Presuppositions vs. Asserted Content in Online Processing

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Abstract We report two experiments that investigate the time-course of the online interpretation of the presupposition of *also*, first relative to a control, and secondly relative to asserted content, namely the exclusivity of *only*, using the visual world paradigm. Both studies reveal rapid shifts in fixations to target pictures based on the presupposition expressed by *also*, after 200-300ms after its onset. In contrast, the asserted exclusivity introduced by *only* arises roughly 400ms later, suggesting that - if anything - presupposed content is evaluated prior to asserted content. This is as expected on semantic accounts of presuppositions, which see them as preconditions on interpreting the sentence in the first place, but somewhat surprising (though not necessarily strictly inconsistent) with pragmatic accounts that derive presuppositions via conversational reasoning, which has been found to require additional processing time in the case of scalar implicature computation.

1 Introduction

An early and crucial insight in the modern study of linguistic meaning is that what speakers and hearers generally seem to perceive as the overall conveyed meaning of a given utterance should be broken down theoretically into distinct components. The motivation for this is that upon closer inspection, they can be differentiated by their role in utterances in general as well as their behavior in different linguistic environments. To account for these differences, theorists generally appeal to distinct underlying mechanisms that give rise to these various aspects of meaning as well as to differences in how they affect the computation of the overall conveyed meaning of a complex utterance. Put very briefly, the literal, truth-conditional content of the lexical items in a sentence together with the structure they appear in is the

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basis for the core semantic impact of the sentence, standardly captured in terms of truth-conditions. Presuppositions, our main concern here, constitute a type of backgrounded meaning that does not form part of the main point of the utterance, but which relates it to the discourse context, specifically with respect to the shared assumptions of the discourse participants. Presupposed content is typically (but not necessarily) taken for granted, i.e., it is something that all parties in the discourse are already aware of. Crucially, presuppositions display some distinct behaviors in embedded environments in that they do not seem to be affected by operators such as negation and conditionals in the same way as literal, asserted content. While these basic points are shared quite generally in the literature, there is no broad consensus about how presupposed content originates, as we will discuss in more detail below. A third major class of meaning is that of conversational implicatures, which - following Grice (1975) - are generally thought to arise via general reasoning about the role of rational agents in cooperative communication. One specific class of implicatures that has been particularly well-studied is that of scalar implicatures, which arise due to reasoning about possible alternative utterances where a given scalar expression is replaced with a logically stronger one.

While there has been decades of theoretical work on these phenomena, until recently little has been known about how the human mind constructs these various aspects of meaning in real time. However, work in experimental pragmatics over the last decade has made clear that a detailed investigation of different aspects of meaning in online processing not only enriches our psycholinguistic understanding of language comprehension in general, but also can help to inform theoretical debates about their nature and origin. In particular, a by now substantial body of work on the processing of scalar implicatures has argued that the secondary nature of implicatures, which on a Gricean view are derived by general reasoning about the literal semantic content, is reflected in delays in a number of processing measures, such as reaction times, reading times, and eye movements in the visual world paradigm, all of which are taken to indicate additional processing time and effort involved in computing implicatures (e.g. Bott and Noveck, 2004; Breheny et al., 2006; Huang and Snedeker, 2011; Bott et al., 2012). However, there also are studies that have found evidence for rapid computation of scalar implicatures, and the debate in the literature is far from settled (Grodner et al., 2010; Degen and Tanenhaus, 2011, 2012; Breheny et al., 2013).

Turning to presuppositions, there is less evidence to date about their online processing properties, but just as with implicatures, much can be gained from such evidence. In particular, one central point of contention throughout the history of research on presuppositions is the question of whether they are primarily semantic or pragmatic in nature. In many ways, the issue comes down to the question of whether presuppositions are part of what is conventionally encoded as part of the lexical meaning of certain expressions or not. Much early work saw it as a primarily pragmatic phenomenon in terms of constraints on possible utterance contexts (e.g., Stalnaker, 1970, 1973, 1974). Later linguistic analyses, such as dynamic semantics (Heim, 1983; Chierchia, 1995; Beaver, 2001) and Discourse Representation Theory (DRT Kamp, 1981; van der Sandt and Geurts, 1991; van der Sandt, 1992; Geurts,

1999) propose semantic theories that integrate aspects of the context more closely, (e.g., by seeing the meaning of sentences in terms of their potential for changing contexts), and thus integrate such contextual constraints into the semantics proper. But in recent years, pragmatic theories have seen a revival (Simons, 2001; Abusch, 2002, 2010; Schlenker, 2008, 2010; Abrusán, 2011). These are broadly based on the claim that presuppositions are derived via reasoning over conversational maxims (Grice, 1975) and potential alternative expressions, similar to scalar implicatures (though possibly via different maxims).

Earlier work on presuppositions has begun to explore experimental methods for investigating them. Schwarz (2007) showed that presuppositions can affect the interpretation of ambiguous sentences and overrule syntactic parsing preferences, and found reading time effects (in self-paced reading) related to the presupposition of *also* when the context did not support it. Building on this paradigm, Tiemann et al. (2011) investigated a broader range of presupposition triggers and found that unsupported presuppositions gave rise to decreased acceptability and increased reading times in word-by-word self-paced reading. Schwarz and Tiemann (2012) extended this approach methodologically by using eye tracking in reading, focusing on *again* in German ('wieder'), and provided further evidence for rapid presupposition evaluation at a more fine-grained temporal resolution, namely in first fixation duration effects (at least for unembedded cases, which will be what we are concerned with in the present experiments as well).

