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Abstract	We present the results of two visual-world experiments investigating whether the presupposition of ‘also’ is used to predict upcoming linguistic material during sentence comprehension. We compare predictions generated by ‘also’ to predictions from a parallel inference generated by ‘only’ (i.e., that the upcoming material will be unique). The results show that adults do use the presupposition of ‘also’ incrementally in online sentence comprehension and they can do so within 200 to 500 ms of the onset of the presuppositional trigger. Furthermore, they use it regardless of whether contextual support is explicit or implicit. On the other hand, we did not observe effects of the inference generated by ‘only’ at any point during the sentence, even though this information was used in an offline task.

Keywords	Presuppositions - Entailments - Processing - Visual-world - Semantics - Pragmatics - Psycholinguistics

Resolving Temporary Referential Ambiguity Using Presupposed Content

Jacopo Romoli, Manizeh Khan, Yasutada Sudo and Jesse Snedeker

Abstract We present the results of two visual-world experiments investigating whether the presupposition of 'also' is used to predict upcoming linguistic material during sentence comprehension. We compare predictions generated by 'also' to predictions from a parallel inference generated by 'only' (i.e., that the upcoming material will be unique). The results show that adults do use the presupposition of 'also' incrementally in online sentence comprehension and they can do so within 200 to 500 ms of the onset of the presuppositional trigger. Furthermore, they use it regardless of whether contextual support is explicit or implicit. On the other hand, we did not observe effects of the inference generated by 'only' at any point during the sentence, even though this information was used in an offline task.

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1 Introduction

Presuppositions are a class of inferences that we draw from utterances and are generally characterized along two dimensions: their discourse role and their behavior in embeddings.[1] To illustrate, consider a sentence like (1), from which we typically draw the two conclusions in (2a) and (2b).

(1) Fred stopped smoking.

(2) a. Fred doesn't smoke.
b. Fred used to smoke.

In the literature, inferences like (2b) are referred to as 'presuppositions,' while those like (2a) as 'entailments.' These two inferences are considered to be different for two reasons. First, they intuitively play different conversational roles: (2a) is new information added to the context, whereas (2b) is typically assumed to convey information that is given at the point of utterance of (1). We can refine this intuition by explicitly adding each of these inferences before the statement itself. When we add the presupposition to the statement, the result (shown in (3b)) is a natural discourse. In contrast, when the other inference is placed before the statement, the result (shown in (3a)) is unnatural. The standard way to account for the oddness of (3a) is to appeal to a condition that requires a speaker to not assert anything that is redundant in its context of utterance (see Stalnaker 1978 and much subsequent work). Crucially, this condition does not apply to presuppositions, resulting in the contrast between (3b) and (3a).[2]

(3) a. Fred doesn't smoke and he now stopped.
b. Fred used to smoke and he now stopped.

The second distinctive property of presuppositions is their behavior in complex sentences. Consider (4a)–(4d) below in which the statement (1) is embedded in different complex sentences.

(4) a. Fred didn't stop smoking.
b. Did Fred stop smoking?
c. If Fred stops smoking, Lisa will be happy.
d. It's possible that Fred stopped smoking.

All of these sentences still generate the inference in (2b) but they do not generate the conclusion in (2a). In other words, the presuppositions of sentences like (1), unlike entailments, appear to be 'inherited' by most of the complex sentences containing them. This pattern, traditionally called 'projection behaviour', is characteristic of presuppositions and it is generally used as the primary diagnostic for distinguishing

[1] For an introduction to presuppositions see Chierchia and McConnell-Ginet 2000 and Beaver and Geurts (2011).

[2] In fact, one approach, stemming again from the work of Stalnaker (1974, 1978), is to think that presuppositions not only *can* but *have to* be redundant in the context of utterance.

presuppositions from other inferences. Accounting for how presuppositions project is a central topic in semantics and pragmatics (Karttunen 1974; Stalnaker 1974; Gazdar 1979; Heim 1983; van der Sandt 1992 and Beaver 2001. For some recent proposals see Schlenker 2008 and Schlenker 2009).

While presuppositions have been studied extensively, we still known little about how they are used during comprehension, as the sentence unfolds. This gap is important to fill because presuppositions carry information that could be used incrementally to guide interpretation during language processing. By tracing how this information becomes available over time, we could learn more about the interplay between pragmatics and compositional semantics during language comprehension.

1.1 The Processing of Presupposed Content

Recently, people have started looking at the question of how presuppositions are processed during comprehension (Kim 2007; Schwarz 2007; Schwarz and Tiemann 2013a, 2013b). Three broad questions have guided this work. First, is the presupposed content of an utterance available as quickly as its assertive content? Or do new presuppositions systematically lag behind assertions, in a manner that parallels scalar implicatures (Bott and Noveck 2004; Huang and Snedeker 2009 among many others)? Second, is there a processing cost to presupposition violation? Observing such a cost would also inform the first question (by placing an upper bound on the time by which presupposition was calculated). Third, once presuppositions are available, how do they affect sentence processing? Are they used to resolve ambiguities at other levels or make predictions about upcoming referents? Again, data on this question would also constrain answers to the first.

Kim (2007) explored how presupposed content and asserted content are accessed during a sentence verification task. Participants were shown various visual displays and asked to judge whether sentences like (5) were true or false. Their task was to press a button corresponding to 'yes' if the sentence accurately described the visual context and 'no' if it did not.

(5) Only the girls have books.

