Event-related potential investigation of scalar implicature processing using picture-sentence verification

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Scalar implicatures (SIs)

Some of has both logical and pragmatic readings:

1) "Some of the students are hard-working."
   a) Logical: "There exists some subset of students that are hardworking." (***some*="at least one"**)
   b) Pragmatic: "Not all of the students there are hardworking." (***some*="not all"**)

Computing the pragmatic reading (1b) requires processing the speaker's communicative intention—s/he chose not to say "all", thus must have meant "not all" (Katsos & Cummins, 2010; Noveck & Sperber, 2007) and the pragmatic meaning is defeasible (Rullman & You, 2006).

How quickly is ***some*="not all"** computed?

- *Default approach*: SI immediate and effortless, can later be cancelled (Levinson, 2000)
- *Context-driven approach*: SI effortful, not computed unless necessary, delayed until after context has been evaluated (Katsos & Cummins, 2010)
- *Constraint-driven approach*: Numerous local and global constraints interact rapidly to facilitate or inhibit SI; SI may be rapid or delayed depending on constraint interaction (Degen & Tanenhaus, 2011)

Previous studies

- Eye-tracking has provided conflicting evidence as to whether SIs are realized slowly (Huang & Snedeker, 2009; Panizza et al., 2009) or rapidly (Grodner et al., 2010; Degen & Tanenhaus, 2010).
- ERPs can provide information on both the time course and nature of SI processing, but have not yet been used to strongly test the time course issue.
  - ERPs have shown that the ***some*="not all"** reading rapidly influences processing of later content words (Hunt et al., 2011; Nieuwland et al., 2010). But no study has measured ERPs on the quantifier itself.

Current study

- Used picture-sentence verification (Wu & Tan, 2009) to evaluate ERP responses at the quantifier itself and examine how quickly the pragmatic interpretation became available
- Kept lexico-semantic content identical across conditions

Design and method

- **Conditions** (see figure for examples)

	No violation	Violation
Quantifier *some*	Correct *some*	Pragmatically inconsistent
Quantifier *all*	Correct *all*	Logically inconsistent

- Participants: 19 native Chinese speakers from the University of Kansas
- Stimuli: 40 per condition, 148 fillers (74 correct "some" and "all", 37 incorrect object, 37 incorrect verb)
- Procedure: Picture displayed for 4000 ms, sentence displayed word-by-word (425 ms + 80 ms per character over 3, 400 ms ISI)
  - Task: 10% of trials followed by judgment probe ("Is that correct?"), 10% by irrelevant comprehension question (e.g. "Are they wearing swimsuits?")
- EEG recording: EEG continuously recorded using Synamps2 amplifier (Compumedics Neuroscan, Inc.) and 32-channel Ag/AgCl electrode cap (Electro-Cap International, Inc.), data digitized at 1kHz with a 200Hz low-pass filter/0.1Hz high-pass filter
- Data processing: Re-referenced offline to average of both mastoids. Epoched from −1000 to +1000ms relative to appearance of quantifier. Manual removal of non-ocular artifacts, ocular artifact correction using ICA (EEGLAB), manual removal of remaining artifacts. -200ms baseline correction, filtering (30 Hz low-pass), and averaging.
- Statistical analysis: Mean voltage amplitudes over selected time windows. Greenhouse–Geisser repeated measures ANOVAs with factors Type (pragmatic, logical), Violation (violation, no violation), and scalp Region (9 levels)