One limitation of the reading time studies is that the effects generally arise due to lacking support or contradiction of presuppositions in the context. While the timing of these effects is indicative of the time course of presupposition interpretation, it does not allow for a direct assessment of felicitous presupposition comprehension in online processing, nor does it lend itself to a comparison with other types of content. The visual world paradigm (Tanenhaus et al., 1995), where participants' eye movements relative to a visual scene are tracked while they are listening to auditorily presented linguistic stimuli, seems better suited for addressing these issues. In particular, it allows the tracking of evolving interpretations of any type of content in real time with natural stimuli that do not involve any conflicts between the context and the presupposed information. While there are plenty of studies on reference resolution using the visual world paradigm, many of which also involve issues related to presuppositions (e.g. Keysar et al., 2000; Hanna et al., 2003; Grodner and Sedivy, 2005), relatively little work has been directly focused at presupposition triggers other than referential expressions (but see Chambers and Juan, 2008, for a study of the presuppositional verb *return*).[1]

This paper presents two studies using the visual world paradigm that investigate the time-course of presupposition interpretation, focussing on the presupposition of *also*. The first study, presented in section 2, assesses the time course of interpreting (unstressed) *also* by comparing visual contexts where the presupposition singles out one of the displayed figures with control contexts where it does not. The second study, discussed in section 3, attempts a first direct comparison of presupposed con-

[1] For other recent studies on presuppositions using the visual world paradigm, see Kim's and Romoli et al.'s contributions in this volume, as well as Romoli et al. (2013).

tent with literal, asserted content, by including sentences with *only* and visual contexts where the exclusivity asserted by *only* singles out one of the displayed figures early on, and compares these to sentences with stressed *also* (in appropriately adjusted contexts). Control conditions in this experiment used sentence variants without *also* and *only*. The results from these studies provide clear evidence for rapid consideration of presuppositions in online processing, and the second study finds even earlier effects for the presupposition of *also* than for the asserted exclusivity of *only*. The implications of these findings are discussed in section 4.

2 Experiment 1: The Time Course of Processing *Also*

The basic tenet of the visual world paradigm is that when listener's are presented with auditory linguistic stimuli while visually inspecting a display presented to them, their eye-movement behavior tends to reflect what is currently on their mind. When carefully controlling how the parts of the displayed image relate to the information conveyed by the linguistic input at a given point in time, this can be utilized to investigate what interpretation, if any, a listener is entertaining at a given point in time as the sentence in question unfolds. For present purposes, the target sentences crucially involved the additive particle *also*. When unstressed, *also* associates with the part of the sentence following it that is in focus and introduces a presupposition to the effect that there is some alternative to the interpretation of that part that yields truth in the remaining sentence frame as well (Kripke, 1991; Krifka, 1999; Chemla and Schlenker, 2012). For example,

(1) Mary is also holding a [FORK]$_F$.

with focal accent on *fork*, presupposes that Mary is holding something else besides a fork, and furthermore requires that whatever else she is holding, say a spoon, is sufficiently salient in the discourse context (Kripke, 1991). Assuming this is the case, it thus becomes in principle possible to infer that Mary is holding a spoon as well as something else at the point that *also* (or at the latest *also holding*) has been heard. It is this inference based on the presupposition of *also* that we utilize in our experimental task set within the visual world paradigm, where participants are instructed to click on one of the characters in a display. This allows us to assess the time-course of linguistic information of interest becoming available in online interpretation. In our case, this is done by manipulating whether only one or both of the characters within the display in question are in fact holding a spoon, and by framing the relevant descriptions as part of a instruction to click on one of the pictures (see (2) below). If the inference is available and reflected in eye-movement behavior, we thus expect different distributions of looks during the relevant time-window depending on whether or not one of the characters can be identified based on the information available from the linguistic input during the time-window in question. With this general characterization of the task in place, let us turn to a more detailed presentation of the actual materials and experimental design utilized.

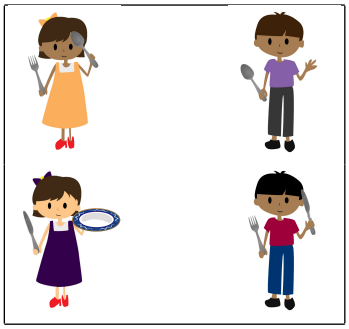
2.1 Materials & Design

The experimental materials consisted of pairs of displays and auditory linguistic stimuli such as the following:

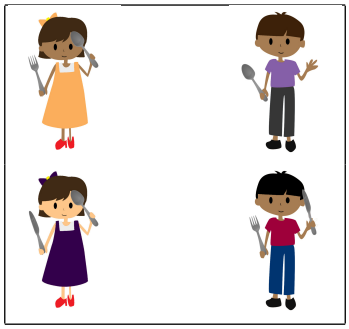
(2) a. *Context:*
One of the boys is holding a spoon.

b. *Target:*
Click on the girl who is also carrying a fork.

i. Critical



ii. Control



(Illustrations courtesy of Dorothy Ahn)

The target sentence, a variant of (1) above adjusted to suit the experimental task, contained a non-stressed *also* and had the main focal accent on *fork*. The initial context sentence served to ensure that the use of *also* is felicitous by providing an antecedent, in this case *a spoon*. The presupposition introduced by *also* in this context thus is that the girl to be clicked on is holding a spoon. Crucially, this presupposition can in principle already be inferred prior to encountering the final noun *fork*. The Critical display version contained only one girl that was holding a spoon (the one on the top left, henceforth referred to as the target), whereas the Control version had both of the girls in the display holding a spoon (with the other girl serving as a competitor). In the latter case, it is only at the point in time where the information provided by *fork* is available that it becomes possible to determine which girl to click on. In the former, however, this can already be done at an earlier point in time, namely as soon as *also* is encountered. This is possible if and only if the presupposition of *also* - that the girl in question be holding a spoon - is available. We thus are interested in eye movement patterns during the time window corresponding to the underlined part of the sentence in (2). If the presupposition of *also* is available in online processing, we expect a relative shift of fixations towards the target, as compared to the competitor in the Critical display condition.