Kim (2007) adopted the analysis of 'only' in which a sentence like (5) asserts (6a) and presupposes (6b) (see Beaver and Clark 2009 and references therein).

(6) a. No people other than the girls have books.
b. The girls have books.

There were two types of critical trials which varied in terms of the picture that was paired with the utterance. On the false assertion trials, (5) was matched with a picture in which two girls out of eight characters had books (i.e., the presupposition was satisfied) and some of the other six characters also had books (i.e., the assertion was false). On the presupposition violation trials, (5) was matched with a picture in which the two girls didn't have books and the other characters did not have them

either (i.e., presupposition false, assertion true). She found that participants were faster to reject the false assertion trials than they were to reject the presupposition violations. On the basis of these results, Kim (2007) concludes that the information conveyed by presuppositions and the information conveyed by assertions are used differently in sentence comprehension. Comprehenders do not have to verify presuppositions before evaluating the truth of a sentence. Instead, they assume that the presuppositions are true and only check them afterwards.

Schwarz (2007) used a reading time paradigm to explore the comprehension of sentences with presupposition triggers in both German and English. In one of the experiments, participants had to read sentences like (7) and (8), which differ in the content of the relative clauses. Crucially the relative clause (7) satisfies the presupposition of 'also' (i.e., that there is some other relevant person to whom the congressman wrote to), but (8) does not.

(7) The congressman, *who wrote to John*, had also written to the mayor to schedule a meeting for the fundraiser.

(8) The congressman, *who John wrote to*, had also written to the mayor to schedule a meeting for the fundraiser.

The stimuli were presented in a phrase-by-phrase self-paced reading paradigm in which multiple words were presented at once. The experimental region included the presuppositional trigger and several subsequent words (e.g., *had also written to the mayor*). The participants were slower to read the experimental region when the relative clause did not satisfy the presupposition associated with 'also' (8) than when it did (7).

This finding demonstrates that there is a processing cost in cases where there is also presupposition failure. We believe that there are at least two possible explanations for this processing cost. First, this cost could be a direct consequence of presupposition failure: participants could slow down in (8) because they fail to find any prior event of the relevant kind (one with the congressman writing someone) and thus cannot integrate the presupposition triggered by 'also'. In this case, the cost should only come after encountering the main verb in the active voice (*had also written*), since that information is needed to determine that the relative clause does not satisfy the presupposition (e.g., see (9)).[3] Alternatively, the cost could reflect the participants' predictions about the form or meaning of the verb, given the relative clause and presuppositional trigger. Specifically, in (7) the participant should expect the verb that is used (*written*), while in (8) they might expect a verb with a different argument structure (again see (9)).

[3] Schwarz seems to interpret his online data as a reflection of presupposition failure, rather than prediction (see p. 402). However, his work also provides evidence that presuppositions can be used to predict and/or revise the thematic roles in an event. Specifically, in an offline study in German, he finds that readers tend to interpret a relative clause with ambiguous case marking in a manner that would allow to satisfy the presupposition of 'auch' (*also*).

(9) The congressman who John wrote to had also received a letter from the mayor to schedule a meeting for the fundraiser.

In this paper, we report the results of two experiments that investigate the time course of presupposition calculation by looking for effects of a presupposition on the interpretation of an upcoming noun. Like Schwarz (2007), we focus on the presupposition of 'also'. Unlike Schwarz (2007), we are not concerned with the effect of presupposition failure on processing. Instead we investigate how early participants are able to use the information associated with presuppositions to determine the referents of upcoming nouns. In addition, we compare this effect to a parallel inference based on the entailments associated with 'only'. Our focus differs from that of Kim's (2007) study, as we are not looking at how presupposed versus asserted content is used in verification but whether presupposed content is used to predict an upcoming word.[4]

1.2 Experimental Paradigm

In the experiments reported in this paper, we use the visual world paradigm, because it provides a sensitive and time-locked measures of language comprehension. Prior studies have successfully used this method to study a broad range of linguistic processes including: word recognition (e.g., Allopenna et al. 1998), syntactic ambiguity resolution (e.g., Tanenhaus, Spivey-Knowlton, Eberhard, and Sedivy 1995) and the calcuation of scalar implicatures (e.g., Huang and Snedeker 2009). The stimuli and task used in Experiment 1 are closely modeled on a series of experiments conduced by Kim et al. (2008).

Kim and colleagues presented participants with pairs of sentences like (10) and (11). As mentioned above, a sentence like (11) is generally assumed to presuppose (12a) and assert something along the lines of (12b).

(10) Mark has some candies and some shoes.

(11) Jane only has some candies.

(12) a. Jane has candies.
b. Jane has no relevant things other than candies.

Kim and colleagues were interested in how listeners restrict the assertion of a sentence like (11). Can context be used to determine the set of relevant things as the

[4] There are two other recent studies on presupposition processing that are not directly relevant to the question posed here (Schwarz and Tiemann 2013a, 2013b and Chemla and Bott 2013). Schwarz and Tiemann look at whether the position of the trigger in a complex sentence influences the processing of presuppositions. On the basis of their results they argue that there is a processing cost associated to the 'length of projection', that is the distance between the position of the trigger and the clause associated to the information satisfying the presupposition appears. Chemla and Bott, on the other hand, concentrates on whether the accommodation of presupposition is more costly when it occurs above or below negation (see also Romoli and Schwarz (this volume)).

