Incremental Computation of Scalar Implicatures: An ERP Study

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Introduction

- Speakers often mean more than they say:

  "Some students passed the test."

  Speaker: *"some but not all"*
  Sentence: *"some and possibly all"*
- Cooperative speakers are expected to deliver strongest (most informative) utterance [1]
  - If a speaker uses a weak form (*some* or *many*), we infer that they were not in a position to use a stronger form (*all*)

    → classic Scalar Implicature (SI)
- Recent evidence on time course of processing SIs is mixed
  - Some results suggest that SIs are processed immediately at a scalar expression [2,3]
  - Others suggest that SIs are delayed relative to their literal meanings [4,5]
  - Previous ERP work has demonstrated that underinformative clauses ("*Some people have lungs*") elicit processing difficulty (N400 effect) compared to informative clauses ("*Some people have pets*"), though only for pragmatically skilled participants [6]

Research Goals

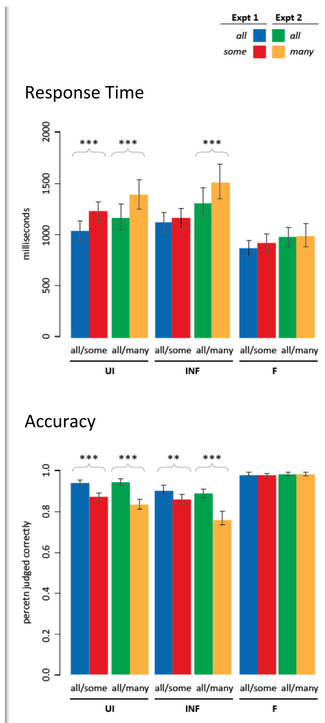
- Use a more interactive task than previous work
- Compare scalar vs. non-scalar quantification within levels of informativity
- Compare brain responses at the quantifier and the sentence-final word
- Compare individual differences in pragmatic skills, as assessed via the Autistic Spectrum Quotient Communications subscale (AQ-Comm)

Research Questions

- Is there evidence for inference generation immediately upon encountering scalar quantifiers?
- If so, do SIs modulate retrieval / integration of subsequent word meanings at the sentence-final Target Noun?

Results and Discussion

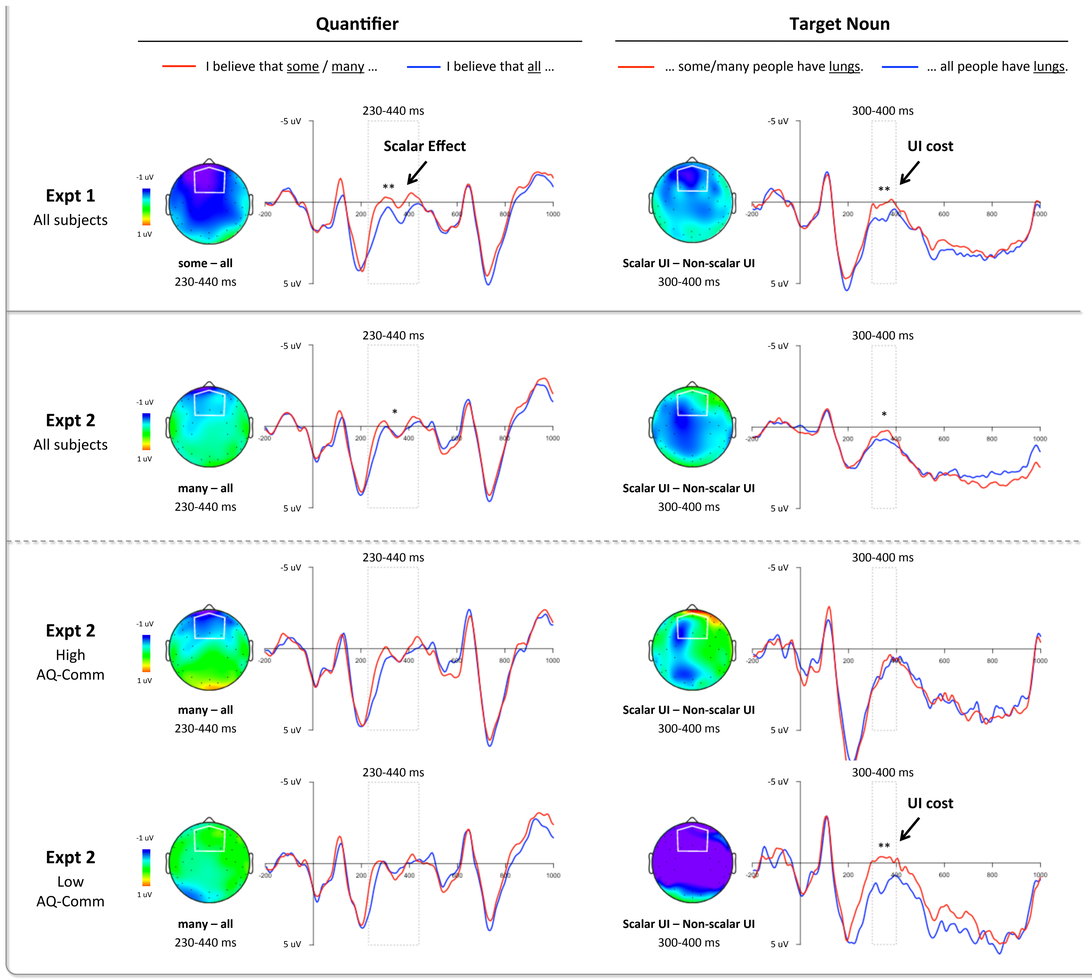
Behavioral Results



- Participants were slower and less accurate when making a SI, consistent with previous studies
- *Many* was slower and less accurate than *some*

