Scalar implicature:
a whirlwind tour with stops in processing, development and disorder

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Outline

• Grounding assumptions
• A modest proposal
• The data behind the proposal
  1. Implicature typically takes time and effort
  2. Instant SI’s occur only when pre-encoding is plausible
  3. SI proficiency develops slowly
  4. In disordered populations SI patterns with language ability
21st century standard model

1. Comprehension builds a partially ordered series of representations
21\textsuperscript{st} century standard model

2. Cascaded processing (incrementality)
21st century standard model

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21st century standard model

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21st century standard model

2. Cascaded processing (incrementality)
21st century standard model

3. Processing is interactive: both directions
3. Interactivity: many inputs

semantics

∃x [ cat (x) ∧ on mat (x) ] ∧ ∀y [ cat (y) ∧ on mat (y) ] x=y

lexicon

/kæt/: noun, singular, animate
/sæt/: verb, past, intransitive
/mæt/: noun, singular, inanimate

phonology

əkætsətmæt

acoustic processing

prosody

syntactic interpretation
21st century standard model

4. No walls around language
21st Century Standard Model

1. Levels of representation
2. Incremental
3. Interactive
   - Corollary: under many circumstances processing will be predictive
4. In contact with perception and action
   - Corollary: introduces the possibility of top-down prediction of speech
• Does this mean that all natural inferences are made instantly, with no delay?
• Of course not, cognitive operations unfold over time
  – Can be done ahead of time
  – Can be stored
  – But they are not atemporal
How are scalar implicatures calculated?

Bottom-up

- Hear “some”
- Retrieve its meaning
- Activate stronger alternative (*all*)
- Construct enriched meaning
- Evaluate / link to context

Remember, this is incremental and interactive (we reject the “2-stage” label)
Auditory input: "some of"

Lexical Access: "some"

Semantic analysis: SOME (possibly all)

Pragmatic analysis: SOME-AND-NOT-ALL

Bottom-up analysis
How are scalar implicatures calculated?

Top-down

- Listener sees display (knows the situation)
- Encodes a “message level” representation of possible referents (GIRL + SUBSET OF X’S)
- Begins to link to lower levels of representation (semantic, maybe even lexical)
Pragmatic analysis

SOME-AND-NOT-ALL

Visual input
SUBSET

Top-down analysis
Top-down analysis

Visual input

SUBSET

Pragmatic analysis

SOME-AND-NOT-ALL

Semantic Analysis

SOME

Lexical access

“some”
Lexical access

"some"

Semantic Analysis

SOME

Pragmatic analysis

SOME-AND-NOT-ALL

Visual input

SUBSET

Top-down analysis

Auditory input

“some of”
Top-down analysis

Auditory input "some of"

Visual input
- SUBSET
- Pragmatic analysis
  - SOME-AND-NOT-ALL
  - Semantic Analysis
    - SOME
    - Lexical access "some"
Predictions

• Bottom-up
  – Scalar upper bound delayed relative to lexically encoded upper and lower bounds
  – Occurs when verbal encoding is difficult
    • Messages more unpredictable to comprehender
    • Multiple construals of given referent

• Top-down
  – Scalar upper bound guide reference resolution as rapidly as lexical bounds
  – Occurs when a verbal encoding is easy
    • Facts already known to listener (visual world)
    • Single salient construal of each referent in task
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SI’s typically require time and effort

1. **Sentence judgment studies**
   Bott & Noveck, 2004; Bott, Bailey & Grodner, 2012; Marty & Chemla, 2011

2. **Dual-task studies**
   DeNeys & Schaeken, 2007; Dieussaert, Verkerk, Gillard & Schaeken, 2011; Marty & Chemla, 2011; Marty & Chemla, 2011

3. **Reading studies**
   Breheny, Katsos & Williams, 2006; Bergen & Grodner, 2010; Hartshorne & Snedeker, still under review; Nieuwland, Dittman & Kuperberg, 2010
Judgment tasks: Bott, Bailey & Grodner (2012)

- Speeded verification of underinformative sentences (SAT task)
- Delay for calculating SI
- Not due to speed accuracy tradeoff: shift in starting point and slope
- Not merely verification: pragmatic “some” slower than “only some”
Dual-task paradigm

Dual-task paradigm

• Cognitive load reduces calculation of scalar implicatures (DeNeys & Schaeken, 2007; Dieussaert, Verkerk, Gillard & Schaeken, 2011; Marty & Chemla, 2011; Marty, Chemla & Spector, 2011)