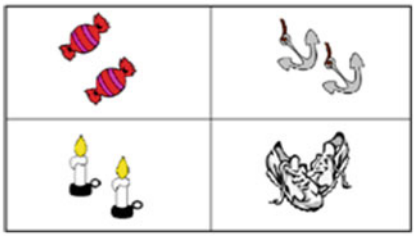

Fig. 1 An example of a display from Kim et al 2009. The relevant sentences are listed in (13). Illustration courtesy of Christina Kim

sentence unfolds and what kinds of contextual cues are relevant? They assessed this by measuring the participants' ability to predict the upcoming noun on the basis of the context.

Participants are presented with spoken instructions, asking them to choose among different objects within a visual reference world and their eye movements are measured. Each trial contained a context sentence (10) and one of four target sentences (13a-13d) below.

At the onset of the target sentence, a grid of four images appeared (Fig. 1) which consisted of the target object (for (11) 'candies'), a cohort competitor (for (11) 'candles') and two distractors (for (11) 'anchors' and 'shoes'). The competitor is crucial in this design, because it insures that the identity of the noun is unclear even after the word begins providing a longer window in which predictions generated by the context and the structure of the sentence can guide interpretation.

The target sentences were constructed by manipulating two variables: whether 'only' was present and whether the target noun was mentioned in the context sentence ('old' versus 'new'). This resulted in four conditions, as summarised in (13).

(13) a. Jane only has some candies. (only/old)
b. Jane has some candies. (control/old)
c. Jane only has some candles. (only/new)
d. Jane has some candles. (control/new)

If context is used to restrict the relevant set, then participants who heard the sentences with 'only' should assume that the upcoming noun will be one of the previously mentioned items (e.g., candies). Thus they should be faster to reach the target in sentences like (13a) than in sentences like (13b). This systematic preference for the previously mentioned object should be absent or reduced in sentences without 'only' resulting in an interaction between the two variables. This is precisely what Kim and colleagues found, leading them to conclude that context is used to rapidly restrict the comparison class. We return to these findings in the general discussion section (to explore their relevance to our 'only' control condition).

Our study employs a similar design to explore a different question. Like Kim and colleagues, we provided participants with: a context sentence that introduced two objects, a target sentence referring to one of them, and a display that contained two cohort competitors. However, our goal was to use this paradigm to explore how the presupposition of 'also' can be used to predict an upcoming referent. Our

critical items consisted of series of three sentences (14). The first (14a) established a set of two characters, making it natural to draw comparisons between them. The second sentence (14b) described what one character had. The critical third sentence (14c) contained the presupposition trigger. This sentence was intended to have the interpretation where 'also' is associated with the subject. To achieve this the utterances were produced with stress on the subject and a prosodic break after 'also' (see Appendix B).

(14) a. Mark and Jane are friends (*introduction*)
b. Mark has some candies and some shoes (*context*)
c. JANE, also, has some candies. (*target*)

We are assuming that a sentence like (14c) presupposes something along the lines of (15a) and asserts (15b) (see Kripke 2009 and Heim 1992 among others).

(15) a. A relevant individual in the context other than Jane has some candies.
b. Jane has some candies.

In both of the following experiments, we manipulated whether the intended target referent was mentioned or not in the context sentence ('old' versus 'new') whether there was a focus particle in the sentence which could allow participants to predict the discourse status of the referent before encountering it ('disambiguated' versus 'control'). For old referents the disambiguating focus particle was 'also', for new referents it was 'only.' This resulted in the following four conditions in (16).

(16) a. Jane, also, has some candies. [also/old]
b. Jane has got some candies. [control/old]
c. Only Jane has some candles. [only/new]
d. Jane has got some candles. [control/new]

The logic of the design is as follows. In the control conditions, participants have no basis on which to predict the final object, and thus they should split their gaze between the two cohort members from the onset of the final noun until phonological disambiguation, after which they should quickly converge on the target object. In contrast, in the also/old condition, the presuppositional trigger provides information that could allow participants to infer the target nouns before phonological disambiguation. Specifically, if participants are able to rapidly determine the presupposition of *also* they could potentially infer that the target is one of the previously mentioned items (candies or shoes) anytime after the trigger, allowing them to determine which noun it is (candies) after hearing the first phoneme. Thus we expect that folks will look at the correct target more often and more quickly in the also/old condition than in the control/old condition.

The only/new condition was included to ensure a balanced design. In this case the focus particle favors the novel referent: if participants incrementally recover the assertion in the 'only' sentences they should recognize that the upcoming object must be something that only Jane has, and thus cannot be one of the previously mentioned objects. This should lead them to resolve the referential ambiguity in favor of the new target before phonological disambiguation (Fig. 2).

Fig. 2 An example of a display from Experiment 1. The relevant sentences are listed in (13). Illustration–author's own

2 Experiment 1

2.1 Method

2.1.1 Participants

Thirty two participants were recruited from the Harvard community, including undergraduate students. They received either course credit or $ 5 for their participation. All participants were native speakers of English. One participant was excluded due to low accuracy with the fillers.

2.1.2 Material

Each item consisted of: a set of four pictures, an introduction sentence (17), a context sentence (18), and a critical sentence (13). The four pictures included two pictures which could readily be described by nouns sharing an onset (e.g., *candies* and *candles*). The introduction sentence presented two characters. The context sentence indicated that one character had two items: one of the cohort members (candies) and one of the non-cohort members (watches). As we noted above, there were four different variants of the target sentence.

(17) *Introduction sentence*
Mark and Jane are friends

(18) *Context sentence*
Mark has some candies and some watches.

