t(38)=-2.40$, $p<0.05$) relative to sentences without *only*. If prosodic prominence is associated with

larger pitch excursions and longer duration, then subjects in *only* sentences are actually *less* prominent than are subjects in sentences without *only*, and consequently less likely to signal contrastive prominence on the direct object. We think that early anticipation of direct object focus is therefore unlikely to be associated with increased prominence on the subject argument.

Table A1

F_0 , duration means (standard deviation) for target sentence subject, Experiment 1.

	Min F_0 (Hz)	Max F_0 (Hz)	F_0 (Hz)	Mean F_0 (Hz)	Duration (ms)
<i>Only</i>	216.6 (7.4)	245.4 (8.2)	28.8 (6.1)	232.2 (1.6)	233.7 (12.5)
<i>No only</i>	217.3 (5.4)	253.5 (8.5)	36.2 (6.7)	236.6 (1.4)	243.2 (12.5)

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Highlights

- We investigate the processing of discourses containing focus-sensitive operators.
- Interpretation is predictive even when expectations are for implicit alternatives.
- Focus alternatives are restricted on the basis of the prior discourse context.
- The choice of focus operator predicts how alternatives are used in interpretation.
- Category effects reflect general processing, not just focus-sensitive meanings.

Figure 1.
Example display for Experiment 1 (labels for illustration only).

Figure 2.

Mean proportion of fixations to display items, Experiment 1. Top left=No Mention-No *only* condition; Top right=No Mention-*Only*; Bottom left= Mention-No *only*; Bottom right=Mention-*Only*. Vertical lines represent (left to right): average focus particle onset; target word onset. Error bars represent standard error.

Figure 3.

Mean proportions of target fixations, Experiment 2. Left=*No Only* condition; Right=*Only*.

Vertical lines indicate (left to right): average target sentence onset, average particle onset, target word onset.

Figure 4.

Mean proportion target fixations, Experiment 3. Top left=Neutral context, Mention condition; Top right=Neutral context, No mention; Bottom left=Biasing context, Mention; Bottom right=Biasing context, No mention. Vertical lines indicate (left to right): average target sentence onset, average particle onset, target word onset.

Figure 5.
Example displays for Experiment 4 (labels for illustration only). Left panel: *Only* conditions; Right panel: *Also* conditions.

Figure 6.

Mean proportions of target fixations, Experiment 4—*Also* conditions. Top left=*Also-Novel* condition; Top right=*Also-Mention* (subset responses); Bottom right=*Also-Mention* (same set responses). Vertical lines indicate (left to right): average target sentence onset, focus particle onset, average target word onset, average response time (mouse click).

Figure 7. Mean proportions of target fixations, Experiment 4—*Only* conditions. Left=*Only-Novel*; Right=*Only-Mention*. Vertical lines indicate (left to right): average target sentence onset, focus particle onset, average target word onset, average response time (mouse click).

Figure 8.
Distribution of responses by condition, Experiment 4.

Figure 9.
Proportion of completion types, Sentence completion experiment.

Table 1

Design and example stimuli for Experiment 1.

	<i>Only</i>	<i>No only</i>
Mention	Neil has some apples and some cards.	Neil has some apples and some cards.
	Jane only has some <i>apples</i> .	Jane has some <i>apples</i> .
No mention	Neil has some lanterns and some cards.	Neil has some lanterns and some cards.
	Jane only has some <i>apples</i> .	Jane has some <i>apples</i> .

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Table 2

Estimates of fixed effects, Experiment 1—early window.

TargetFix ~ Only + Mention + Time + State + (1 Participant) + (1 Item)				
	Estimate	SE	z	p
Intercept	−6.90	0.37	−23.32	<0.0001
Only	−0.099	0.23	−0.44	<i>n.s.</i>
Mention	0.48	0.18	2.64	<0.01
Time	3.63	0.34	10.83	<0.0001
State	10.41	0.29	35.85	<0.0001

Table 3

Correlations of fixed effects, Experiment 1—early window.

	Intercept	Only	Mention	Time
Only	0.26			
Mention	0.13	0.073		
Time	−0.54	0.014	0.064	
State	−0.61	−0.041	0.026	0.55

Table 4

Estimates of fixed effects, Experiment 1—late window.

