

Pupil dilation as an index of processing load during pronoun resolution

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Pupillometry has long been used in psychology as a measure of processing cost.¹ The current work explores this measure as a tool for psycholinguistic research. Prior studies on spoken language comprehension have examined pupillary responses to grammatical violations or semantic anomalies,^{2,3} so it is unclear whether pupillometry is sensitive to increased cognitive load during typical comprehension. Pronoun resolution provides an interesting test case for examining pupillary responses, as conflicts can occur at the referential level without necessitating re-analysis at the syntactic or semantic levels.

Two experiments compared cases of ambiguous and unambiguous pronouns that were resolved to either the preferred (first-mentioned) or dispreferred discourse referent. In experiment 1, participants watched videos of a speaker describing vignettes (1, 2). In the unambiguous condition the names indicated different genders. Pronoun resolution was disambiguated by the possessive noun, which could not be the referent of the pronoun. Following disambiguation, sentences continued with a final verb phrase, without explicit re-mention of the subject. Figure 1 shows the change in pupil diameter from baseline while listening to the sentences, with time windows offset by 200ms to allow for lexical access.² There was a marginal early effect of ambiguity, significant by subjects only, in which pupil dilation was greater for unambiguous items. This may be driven by the fact that when the pronoun is unambiguous, there is early information about dispreferred resolutions. In the time window from the final verb until sentence-offset, there was a significant interaction of pronoun ambiguity and resolution, driven by the increased pupil diameter in sentences with an ambiguous pronoun that resolve to the second-mentioned character.

Experiment 2 used psych-verbs followed by a pronoun in a “because” clause (3,4). Verbs were chosen such that the initial preference would be to resolve the pronoun to the subject.⁴ Each item continued with a second sentence that started with the pronoun and reinforced the same resolution. Figure 2 shows pupil dilation over two time windows, offset by 200ms. There was no effect of ambiguity or subject vs. object resolution on pupil dilation in the time window from the onset of “because” until the beginning of the second sentence. Following the second occurrence of the pronoun, in the time window until sentence-offset, there was greater pupil dilation in the ambiguous pronoun condition ($p < .05$).

In both experiments, a reliable effect of pronoun ambiguity on pupil dilation occurred following a point in the sentence where the referent had to be reactivated; consistent with an account where initial pronoun processing is shallow.⁵ These data suggest the pupillary response is sensitive to difficulties encountered in day-to-day language comprehension. We discuss time-course analyses, along with the potential utility of pupillometry as a measure of processing cost in young children’s sentence processing.

Example Sentences

1. First-mention resolution: Diego/Dora built a snowman with Arthur last December. He/She made arms using sticks from Arthur's backyard and used a carrot for the nose.
2. Second-mention resolution: Diego built a snowman with Arthur/Dora last December. He/She made arms using sticks from Diego's backyard and used a carrot for the nose.
3. Subject Resolution: Mary scares Sally/John because she is so violent. She even hits her best friends.
4. Object Resolution: Mary/John scares Sally because she is afraid of everything. She's even afraid of her own shadow.

