A CONSTRAINT-BASED APPROACH TO THE MEANING AND USE OF QUANTIFIED EXPRESSIONS

Chris Cummins¹, Uli Sauerland², Stephanie Solt²

¹ Research Centre for English and Applied Linguistics, Cambridge
² Zentrum für Allgemeine Sprachwissenschaft, Berlin

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Motivation

- Between 91 and 93
- Between 90 and 100
  - Between 90 and 91
  - More than 91
- More than 90
- More than 80
- More than 50
- …

- Fewer than 93
- Fewer than 94
- Fewer than 100
- Fewer than 1000
  - More than 80
  - More than 50
  - …

- 92
- About 90
- About 100
Constraint-based model

- Idea: quantified expression as output of multiple constraint satisfaction problem
- Potential constraints:
  - Informativeness
  - Granularity/numeral salience
  - Quantifier simplicity
  - Contextual activation of numeral/quantifier

Interpretation in constraints model

- Hearer uses speaker’s output to draw inferences about the situation
  - Hearer knows that speaker chose to use utterance $U_1$ instead of utterance $U_2, U_3, \text{etc.}$
  - Therefore speaker considers $U_1$ more appropriate for situation than any given alternative
- Example:
  - If some utterance $U_n$ is more informative than $U_1$, and just as good in every other way, then hearer can infer than speaker does not think $U_n$ is valid (classic SI)
Granularity

*The distance between Amsterdam and Vienna is one thousand kilometers*

*The distance between Amsterdam and Vienna is nine hundred sixty-five kilometers*

- Krifka (2009): Granularity modelled via scales that differ in density of scale points:

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SIs with modified numerals

- Has been observed that modified numerals do not give rise to scalar implicatures
  
  *John has 3 children*
  
  → ‘not more than 3’
  
  *John has more than 3 children*
  
  → ‘not more than 4’, i.e. exactly 4

- **Prediction of Constraints Model**: Expressions with modified numerals (e.g. “more than n”) should give rise to SIs at the appropriate granularity level
Experiment 1
Stimuli

A newspaper reported the following:

**More than 100** people attended the public meeting about the new highway construction project

Based on reading this, how many people do you think attended the meeting?
A) Between _____ and _____ people attended.
B) _____ people attended.

<table>
<thead>
<tr>
<th>More than n</th>
<th>At least n</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>149, 110</td>
</tr>
<tr>
<td>110</td>
<td>127.5, 112</td>
</tr>
<tr>
<td>93</td>
<td>100, 94</td>
</tr>
</tbody>
</table>

- Online survey via Amazon MTurk
- n= 100/condition

Experiment 1
Results

Median Estimates

<table>
<thead>
<tr>
<th>n =</th>
<th>More than n</th>
<th>At least n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper bound</td>
<td>Most Likely</td>
</tr>
<tr>
<td>100</td>
<td>149</td>
<td>110</td>
</tr>
<tr>
<td>110</td>
<td>127.5</td>
<td>112</td>
</tr>
<tr>
<td>93</td>
<td>100</td>
<td>94</td>
</tr>
</tbody>
</table>
Experiment 1

Results

Median Upper Bound – Relative to $n$

Subject Comments

- ‘More than 100’ condition:
  I feel that if there was more than 150, the newspaper would say more than 150.
  I chose the above number because I felt had the numbers been higher the paper would have said more than 200.
  I think 125 would be the next increment worthy of mentioning.

- ‘More than 110’ condition:
  I chose 135 because I felt that a number higher than that would have been described as, "Close to 150 people attended...".
  If it had been >120 it would have described them as such
  If it was more than 115 the writer would have probably said "Almost 120 people attended the meeting"
Prediction from constraints model

- Expressions with modified numerals (e.g. “more than \( n \)) should give rise to SPLs at the appropriate granularity level
  
  ✔️

- Though assumed granularity level not consistent

However...

- Non-round numbers (e.g. 93) occur only on scale of granularity 1
  (\[91 \ldots 92 \ldots 93 \ldots 94 \ldots 95\ldots\])
  
  - Strongest claim: ‘more than 93’ should implicate ‘not more than 94’, i.e. ‘exactly 94’
  
  - Instead, respondents typically give range of 94-100

- Why?
Non-round numbers

- When is it felicitous to use ‘more than n’ when \( n \) is not round?
  - Odd in out-of-the-blue context
  - But:
    
    U.S. coach Bob Bradley will call in more than 23 players when the Americans start their final training camp ahead of the World Cup.
  - Non-round numerals frequently occur in modified form when the numeral is salient in the context

Prediction from constraints model - 2

- Prior activation of the numeral will weaken granularity-based scalar inference
  - Gives speaker a potential additional reason to (re-) use numeral
  - Hearer is aware of this, and moderates strength of inference from this numeral accordingly
Experiment 2
Stimuli

**Primed:**
- A: We need to sell 60 tickets to cover our costs. How are the ticket sales going?
- B: So far we’ve sold fewer than 60 tickets

**Unprimed:**
- A: We need to sell tickets to cover our costs. How are the ticket sales going?
- B: So far we’ve sold fewer than 60 tickets

How many tickets have been sold?
From _____ to _____, most likely _____.