(19) a. Jane, also, has some candies. [also/old]
b. Jane has got some candies. [control/old]

c. Only Jane has some candles. [only/new]
d. Jane has got some candles. [control/new]

Both the presence of the focus particle and the discourse status of the final noun were manipulated within subjects and within items. It is important to note that the 'only' sentences predict a target noun that was not in the context sentence, in contrast to the 'also' sentences that presuppose that the target noun was in the context sentence. The predictions for these sentences were confirmed in a norming study conducted on Amazon Mechanical Turk (Appendix A). As mentioned, we also conducted a norming task to ensure that the intonation used in the 'also' sentences evoked the expected interpretation (Appendix B). In addition, we wanted to control which of the two cohort members appeared in the context sentence. To counterbalance all three of these variables, we created eight versions of each of the 32 base items. We then created eight lists such that each base item appeared only once on a given list and in all eight cells across the lists. Thus each participant heard each of the four target sentence types eight times over the course of the experiment. Eight filler trials were included. Two fillers appeared at the beginning to make sure participants were familiar with the task before the first experimental trial. The remaining six filler trials were interspersed throughout the experiment. Trial order was pseudo-randomised, with each participant seeing base items in the same order. The positions of the different kinds of objects (target, competitor and distractors) in the visual display were counterbalanced across trials.

2.1.3 Procedure

Participants were seated at a comfortable distance from the screen of a Tobii T-60 eye-tracker. The auditory stimuli were played by the computer through external speakers. First, participants heard the introduction sentence and context sentence. Then a fixation point appeared in the middle of the screen. After the participant had fixated on this point for 500 ms, the target sentence began. This was done to ensure that participants were always looking in the same place at the beginning of the critical sentence. At the onset of the target sentence, the images appeared and participants' fixations were measured. The participants were told that their task was to pick the last object mentioned in the target sentence by clicking the relevant picture. Once the participant did this the trial ended and the next trial began.

2.1.4 Results

We analyzed the log-odds of the proportion of fixations to the old cohort item (the competitor that had been mentioned in the context sentence) versus the new cohort item (Fig. 3). Prior to the disambiguation point of the noun, the control sentences are compatible with either image. If participants incrementally incorporate the presupposed content of 'also' during sentence processing, then we should expect to

see more looks to the old cohort item in sentences with 'also' compared to control sentences.

Also Our primary analyses compared the also-old trials to the control-old trials. We conducted linear mixed-effects regressions, with the maximally appropriate random effects structure, looking at the log-odds of proportion of looks to the old cohort. We estimated p-values using the pnorm function in R. We examined four time windows: the first of these time windows coincided with the noun (offset by 200 ms), while the other three spanned the 900 ms before the noun (-700 to -400, -400 to -100, and -100 to 200). On average, the onset of the word 'also' occurred 806 ms before the onset of the target noun, so these time windows would cover saccades programmed at the very onset of 'also' (early pre-noun), as well as the period in which the presuppositional trigger could potentially generate predictions about upcoming referents (the mid and late pre-noun windows).

During the noun window, participants were significantly more likely to look at the old cohort in also-old sentences compared to control-old sentences ($t = 4.20$, $p < 0.001$). This pattern was already evident in the late pre-noun window which covered the 300 ms immediately preceding the noun ($t = 3.13$, $p < 0.002$). There were no significant differences between the 'also' and the control-old sentences in early and mid pre-noun time windows.

Only We were also interested in whether participants used the information from 'only' to anticipate unique referent. That is, did participants look at the old cohort less in the 'only' sentences compared to the control-new sentences? We conducted linear mixed-effects regressions, parallel to those above. Again we used the maximally appropriate random effects structure and looked at the log-odds of proportion of looks to the old cohort during the four time windows described earlier. There were no significant differences between looks to the old cohort in the 'only' sentences and the control-new sentences ($ts < 1$, $ps > 0.3$). This null effect is surprising given that participants correctly predicted the target noun on the basis of 'only' in an offline task (see Appendix A).

2.1.5 Discussion

Experiment 1 provides a clear answer to our original questions about the processing of presuppositions during language comprehension. First, we found that presupposed content can be used to guide lexical (or referential) predictions. In the 'also' condition, participants showed a preference to look at the previously-mentioned cohort member. This preference began well before noun onset, resulting in a robust difference between the 'also' sentences and their controls in the late pre-noun time window (-100 ms to 200 ms unshifted). Second, the timing of effect places an upper-bound on the point at which the presupposition is calculated. The effect of the presupposition became robust in a time window that began about 700 ms after the onset of 'also'. If we make the standard assumption that it takes a minimum of 200 ms for information in the speech stream to affect saccades (Matin et al. 1993; Allopenna et al. 1998),

