Information integration and domain restriction: Interpreting *only* in context

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1. Introduction

In this paper we report results of two eye-tracking experiments investigating on-line processing of the focus-sensitive expression 'only'. The experiments described address two sets of questions having to do with the role of contextual information in restricting focus alternatives. First, there is the question of whether the preceding discourse context influences the referential domain with respect to which a sentence with 'only' is interpreted; specifically, does previous mention increase the likelihood of associating with 'only'? This question is addressed by Experiment 1. Experiment 2 asks whether the relative informativity of the linguistic context influences what listeners expect to be in the alternative set.

The remainder of this section reviews some properties of 'only' and its interpretation, then some of the relevant psycholinguistic findings using eye-tracking and the visual world paradigm. Experiment 1 is presented in Section 2, and Experiment 2 in Section 3. Section 4 concludes with a general discussion of the results, and suggests future research directions.

1.1. Only

'Only' belongs to a class of elements whose interpretation depends on association with some focused constituent in their scope. What 'only' associates with can make a difference for the sentence's truth conditions: take (1), where focal stress falls on different elements (underlined).

(1) a. Lauren only invited Sameer to the 4th of July party.
b. Lauren only invited Sameer to the 4th of July party.

(1a) and (1b) are true in different circumstances—for example, (1a) would be true but (1b) false if Lauren invited Sameer and no one else to a number of events: the 4th of July party, the post-dissertation-defense party, the baby shower, and so on. We can characterize this meaning difference as a difference in the alternative propositions that these sentences are interpreted with respect to. Following a standard Roothian semantics for interpreting focus (Rooth (1985)), we assume the focused constituent e.g. in (1a) gives rise to a focus value (2a), in addition to its ordinary semantic value (2b).

(2) a. $[\![Sameer]\!]^f$ = {sameer, justin, chris, joanna,...}
b. $[\![Sameer]\!]^o$ = sameer

The focus value will be the set of elements of the same semantic type as the focused element, here, the set of individuals, including Sameer. To get a set of alternative propositions for (1a), we take the proposition *'Lauren invited X to the 4th of July party'* and swap in different same-type elements (from (2a)) for *X*.

What different focus-associating lexical items do is specify how these focus alternatives relate to the meaning of the sentence with its ordinary semantic value. 'Only' presupposes the truth of the sentence with the ordinary semantic value (*'Lauren invited Sameer to the 4th of July party'*), and denies the truth of every other alternative (*'Lauren invited Justin to the 4th of July party', 'Lauren invited Chris to the 4th of July party', 'Lauren invited Joanna to the 4th of July party',* etc.) (Horn (1969, 1996); Geurts & van der Sandt (2004)).

The topic of this paper is where the values in (2a) come from. It is clearly too weak to say that the focus value simply comprises the set of all things type-identical to the focused element. Instead, (1a)

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seems like it ought to mean *'Of all the people one might expect Lauren to invite, she only invited Sameer'*, or *'Of all of her friends,...'*; that is, the focus alternatives need to be restricted to a narrower, contextually salient set. Likewise, in (3b), we can infer from the context provided by the preceding sentence (3a) that the relevant class of things is something like 'modes of transportation'.

(3) a. Natalie has a car, and a bike, and she lives near a bus line.
b. Katie only has a bike.

Here it is even more obvious that (3b) does not mean that Katie's sole worldly possession is a bike, but rather that her only way of getting around town is on her bike.

This context-dependence is typically implemented by assuming the context provides some salient set that is intersected with the focus alternatives generated by the interpretive machinery (e.g. Rooth (1992) proposes that the domain of quantification C is a subset of the alternative set). But exactly what aspects of the information available in an interpretive context contribute to restricting focus alternatives has not been addressed thus far. The current study uses the visual world eye-tracking paradigm to ask this question, by observing how listeners' expectations of the resolution of a sentence containing 'only' change as the information provided in the linguistic context is manipulated.