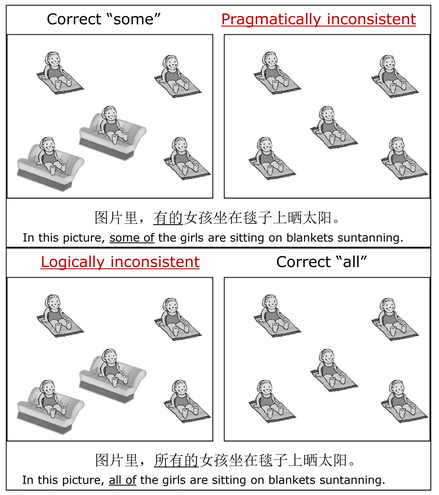


Fig 1) A sample stimulus set

Results

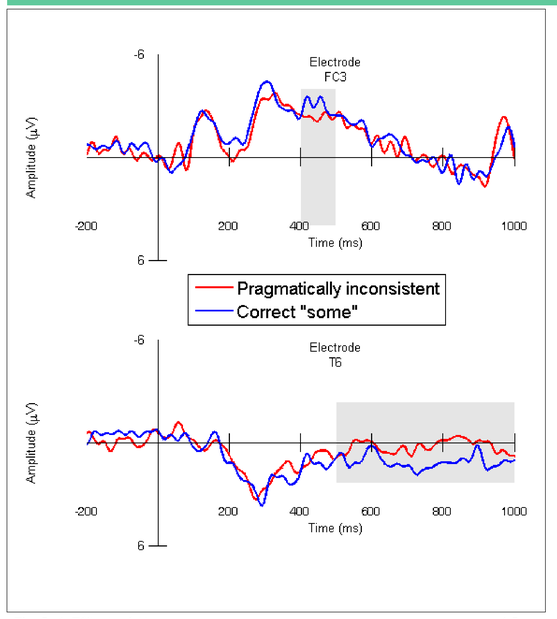
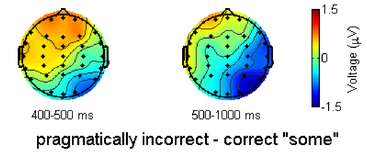


Fig 2a) Effect of the pragmatic violation at two representative electrodes (above) and in topographical plots at two time windows of interest (right)



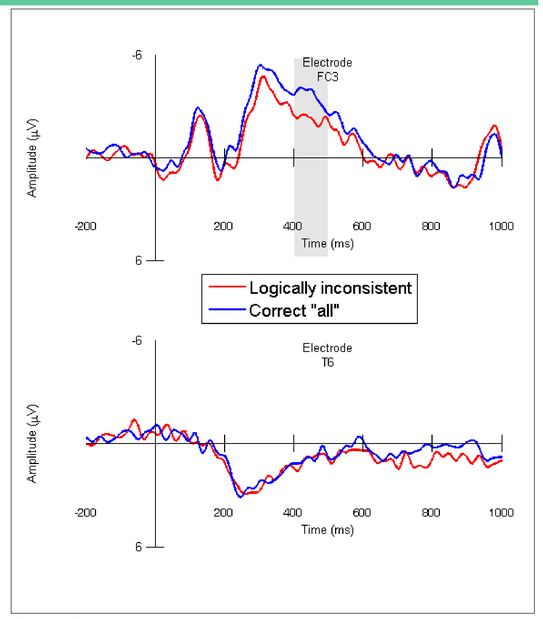
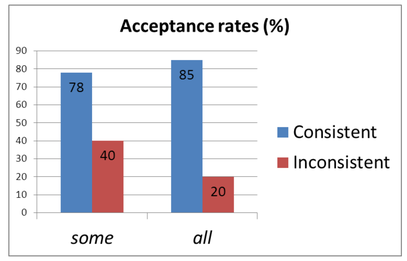


Fig 2b) Effect of the logic violation at two representative electrodes (above) and in topographical plots at two time windows of interest (right)

- No significant effects of **Violation** before 400 ms
- 400-500 ms: **Violation×Region** (lateral p=.021, midline p=.027)
  - Inconsistent quantifiers less negative than consistent (regardless of quantifier type). Effect limited to anterior and central sites.
- 500-1000 ms: **Type×Violation×Region** (lateral p=.047)
  - Pragmatically inconsistent quantifier more negative than control (p=.016), effect limited to right posterior and right central sites. No effect for logically inconsistent quantifier (p=.539)

Behavioral results

- Pragmatically inconsistent sentences were accepted more often than logically inconsistent (p<.001).
- 2 participants consistently rejected pragmatically inconsistent sentences (pragmatic responders), 5 consistently accepted (logical responders), and 11 were inconsistent.



Discussion

- Pragmatic and logical violations both recognized within 400 ms: no evidence for "logical stage" preceding SI or for delay in SI computation
- Early reduction of negativity may reflect reduced effort to link quantifier with referents (after participant realizes quantifier is inconsistent)
- Late negativity may reflect inhibition/reanalysis of the SI (c.f. Pijnacker et al., 2010; Jiang et al., 2011)
- SI can be computed immediately and automatically (present study; Grodner et al., 2010). When computed automatically, SI may then be inhibited, which is costly (present study; Feeney et al., 2004).
- However, SI speed in other paradigms has been modulated by global context and other cues (Degen & Tanenhaus, 2011).
- Bottom line: SI can be processed in a "default" manner in this context, consistent with default approach. Not consistent with predictions of strong context-driven account. Combination of results from this and other experiments may also be consistent with constraint-driven accounts (Degen & Tanenhaus, 2011; Noveck & Sperber, 2007).

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