A total of twelve sentence-picture pairs along the lines of the one illustrated above were created, with a variety of characters and objects. The crucial variation always involved whether the competitor figure had the object mentioned in the context sentence. In addition to the experimental items, there were a total of 32 fillers.

The first group of fillers consisted of 6 items with sentences parallel to the experimental ones, but without *also*. Furthermore, the figure to be clicked on never had what the figure in the context sentence had, to avoid general predictability of the target picture based on the context sentence. A second set of 6 fillers was again similar to the experimental items, but contained a conjunction in the target sentence (*... who has a fork and a spoon*). In half of these, the target had the object mentioned in the context sentence, and in the other half not. Both of these filler sets furthermore varied whether target and competitor each included two objects or whether one of them had just one object. A third set of 6 fillers included context sentences with a conjunction and target sentences with *only*, again varying whether the competitor had one or two objects between items. A final set of 12 items came from another experiment on the interpretation of *either ... or*, with disjunctions in the target sentences and systematic variation of whether the target had one or two objects. Altogether, the fillers were designed to counter-act possible biases with respect to the likelihood of the eventual target picture containing the object mentioned in the context sentence. Furthermore, they introduced some variation in the distribution of objects, as well as in the types of target sentences subjects were to encounter.

2.2 Procedure & Participants

After signing a consent form, subjects were seated in front of a computer monitor (size: 21 inch, resolution: 1680×1050) connected to an EyeLink 1000 eye tracker by SR Research (used in desktop mode). After calibration, subjects saw instructions on the screen that they would be seeing pictures and listening to sentences that would provide instructions to click on one of the pictures. After doing a practice trial and having the chance to ask any questions they might have, the experiment began. Each trial started by the subject looking at a fixation point at the center of the screen to control for their initial eye position. Next, the visual display was previewed for 1500ms, and subjects were free to look around in the display during this time. After the preview, an audio file with the pre-recorded linguistic stimuli was played back, after which subjects carried out the instructions by clicking on the appropriate picture using a mouse. The positions of target and competitor were counter-balanced across the experiment, though they were always vertically or horizontally aligned.

16 undergraduate students from the University of Pennsylvania, all native speakers of English, participated in the experiment for course credit. Subjects were split into 2 groups, where each subject saw 6 of the experimental sentences per condition, yielding a counter-balanced data set altogether.

2.3 Results

2.3.1 Data Treatment

Fixations and Responses were coded according to which of the four figures in the display they corresponded, with interest areas of 300×400 pixels, and a 400 pixel distance between image edges horizontally and 200 vertically. Unsurprisingly given the straightforward nature of the task, subjects's accuracy was at ceiling throughout (except for in the *or* sub-experiment, where there was some ambiguity).

To ensure proper eye tracking data without excessive amounts of track loss, we inspected the critical time window of interest, from the onset of *also* to the onset of the disambiguating noun (shifted by 200ms to account for the time standardly assumed to be required for planning and initiating a saccade), and removed any trials where track loss exceeded 30% of the samples taken. Only three trials had to be removed based on that standard.

2.3.2 Statistical Analysis

Given the design of the experiment, we were primarily interested in the frequency of looks to the target picture as compared to the frequency of looks to the competitor picture after hearing *also* but before encountering the noun. We therefore computed Target Advantage scores for time windows of interest by subtracting the proportion of looks to the competitor from the proportion of looks to the target. The resulting raw proportions were transformed into empirical logits (Barr, 2008). Statistical analyses used mixed-effect models with subjects and items as random effects, using the *lmer* function of the *lme4* package in *R* Bates (2005). Following Barr et al. (2013), the maximal random effect structure that would converge was used in each case, with a random intercept as well as a random slope. Full random effect structures converged and were used unless otherwise noted. To assess whether inclusion of a given factor significantly improved the fit of the overall model, likelihood-ratio tests were performed that compared two minimally different models, one with the fixed effects factor in question and one without, while keeping the random effects structure identical (Barr et al., 2013). We report estimates, standard errors, and t-values for all models, as well as the χ^2 and p-value from the likelihood-ratio test for individual factors.

Figure 1 shows mean Target Advantage scores by condition as a function of time. As can be seen from the consistently higher line for the Critical condition from the onset of *also* to the mean onset of the disambiguating noun, there were relatively more looks to the target in this condition than in the control condition.

To assess this difference statistically, we first computed empirical logits for the average Target Advantage scores for the entire ambiguous region, defined as beginning 200ms after the onset of *also* and ending 200ms after the onset of the noun, as any significant shift in fixations to the target during this time should be attributable to the availability of the presupposition of *also*. On average, this time window lasted

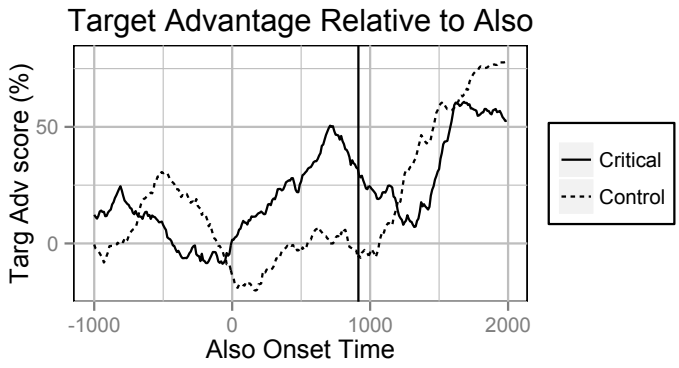


Fig. 1 Target advantage scores as a function of time aligned to the onset of *also*. The vertical black line indicates the average onset point of the disambiguating noun.

for 976ms, though this varied somewhat between items. The expression *also* itself lasted 334ms on average.