1.2. Evidence from eye-tracking: Integrating information about the world

Previous experimental work has shown that language comprehenders rapidly integrate multiple sources of information for the purpose of referential disambiguation. In a typical visual world eye-tracking study, participants move or click on objects in a visual display as they are listening to a sentence that indicates what item in the display is the target. Eye-movements have been shown to be closely time-locked to salient linguistic events in auditorily presented stimuli (Tanenhaus et al. (1995)), and therefore provide a means to track listeners' expectations about upcoming linguistic input given the visual context and what they have heard so far. By manipulating the availability of different information types available in the visual or linguistic context, one can ask to what extent each of these potential information sources helps the listener restrict the referential domain to the point that the single intended referent can be picked out. Previous studies have found that visual information about the possible referents in a display (Tanenhaus et al. (1995)), selectional properties of lexical items (Altmann & Kamide (1999)), knowledge about possible and impossible actions or events given the state of the world (Chambers et al. (2004)), the presence of contrast in the visual display (Sedivy et al. (1999)), and information about the preceding linguistic discourse (Chambers et al. (2002)) are used online during sentence comprehension to restrict the set of likely interpretations.

For example, in Chambers et al. (2004), participants heard instructions and manipulated objects in a visual display accordingly. The instructions contained ambiguously attached prepositional phrases (underlined in (4a)), which could turn out to be a location modifier (4b) or a goal (4c).

(4) a. Pour the egg <u>in the bowl</u>...
b. ...over the flour.
c. ...while stirring continuously.

In a display with multiple objects including a hard-boiled egg and a liquid egg, participants looked to the liquid egg soon after hearing the verb 'pour', indicating that they had already disambiguated the intended referent using their knowledge about what types of things are pourable (i.e. liquids, but not solids). This indicates that listeners actively integrate their knowledge about the world in order to exclude continuations that are unlikely or impossible eventualities in the world.

Restricting the set of focus alternatives, in a sentence like (5), would be another way of restricting referential domains for the purpose of picking out a target object.

(5) Jane only has <u>some candy</u>.

Since the eventual target word must be included in the focus values, having an expectation about what that word will be amounts to having stronger or weaker expectations about what will be a possible alternative.

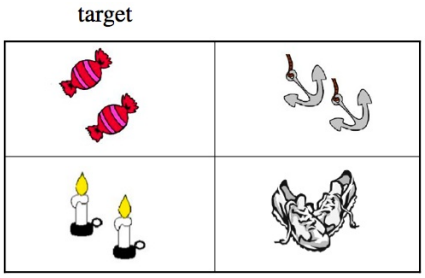


Figure 1: Example visual display for Experiment 1.

In the present study, we ask whether recent mention (Experiment 1) and context informativity (Experiment 2) constrain referential domains for interpreting sentences with 'only', by increasing listeners' expectations that certain elements will be included in the alternative set.

2. Experiment 1: Restricting alternatives to recently mentioned items

Does recent mention in the context of 'only' make something a good candidate for inclusion in the alternative set? To begin with, there may be a general expectation for the content of the current sentence to be related or relevant to recent material in the discourse. On top of this general preference, it may be that alternative-triggering elements like 'only' create an even stronger expectation that the focus will be interpreted with respect to just mentioned items.

2.1. Design, Procedure, Materials

Experiment 1 looks at the effect of previous mention on the interpretation of sentences with and without 'only'—in particular, does previous mention make it easier for listeners to disambiguate the target referent? It manipulates (1) whether the target item is mentioned in the context sentence, and (2) the presence of 'only' in the target sentence. The four resulting conditions are in (6). All the target sentences in (6) are to be interpreted with respect to the four-item visual display in Fig. 1.