TargetFix ~ <i>Only</i> + Mention + Time + State + Only:Mention + (1 + Mention Participant) + (1 Item)				
	Estimate	SE	z	p
Intercept	−6.49	0.23	−28.14	<0.0001
<i>Only</i>	−0.18	0.22	−0.83	<i>n.s.</i>
Mention	0.29	0.21	1.36	<i>n.s.</i>
Time	2.18	0.49	4.41	<0.0001
State	10.80	0.17	65.34	<0.0001
<i>Only</i> :Mention	0.66	0.29	2.28	<0.05

Table 5

Correlations of fixed effects, Experiment 1—late window.

	Intercept	Only	Mention	Time	State
Only	−0.43				
Mention	−0.52	0.47			
Time	−0.60	−0.012	0.013		
State	−0.34	0.010	0.013	0.14	
Only:Mention	0.31	−0.76	−0.66	0.012	0.071

Table 6

Design and example stimuli for Experiment 2.

	<i>Only</i>	<i>No only</i>
Explicit mention	Neil has some pears and some apples. Alex only has some <i>apples</i> .	Neil has some pears and some apples. Alex has some <i>apples</i> .
Same category Novel	Neil has some pears and some oranges. Alex only has some <i>apples</i> .	Neil has some pears and some oranges. Alex has some <i>apples</i> .
Different category Novel	Neil has some sandals and some boots. Alex only has some <i>apples</i> .	Neil has some sandals and some boots. Alex has some <i>apples</i> .

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Table 7

Estimates of fixed effects, Experiment 2—pre-particle window.

TargetFix ~ TargetType + Only + Time + State + TargetType: Only + TargetType:Time + Only:Time + TargetType:Only:Time + (1 + TargetType Participant) + (1 Item)				
	Estimate	SE	z	p
Intercept	−6.04	0.51	−11.90	<0.0001
TargetType[Same v. Different Category]	1.72	0.61	2.80	<0.01
TargetType[Mentioned v. Same/Diff Cat]	0.72	0.37	1.98	<0.05
Only	−1.68	0.64	−2.64	<0.01
Time	−0.35	0.59	−0.59	<i>n.s.</i>
State	10.25	0.13	80.22	<0.0001
TargetType[Same v. Diff Cat]:Only	−1.59	0.84	−1.90	0.06
TargetType[Mentioned v. Same/Diff Cat]:Only	−1.47	0.42	−3.47	<0.001
TargetType[Same v. Diff Cat]:Time	2.28	0.73	3.12	<0.005
TargetType[Mentioned v. Same/Diff Cat]:Time	0.44	0.40	1.10	<i>n.s.</i>
Only:Time	−2.06	0.78	−2.65	<0.01
TargetType[Same v. Diff Cat]:Only:Time	−2.35	1.02	−2.31	<0.05
TargetType[Mentioned v. Same/Diff Cat]:Only:Time	−1.75	0.51	−3.40	<0.0001

Table 8

Estimates of fixed effects, Experiment 2—pre-target window.

TargetFix ~ TargetType + Only + Time + State + TargetType:Only + (1+Only Participant) + (1 Item)					
	Estimate	SE	z	p	
Intercept	−5.46	0.13	−41.99	<0.0001	
TargetType[Same v. Diff Category]	0.21	0.089	2.37	<0.05	
TargetType[Mentioned v. Same/Diff Cat]	0.041	0.049	0.84	<i>n.s.</i>	
Only	0.014	0.14	0.10	<i>n.s.</i>	
Time	0.14	0.31	0.45	<i>n.s.</i>	
State	9.91	0.10	98.04	<0.0001	
TargetType[Same v. Diff Cat]:Only	−0.17	0.12	−1.37	0.17	
TargetType[Mentioned v. Same/Diff Cat]:Only	0.034	0.070	0.49	<i>n.s.</i>	

Table 9

Estimates of fixed effects, Experiment 2—post-target window.

