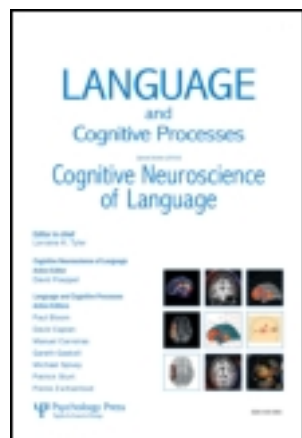


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***Logic and conversation* revisited: Evidence for a division between semantic and pragmatic content in real-time language comprehension**

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The distinction between *semantics* (linguistically encoded meaning) and *pragmatics* (inferences about communicative intentions) can often be unclear and counterintuitive. For example, linguistic theories argue that the meaning of *some* encompasses the meaning of *all* while the intuition that *some* implies *not all* results from an inference. We explored how online interpretation of *some* evolves using an eye-tracking while listening paradigm. Early eye-movements indicated that while *some* was initially interpreted as compatible with *all*, participants began excluding referents compatible with *all* approximately 800 ms later. These results contrast with recent evidence of immediate inferencing and highlight the presence of bottom-up semantic–pragmatic interactions which necessarily rely on initial access to lexical meanings to trigger inferences.

Keywords: Semantics; Pragmatics; Scalar implicature; Quantifiers.

Imagine overhearing the following conversation:

- (1) Mother: Did you finish the ice cream sandwiches?
Child: I ate some of them.

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Now suppose that you know that the child had in fact polished off the frozen novelties. Did she lie? Logicians would be inclined to say no—the child’s statement is logically consistent with the fact that she ate *all* of the ice cream sandwiches. Ask the mother, however, and she would most likely disagree—if the child says she ate *some* of them, she is indicating that she didn’t eat all of them. Who is correct in this situation?

The philosopher Grice (1975) would have said that both of them are. He argued for a division between interpretations that emerge from the meanings of words (*semantics*) and those that depend on inferential analysis of the speaker’s communicative goals (*pragmatics*). This distinction sheds light on why terms like *some* have two different interpretations (Gadzar, 1979; Horn, 1989). The logician’s answer depends on the semantics of the quantifier whose referents include the stronger term on the same scale (*some* and possibly *all*). In contrast, the likely interpretation from the mother’s point of view incorporates a pragmatic inference called a *scalar implicature* which imposes an additional upper-boundary that excludes referents compatible with the maximal term (*some* but not *all*). This interpretation is motivated by the expectation that if the child had eaten all of the frozen novelties, she would have simply said so, but since she did not, she must have eaten only a subset of them.

Scalar implicatures are both frequent and robust in everyday speech, thus it might seem unlikely that listeners would ever entertain the less common and less precise semantic meaning. Considerations such as these have led some to posit that these inferences are stored in the lexicon (Levinson, 2000) or generated directly by the grammar (Chierchia, 2004). This view is also consistent with empirical findings demonstrating listeners’ rapid use of contextual cues to infer the speaker’s intent (Sedivy, Tanenhaus, Chambers, & Carlson, 1999). Evidence of this kind has been so persuasive that it has become increasingly implausible that any well-practiced process would show measurable delays (Altmann & Kamide, 2004; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995).

Recent data, however, suggest that scalar implicature may involve a slower, more effortful process (De Neys & Schaeken, 2007; Noveck & Posada, 2003). Bott and Noveck (2004) compared the response times for truth-value judgements of sentences like “Some elephants are mammals” and found that participants who spontaneously generated the implicature (judged the statement to be false) took longer than those who interpreted the statement according to its semantic meaning (judged it to be true). Huang and Snedeker (2009a) explored the nature of this temporal delay by presenting participants with instructions like “Point to the girl that has some of the socks” and monitoring their eye-movements to displays featuring a girl with two of four socks and another with three of three soccer balls. This procedure features a critical period of ambiguity at the

onset of the quantifier where the semantics of *some* is compatible with both characters. This ambiguity could be immediately resolved by calculating a scalar implicature to restrict interpretation to the girl with the subset of items. Instead, participants' reference resolution following *some* was substantially delayed, suggesting a temporal lag between semantic processing and the calculation of the pragmatic inference.