In a mixed effect model analysis, the factor manipulating the picture for the competitor contributed significantly to model fit ($\beta = 3.07$, $SE = 1.07$, $t = 2.88$; $\chi^2 = 7.09$, $p < .01$), with average empirical logit scores of 2.86 ($\approx 30.1\%$) for the Critical condition and -0.20 ($\approx 1.9\%$) for the Control condition. As the Critical level of the factor was used as the reference level, the Intercept t-value of 2.81 furthermore shows that the mean for that condition was significantly different from 0, thus indicating a significant bias towards the target picture. This provides evidence that the interpretation of the presupposition of *also* is available during this time window.

To get a more fine-grained perspective on the time course of the interpretation of *also* having an effect, we furthermore divided the first 800ms of the ambiguous period (as defined above) into 100ms chunks and ran the same analysis for each separately. The results are summarized in Table 1.

Time window:	200	300	400	500	600	700	800	900
β_0	1.68	2.45	2.73	3.24	4.36	5.09	4.09	3.03
t-value	1.51	1.92	2.26	2.91	3.669	5.11	3.89	2.45
β_1	-3.09	-3.01	-2.90	-3.20	-3.92	-4.78	-3.94	-3.48
t-value	-2.445	-2.31	-2.28	-2.45	-3.06	-3.65	-2.73	-2.28
p-value	$< .05$	$< .05$	$< .05$	$< .05$	$< .05$	$< .01$	$< .05$	$< .05$

Table 1 Estimates and t-values for Intercept (β_0) and effects of the picture manipulation (β_1) in 100ms time windows (starting from 200ms after the onset of *also*), as well as p-values from model comparisons for the latter.

The effect of the central competitor-picture manipulation significantly contributed to model fit right from the start in the 200-300ms time window, and continued to do so throughout all remaining time windows we analyzed. Note, however, that the initial effect may at least in part be due to an apparent bias towards the competitor in the Control condition during the first few hundred milliseconds after the onset of *also*. It is unclear what this is due to, and analyses with Control as the reference level suggest that this is not significantly different from 0 (t's < 1.5) at any point. Be this as it may, this short-lived competitor tendency ends around 400ms, so that it cannot contribute to effects throughout. the t-values for the Intercept provide a further indication of when the presupposition of *also* start affecting eye movement behavior and show that a significant preference for the target begins to emerge in the 300-400ms time window.[2]

In order to evaluate whether the effects found for the experimental items might reflect any other general biases towards certain types of pictures in combination with the context sentences, fixation proportion plots for the three types of filler items were visually inspected as well. The only apparent effect found here was that whenever the target and competitor differed in that one involved one item and the other two, there was a slight preference for the one with two objects. Otherwise, Target Advantage scores up to the disambiguating noun fluctuated around zero, suggesting that none of the potential biases controlled for by the fillers are behind the result for our experimental manipulation.

2.4 Discussion

This first experiment investigated eye movements during a time window where relative shifts in fixation towards the target should only be possible if the presupposition of *also* is available. We find significant differences from the Control condition right from the earliest points on in the first one hundred milliseconds during which eye movements affected by *also* can arise (again assuming 200ms for planning and implementing eye movements). This suggests that the presupposition of *also* is available right away in online processing, and that it is utilized in selecting the referent for the noun phrase in the target sentences.

However, one caveat is in order. While we controlled for several properties of the stimuli using filler sentences, there is one potential further factor that we could not assess based on the fillers, and which would be relevant for the experimental materials: it is quite plausible that subjects' looking behavior might display a preference for parts of the display that contain an object of the type mentioned in the context sentence (despite our attempts to vary the stimuli in this regard through the fillers). In the Critical picture, only the target had this property, whereas both target and competitor did in the Control condition. We can thus not rule out that such a potential preference could have at least partially contributed to the experimental effect

[2] The Intercept can be interpreted in this way because the Critical condition was used as the reference level.

of interest. The second experiment addresses this concern by keeping the pictures for Critical and Control conditions constant.

3 Experiment 2: Presupposition vs. Assertion - *Also* vs. *Only*

While the first experiment provides evidence for essentially immediate availability of the interpretation of the presupposition of *also* based on the fine-grained temporal resolution of the visual world paradigm, it does not provide any direct point of comparison to other aspects of meaning. This, however, is in many ways where much of the real theoretical interest lies, in light of the larger project of informing how different aspects of meaning relate to one another in terms of their processing properties. Most of the scalar implicature literature, for example, is concerned with trying to establish differences between asserted and implicated content. The second experiment attempts to contribute a first direct comparison between presupposed and asserted content. It does so by varying *also* with *only*, where the exclusivity asserted by the latter makes it possible to identify the target in the critical condition. There are two further changes in design from the previous experiment. First, rather than looking at unstressed *also*, we used stressed *also*, which associates with an element preceding it (Krifka, 1999):

(3) John ALSO is carrying a fork.

The presupposition introduced here is that somebody other than John is carrying a fork. The main motivation for switching to stressed *also* was to allow for a maximally natural minimal variation with the *only* sentences.[3] The second change was that the control conditions used pictures identical to the critical conditions, while the sentences were manipulated by leaving out the *also*/*only*.