TargetFix ~ TargetType + Only + Time + State + TargetType:Only + TargetType:Time + Only:Time + TargetType: Only:Time + (1 Participant) + (1 Item)				
	Estimate	SE	z	p
Intercept	−5.78	0.18	−32.58	<0.0001
TargetType[Same Category]	0.39	0.19	2.04	<0.05
TargetType[Mentioned]	0.014	0.11	0.12	<i>n.s.</i>
Only	0.40	0.21	1.85	0.06
Time	3.03	0.53	5.78	<0.0001
State	10.36	0.12	84.24	<0.0001
TargetType[SameCat]:Only	−0.44	0.26	−1.66	0.10
TargetType[Mentioned]:Only	0.30	0.15	1.99	<0.05
TargetType[SameCat]:Time	−1.34	0.65	−2.08	<0.05
TargetType[Mentioned]:Time	0.53	0.37	1.46	0.14
Only:Time	−0.99	0.71	−1.39	0.16
TargetType[SameCat]:Only:Time	2.97	0.87	3.42	<0.001
TargetType[Mentioned]:Only:Time	−2.65	0.51	−5.22	<0.001

Table 10

Design and example stimuli for Experiment 3.

Biasing context	Mention	Neil and Alex are at the baseball game. Alex wants to buy some hot dogs and some nachos. Neil (only) wants to buy some <i>hot dogs</i> .
	No mention	Neil and Alex are at the baseball game. Alex wants to buy some Coke and some nachos. Neil (only) wants to buy some <i>hot dogs</i> .
Neutral context	Mention	Neil and Alex are at the supermarket. Alex wants to buy some hot dogs and some cherries. Neil (only) wants to buy some <i>hot dogs</i> .
	No mention	Neil and Alex are at the supermarket. Alex wants to buy some bell peppers and some cherries. Neil (only) wants to buy some hot dogs.

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Table 11

Estimates of fixed effects, Experiment 3—pre-particle window.

TargetFix ~ Bias + Mention + <i>Only</i> + Time + State + Mention:<i>Only</i> + <i>Only</i>:Time + (1 Participant) + (1 Item)				
	Estimate	SE	z	p
Intercept	−11.16	4.50	−2.48	<0.05
Bias	0.51	0.75	0.68	<i>n.s.</i>
Mention	−0.87	0.99	−0.88	<i>n.s.</i>
<i>Only</i>	−9.76	7.58	−1.29	<i>n.s.</i>
Time	1.43	2.91	0.49	<i>n.s.</i>
State	15.13	1.28	11.86	<0.0001
Mention: <i>Only</i>	1.61	1.48	1.10	<i>n.s.</i>
<i>Only</i> :Time	−5.65	4.72	−1.20	<i>n.s.</i>

Table 12

Estimates of fixed effects, Experiment 3—pre-target window.

TargetFix ~ Bias + Mention + <i>Only</i> + Time + State + Bias:Mention + Bias: <i>Only</i> + Bias:Time + Mention: <i>Only</i> + Mention:Time + <i>Only</i> :Time + Mention: <i>Only</i> :Time + (1 Participant) + (1 Item)				
	Estimate	SE	z	p
Intercept	−6.05	0.16	−38.81	<0.0001
Bias	0.31	0.16	2.02	<0.05
Mention	−0.36	0.19	−1.88	0.06
<i>Only</i>	−0.24	0.19	−1.23	<i>n.s.</i>
Time	−0.25	0.27	−0.92	<i>n.s.</i>
State	10.71	0.066	162.73	<0.0001
Bias:Mention	−0.068	0.13	−0.53	<i>n.s.</i>
Bias: <i>Only</i>	−0.10	0.13	−0.78	<i>n.s.</i>
Bias:Time	0.12	0.24	0.50	<i>n.s.</i>
Mention: <i>Only</i>	0.67	0.25	2.62	<0.01
Mention:Time	−0.61	0.34	−1.80	0.07
<i>Only</i> :Time	−0.061	0.34	−0.18	<i>n.s.</i>
Mention: <i>Only</i> :Time	1.03	0.48	2.12	<0.05

Table 13

Estimates of fixed effects, Experiment 3—post-target window.

TargetFix ~ Bias + Mention + <i>Only</i> + Time + State + Bias:<i>Only</i> + (1 Participant) + (1 Item)				
	Estimate	SE	z	p
Intercept	−6.08	0.10	−59.20	<0.0001
Bias	0.22	0.089	2.52	<0.05
Mention	−0.015	0.064	−0.24	<i>n.s.</i>
<i>Only</i>	−0.11	0.092	−1.18	<i>n.s.</i>
Time	−0.25	0.12	−2.07	<0.05
State	10.70	0.066	163.40	<0.0001
Bias: <i>Only</i>	−0.10	0.13	−0.80	<i>n.s.</i>

Table 14

Design and example stimuli for Experiment 4.