- Paper and pencil questionnaire

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Experiment 2
Stimuli

- 3 levels of granularity
  - Multiple of 100
  - Multiple of 10
  - non-round

- 3 numerical expressions:
  - more than $n$
  - fewer than $n$
  - about $n$
Experiment 2
Results

Median Upper/Lower Bound – Relative to $n$

Experiment 2
Results

Most Likely Value (vs. $n$)

- ANOVA shows significant effects for both granularity and priming ($p < .001$)
Experiment 3

**Primed:**
Salesperson: This shelf unit is designed to hold 60 CDs. How many CDs do you own?
Customer: I have more than 60 CDs

**Unprimed:**
Salesperson: This shelf unit is designed to hold CDs. How many CDs do you own?
Customer: I have more than 60 CDs

How many CDs do you think the customer owns?
Between ____ and ____; most likely number _____

- 1-question MTurk survey

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Experiment 3
Results

**Upper Bound**

<table>
<thead>
<tr>
<th>Upper bound given</th>
<th>% of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>90</td>
<td>15</td>
</tr>
<tr>
<td>110</td>
<td>20</td>
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<tr>
<td>130</td>
<td>25</td>
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<tr>
<td>150</td>
<td>30</td>
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<tr>
<td>170</td>
<td>35</td>
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<tr>
<td>190</td>
<td>40</td>
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<tr>
<td>210</td>
<td>45</td>
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<td>230</td>
<td>50</td>
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<td>250</td>
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<td>270</td>
<td>60</td>
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<td>310</td>
<td>70</td>
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<tr>
<td>330</td>
<td>75</td>
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<tr>
<td>350</td>
<td>80</td>
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<tr>
<td>370</td>
<td>85</td>
</tr>
<tr>
<td>390</td>
<td>90</td>
</tr>
<tr>
<td>410</td>
<td>95</td>
</tr>
<tr>
<td>430</td>
<td>100</td>
</tr>
</tbody>
</table>

**Median Responses**
- Upper bound:
  - Unprimed: 81
  - Primed: 100

**Best estimate**
- Unprimed: 70
- Primed: 80
Prediction from constraints model - 2

- Prior activation of the numeral will weaken granularity-based scalar inference

Implications for theory – Exp 1

- SI predicted by standard Gricean means
  - Now no need to stipulate absence of SI with these structures
- From RT point of view, also reasonable
  - Use of “more than n” indicates that “more than m” is not valid, if m > n, assuming m could be used without additional cognitive costs
  - In either case, need to incorporate notion of granularity/numeral salience into model
Implications for theory – Exp 2/3

- Still in the spirit of the Gricean approach
  - Inferences arise from what we choose not to say; no choice, no inference!
- Also agrees with a Relevance-based account
  - Previously-mentioned numerals advantaged in Relevance
  - Therefore more likely to be selected in broader range of contexts
  - Hence less ‘cue validity’ for SIs

Is this actually RT?

- Selecting optimal output by constraint-based model similar to RT approach
- Could be viewed as a proposal unpacking the notion of Relevance in quantifier case
  - Elaborates Relevance by
    - Identifying its contributory factors
    - Quantifying their contribution
    - Evaluating which option achieves greatest Relevance
Role of constraint-based model

- Model does not appear *so far* to challenge
  - Relevance-theoretic accounts
  - traditional Gricean intuitions
- However, does present a useful means of generating non-obvious predictions
  - So far, restricted to the domain of quantification
  - Possible extension?
    - Issues: constraint set, assessing extent of violations

Summary

- SIs available with “more/fewer than n”
  - contrary to previous literature
  - restricted to appropriate granularity
- Inferences tempered by contextual activation
- Novel predictions from constraint-based account empirically validated
  - Not necessarily evidence for this account versus alternative accounts of pragmatic inference
  - However, do indicate that granularity and context effects *must be incorporated in models*
Thank you!