(6)

Condition	Context sentence	Target sentence
1 NoMention, No*Only*	Mark has some candles and some shoes.	Jane has some candy.
2 Mention, No*Only*	Mark has some candy and some shoes.	Jane has some candy.
3 NoMention, *Only*	Mark has some candles and some shoes.	Jane only has some candy.
4 Mention, *Only*	Mark has some candy and some shoes.	Jane only has some candy.

On each trial, participants hear a context sentence (*'Mark has some candles and some shoes'*), then a target sentence (*'Jane only has some candles'*). At the onset of the target sentence, four pictures appear (Fig. 1), one at each corner of the computer screen; the participants' instructions are to click on the items mentioned in the target sentence (i.e. the things that Jane has).

Each display consists of four pictures: the target item (*candy*), a phonological "cohort" competitor (*candles*), and two unrelated distractor items (*anchors, sneakers*). We chose to use phonological cohorts because, in a neutral context, participants will begin to shift fixation to words that match the acoustic input about 200 ms after the onset of the word (Allopenna et al. (1998)). Therefore we expect participants to look equiprobably at the target item and the cohort competitor at the point in the target sentence when they've heard just the beginning of the direct object (*'can...'*). As the unfolding auditory input disambiguates the target referent (*'...ndy'*)—call this the point of disambiguation—the proportion of fixations to the target item should rise as fixations to the competitor drop off. This means that if looks

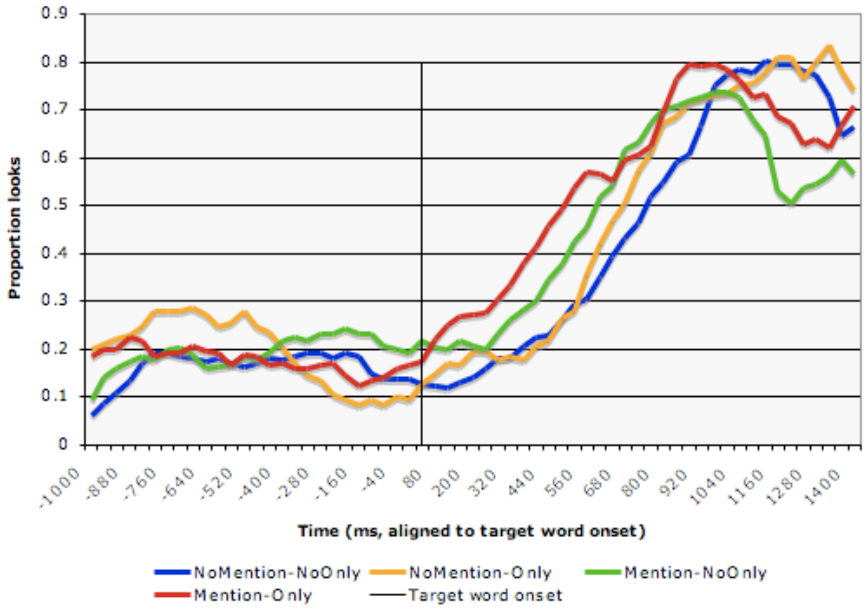


Figure 2: Experiment 1. Proportion looks to the target item (only target looks plotted for each condition). Aligned to target word onset.

to the target item increase earlier than the point of disambiguation, there is a bias toward the target item due to some other property of the stimulus.

2.2. Predictions

Under the hypothesis that there is a preference to interpret 'only' with respect to referents previously mentioned in the discourse, participants will be faster to identify the target item in the Mention conditions. Upon hearing a Context sentence like *'Mark has some candy and some shoes'*, the listener may already have an expectation that the Target sentence will refer to an item from the narrower set of items already referred to (*candy, shoes*). Since the target item in critical trials is always either an item mentioned in the Context sentence, or a phonological competitor of a mentioned item, using previous mention as a cue will effectively allow participants to identify the target early, despite the fact that target and competitor will be phonologically indistinguishable word-initially.