Nevertheless, the presence of a delay in calculating the scalar implicature meant that this study failed to find clear evidence that participants ever generated the inference online, raising questions about the sensitivity of the task. Furthermore, more recent studies adopting a similar paradigm have failed to find temporal discrepancies between semantic and pragmatic processing (Breheny, 2009; Grodner, Klein, Carbary, & Tanenhaus, 2010). Thus, this present study borrows the methods established by Huang and Snedeker (2009a) but seeks evidence for the hypothesised switch from a bare semantic analysis to a pragmatically enriched one. By contrasting pairs of compound nouns as potential referents (e.g., ice cream sandwiches vs. ice cream cones), we can extend the period of semantic ambiguity and ascertain when scalar implicatures occurs.

METHODS

Twenty English-speaking undergraduates sat before an inclined podium with shelves in each quadrant and a camera at the centre to record their direction of gaze. On every trial, the experimenter acted out a story in which two sets of items were divided among four characters. These stories were followed by auditory instructions like (2).

- (2) Point to the girl that has *some*/*two*/*all*/*three* of the ice cream sandwiches.

The number trials served as controls to ensure that any delay in reference resolution for *some* compared to *all* could not be attributed to a preference to look at larger sets. Since these terms do not require a pragmatic inference to restrict reference, they do not generate the same temporary ambiguity as *some*.

The visual displays featured characters arranged so that the vertically adjacent characters matched in gender while the horizontally adjacent characters did not (Figure 1). For *some* and *all* trials, one set of four items was split between a horizontally adjacent pair (boy-with-2 vs. girl-with-2) and another set of three items was given to one of the remaining children (boy-with-0 vs. girl-with-3). For *two* and *three* trials, the first set was again evenly split between a boy-girl pair while the second set now included four items, which were split unevenly between the second pair (boy-with-1 vs.

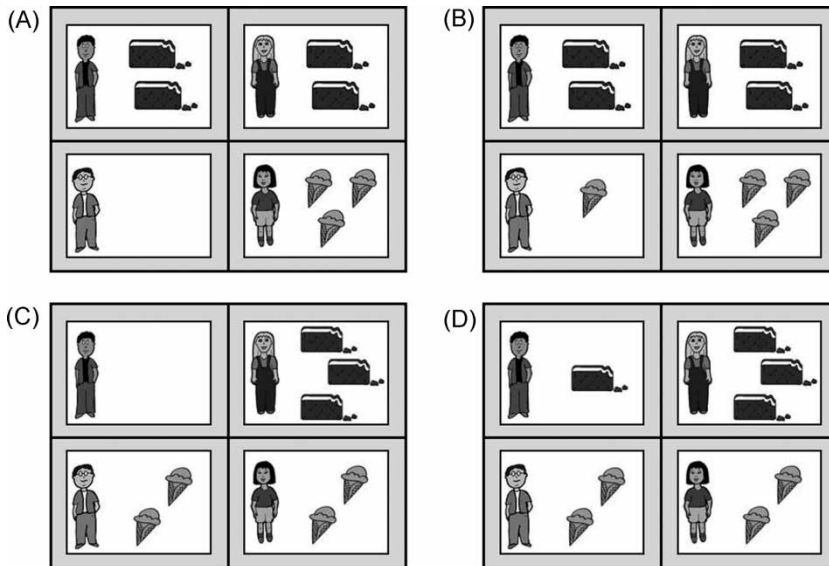


Figure 1. Examples of visual-world displays for (A) some, (B) two, (C) all, and (D) three trials. Participants here were instructed to “Point to the girl that has ___ of the ice cream sandwiches.” The girl with ice cream sandwiches was the Target while the girl with ice cream cones was the Distractor.

girl-with-3). This difference between the number and quantifier trials was necessary to ensure that the partitive construction was felicitous for all trial types but it did not change the visual properties of the potential Targets.