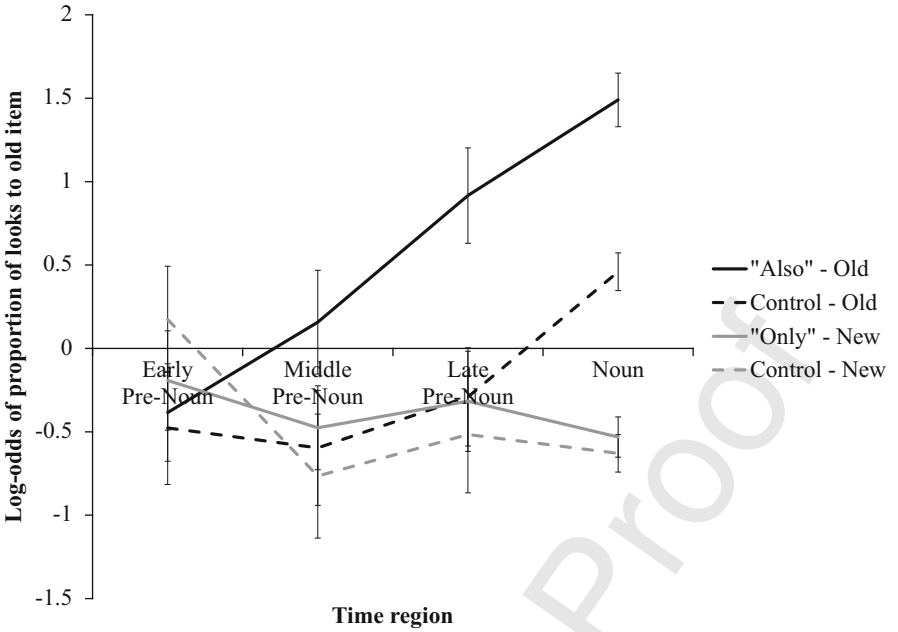

Fig. 3 Experiment 1: gaze data

then this suggests that it takes 500 ms or less, from the onset of the trigger, for the presupposition to be calculated.

However, this experiment also provided an unexpected surprise. To ensure balance in our stimuli, we had included a condition in which 'only' had subject scope (20). As we noted earlier, it is standard to assume that these utterances have the presupposition given in (21a) and express the assertion given in (21b).

(20) Only Jane has some candles.

(21) a. Jane has some candles.
b. No other relevant people have candles.

Thus we expected that the 'only' sentences would allow the participants to rule out the previously mentioned items as potential referents for the final noun, because they would make the assertion false (since the other character did have those items). But curiously, we failed to find smallest hint of this effect in the eye-movement data, even though an offline norming study confirmed that participants were sensitive to this constraint (Appendix A).

Experiment 2 had three goals. First, we wanted to replicate our critical finding that presuppositions can be used to predict upcoming words or referents. Second, we wanted to extend these results by exploring whether more indirect contextual support would be sufficient to satisfy the presupposition and guide online processing. Specifically, in Experiment 1, the presupposed content had been explicitly mentioned ('Michael has some candles'). In Experiment 2, we compare explicit mention to implicit mention ('Look at what Michael has').

Finally, we wanted to create a discourse context that would be more appropriate for the 'only' sentences, to determine whether this would allow people to use this assertion to predict the upcoming noun in real time. We reasoned that sentences like (20) are felicitous only in contexts in which there is some relevant set of people that the subject ('Jane') is being contrasted with. In Experiment 1, the discourse included just two people. Since we had already stated what the other person had, the assertion in the 'only' sentence was actually no more informative than the presupposition. Consequently, the control-new sentence was arguably a more felicitous way to express this idea. In Experiment 2, there are a total of three people in the context and the task centers around distinguishing the person in the target sentence from another person.

3 Experiment 2

3.1 Method

3.1.1 Participants

Thirty two participants were recruited from the Harvard community, including undergraduate students. Half of the participants were assigned to the explict context condition and half to the implicit context condition. They received either course credits or $ 5 for their participation. None of them had participated in Experiment 1. All participants were native speakers of English. Eight participants were excluded (2 for low response accuracy, 1 for software error, and 5 for excessive track loss).

3.1.2 Procedure and Material

Three changes were made to the materials from Experiment 1. First, two between participant conditions were created. In the explicit context condition (22), the context sentence (22a) overtly mentions the critical objects, just like the context sentence in Experiment 1.

(21) *Explicit Context*
   a. *Context Sentence*: Michael has got candies and watches.
   b. *'Also' Target*: Sarah also has some candies.
   c. *'Only' Target*: Only Sarah has some candles.

In the implicit context condition (23), the context sentence (23a) directs attention to these objects but does not mention them by name.

(22) *Implicit Context*
   a. *Context Sentence*: Look at what Michael has!
   b. *'Also' Target*: Sarah also has some candies.
   c. *'Only' Target*: Only Sarah has some candles.

Fig. 4 An example of the visual context used in Experiment 2. The relevant sentences are in (22) and (23). Illustration—author's own

Second, we created new visual displays which included three new characters (Fig. 4). One character matched the gender of the person in the context sentence (the man at the top). This character had the two objects mentioned in the context sentence and was always placed on the top half of the screen in the center. The two other characters matched the gender of the person in the target sentence. One of these characters was the expected referent for the 'also' sentences because s/he had the old cohort object as well (the woman with candies on the right). The other character was the expected referent for the 'only' sentences because she had a unique object (the woman on the left with the candles). These characters appeared on the bottom half of the screen, with their relative position counterbalanced across trials.

Third, because the characters were now visible on the slide, we removed the introductory sentence which had linked the two protagonists.

The procedure was also modified. Participants were told that their task was to click on the person mentioned in each sentence. At the beginning of each trial, the visual display appeared, followed by the context sentence. After the participant clicked on the character mentioned in the context sentence, the target sentence was played. The trial ended when the participant clicked on the character mentioned in the target sentence. As in Experiment 1, each participant heard four different kinds of target sentences (also-old, control-old, only-new, and control-new) and there were eight trials per participant, in each condition.

