

# PUPILLOMETRIC EFFECTS OF VISUAL AND PROSODIC INFORMATION ON PARSING

Paul E. Engelhardt, Alena G. Patsenka, Andrea P. Francis, & Fernanda Ferreira

Department of Psychology and Cognitive Science Program, Michigan State University

## INTRODUCTION & BACKGROUND

- The purpose of the current experiments was to investigate the effects of prosody and visual context on the processing of temporarily ambiguous sentences.
  - Prosody is the stress, timing, and intonation of an utterance, and is related to syntactic structure (Selkirk, 1984). Several studies have shown that prosody affects both the online processing and the final interpretation of ambiguous sentences (Price et al., 1991).
  - Visual context has also been argued to influence the processing of ambiguous utterances (Tanenhaus et al., 1995; cf. Engelhardt et al., 2006). The general finding is that subjects may be able to avoid the garden-path, if given an appropriate visual context.
  - The current experiments investigated the effects of these information sources on the processing of ambiguous sentences like (1).
1. While the woman cleaned the dog that was small and cute stood in the yard.
  2. Did the woman clean the dog? (Subordinate clause - "No" question)
  3. Did the dog stand in the yard? (Matrix clause - "Yes" question)

- Christianson et al. (2001) found that readers answered "yes" 75% of the time to a question like (2). They argued that incorrect thematic assignments persist in final interpretations. Further studies indicate that readers only partially reanalyze these structures, meaning that they simultaneously believe that the woman cleaned the dog and that the dog stood in the yard (Patson et al., this conference).

## MODELS OF SENTENCE PROCESSING

- Restricted processing models assume that initial parsing is based on a limited amount of information. Speer et al. (1996) argued that prosodic structure determines the initial syntactic constituency the parser creates (see also Frazier, 1987). In contrast, Marcus & Hindle (1990) proposed that prosody affects parsing only after an initial syntactically based parse.
- Unrestricted processing models assume that any type of relevant information can influence initial parsing. Therefore, visual context which either supports or refutes a garden-path interpretation should affect initial syntactic decisions (Spivey & Tanenhaus, 1998).
- The primary research question addressed in this work was: What is the time course of integration for prosodic and visual information?

## EXPERIMENT 1

- Design was 2 x 3 (Question type x Prosody type).
- Question type queried either the subordinate (2) or matrix clause (3).
- Prosody was either Neutral or Cooperative. Neutral prosody sentences were uttered as a single intonational phrase. Cooperative prosody was created in a separate utterance by lengthening the intransitive verb (~150 ms), and decreasing the pitch (f0). Two levels of Cooperative prosody were created by varying the length of the pause following the subordinate verb (200 ms or 400 ms).

- If prosody influences comprehension, as expected, then we expect more misinterpretations for subordinate questions (2) with Neutral prosody compared with Cooperative prosody. Prosody should not influence matrix question (3) accuracy.

## Methods

- N = 18 (5 items per condition)

## Results

- Both main effects were significant (Question type  $F(1,17) = 12.63, p < .01$  & Prosody type  $F(2,34) = 13.29, p < .01$ ), and so was the interaction  $F(2,34) = 9.4, p < .01$  (see Figure 1).
- Simple effects showed that the Neutral prosody/subordinate clause condition was significantly worse than the Neutral prosody/matrix clause question, and it was also worse than the Cooperative (200) prosody/subordinate clause question.
- Summary: Neutral prosody leads to misinterpretations with subordinate clause questions. Prosody did not affect matrix question accuracy.

Figure 1.