The critical utterances differed only in the gender of the child that was requested and the identity of the final word. The character who was requested was called the Target (girl-with-ice-cream-sandwiches) while the one who matched in gender but had a different item was called the Distractor (girl-with-ice-cream-cones). The names of the two items were always compound nouns that shared the same two-syllable onset. Each of the 16 items was rotated through the four quantifier conditions across four presentation lists such that each list contained four items in each condition and each item appeared once in every list.

To determine the earliest point in the utterance at which the Target could logically be identified (assuming no processing delays), we conducted two separate off-line gated-listening tasks with additional groups of participants. To establish the length of the period of ambiguity between the compound noun pairs, we presented 16 participants with 100 ms incremental segments of the audio instructions (Tyler & Wessels, 1983). After each segment, they were asked to indicate whether they heard the Target or Distractor word.

Participants correctly disambiguated the utterance at above chance levels 1,400 ms after quantifier onset ($M = 77\%$; all $p < .01$).

This extended window also allows us to more rigorously test accounts favouring early scalar implicatures by mapping the time-course of on-line processing onto the phonological markers associated with inferencing in an off-line task. To determine how much phonological information is necessary to derive a scalar implicature, we presented 20 participants with the relevant stories/displays and phrasal increments of the critical utterance (*Point to the girl that has some/two/all/three | of the | ice-cream | sandwiches*). Each of the 16 items was rotated through the four continuation conditions across four presentation lists such that each list contained four items in each condition and each item appeared once in every list. After each segment, they were asked to select the character that corresponded to what they had heard and saw. Selections of the Target were above chance in the first segment across all quantifiers ($M = 91\%$; all $p < .05$), indicating that our materials were successful in establishing expectations that (1) quantifiers would refer specifically to the sets in the display, (2) objects would be identified by basic-level labels, and (3) *some* would be interpreted with a scalar implicature.

Our critical question concerns the timing of semantic and pragmatic processing during real-time comprehension. If scalar implicatures are immediately calculated following the onset of the quantifier, we should expect reference restriction via the inference to be time-locked to this moment. If instead the inference is preceded by prior semantic analysis of the quantified expression, then we might expect delays in looks to the referent to persist beyond this point.

RESULTS

Eye-movements were coded by noting each change in gaze direction towards one of the quadrants or the centre (Snedeker & Trueswell, 2004). Twenty-five percent of the trials were checked by second coder who confirmed the direction of fixation for 95% of the frames. Our dependent measure was looking time to the Target as a proportion of looking time to the Target and Distractor. Looks to the other characters accounted for less than 5% of fixations after onset of the gender cue. Each time window was analysed with ANOVAs listing quantifier Scale (number vs. scalar) and Strength (lesser vs. greater) as within-subjects and items variables and list/item group as a between-subjects and items variable.

We first examined fixations from the onset of the gender cue to the onset of the quantifier (*girl that has*) to compare baseline looks to the Target and Distractor before the influence of the quantifier. During this period, Target looks remained around chance for all terms, leading to no reliable effects of

Scale or Strength (all $p > .15$). We then examined Target fixations for 100 ms intervals beginning from the onset of the quantifier to the point where the compound noun was phonologically disambiguated (Figure 2). For the *some* trials, this defined a 1,400 ms period of semantic ambiguity. Each time window is labelled by its onset relative to the quantifier.