3.1 Materials & Design

The experimental materials consisted of 24 sentence and picture pairings along the lines illustrated in (4), using a 2×2 interaction design. The sentences varied whether or not *also* and *only* were present in the respective conditions. The images were kept constant within the *also* and *only* Critical and Control sentence versions respectively, but were slightly different for the *also* and *only* conditions. In particular, the target in the *also* condition involved two objects, while the *only* target only involved one. The latter was necessary in order for the picture to match the exclusive condition contributed by *only*. The second object in the *also* condition was added to avoid any potential confusion arising from subjects (perhaps just temporarily) considering

[3] Unstressed *also* in the pre-copula position was found to be non-optimal in a pilot study for Experiment 1.

the interpretation associated with the unstressed *also* interpretation, which would require two objects to be involved.

(4) a. Also:

Context: One of the boys is carrying a fork.

Critical: Click on the girl who ALSO is carrying a fork.

Control: Click on the girl who is carrying a fork and a spoon.

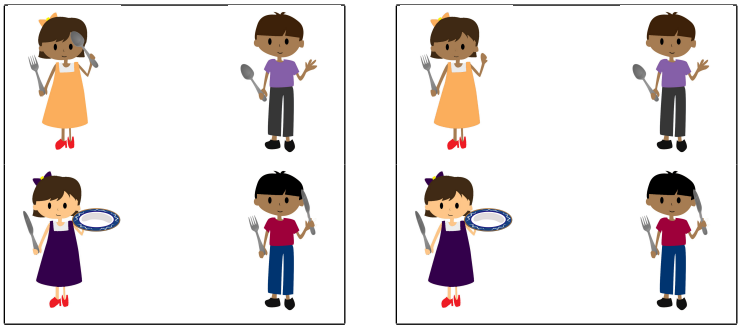
b. Only:

Context: One of the boys is carrying a fork and a knife.

Critical: Click on the girl who only is carrying a fork.

Control: Click on the girl who is carrying a fork.

c. *Also* Display *Only* Display



(Illustrations courtesy of Dorothy Ahn)

In addition to the crucial variation of the presence of *also* and *only*, several other minor variations were introduced to ensure maximal felicity of the sentences in their context and to avoid potential prosodic cues that might undermine the function of the control condition. First, the context sentence for the *only* sentences contained a conjunction to motivate the use of *only* in the target sentence while still being able to mention the object type of the noun in the the target sentence. Without the conjunction, the use of *only* here would seem unmotivated and somewhat out of place in intuitive terms. Secondly, the target sentence in the *also*-Control sentence contains a conjunction, in order to avoid a potential issue with the intonation of the verb and the noun phrase *a fork*. In particular, the verb phrase *is holding a fork* in the context *One of the boys is holding a fork* is Given (in the sense of Schwarzschild, 1999) and normally would require de-accenting, which in turn would shift the main accent onto *girl*. This could provide an early prosodic cue of the verb phrase to come, thus undermining the control purpose of this condition, where disambiguation is not meant to occur until *fork* is heard. However, once we add a second conjunct, the verb phrase as a whole is no longer Given and as a result, de-accenting is not required and there is no accent shift onto *girl*.

Generally speaking, the logic of the design was parallel to the first experiment. In the Critical *also* condition, it is possible to identify the girl on the top left as the target as soon as *ALSO* is encountered, but only when its presupposition is available in online processing. Apart from this, disambiguation takes place with the (initial) noun, so its onset serves as the end-point for the time window of interest, both in the Critical and Control condition. As for the *only* conditions, it is the exclusive literal meaning expressed by *only* - that the girl is holding no more than one thing - that allows to single out the girl on the top left as soon as *only* is interpreted. Otherwise, disambiguation again comes with the introduction of the noun *fork*, which therefore also constitutes the end of the time period of interest for both *only* conditions.

Given the slight variations between sentences and contexts, we tried to ensure that the audio recordings varied as little as possible by splicing together recordings. In particular the recording of the context up to the beginning of the relative clause (including *who*) was identical for the critical and control conditions for both *only* and *also*. This was done by recording the entire context-target sentence sequences, and subsequently replacing the context in one of the recordings with that from the other. Final items used the context from the original critical and control recordings half of the time respectively.

Yet another pre-caution we took to avoid any potential biases not related to our experimental manipulation was to counter-balance which conjunct in the *only*-context sentence occurred again in the target sentence, i.e., half of the *only* target sentences used the first conjunct from the context sentence and the other half the second.

A total of 18 fillers were included to distract from the patterns of the experimental manipulation and to control for general distributional properties of targets and competitors throughout the experiment. A first set of 6 fillers contained a conjunction in the context sentence. The subsequent target sentence picked out a target picture with just one object (while the competitor had two objects). In all these regards, the fillers were parallel to the *only*-Control sentences, the only difference being that the target sentence in the fillers introduced a new noun phrase that matched neither conjunct from the context sentence. Another set of 6 fillers was modeled after the *also*-control sentences, with a single noun phrase in the context and a conjunction in the target sentence. However, both noun phrases in the conjunction were new and did not match the one mentioned in the context sentence. Correspondingly, the target picture also did not involve the object mentioned in the context sentence. A final set of 6 fillers yet again involved a single noun phrase in the context sentence, while the target sentence involved a disjunction of the form *who is either holding a fork or a knife.* In this set, it was always the second disjunct that matched the noun phrase in the context sentence.