3.1.3 Results and Discussion

As with Experiment 1, we analyzed the log-odds of the proportion of fixations to the old cohort item. We defined looks to the old cohort item as looks to the quadrant that contained the new person who had the old cohort object (lower right quadrant in Fig. 4). Similarly, we defined looks to the new cohort item as looks to the quadrant with the person who has the new cohort object (lower left quadrant in Fig. 4). We analyzed the also-old sentences in comparison to the control-old condition, and the only-new sentences in comparison with the control-new sentences. We were interested both in main effects of the markers and potential interactions between the marker and the context condition.

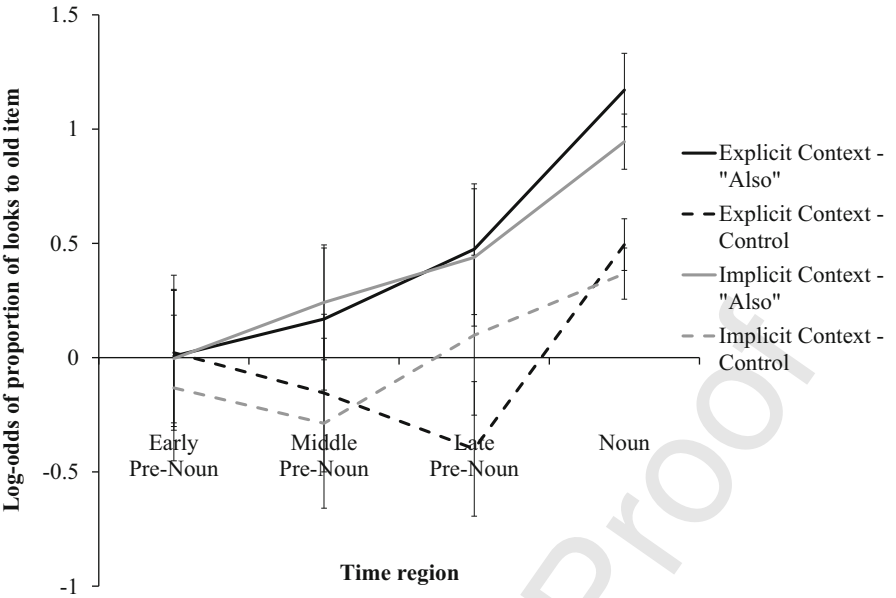

Fig. 5 Experiment 2: comparison of the also and control-old sentences

Also We conducted linear mixed-effects regressions with sentence type (also vs. control) and context condition (explicit vs. implicit) as predictors, with the maximally appropriate random effects structure. We estimated p-values using the pnorm function in R. We examined the same four time windows used in Experiment 1: the noun window and the three 300 ms timebins before the noun (early, mid, and late pre-noun). As in experiment one, on average, the onset of the word 'also' occurred around 800 ms before the onset of the target noun.

During the noun window, there was a main effect of sentence type ($t = 5.26$, $p < 0.001$) (Fig. 5). When the sentence contained 'also', participants shifted their gaze to the old cohort item. Critically, this effect was also significant in both the mid and late pre-noun windows (both t's > 3, p's < 0.002), but not in the early pre-noun time window. This pattern indicates that the presupposed information was available and able to guide reference resolution within 200 to 500 ms after encountering the trigger (allowing 200 ms to program a saccade). There was no main effects of or interactions with the context condition, suggesting that the presupposed content was integrated incrementally regardless of whether the anaphoric antecedent of 'also' was explicitly mentioned. To address this question more directly, we conducted separate analyses of each context condition. We found a reliable difference between the also and control-old sentences in both the explicit and implicit conditions ($t = 3.60$, $p < 0.001$ for the explicit context condition; $t = 3.68$, $p < 0.001$ for the implicit context condition).

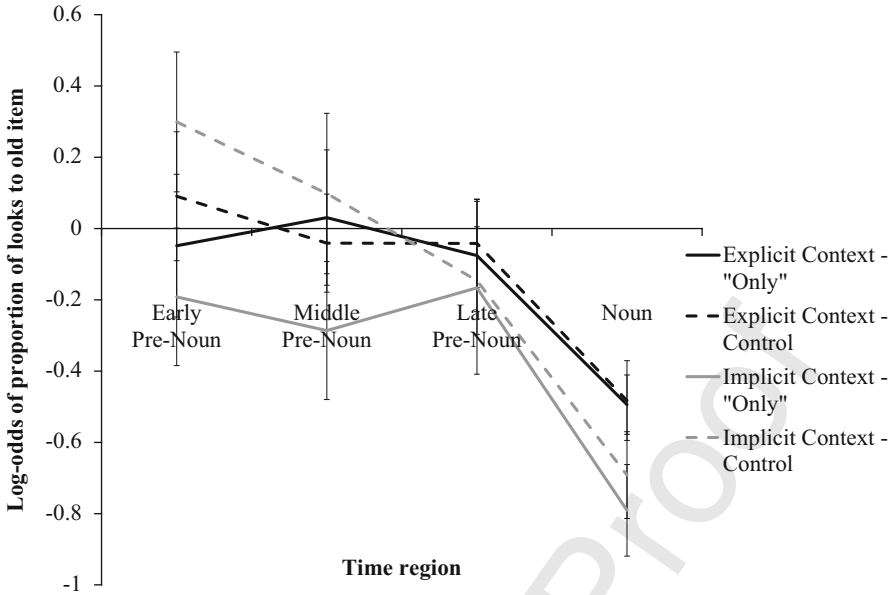

Fig. 6 Experiment 2: Comparison of only and control-new sentences

Only We conducted a parallel analysis of the 'only' and control-new sentences using the same variables and approach. If participants were using the information from 'only' to anticipate a unique referent, then we would expect them to shift away from the old cohort item well before the noun onset, resulting in a main effect of sentence type. This is not what we observed (Fig. 6). We found no significant differences between the sentence types in any of the time windows (all t's < 0.9, p's $> .3$). In addition, there was no effect of context condition and no interactions between context and sentence type (all p's $> .3$).