Figures

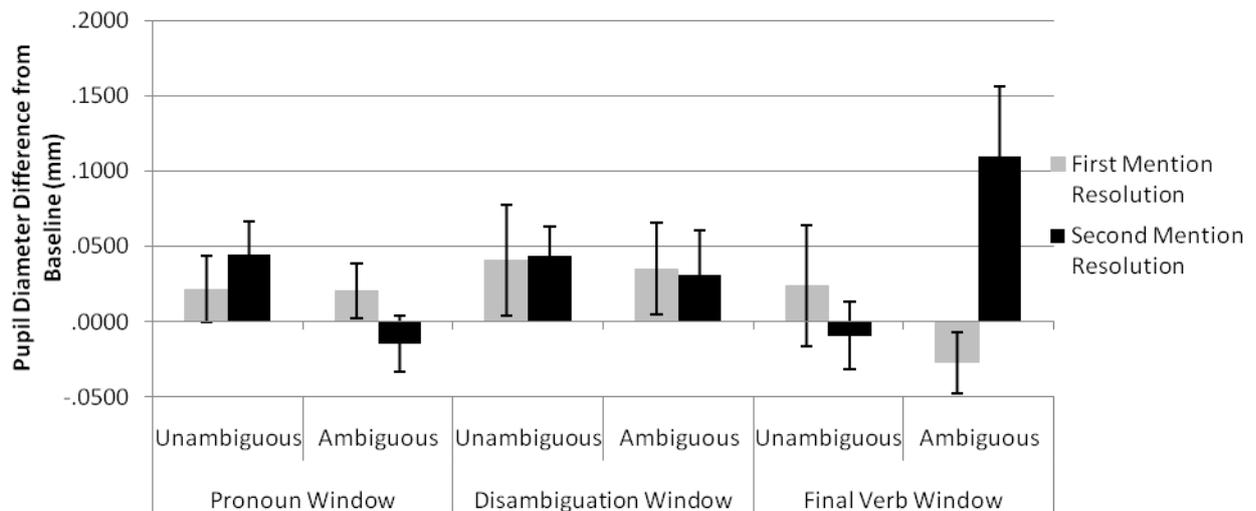


Figure 1. Average pupil diameter change from baseline (500ms prior to Pronoun Window onset) in Experiment 1. In the Final Verb Window, there was a significant interaction between ambiguity and first vs. second mention resolution $F_1(1,10)=8.925, p<.05, F_2(1,12)=11.537, p<.01$. There was also a marginally significant effect of ambiguity in the Pronoun Window, $F_1(1,11)=10.106, p<.01, F_2(1,11)=1.726, p=.22$.

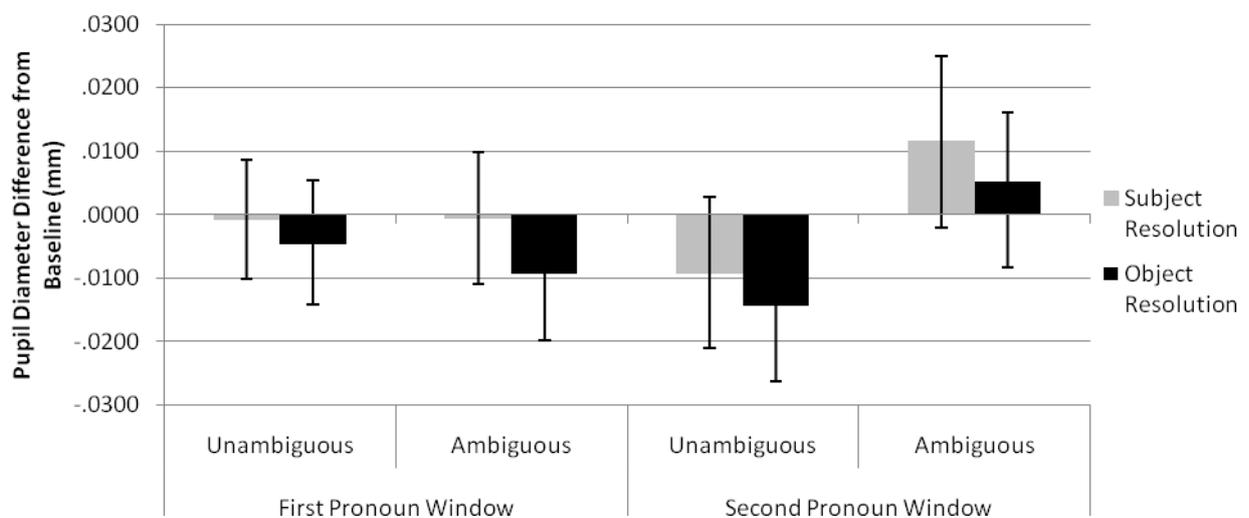


Figure 2. Average pupil diameter change from baseline (500ms prior to First Pronoun Window onset) in Experiment 2. In the Second Pronoun Window, pupil dilation was significantly larger for ambiguous compared to unambiguous pronouns, $F_1(1,23)=6.418, p<.05, F_2(1,31)=7.927, p<.01$.

References

- ¹ For example, Beatty & Wagoner (1978). *Science*, 199.
- ² Engelhart, Ferreira & Patsenko (2009). *Quarterly Journal of Experimental Psychology*, 63.
- ³ Gutierrez et al. (2011). *CUNY 2011: Conference on Human Sentence Processing*.
- ⁴ Hartshorne & Snedeker (*under review*).
- ⁵ Stewart, Holler & Kidd (2007). *Quarterly Journal of Experimental Psychology*, 60.