3.2 Procedure & Participants

The procedure was identical to that in Experiment 1 described above. 26 undergraduate students from the University of Pennsylvania, all native speakers of English, participated in the experiment for course credit. For counter-balancing, subjects were split into 4 groups, where each subject saw 6 of the experimental sentences per condition.

3.3 Results

3.3.1 Data Treatment

As in Experiment 1, fixations and responses were coded according to which figure in the display they corresponded to. Response accuracy in terms of following the instruction in the target sentence again was at ceiling, with almost no errors. Applying the same criterion for excessive track loss during the overall time window of interest of 30%, 3 trials were removed from the full data set.

3.3.2 Statistical Analysis

The time window of interest in this experiment started with the onset of *also* and *only* in the critical conditions and ended with the onset of the noun (e.g., *fork* in (4)). In order to have a time window of equal size in the control conditions, which did not include *also* or *only*, we calculated by how much the onset of *also*/*only* preceded the onset of the copula in the Critical condition for each item and then included the same amount of time preceding the copula in the Control condition of each item in the time window. On average, the resulting time window lasted 1073ms, with some modest variation between items and conditions, given the separate recordings that had to be used for this part of the stimuli. Target advantage scores were computed as detailed above and transformed into empirical logits.

As before, we used mixed-effects models to analyze the data. As the range of possible random effect structures (RES) becomes more complex in an interaction design, we use the following shorthand indications to facilitate presentation of results. The maximal random effects structure is represented as RES-1 and models possible variation between subjects and items for all aspects of the model, including the main effects and interaction. When the full structure did not converge, the random effect structure was simplified by removing the interaction term for items. Results are reported for the maximal random effect structure (RES-1), unless this failed to converge, in which case RES-2 was used (no further simplifications were necessary).

- RES-1: $(1 + factor1 * factor2 |\ subject) + (1 + factor1 * factor2 |\ item)$

- RES-2: $(1 + factor1 * factor2|\ subject) + (1 + factor1 + factor2|\ item)$

For the overall interaction analyses, predictors were centered, so as to render estimates of main effects. Planned comparisons between individual conditions were conducted using the appropriate treatment-coding.

Target Advantage scores are plotted as a function of time by condition in Figure 2. Descriptively speaking, there are several obvious things to notice. First, the Control conditions hover in an overall more or less flat pattern up until the onset of the noun, which is as as expected since the disambiguation is only introduced by the noun. Both of the Critical conditions, on the other hand, contain a sharp rise during the time period of interest. Secondly, the rise in the Critical *also* condition appears to occur earlier than in the Critical *only* condition. Yet another observation is that the scores for the *also* conditions seem to be consistently higher than those for the *only* conditions. This is likely due to the fact that the target in the *only* conditions only contains one item, in contrast with the competitor (see discussion of fillers below).

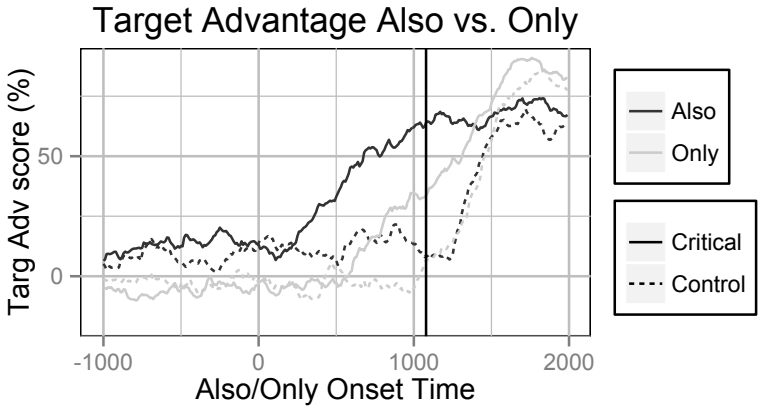


Fig. 2 Target advantage scores as a function of time aligned to the onset of *also* / *only*. The vertical black line indicates the average onset point of the disambiguating noun.

To analyze these patterns statistically, we first looked at the means for the entire time window (from 200ms after the onset of *also*/*only* to 200ms after the onset of the noun) using a 2×2 interaction mixed effect model analysis. The mean Target Advantage scores and empirical logits are provided in Table 2. There was no significant interaction, but there were significant main effects of *also* vs. *only* (RES-1: $\beta = 2.66$, $SE = 0.59$, $t = 4.50$; $\chi^2 = 14.79$, $p < .001$) and of Control vs. Critical (RES-1: $\beta = 2.43$, $SE = 0.45$, $t = 5.40$; $\chi^2 = 20.06$, $p < .001$), reflecting higher scores in the *also* conditions as well as in the Critical conditions. Planned comparisons between the Critical and Control conditions yielded significant simple effects for both *also* (RES-2: $\beta = 2.82$, $SE = 0.63$, $t = 4.46$; $\chi^2 = 16.21$, $p < .001$) and

only (RES-2: $\beta = 2.03$, $SE = 0.63$, $t = 3.22$; $\chi^2 = 9.86$, $p < .01$), suggesting that subjects' eye movements reflected the interpretation of both expressions during the time window where no other information could differentiate between the target and the competitor.

	also		*only*	
	Control	Critical	Control	Critical
Target Advantage	11.9	47.5	-3.7	12.8
Empirical Logit	1.39	4.22	-0.87	1.17

Table 2 Target Advantage scores (in %) and corresponding empirical logits for the time window lasting from 200ms after the onset of *also*/*only* to 200ms after the onset of the noun.