We found that Target fixations in the *three* trials rose above chance during the initial 200 ms time window [67%; $t_1(19) = 3.45$, $p < .01$; $t_2(15) = 3.71$, $p < .01$] while those in the *two* [63%; $t_1(19) = 2.87$, $p < .05$; $t_2(15) = 3.45$, $p < .01$] and *all* trials [66%; $t_1(19) = 3.13$, $p < .01$; $t_2(15) = 4.75$, $p < .01$] quickly followed in the 300 ms window. Since saccadic eye-movements take up to 200 ms to be programmed after the relevant marker in the speech stream (Matin, Shao, & Boff, 1993), these results indicate that the semantics of these terms was used to restrict reference at the earliest moments of language processing. In contrast, Target looks for the *some* trials did not reliably exceed chance until the 1,100 ms window [63%; $t_1(19) = 2.13$, $p < .05$; $t_2(15) = 1.88$, $p < .10$].¹ Participants initially looked equally at both characters, suggesting that the scalar implicature was not available to rule out the Distractor during this early period of processing. The difference in Target fixations across these four terms led to a significant Scale by Strength interaction from the 400 ms

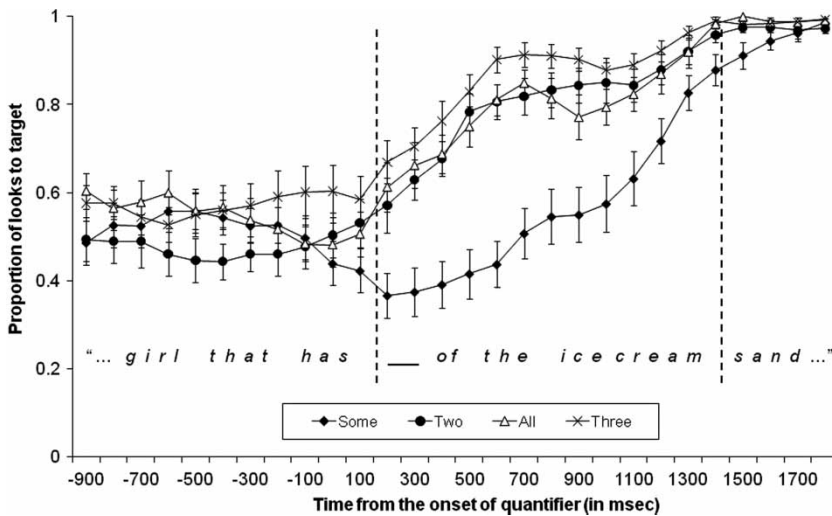


Figure 2. The time-course of looks to target for the four trial types.

¹ Due to the relatively small number of items used, some effects that were robust in the subjects analysis failed to reach conventional levels of significance in the items analysis.

window, $F_1(1, 16) = 5.06$, $p < .05$; $F_2(1, 15) = 8.47$, $p < .05$, through the 1,100 ms window, $F_1(1, 16) = 5.39$, $p < .05$; $F_2(1, 15) = 4.16$, $p < .10$.

To determine when the scalar implicature reliably occurred, we conducted a second analysis examining the saccades that occurred during each time window, rather than the fixations. This allows us to isolate the point at which new eye-movements to the Target outnumber those to the Distractor. We separated the trials based on the object that the participant was initially fixating on during the frame preceding a critical 200 ms window of interest (the Target or Distractor) and calculated the probability of switching to the other object during that period (Table 1).

We found that at the onset of the quantifier, there was a Distractor preference in the shifts for the *some* trials, suggesting that participants had a visual preference for the total set prior to calculating the implicature.² In the following 200 ms time window, we found a robust Target preference in shifts for *two*, *all*, and *three* but not for *some*. This led to a significant Scale by Strength by Initial-fixation interaction from the 200 ms window, $F_1(1, 16) = 5.04$, $p < .05$; $F_2(1, 15) = 7.33$, $p < .05$, through the 600 ms window, $F_1(1, 16) = 5.00$, $p < .05$; $F_2(1, 15) = 4.24$, $p < .10$. Critically in the 800 ms window, participants in the *some* trials were more likely to switch to the Target on the Distractor-initial trials than they were to switch to the Distractor on Target-initial trials. This time window roughly corresponds to the onset of the compound noun and indicates that a Target preference emerged well after the onset of the phonological cues necessary for the scalar implicature. These results suggest the presence of an extended period semantic analysis which proceeds the generation of this inference.³