Data from: DeNeys & Schaeken (2007)
Dual-task paradigm

• Cognitive load reduces calculation of scalar implicatures (DeNeys & Schaeken, 2007; Dieussaert, Verkerk, Gillard & Schaeken, 2011; Marty & Chemla, 2011; Marty & Chemla, 2011)

• Load does not reliably interfere with semantic upper bounds (“only some”) (Marty & Chemla, 2011)

• Opposite effect for numbers (Marty, Chemla & Spector, 2011)
Reading time experiments

Recipe (from Breheny et al., 2006, illustrated with Bergen & Groder, 2012)

• Contexts
  – Supportive: “Before the hurricane landed, I checked every house in town.”
  – Non-supportive: “Before the hurricane landed, I volunteered to help out in town.”

• Trigger
  – Scalar: “Some of the residents had evacuated”
  – Control: “Only some of the residents had evacuated”

• Anaphor (probes upper bound)
  – “The rest stayed home and foolishly risked their lives”
Reading time experiments

- Slow down at trigger for Scalar in **supportive contexts**

*But see Hartshorne & Snedeker for caveats*
Reading time experiments

• Slow down at trigger for Scalar in supportive contexts*

Interpretation:
• SI takes effort
• Effort begins immediately
• But only when context calls it up

* But see Hartshorne & Snedeker for caveats
Reading time experiments

- Slow down after anaphor for scalars in **unsupportive** contexts

Data from Bergen & Grodner
Reading time experiments

- Slow down after anaphor for scalars in **unsupportive** contexts

Interpretation:

- Upper bound calculated in supportive contexts and controls
- Not in unsupportive contexts

[Data from Bergen & Grodner]
Reading time experiments

- How fast is that upper bound calculated?
- Mean time from trigger to anaphor effect
  - Bergen & Grodner: ~2,400 ms
  - Breheny et al: ~2000 ms
  - Nieuwland et al: ~1700 ms
Reading time experiments

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• Hartshorne & Snedeker manipulate distance
  – No anaphor effect at 1500 ms
  – Robust anaphor effect at 3000 ms
  – Adding upper bound takes time
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Divergent Findings in Visual World Paradigm

Delayed Upper Bound for “Some”

Huang & Snedeker (2009)

Instant Upper Bound for “Some”

Grodner et al. (2010)
Methodological differences

– Pronunciation “summa” vs. some of
– Embedded in stories vs. not
– Length of experiment
– **Number trials** (Huang, Hahn & Snedeker; Degen & Tanenhaus)
Comparison of studies

Dual Encoding:
The girl with some of the soccer balls
The girl with two of the soccer balls.
SI delayed

Single Encoding:
The girl with some of the balls
Immediate SI
Lexical access

"some"

Semantic analysis

SOME (possibly all)

Pragmatic analysis

SOME-AND-NOT-ALL

Visual input

SUBSET

Pragmatic analysis

SOME-AND-NOT-ALL

Semantic Analysis

SOME

Lexical analysis

"some"

Bottom-up analysis

Top-down analysis

Dual encoding

Single encoding
Robust generalization across experiments

Red: slow SI, fast semantic; Green: both fast

Dual Encoding
• H&S, 2009
• H&S, 2011
• Panizza, Huang, Chierchia & Snedeker (2009)
• Huang, Hahn & Snedeker
• Degen & Tanenhaus
• Hartshorne et al

Single Encoding
• Grodner et al., 2010
• Breheny, Ferguson & Katsos, (2012)
• Breheny, Ferguson & Katsos (2013)
• Huang, Hahn & Snedeker
• Degen & Tanenhaus
• Hartshorne et al.
• Huang (*most, start, pc*)

Underlined studies manipulated encoding
Alternative proposal

• Including numbers makes “some” less natural
  – By what mechanism does naturalness influence processing?
  – Depending on answer this may be the same account....
  – In Degen & Tanenhaus (eyetracking) naturalness doesn’t predict speed of reference resolution
  – Naturalness ratings for sentences embedded in our story task do not support (some = two )

• Bayesian proposal
  – May describe what gets computed
  – But doesn’t provide a clear story of how
Bayes Theorem

Meanings $M = \{m_0, m_1, m_2, \ldots, m_N\}$

Utterances $U = \{u_{\text{some}}, u_{\text{all}}, u_{\text{none}}, u_{\text{number}}\}$

QUD $Q = \{\text{qud}_{\text{all?}}, \text{qud}_{\text{any?}}\}$

$$P_{\text{listener}}(M|U, Q) \propto P_{\text{speaker}}(U|M, Q)P(M)$$
Bayes Theorem

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$$P_{\text{listener}}(M|U, Q) \propto P_{\text{speaker}}(U|M, Q)P(M)$$

Awesome, how does the listener get that?