In sum, as in Experiments 1, hearing 'also' led to anticipatory eye movements to the target image but hearing 'only' did not, despite our attempt to create a more felicitous context for the use of 'only'. Further, participants used the information from the presupposition of 'also' regardless of whether the discourse context explicitly mentioned the repeated item or only implicitly referred to it.

4 General Discussion

The primary goal of these experiments was to explore the online processing of presupposition, and we were largely successful in doing this. Along the way, however, we encountered a strange failure in the interpretation of 'only'. We discuss these two findings in turn.

4.1 Presuppositions and Incremental Interpretation

We had three specific questions about the processing of presuppositions, which we were able to answer in these experiments.

First, can presupposed information be used to make predictions about upcoming lexical items during language comprehension? In other words, do presuppositions feed back into language comprehension creating expectations about how a sentence will end? In both Experiment 1 and Experiment 2, we found that the presupposition lead participants to identify the correct referent well before they had any information about the critical word.

Second, how soon after the trigger is the presupposition calculated? As we noted earlier, Schwarz (2007) found that readers slow down when they encounter a clause with a presuppositional violation, demonstrating that presuppositions are calculated as we read. Schwarz's data place a loose upper bound on the timing of this process: on average the presupposition must have been available at some point within 1500 ms after the clause was presented. Our findings refine that estimate. In Experiment 2, the difference between the also-old and control-old conditions was robust in the middle pre-noun time window, a period roughly 400 to 700 ms after the onset of the presuppositional trigger. If we make the standard assumption that it takes about 200 ms to launch a saccade in response to a phonological cue (Matin et al. 1993, Allopenna et al. 1998), then we can conclude that the presupposition was available within 200 to 500 ms of word onset. Put another way, it appears that the presupposition generated by 'also' can sometimes be calculated before the word itself is finished.

At first glance, our findings might seem hard to reconcile with Kim's (2007) picture verification study. Recall that she found that a sentence with 'only' was faster to evaluate when the assertion was false and the presupposition was true, than when the presupposition was false but the assertion was true. She concluded that the presupposition of a sentence is checked after the asserted content has been checked. That could be taken to suggest that presuppositions are not calculated until a late stage in verification. If that was the intended interpretation, then it would be incompatible with our findings (as well as with Schwarz's 2007). However, we see no reason to interpret the finding in that way. It is entirely possible that folks calculate presuppositions rapidly and incrementally but do not check these presuppositions immediately when verifying a statement against a single stable context. In fact, that might be a very smart thing to do: if presuppositions can generally be assumed to be true, then we ought to put highest priority on verifying the more contentious assertions.

The final question that we explored was: What forms of context can be accessed to satisfy a presupposition during online processing? The predictive inference that we saw in these experiments was based on the assumption that the presupposition of 'also' would be satisfied if the direct object of the target utterance referred to something that someone else in the discourse context also had in their possession. The results of Experiment 1 demonstrate that participants can quickly access material from the sentence immediately before the target sentence to find a suitable

prior referent. Experiment 2 refines this in several ways. First and most obviously, it shows that participants will infer that an indirect reference can satisfy a presupposition even when no direct reference is available. This is interesting in part because the presuppositional trigger that we used ('also') is typically argued to be more difficult to accommodate than soft triggers such as verbs like *win* or *stop* (Simons 2001, Abusch 2010, Romoli 2012, Romoli (to appear) among others). Our present findings do not challenge theories that propose that the presupposition of 'also' has pronominal characteristics—our indirect contexts would be sufficient to ground a pronoun (24). But they point the way toward manipulations which could explore this more thoroughly. For example, contexts like the one in (25) do not support the use of a pronoun but might allow for the predictive use of presuppositions (26).

(23) Look at what Michael has! It is good to eat.

(24) Look at Michael.? It is good to eat.

(25) Look at Michael. Jane, also, has some candies.

The parallelism between the implicit and explicit context conditions is important because it suggest that, in this paradigm at least, there is no apparent cost to indirectness. Not only did participants use the indirect context to predictively, they did so as rapidly and efficiently as participants in the explicit context conditions. This suggests that the processes involved operate over discourse entities, rather than over lexical items. Perhaps this isn't surprising, since presuppositions are typically characterized as discourse level expectations, but it is reassuring.

4.2 A Surprising Failure

In both Experiment 1 and Experiment 2, we found absolutely no evidence that participants could use the inference associated with 'only' to predict that the upcoming object would be new to the discourse. We find this surprising for three reasons.

First, our intuition that this inference is accessible was validated in an offline study (see Appendix A). When given sufficient time, folks realize that only the new cohort item can complete the sentences with 'only'.

Second, in our task at least, the 'only' inference seems roughly comparable in complexity and constraint to inference in the 'also' condition. In both cases, participants must track the referents mentioned in the context sentence and then use this information to pick a possible referent in the target sentence. In Experiment 1, both of the critical words could potentially be used to focus in on two out of four referents prior noun onset. In Experiment 2, both the critical words could potentially allow the listener to focus on a single correct referent prior to the noun. In both cases, the critical word is associated with the subject but is being used to make an inference about the direct object. In fact, the differences that exist seem to favor 'only': the critical cue comes earlier in the sentence and the focused element is disambiguated by word order alone.