DISCUSSION

This study provides evidence of the dynamic interplay between semantic and pragmatic processes during real-time comprehension. We found that when

² We believe that this pattern largely reflects differences in visual saliency across the different displays. In the *some* trials, participants preferred to look at the character that has the unique item (the Distractor) over one that has the shared item (the Target) prior to the onset of the quantifier. Qualitative patterns of this sort are also seen in prior studies with both adults (Grodner et al., 2010; Huang & Snedeker, 2009a) and children (Huang & Snedeker, 2009b). Critically, this preference was short-lived and disappeared following the onset of the quantifier, suggesting that they reflect perusal of the display prior to an informative linguistic cue.

³ Further evidence that this delay reflects initial semantic analysis of *some* comes from Experiment 3 in Huang and Snedeker (2009a). Participants were able to immediately disambiguate the Target after quantifier onset when a scalar implicature was not necessary for reference restriction, i.e., when the subset was contrasted with an empty set (girl-with-none-of-the-socks). This suggests that this current delay can be attributed to the initial unavailability of a necessary implicature for ruling out the total set.

TABLE 1
The percentage of switches to the Target as opposed to the percentage of switches off the Target are listed for each 200 ms time window along with the approximate corresponding word in the instruction.

Time from the onset of the quantifier								
...	<i>has</i>		<i>some/two/all/three</i>		<i>of</i>	<i>the</i>	<i>ice</i>	...
	-200ms	0ms	200ms	400ms	600ms	800ms	1000ms	
some	8% vs. 15%; t1(19)=0.85, p>.40; t2(15)=0.20, p>.80	5% vs. 17% ; t1(19)=2.21, p<.05; t2(15)=1.36, p>.15	9% vs. 21%; t1(19)=1.60, p<.10; t2(15)=2.93, p<.05	12% vs. 13%; t1(19)=0.17, p>.90; t2(15)=0.42, p>.60	7% vs. 6%; t1(19)=0.23, p>.80; t2(15)=0.62, p>.60	17% vs. 1% ; t1(19)=2.59, p<.05; t2(15)=2.18, p<.05	24% vs. 9% ; t1(19)=2.22, p<.05; t2(15)=3.00, p<.01	
two	16% vs. 14%; t1(19)=0.28, p>.70; t2(15)=0.31, p>.70	14% vs. 8%; t1(19)=0.85, p>.40; t2(15)=1.10, p>.30	22% vs. 3% ; t1(19)=2.68, p<.05; t2(15)=2.29, p<.05	24% vs. 3% ; t1(19)=3.48, p<.01; t2(15)=2.33, p<.05	N/A	N/A	N/A	
all	4% vs. 9%; t1(19)=1.44, p>.15; t2(15)=2.11, p<.10	7% vs. 11%; t1(19)=0.68, p>.50; t2(15)=0.64, p>.50	32% vs. 11% ; t1(19)=2.51, p<.05; t2(15)=3.34, p<.01	25% vs. 12% ; t1(19)=2.54, p<.05; t2(15)=2.15, p<.05	N/A	N/A	N/A	
three	11% vs. 7%; t1(19)=0.77, p>.40; t2(15)=0.11, p>.90	13% vs. 8%; t1(19)=1.27, p>.20; t2(15)=1.43, p>.15	27% vs. 2% ; t1(19)=4.02, p<.01; t2(15)=3.99, p<.01	N/A	N/A	N/A	N/A	

Subjects and items *t*-tests comparing the two percentages and significant differences between these switches are marked in bold. These switches were not calculated once participants' initial looks to the Target reached a ceiling of 70%

lexical semantics is sufficient to identify a referent, disambiguation of the utterance is quite rapid. However, when a pragmatic inference is required, reference resolution is substantially delayed. Listeners initially access the semantic meaning of *some* but fail to calculate the pragmatic inference until about 800 ms after the requisite phonological input. The pattern is rather remarkable given the preference for the scalar implicature in everyday communication and its robustness in our task.