Option 1: ask 100 people on AMT?

Option 2: use stored knowledge (of Bill & Judy and the soccer balls?)

Option 3: run a production simulation (our proposal)
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The primary observation

Children often accept under informative scalar terms in judgment tasks
- Accept “might be” in context of MUST BE (Noveck, 2001)
- Accept “started” for FINISHED (Papafragou & Musolino, 2003)

Possibility 1: Children must acquire a single discrete skill (implicature)

Non-starter: there is too much variation
- Performance heavily task dependent (Papafragou & Tantalou, 2004; Pouscoulous, Noveck, Politzer, Bastide, 2007)
- Instructions matter (Papafragou & Musolino, 2003 i.a.)
- Variation across scalar terms
- Age range success ~3-10
Possibility 2: Children are simply tolerant (Katsos & Bishop, 2011)

- 5 year olds succeed with 3 point scale
Tolerance can’t explain it all

• Younger children fail at selection tasks
  – Huang, Spelke, & Snedeker 2013 (2;6-4;0)
  – “Can you give me the box where Cookie Monster has some of the cookies?”

See also Hurewitz et al., 2006
Tolerance can’t explain it all

• **Generic bias** *(Leslie & Gelman, 2012)*
  – Adults and children misremember universal statements as generics (all dogs → dogs)
  – 3 yr olds *also* misremember “some” statements as generics (some dogs → dogs)
  – Suggests they aren’t generating implicature

• **Processing failure** *(Huang & Snedeker, 2009, Dev Psych)*
  – Adults slower to interpret underinformative *some* than felicitous *some*
  – Children are not!
Possibility 3: processing account

- Computing SI without pre-encoding is effortful
  - See above
  - Children fail to pre-encode in contexts where adults do (Huang, data)

- Children have difficulty retrieving scales (Barner, Brooks & Bale, 2012)

- Children have difficulty using top-down cues (Snedeker, 2013)
  - SI may involve generating higher-level information to enrich interpretation
  - Such loops unfold over time (see Dell, 1986)
  - Slower processing = fewer time steps….

- As they become faster more efficient processors, they may be able to calculate SI’s more often
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Communicative deficits in autism

- Pragmatics Impaired
- Syntax Impaired
- Vocabulary Impaired
Autism with, and without, language impairment

Kjelgaard & Tager-Flusberg (2001)
Autism and scalar implicature

• Adults and teens with autism make SI’s as often as language-matched controls (Pijnaker et al., 2008; Chevallier et al., 2010).

• Early deficit could disappear by 13
  – Deficits in Theory of Mind task only present until verbal mental age of 6-7 (Happe, 1995)
  – SI improves from 4 to 10 years

• Do persons with autism use the same process?
Our study
(Hahn, Huang & Snedeker, in prep)

• Goals
  – Assess likelihood of calculating scalar implicature at an age where it is rapidly changing (box task)
  – Determine whether mechanisms of comprehension are similar (visual world task)

• 6-9 year olds children
  – 40 with High Functioning Autism
  – 40 Typically Developing
  – Matched on: age, gender, CELF syntax scores
Same online processing profile

Typically Developing

Highly Verbal ASD

Hahn, Huang & Snedeker, in prep
During the period where SI is developing, children with ASD perform as well as controls.

![Graph showing proportion of correct choices for adults and toddlers with ASD and controls, indicating higher performance in adults (92%) compared to toddlers (48%).]
SI is linked to emerging language skills

Katsos, Roqueta, Clemente & Cummins (2011)
The only evidence that SI is linked to ASD....

- Nieuwland, Dittman & Kuperberg (2010)
  - “Some people have lungs/pets”
  - N400 at pets
  - Correlates with AQ communication scale (not social scale)

- My suspicion:
  - In college students, communication scale may capture differences in language skills
In sum

1. Implicature takes some work (bottom up)
2. But the work can be done ahead of time
   • When the conceptual encoding for each message is unambiguous
   • Listener as speaker
3. Thus SI proficiency develops gradually as children become more effective processors
4. Thus SI breaks down with language skills
   • Consistent with a distinction btw grammatical/social inferences or explicatures/implicatures?
Thank you!

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