Effects of processing depth on pronoun interpretation: Use of inferencing and gender cues

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Language processing—including pronoun interpretation—is argued to be susceptible to shallow processing (Ferreira et al., 2000; Sanford & Sturt, 2002; Steward et al., 2007, and others). Although pronouns can be interpreted rapidly (e.g. Arnold et al., 2000), other findings suggest that demands of the task at hand determine whether comprehenders fully resolve pronouns. On the basis of whole-sentence reading-times, Steward et al. (2007) concluded that presence of deep questions (probed pronoun’s antecedent) vs. shallow ones (pronoun antecedent irrelevant) influenced whether readers resolved pronouns. In the deep condition—but not the shallow—gender-ambiguous pronouns (Paul…Rick…he) resulted in a slowdown relative to gender-unambiguous pronouns (Paul…Kate...(s)he). This suggests gender cues are used during deep processing.

With two different-gender referents, gender-marked pronouns offer an unambiguous cue to the antecedent. We investigated (i) how processing of gender cues compares to more complex, probabilistic cues to the antecedent, namely verb-based inferencing, and (ii) how comprehenders’ use of verb-based inferencing is modulated by processing depth. In “Elaine protected Jen. Stephen awarded her…” (ex.1), we can infer that ‘her’ refers to Elaine; the one who protects is awarded something (cf. Kehler et al., 2008). We investigated how rapidly people make probabilistic cross-clausal inferences, and compared them to gender cues.

These issues relate to fundamental questions about the architecture of the reference-resolution system, including the real-time availability/influentiality of information encoded on different levels (morphological gender-marking vs. cross-sentential inferences) and with different levels of determinacy (categorical vs. probabilistic).

In a self-paced reading study, participants read two-sentence mini-stories (ex.1). We manipulated processing depth, pronoun ambiguity and verb informativity:

- Processing depth was manipulated between-subjects (24 participants/group) with Shallow vs. Deep questions after each mini-story (defined as shown in ex.2 below).
- The critical pronoun was gender-ambiguous (1b,d) or clearly subject-referring (1a,c).
- The verb in Sentence1 was a nonword (1c,d), or a real verb (1a,b) that could be used to infer the antecedent.

(1) Sample item [Coherence relation in all targets is ‘result’ (normed, partially adapted from Wolf et al. 2006). Verb-based inferencing pushes pronoun towards preceding subject]

(a) [Realverb|Unamb]: Elaine protected Joel. Stephen awarded her a special prize for bravery and everyone cheered happily.
   - Unambiguous pronoun (=> Elaine/subject)
   - Real verb in first sentence (biases pronoun towards Elaine/subject)

(b) [Realverb|Amb]: Elaine protected Jen. Stephen awarded her a special prize for bravery and everyone cheered happily.
   - Ambiguous pronoun (Elaine or Jen?)
   - Real verb in first sentence (biases pronoun towards Elaine/subject)
(c) [Nonverb|Unamb]: Elaine brondled Joel. Stephen awarded her a special prize for bravery and everyone cheered happily.
  - Unambiguous pronoun (Elaine/subject)
  - Nonsense verb in first sentence

(d) [Nonverb|Unamb]: Elaine brondled Jen. Stephen awarded her a special prize for bravery and everyone cheered happily.
  - Ambiguous pronoun (Elaine or Jen?)
  - Nonsense verb in first sentence

(2) Sample comprehension question
(2a) Shallow Question: Was the prize for bravery?    [yes/no question, simple recall]
(2a) Deep Question: Who did Stephen award a prize to?  [wh-question, interpret pronoun]

Predictions for Shallow processing: We expect no sensitivity to pronoun/verb manipulations. Deep processing: We expect (i) slowdowns with ambiguous pronouns, and, if verb-driven inferences are generated, (ii) alleviation of these slowdowns in conditions where the verb can be used to infer the antecedent.

Results: In general, question-type influenced processing-depth. Deep readers’ RTs were longer at the Pronoun and Spill1 (ex.(3) shows regions) than Shallow readers’ (p’s<.05). Overall, Shallow readers had fast RTs and no clear effects of pronoun/verb manipulations. However, Deep readers showed finer-grained patterns: In Spill2 and Spill3, Deep readers showed significant slowdowns in [Nonverb|Ambig] relative to [Nonverb|Unambig] and [Realverb|Unambig]. [Nonverb|Ambig] was also slower than [Realverb|Ambig] at Spill3 (p’s~.06, n.s. at Spill2): The condition lacking both verb- and gender-cues was slower than unambiguous-pronoun conditions, and marginally slower than the condition requiring verb-based inferencing. This suggests Deep readers use both gender-cues and verb-based inferences, with verb-based inferencing being slightly weaker/delayed. (These analyses focus on the second half of the study, where question-driven processing effects are clearest.)

(3) Analysis regions during the second sentence

<table>
<thead>
<tr>
<th>subject</th>
<th>verb</th>
<th>pro</th>
<th>Spill1</th>
<th>Spill2</th>
<th>Spill3</th>
<th>Spill4</th>
<th>Spill5</th>
<th>Spill6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stephen</td>
<td>awarded</td>
<td>her</td>
<td>a</td>
<td>prize</td>
<td>for</td>
<td>bravery</td>
<td>and</td>
<td>everyone..</td>
</tr>
</tbody>
</table>

Conclusions: Our results support claims that, under shallow processing, pronoun interpretation is not automatic—even with gender-unambiguous pronouns. Under deep processing, comprehenders used both gender-marking and probabilistic higher-level inferences online—though gender-marking effects seem more robust, possibly due to their local, non-probabilistic nature and lack of higher-level inferencing. Our findings suggest processing-depth modulations are far-reaching, impacting both simple, categorical cues and probabilistic, non-local cues.

References:
Ferreira, Bailey, Ferraro (2002). Good-enough representations…. Current Directions in Psych Science
Sanford, & Sturt (2002). Depth of processing in language comprehension. TICS 6, 382-386