Finally, at first glance, our results seem to conflict with those of Kim and colleagues (2008) who found that participants made rapid use of 'only in sentences like 'Jane only has some candy.' Critically, these studies used essentially the same design as we used in Experiment 1. There are two critical differences between the Kim study and the present 'only' condition, which suggest two hypotheses about why adults are unable to make this inference in real time.

One difference is that in the Kim study 'only' associates with the VP, while in our study it associates with the subject. Crain and colleagues have found that children have more difficulty interpreting subject 'only' than object or verb-phrase 'only' (Crain et al. 1994), raising the possibility that this interpretation might be more difficult for adults to process. We think this is unlikely. Other developmental studies find that subject 'only' is no more difficult for children than verb-phrase 'only' and there is no evidence that we know of to suggest that adults have substantial difficulty with these forms (see Paterson et al. 2003; Paterson et al. 2006).

A second difference between the present study and that of Kim and colleagues is whether the inference in question leads one to prefer the previously mentioned item or reject it. In Kim's study, hearing 'only' leads the listener to construct a context set based on the previously mentioned items, encouraging looks to these referents. In our study, hearing 'only' should lead participants to infer that a previously mentioned items cannot be the object of the target sentence. Notice that this inference involves implicit negation (exclude the previously mentioned items) and the need to avoid looking at objects that were previously relevant. Both of these things could make processing more difficult (Wason 1965, Carpenter and Just 1975, Dale and Duran 2011 among others). One virtue of this account is that explains why we see a rapid effect in the 'also' condition: this inference, like Kim's, involves a direct preference for previously mentioned items, rather than an implicit negation.

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5 Appendix A: Off-line Norming Study on *Also* and *Only*

To ensure that inferences that we were studying were robust, we conducted an offline sentence completion study. The goal of this task was to verify that, given adequate time, participants could infer that the direct object in the 'only' sentence must be novel to the discourse, while the direct object in the 'also' sentences must have been mentioned in the context sentence. This experiment employed the materials from Experiment 1.

Sixty-four participants were recruited through the on-line crowd sourcing tool Amazon Mechanical Turk. They received $ 0.50 for their participation. Twenty eight

additional participants were excluded (26 for poor accuracy on the filler trials and 2 because English was not their native language). The design was almost identical to Experiment 1. Instead of hearing instructions, participants read the introduction, context and target sentences, except that last word of the target sentence was truncated after the first letter, as in (27).

(26) Jane also has some c__

Participants were shown the display from Experiment 1 and clicked on the picture that completed the sentence. Note that control-old and control-new trials were identical in this study, since the final word which differentiates these conditions is omitted. There were 8 'also' trials, 8 'only' trials,16 control trials, and 8 fillers which were used to filter out inattentive participants.

A logistic regression analysis was performed comparing 'old-cohort' choices for 'also' and 'only' sentences to the control sentences. Both the 'also' (M = 73.7 %, z = 18.935, $p < 0.001$) and the 'only' (M = 15.8 %, z = 3.973, $p < 0.001$) responses were significantly different from the control responses (M = 23.9 %). Therefore, we confirmed that participants were able to make the relevant inference and select the intended image for both the 'also' and the 'only' sentences.

6 Appendix B: Norming Study on the Intonation of *Also*

When 'also' appears between the subject and the verb it has two possible readings. We wanted our participants to get the reading in which 'also' associates with the subject. There is no other way to convey this reading in contemporary English. While the oldest co-author favored 'John too has some candles,' her younger colleagues insisted that no one spoke like this anymore. So we were forced to use prosody to disambiguate the intended reading. We did this by producing the sentences with the prosody given in (28). The capitalization indicates prosodic focus on the subject and the commas signal a prosodic break before the verb.

(27) JANE, also, has some candies.

It was our intuition that when the sentence was produced in this way, the only possible reading is the one where the presupposition is on the subject (Jane, in addition to someone else, has some candies). However, to make sure that folks did not get the reading where the presupposition was on the verb phrase (Jane, in addition to something else, has some candies), we conducted a norming study.

Ten undergraduate students participated in the experiment. The experiment was conducted using Psyscope X. The participants were been presented with 16 pre-recorded auditory stimuli like (28) above. These were a subset of the utterances that were used in the 'also' condition of Experiment 1. For each one they were asked to select the correct interpretation from two alternatives.

(28) a. Jane has some candies and she has something else too.
b. Jane has some candies and someone else has candies too.

Participants made their selection by pressing a keyboard button corresponding to the side of the screen where the alternatives was presented. The position of the alternatives on the screen was counterbalanced and the presentation order for the items was randomized for each subject. The stimuli were interspersed with 48 fillers. These included utterances with *too* as in (30) (followed by the same possible choices) and utterances like (31), (followed by a choice between 'Justin is Christina's neighbor' or 'Justin is Christina's neighbor and Christina is Justin's neighbor').

(29) JANE, too, has some candies.

(30) Justin and Christina are neighbors.

Participants judged the critical sentences to have the subject-association reading 84 % of the time. A Wilcoxon-Signed-Rank Test showed that this was significantly different from chance ($Z = 2.28$, $p < 0.05$). Thus the intonation pattern on the critical sentences strongly biases participants to interpret 'also' as associating with the subject.

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