Additionally, it is possible that an effect of Mention will interact with the presence or absence of 'only'. Because 'only' is a cue for a comprehender that they will have to interpret some upcoming focused constituent with respect to some set of salient alternatives, the benefit of previous mention on identifying the target item may be restricted to these cases, or have a greater impact on target identification than conditions without 'only'.

2.3. Results

In order to examine the time course of fixations, we calculated the proportion of fixations to the target at every 33 ms time slice, aggregating trials for each condition first within a participant and then across participants. This results in a proportion of fixation curve with fixations plotted as a function of time (Fig. 2). Fig. 3 shows the average time to convergence on the target referent (where looks to the target reliably exceed looks to the competitor) for each condition.

There were main effects of Mention ($F1(1, 23) = 46.8$, $p < .0001$) and *Only* ($F1(1, 23) = 6.2$, $p < .05$), as well as a Mention-*Only* interaction ($F1(1, 23) = 14.8$, $p < .0005$). On NoMention trials, the target referent was disambiguated from the phonological cohort competitor only after the entire word was heard—on average 560 ms after the onset of the direct object (left-hand bars in Fig. 3). There was no advantage for the *Only* condition over the No*Only* condition ($t = 1.4$, $p = .15$).

On Mention-No*Only* trials (right-hand bars, Fig. 3), fixations converge on the target item 404 ms

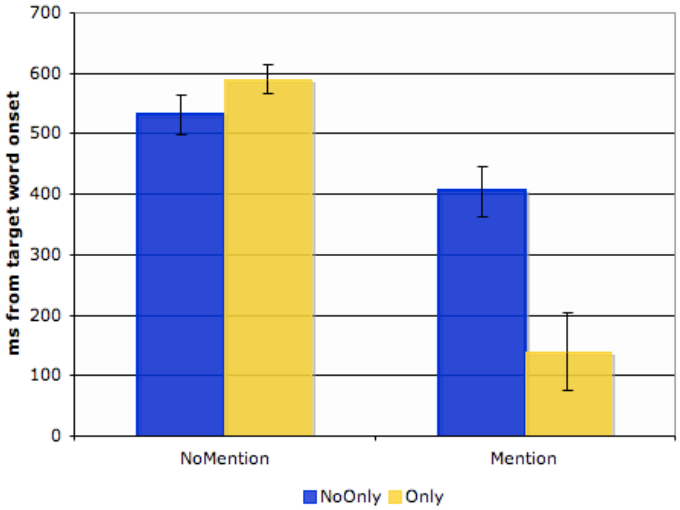


Figure 3: Experiment 1. Average time to target convergence.

after target word onset—thus there is an effect of Mention independent of any effect of *Only*. When 'only' was present, target fixations increase relative to competitor fixations 139 ms after target word onset, well before the input disambiguates the target and the cohort competitor. In the 200-400 ms post-target onset window, there are more fixations to the target item in Mention-*Only* than Mention-No*Only* trials ($t = 10.4$, $p < .001$), while NoMention trials did not differ as a function of *Only* ($t = .9$, $p = .35$). Thus, after hearing only the initial part of the target word, listeners have a strong expectation that the set of possible referents will be constrained by the set mentioned in the previous sentence.

3. Experiment 2: Informative and underinformative contexts

Experiment 1 showed that preceding linguistic context is among the types of information people use to restrict interpretive domains for sentences with 'only'. What other information sources do listeners use? Experiment 2 asks whether enriching the information in the discourse context has a further restrictive effect on top of the Mention-*Only* effect from Experiment 1. Taking the example in (7), a newsstand was considered informative because the range of items that can be purchased is relatively narrow compared to a drugstore, where a wider set of items is available; in other words, the informative contexts were the ones compatible with fewer outcomes in the world.

In addition to repeating the experimental conditions from Experiment 1 (Mention x *Only*), Experiment 2 varies whether the discourse context is highly informative or underinformative.