→ Results suggest that it is harder to generate implicature for *many* than for *some*

ERP Results



Quantifier

- Expt 1: ERPs at scalar quantifier *some* diverged negatively from *all* in an early window (230-440 ms) post word onset, with a left frontal maximum
- Expt 2: *Many* elicited a similar but weaker early frontal negativity relative to *all,* demonstrating that the scalar effect is not idiosyncratic to *some*

→ This "scalar effect" may reflect anticipatory processes related to scalar quantifiers providing a functional signal that more complex conceptual integration is forthcoming

Target Noun

- Expt 1: At sentence-final target words, scalar-UI elicited a broad negativity relative to non-scalar-UI 300-400 ms post word onset, with a left frontal maximum
- Expt 2: Scalar-UI elicited a similar broad negativity, replicating Expt 1

→ The semantic consequences of generating the SI results in further computation upon encountering the critical word

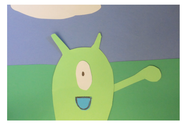
Individual Differences in Pragmatic Abilities

- Expt 1: AQ-Comm scores did not predict differences in ERP effects at either the Quantifier or Target Noun
- Expt 2: The scalar effect was driven by the High AQ-Comm group, while the UI cost was driven by the Low AQ-Comm group

→ If the SI is more difficult to compute for *many* than *some,* High AQ-Comm participants may be delayed in recognizing (or ignore) the under-informativity at the critical word

Methods

Participants and Task

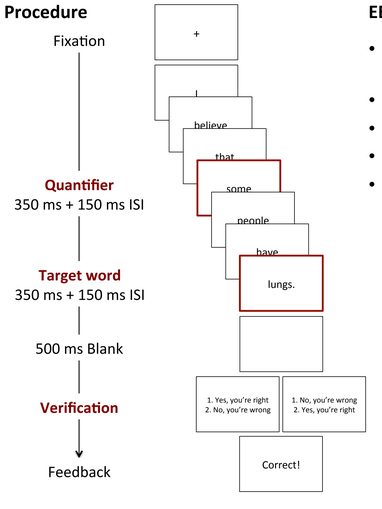


- Participants (N_1=48; N_2=48) read and responded to 216 statements (36 per condition) from a naïve speaker in a simulated dialogue
- Sentence verification: participants trained to respond pragmatically (i.e., *some* = *not all*) [5]

Example Stimuli

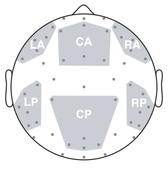
Condition	Stimulus	Veracity
Scalar UI	I believe that some/many people have lungs.	F
Non-scalar UI	I believe that all people have lungs.	T
Scalar INF	I believe that some/many people have pets.	T
Non-scalar INF	I believe that all people have pets.	F
Scalar F	I believe that some/many people have planets.	F
Non-scalar F	I believe that all people have planets.	F

Procedure



EEG Recording

- 64-channel HydroCel Geodesic Sensor Net (EGI)
- Bandpass: 0.1-40 Hz
- Downsample: 200 Hz
- Rereference: avg. mastoids
- Voltages averaged for analysis within six 6-channel groups



Pragmatic Abilities Assessment

To explore the role of pragmatic abilities, participants were divided into groups based on a median split of AQ-Comm scores

Expt 1

- High AQ-Comm (N=16) scores ranged from: 3-6 (M = 3.97)
- Low AQ-Comm (N=18) scores ranged from: 0-1 (M = 0.31)

Expt 2

- High AQ-Comm (N=17) scores ranged from: 4-7 (M = 4.91)
- Low AQ-Comm (N=21) scores ranged from: 0-2 (M = 0.52)

Conclusions

- These findings provide evidence for the immediate computation of scalar implicatures and extend previous results to the weaker scalar quantifier *many*
  - SIs appear to be generated incrementally, beginning as early as 230 ms after onset of the scalar term
  - The scalar inference appears to modulate the retrieval / integration of subsequent words, leading to a processing cost when the inference is underinformative
- Individuals with Low AQ-Comm scores showed larger UI cost effects
  - This extends prior findings that individuals with greater communication skills make immediate use of pragmatic information

References

1. Levinson (2000). *Presumptive meanings: The theory of generalized conversational implicature*. MIT Press, Cambridge, MA.
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3. Grodner, Klein, Carbary, & Tanenhaus (2010). "Some," and possibly all, scalar inferences are not delayed: Evidence for immediate pragmatic enrichment. *Cognition*.
4. Huang & Snedeker (2009). Online Interpretation of Scalar Quantifiers: Insight into the Semantic-Pragmatics Interface. *Cognitive Psychology*.
5. Bott & Noveck (2004). Some Utterances are Underinformative: The Onset and Time Course of Scalar Inferences, *JML*.
6. Nieuwland, Ditman & Kuperberg (2010). On the incrementality of pragmatic processing: An ERP investigation of informativeness and pragmatic abilities. *JML*.

Acknowledgments

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