	Only	Also
Mention	Neil has some pears and some apples.	Neil has some pears and some apples.
	Jane only has some <i>apples</i> .	Jane also has some <i>apples</i> .
Novel	Neil has some pears and some oranges.	Neil has some pears and some oranges.
	Jane only has some <i>apples</i> .	Jane also has some <i>apples</i> .

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Table 15

Estimates of fixed effects, Experiment 4: Effect of focus particle, pre-particle window.

Novel/SupersetFix ~ Mention + Particle + Time + State + Particle:Time + (1 + Mention Participant) + (1 + Mention Item)				
	Estimate	SE	z	p
Intercept	−3.98	0.26	−15.28	<0.0001
Particle[<i>Only</i>]	−0.71	0.18	−3.90	<0.0001
Mention	−0.19	0.20	−0.95	<i>n.s.</i>
Time	6.09	0.53	11.48	<0.0001
State	9.39	0.10	91.29	<0.0001
Particle[<i>Only</i>]:Time	−2.69	0.71	−3.80	<0.001

Table 16

F_0 , duration means (standard deviation) for Experiment 4, target sentence subject.

	Min F_0 (Hz)	Max F_0 (Hz)	F_0 (Hz)	Duration (ms)
<i>Only</i>	170.3 (24.1)	196.2 (8.2)	26.0 (27.3)	307.0 (13.3)
<i>Also</i>	154.7 (35.7)	202.6 (13.6)	47.9 (36.6)	316.7 (13.9)

Table 17

Estimates of fixed effects, Experiment 4: Effects of focus particle and prosodic cues, pre-particle window.

Novel/Superset ~ Particle + Mention + Time + Duration + F₀Rate + State + Particle:Duration + Particle:Time + (1 Participant) + (1 Item)				
	Estimate	SE	z	p
Intercept	−3.71	1.81	−2.05	<0.0001
Particle[<i>Only</i>]	−4.57	2.70	−1.69	0.09
Mention	−0.038	0.11	−0.35	<i>n.s.</i>
Time	0.73	0.47	1.58	<i>n.s.</i>
Duration	−5.64	5.77	−0.98	<i>n.s.</i>
F ₀ Rate	−0.11	0.16	−0.65	<i>n.s.</i>
State	10.70	0.12	92.66	<0.0001
Particle[<i>Only</i>]:Duration	15.89	8.66	1.83	0.07
Particle[<i>Only</i>]:Time	−1.94	0.69	−2.83	<0.01

Table 18

Estimates of fixed effects, Experiment 4: *Only*, pre-target window.

TargetFix ~ Mention + Time + State + (1 + Mention Participant) + (1 + Mention Item)				
	Estimate	SE	z	p
Intercept	-4.86	0.81	-5.97	<0.0001
Mention	1.20	0.94	1.29	<i>n.s.</i>
Time	0.92	0.11	8.45	<0.0001
State	0.31	0.04	7.49	<0.0001

Table 19

Estimates of fixed effects, Experiment 4: Only, post-target window.

TargetFix ~ Mention + Time + State + (1 + Mention Participant) + (1 + Mention Item)				
	Estimate	SE	z	P
Intercept	-4.49	0.46	-9.77	<0.0001
Mention	1.08	0.53	2.03	<0.05
Time	3.15	0.10	32.61	<0.0001
State	0.32	0.03	10.01	<0.0001

Table 20

Estimates of fixed effects, Experiment 4: *Also*, pre-target window.

TargetFix ~ Mention + Time + State + Mention:Time + (1 + Mention Participant) + (1 + Mention Item)				
	Estimate	SE	z	p
Intercept	-2.20	0.31	-7.01	<0.0001
Mention	-1.21	0.61	-1.99	<0.05
Time	1.14	0.12	9.75	<0.0001
State	1.13	0.03	34.42	<0.0001
Mention:Time	-2.22	0.18	-12.35	<0.0001

Table 21

Estimates of fixed effects, Experiment 4: *Also*, post-target window.

TargetFix ~ Mention + Time + State + Mention:Time + (1 + Mention Participant) + (1 Item)				
	Estimate	SE	z	p
Intercept	−2.45	0.38	−6.49	<0.0001
Mention	−0.95	0.59	−1.62	<0.11
Time	1.37	0.13	10.27	<0.0001
State	1.17	0.04	32.96	<0.0001
Mention:Time	−1.09	0.21	−5.17	<0.0001