3.1. Design, Procedure, Materials

An example of the materials in Experiment 2 is given in (7). An introductory sentence ("Context 1") was either informative or relatively underinformative about a shopping scenario. This first sentence was followed by two sentences similar to those in Experiment 1 ("Context 2" and "Target"). As before, the target sentence varied with respect to whether the target word (underlined in (7)) was mentioned in the preceding sentence, and whether it contained 'only'. Each of the three factors (Informativity, Mention, *Only*) had two levels, resulting in eight experimental conditions.

(7)

Sentence	**Underinformative**	**Informative**
Context 1	Jill and Peter are at the drugstore.	Jill and Peter are at the newsstand.
	NoMention	**Mention**
Context 2	Jill is getting some comic books and some cigarettes.	Jill is getting some magazines and some cigarettes.
	No*Only*	***Only***
Target	Peter is getting some magazines.	Peter is only getting some magazines.

Figure 4: Example visual display for Experiment 2.

The procedure was the same as in Experiment 1. Participants heard the first Context sentence (*'Jill and Peter are at the newsstand'*), then the second (*'Jill is getting some magazines and some cigarettes'*). Finally, they heard the Target sentence (*'Peter is only getting some magazines'*) as four pictures were displayed on the screen (Fig. 4). Participants were instructed to click on the item(s) that the person in the Target sentence was buying.

Each display contained a target item (*magazines*), a phonological competitor (*magnets*), and two unrelated distractors (*scissors, lamps*). All scene items, including distractors, were compatible with the Underinformative context (in this example, a drugstore), but crucially they were incompatible with the Informative context (a newsstand).

3.2. Possible outcomes

First, it is possible that more informative contexts will function in the same way as previous mention, by restricting the domain of interpretation specifically when focus-sensitive 'only' is present. If this is the case, faster convergence on the target item would be expected only in the *Only* conditions, on top of the *Only*-Mention effect from Experiment 1.

Alternatively, providing a more specific context might have a restrictive effect on subsequent interpretation, but in a general way that is not specific to the presence of 'only' in the way that Mention is in Experiment 1. Such a general effect would be consistent with similar restrictive effects on referential domains due to information from the visual or linguistic context (see Chambers et al. (2004); Sedivy et al. (1999); others). In this case, across-the-board faster convergence on the target referent would be expected in Informative conditions, irrespective of the presence of 'only'.

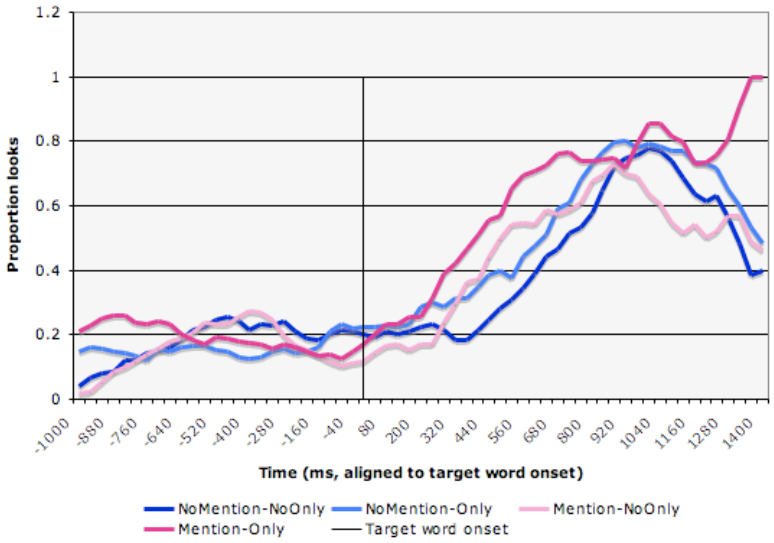
3.3. Results

The results of Experiment 2 are shown in Fig. 5 and Fig. 6. Fig. 5 plots the average proportion of fixations to the target referent over time, for the four Underinformative conditions in Fig. 5a, and for the four Informative conditions in Fig. 5b; the proportions are aligned to the onset of the target word (vertical line). Fig. 6 shows the average time to converge on the target for each condition (Underinformative conditions on the left, Informative conditions on the right).