These findings bear on current debates in the theoretical literature on the nature of pragmatic inferences and their relation to semantic representations (Noveck & Sperber, 2007). Among the variety of post-Gricean pragmatic theories that have been developed, in one category are explanations favouring immediate scalar implicatures. These include Neo-Gricean accounts suggesting that habitual application of these inferences causes the implicated meaning to be stored in the lexicon (Levinson, 2000) and more recent psycholinguistic accounts suggesting that *some* is polysemous between semantic and pragmatic interpretations (Degen, Reeder, Carberry, & Tanenhaus, 2009). In another category are accounts that leave open the possibility of a delay between phonological input and pragmatic inference. Prominent among these is Relevance theory which proposes that all inferences, including implicatures, are guided by a more general tradeoff between the possible gains associated with generating an inference and the amount of cognitive effort necessary to derive it (Sperber & Wilson, 1986/1995).

Our data present a particular challenge to the automatic processes invoked by proposals of the first kind. If scalar implicatures were lexicalised, then we would expect them to emerge as rapidly as semantic content. Yet we found a delay of 600 ms between the use of the lexically encoded upper-bound of *two* and the pragmatically inferred upper-bound of *some*. Alternatively, it may be the case that the two readings of *some* are polysemous and that both meanings are initially activated but after a short delay only the contextually appropriate one persists (Swinney, 1979; Tanenhaus, Leiman, & Seidenberg, 1979). However, if the relative influence of each meaning was proportional to its frequency or contextual fit, then preference for the Target would still be more robust than for the Distractor since the subset is generally preferred in communication and was overwhelmingly preferred in our off-line task (see *Methods* section). Instead we found no evidence of a reliable Target preference during the first 800 ms of the ambiguous region, suggesting that only the semantic meaning was initially available.

The presence of an on-line scalar implicature imposes constraints on the more open-ended processes invoked by Relevance theory (Carston, 1998). One possibility is that the mechanisms that generate interpretations only retrieved the semantic meaning of *some* since an implicature was not relevant

in a task where referents were lexically disambiguated by the end of the sentence. Another possibility is that listeners automatically generated the inferred interpretation first since it is the more typical interpretation of the term. Yet neither of these alternatives neatly captures the initial delay between semantic activation and inferential processes found in our data. To account for this pattern, the Relevance theory would need to predict that initial activation of the lower-bounded interpretation does not meet an internal standard of relevance which motivates subsequent generation of the implicature.

Finally, how can we reconcile these results with evidence demonstrating that pragmatic processing influences interpretation early in comprehension (Altmann & Kamide, 2004; Tanenhaus et al., 1995)? Clearly a complete synthesis awaits more data. In the meantime, we simply note the utility of distinguishing between two types of semantic–pragmatic interactions: (1) Cases in which pragmatic constraints are in place before a particular word is uttered, influencing how this word is understood and incorporated into the analysis; (2) cases in which the meaning of a given word is critical for triggering the pragmatic inference. Many examples of the rapid pragmatic effects are phenomena of the first kind and are compatible with standard models of language processing in which pre-existing top-down constraints shape the perception and interpretation of lower levels of linguistic analysis (Altmann, 2001; Trueswell & Tanenhaus, 1994).

In contrast, our study focuses on an important example of the second kind. Under most linguistic analyses a scalar implicature arises because of the meaning of the scalar term. Consequently, it is unsurprising that access to this meaning must precede the calculation of the inference. These results elucidate the nature of semantic and pragmatic interpretation by highlighting the relationship between these processes during real-time comprehension. They extend Grice's (1975) distinction between meaning and inference by demonstrating that the information provided by these distinct levels of interpretation becomes available at different moments during comprehension. In other words, *some* can be *all* and it cannot be *all* but just not at the same time.

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