A more fine-grained perspective of looking at eight 100ms time-windows following the onset of *also*/*only* (shifted by 200ms) yields a more nuanced picture of the time course of the relevant interpretations becoming available, specifically with respect to the relative timing for the two expressions investigated. Table 3 provides an overview of the results, listing estimated coefficients, t-values, and p-value ranges from model comparisons for the interaction as well as main and simple effects of Critical vs. Condition.

Time:		200	300	400	500	600	700	800	900
Int.	β	-0.32	-1.03	-2.64	-3.22	-2.10	-1.65	-0.55	- 0.5
	t-value	-0.24	-0.76	-1.89	-2.34	-1.40	-1.05	-0.32	-0.36
	p-value	-	-	$< .1$	$< .05$	-	-	-	-
ME	β	0.30	1.12	1.05	1.45	2.27	2.97	3.41	4.11
	t-value	0.41	1.61	1.37	1.89	3.11	3.52	4.51	5.81
	p-value	-	$(.11)$	-	$< .1$	$< .01$	$< .01$	$< .001$	$< .001$
SE *also*	β	0.46	1.63	2.36	3.06	3.32	3.79	3.70	4.40
	t-value	0.49	1.68	2.32	2.97	3.37	3.64	3.67	4.01
	p-value	-	$< .1$	$< .05$	$< .01$	$< .01$	$< .01$	$< .001$	$< .001$
SE *only*	β	0.14	0.60	-0.27	-0.17	1.22	2.15	3.13	3.82
	t-value	0.14	0.62	-0.26	-0.15	1.08	1.71	2.631	3.73
	p-value	-	-	-	-	-	$< .1$	$< .05$	$< .01$

Table 3 Estimates, t-values, and p-values for the Interaction, the main effect ME and simple effects of Critical vs. Control (ME) for *also* (SE *also*) and *only* (SE *only*) for analyses of 100ms time windows (starting from 200ms after the onset of *also*).

This analysis indicates that the effect of *also* emerges prior to the effect of *only*. The most solid statistical evidence for this is the significant interaction in the 400-500 and 500-600ms time windows.[4] Furthermore, looking at the two expressions separately, we see that a simple effect of Critical vs. Control already emerges in the 300-400ms time window for *also*, but not until the 700-800ms time window for *only*. Nonetheless, even for the latter there is clear evidence for participants utilizing the exclusivity expressed by *only* in shifting their eye gaze to the target, prior to any further disambiguating information from the noun becoming available. Further evidence in this regard comes from the reaction times for clicking on the target, measured from the onset of the disambiguating noun. Click times were significantly faster in the Critical *only* condition (1119) than in the Control condition (1406ms) ($\beta = 286.5, SE = 68.63, t = 4.17; \chi^2 = 15.14, p < .001$), suggesting that the earlier disambiguation based on the exclusivity expressed by *only* makes it possible for participants to carry out the clicking instruction more quickly.[5]

Target Advantage plots for the filler sentences that were similar to the experimental ones, aligned to the onset of the noun, were inspected visually to check for any effects due to properties of the stimuli separate from the crucial experimental manipulation. Data from the group of fillers modeled after the *only* control condition suggests that, as in Experiment 1, when target and competitor differed in that one had one object and the other two, there seems to be a bias towards looking at the one with two prior to the onset of the noun. This likely accounts for the main effect of *also* vs. *only* in the present experiment, since the picture types differed in this regard. However, note that this main effect is orthogonal to the critical findings of interest, namely the (temporary) interaction and the simple effects within the *also* and *only* conditions.

Recall that a potential concern with the interpretation of Experiment 1 was that there might be a bias towards pictures that contain an object of the type mentioned in the context sentence. The set of fillers modeled after the *also* control condition allowed us to assess this issue. In the time window of roughly 800ms prior to the noun, such a bias was indeed found. Note that this also could have contributed to the main effect of *also* vs. *only* in the present experiment, since only the target had this property in the *also* conditions, whereas both target and competitor did in the *only* conditions. Crucially, however, within the Critical and Control conditions for each expression respectively, no variation of this sort existed. Thus, this factor cannot have contributed directly to the crucial effects of interest in the present experiment. The results from this filler type do suggest, however, that at least part of the effect in Experiment 1 may be due to it. It still seems unlikely that it is entirely due to this factor, given the size and shape of the effects found in the filler as compared to the experimental items in Experiment 1. However, since there is no straightforward way for testing this claim statistically, and since the same concern does not arise for the results from Experiment 2, we need not settle this question decisively.

[4] Note also that when looking at target proportions (not relativized to looks to the competitor), the interaction already becomes significant in the 300-400ms time window.

[5] Click times were also faster in the Critical condition for *also*, but given the different length in the target sentences between conditions here, this is not straightforwardly interpretable.

3.4 Discussion

Experiment 2 sheds further light both on the time course of interpreting the presupposition of *also* in general and in comparison to the exclusivity asserted by *only* in particular. With respect to the first point, using identical pictures for the Critical and Control conditions avoided the issue that arose for Experiment 1 concerning preferences for pictures matching the context sentence in terms of including the object mentioned there. We thus have a cleaner, and more decisive result showing that the presupposition of *also* is available in online processing within about 200ms (based on eye gaze effects within 400ms after the onset of *also* and assuming the standard 200ms needed for planning and implementing eye movements).

In addition to this insight into the absolute timing of interpreting *also*, an even more important aspect of this experiment was to relate the processing time line of a presupposition trigger to that of the asserted content of another expression, namely *only*. While the entire time-window between the onset of *also* and *only* did not reveal any direct differences between the two, with no interaction present and a main effect of Critical vs. Control, as well as corresponding simple effects in both the *also* and *only* conditions, a more fine grained perspective of looking at eight 100ms time windows following the onset of *also* / *only* provided a more nuanced picture. In particular, shifts to the target did not reach significance for *only* until about 600ms after the earliest possible point, i.e., about 400ms later than they did for *also*. This difference in simple effects is supported most solidly in statistical terms in the 500-600 and 600-700 time windows, where there was an interaction between the type of expression and the Critical vs. Control conditions.