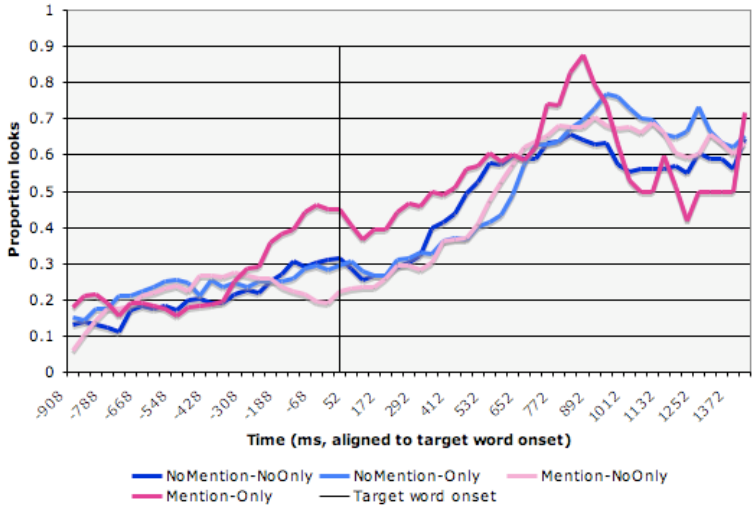
3.3.1. Underinformative contexts

There were main effects of Informativity ($F(1, 20) = 34.0$, $p < .0001$), Mention ($F(1, 20) = 11.5$, $p < .001$), and *Only* ($F(1, 20) = 9.8$, $p < .005$), and no interactions.

As expected, Underinformative contexts patterned much like Experiment 1. The target referent was disambiguated latest in the NoMention-No*Only* and Mention-No*Only* conditions, earlier in the NoMention-*Only* condition, and earliest in the Mention-*Only* condition (Fig. 6, left-hand bars). As in Experiment 1, 'only' prefers to be interpreted with respect to information in the preceding linguistic context.



(a)



(b)

Figure 5: Experiment 2. Proportion looks to the target item in (a) Underinformative context, (b) Informative context conditions. Aligned to target word onset.

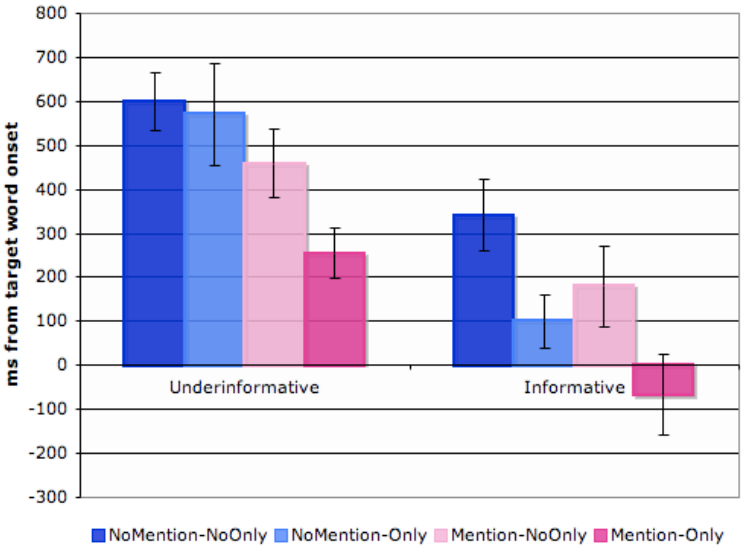


Figure 6: Experiment 2. Average time to target convergence.

3.3.2. Informative contexts

First, there was a general restrictive effect of context informativity: Informative context conditions had on average a 335 ms earlier convergence on the target referent relative to the corresponding Underinformative context conditions.

In addition, the benefit due to context informativity was strengthened in the presence of 'only': there was a 399 ms advantage due to Informative context in *Only* conditions, compared to a 271 ms advantage for No*Only* conditions.

4. Discussion

Experiments 1 and 2 show that, when interpreting sentences that require computing focus alternatives given contextual constraints, listeners make rapid, online use of both the preceding discourse context (Experiment 1) and implicit conceptual knowledge about real-world scenarios (Experiment 2). In Experiment 2, enriching the information available in the context had a general restrictive effect, speeding target identification; the effect is strongest in the presence of 'only'. The enhancement of the contextual effect by 'only' suggests a hypothesis: in addition to its semantic contribution, 'only' may function as a cue to the listener to be extra sensitive to information in the context. We would expect such effects to extend to other focus-sensitive operators as well.

The results of these experiments are compatible with at least two different hypotheses. On the one hand, it is possible to maintain a view under which any number of information sources—including what has been mentioned recently, or visual or linguistic information about states of the world—potentially contribute to the general process of incrementally eliminating impossible or unlikely interpretations as a sentence is being processed. Note that if this is the right characterization of the data, there would not need to be any mention of focus alternatives.

A more interesting possibility is that focus operators like 'only' in fact trigger the construction of a set of candidate alternatives: in other words, comprehenders use the available linguistic and non-linguistic information to generate hypotheses about probable alternatives. While the present data cannot distinguish between these two explanations, one way to show that people are hypothesizing (instead of merely restricting) is by finding effects of conceptual similarity. For example, a continuation like (9a), where the focus (*pears*) is conceptually close to the items mentioned in (8) (*apples, oranges*), seems preferable to a continuation like (9b), where the focus (*shoes*) is conceptually distant from the mentioned items.

(8) Kim bought some apples and some oranges.

(9) a. Neil only bought some pears.
    b. ?Neil only bought some shoes.

Since both sentences contain only discourse-new items, any different between the two would have to be due to a difference in expectations (for *pears* vs. *shoes*) given the information available up to that point.

A further question is what part of the results reported here is due to the meaning of 'only' in particular, and which part is true of alternative-sensitive particles in general. This question will be addressed in future research by comparing the behavior of 'only' with a different lexical item, 'also'. 'Also' seems to require the focused constituent it associates with to *not* be among the Mentioned items (11a). (This assumes a particular intonation for the sentences in (11), where the direct object is prominent and 'also bought' is deaccented.) This is the opposite of what happens with 'only' (Experiment 1).

(10) Kim bought some apples and some oranges.

(11) a. #Neil also bought some apples.
     b. Neil also bought some pears.
     c. ?Neil also bought some shoes.

But here, unlike with 'only', it becomes necessary to distinguish the Mentioned items from the larger set of contextually salient things that are a superset of the Mentioned items: in addition to the Novelty

(anti-Mention) preference, there seems to be an expectation that the focus element be conceptually close to the Mentioned items (compare (11b) with (11c)). If there is a systematic difference between sentences like (11b) and (11c) as continuations of (10), it might be due to an expectation that members of the alternative set will be conceptually similar (or relevant) to the mentioned items.

5. Conclusion

In the present paper we have shown that both previous mention and context informativity contribute to restricting focus alternatives in the presence of 'only'. In addition, the findings for 'only' raise questions and suggest hypotheses about the behavior of other operators. In future work, we anticipate that other focus operators like 'also' will provide an interesting contrast with 'only', and enable us to substantiate the hypothesis that comprehenders actively generate candidate alternatives. More generally, our results suggest that the visual world eye-tracking paradigm is likely to be a powerful experimental tool for determining the factors, and eventually the principles, that guide the listener in constructing focus alternatives.

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