The difference between the two expressions suggests that not only do presuppositions not involve a delay, in contrast with what has commonly been argued for scalar implicatures, but - if anything - their availability in fact may precede that of asserted content. The extent to which this conclusion holds of course depends on whether the exclusivity asserted by *only* indeed serves as a fair comparison. We will discuss this question in the next section.

4 General Discussion

The results from the two experiments reported here suggest that the presupposed information introduced by *also* is available early on in online processing, based on eye movement effects 200-300ms after the onset of *also* (i.e., while still hearing *also*, which lasted 300-400ms itself). The second experiment furthermore showed that eye movement effects based on the presupposition of *also* arise earlier than ones based on the asserted exclusivity of *only*. This suggests that presupposed content may be available even earlier than asserted content. However, the validity of such a conclusion hinges on the question of whether or not we are dealing with a fair comparison between the two types of meaning here, which we will turn to now.

Finding minimal comparisons between asserted and presupposed content is not a trivial challenge. We chose to compare (stressed) *also* to *only* based on their ability to occur in the same sentential context. Furthermore, they are similar in that they crucially relate to the focus of the sentence, and in the given contexts, they would seem to relate to the context sentence in an at least broadly parallel manner. Given that we do find online effects for *only*, albeit later than for *also*, furthermore suggests that there is nothing fundamentally wrong with our basic setup aimed at differentiating pictures in the critical conditions in terms of the exclusivity expressed by *only*. Finally, it seemed that the relation of what is linguistically expressed to the way that the contrast between the target and the competitor is implemented in the pictures is slightly more salient, if anything, in the *only* condition, since the target has just one object whereas the competitor has two (in the *also* conditions, both had two).

However, there are a differences between the two cases that we need to duly acknowledge as well, as they may in principle be relevant for the differences in the time-course of interpretation we found. First, *only* associates with a focus down-stream, later in the sentence, whereas stressed *also* associates with a preceding expression. This could mean that it is easier to flesh out the interpretation of *also* at the time the expression itself is encountered. At the same time, we found comparable effects for unstressed *also*, which also associates with a down-stream focus, so it's unclear whether this issue could really make all the difference in timing. Another potential complication present for *only* is that both the target and the competitor picture have one of the objects mentioned in the context sentence. While the competitor does contain yet another object, which excludes it from consideration if *only* is interpreted relative to a domain containing all the objects in the display, it could be considered a viable candidate if the domain for *only* is taken to just include the two objects mentioned in the context sentence. In the illustration above, a competitor holding a knife and a plate in a context where a fork and a knife have been mentioned could be thought to match the description *... only is holding a ...* based on the notion that out of a fork and a knife, this one is holding a knife. Consideration of this possibility could in principle contribute to a delay in deciding which picture is to be clicked on. However, even if this is the case, this option could only be considered temporarily, as we do find a significant shift in fixations to the target prior to the onset of the disambiguating noun. A final potential issue concerns the naturalness of *only* in the pre-auxiliary position in the experimental materials (which was chosen to keep the word order parallel to the *also*-sentences). At least some native English speakers have reported this word order to be somewhat degraded, and if this were true for our subjects, it could also contribute to delays in interpretation. In sum, given these issues, it seems reasonable to conclude that we are left with at least tentative evidence for presupposed content preceding asserted content in online processing, but clearly more work using other expressions, and possibly other paradigms, is needed in order to assess whether this interpretation of the results can be maintained in the long run and whether we are dealing with a phenomenon of a general nature.

Returning to the first aspect of our conclusions to be drawn from our experiments, the evidence for immediate interpretation of presupposed content is rather strong,

and in line with other findings, both based on other methodologies (e.g., the reading time studies of Schwarz, 2007; Tiemann et al., 2011; Schwarz and Tiemann, 2012, 2013) and other recent approaches using the visual world paradigm (Romoli et al. 2013 and this volume, Kim, this volume). In theoretical terms, this type of result is more consistent with a semantically based notion of presuppositions, where presupposed content is part of what is conventionally encoded as the lexical meaning of the expression in question. In the final words of Beaver (2001), 'presupposition is what comes first in dynamic semantics,' for example, and other semantically based theories would lead us to expect that presuppositions are among the first things that are evaluated in the interpretation process, at least under the assumption that the theoretical procedures are mirrored more or less straightforwardly in processing. For pragmatic theories, on the other hand, the contrast of the present findings (and the other parallel results mentioned) with those for scalar implicatures are surprising, as such approaches take both types of meaning to arise based on considerations based on rational reasoning about the behavior of interlocutors in conversation. However, this point only stands to the extent that the results for scalar implicatures are a) indeed of a general nature and b) due to processes comparable to what is involved in interpreting presuppositions. Both points can be challenged, of course: various authors have argued recently that implicatures are not delayed after all, and despite the commonality of a basis in general conversational reasoning, there likely still are differences in the exact processes involved in computing implicatures and presuppositions, which could translate into processing differences. Finally, we need to keep in mind that it is by no way clear that presuppositions constitute a homogeneous phenomenon, as more and more attention is paid to possible differences between triggers. Assessing the more general implications of the present findings thus will require a much broader approach looking at a variety of triggers and suitable controls, and integrate the various recent developments in presupposition theory in more depth as well.

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