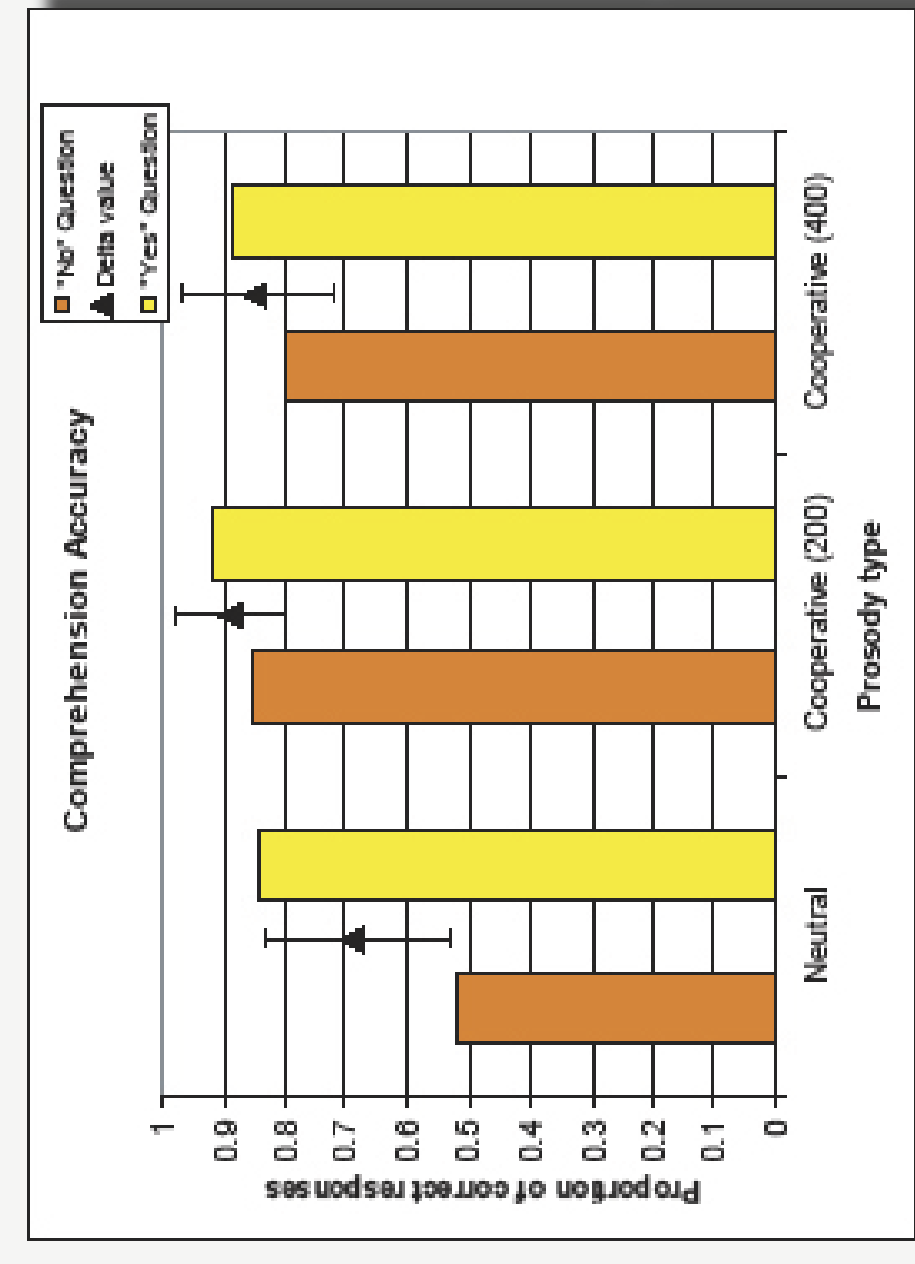


Figure 2.



Figure 3.



## EXPERIMENT 2

- Design: 2 x 3 (Visual context x Prosody type).
- Visual contexts consisted of single pictures. For example (1), Inconsistent visual context depicted a woman cleaning a dog (see Figure 2). Consistent visual context depicted a woman cleaning a non-dog (see Figure 3).
- The dependent measures were comprehension accuracy and pupil diameter. Pupil diameter is sensitive to processing intensity during sentence comprehension. Just & Carpenter (1993) investigated processing of subject and object relative sentences. Pupil diameter showed a reliable increase during a 1.2 sec time window following the location in the sentence where processing demands increased.
- If visual information influences initial parsing, then there should be an interaction between visual context and prosody type. However, if initial parsing is based only on bottom-up information, then we should find only a main effect of prosody.

## Methods

- N = 18 (5 items per condition)
- Pupil diameter was monitored with an EyeLink II at 500 Hz.
- Pupil data were analyzed in a 1200 ms window beginning 200 ms past the onset of the disambiguating word. Blinks were filtered and missing data was replaced using linear interpolation (see Figure 4). Only correct trials were analyzed, and a simple regression using time as an IV and pupil diameter as a DV was used to determine pupil diameter slope (see Figure 5a).

Figures 4a & 4b.

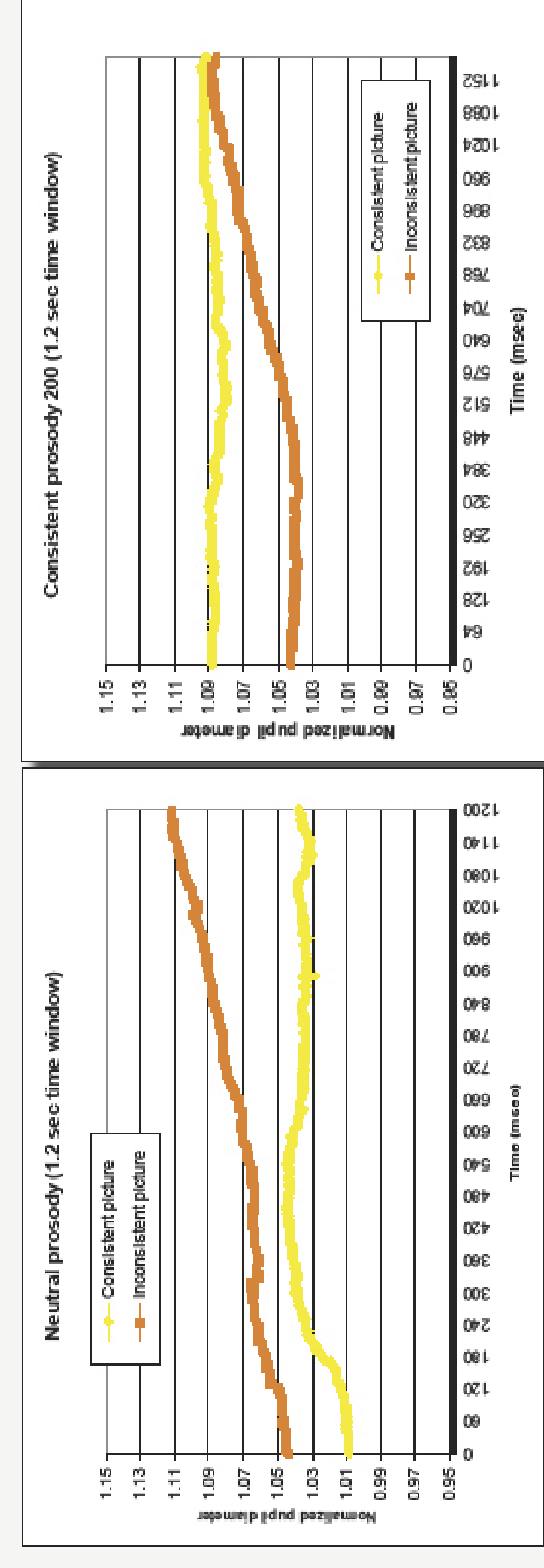
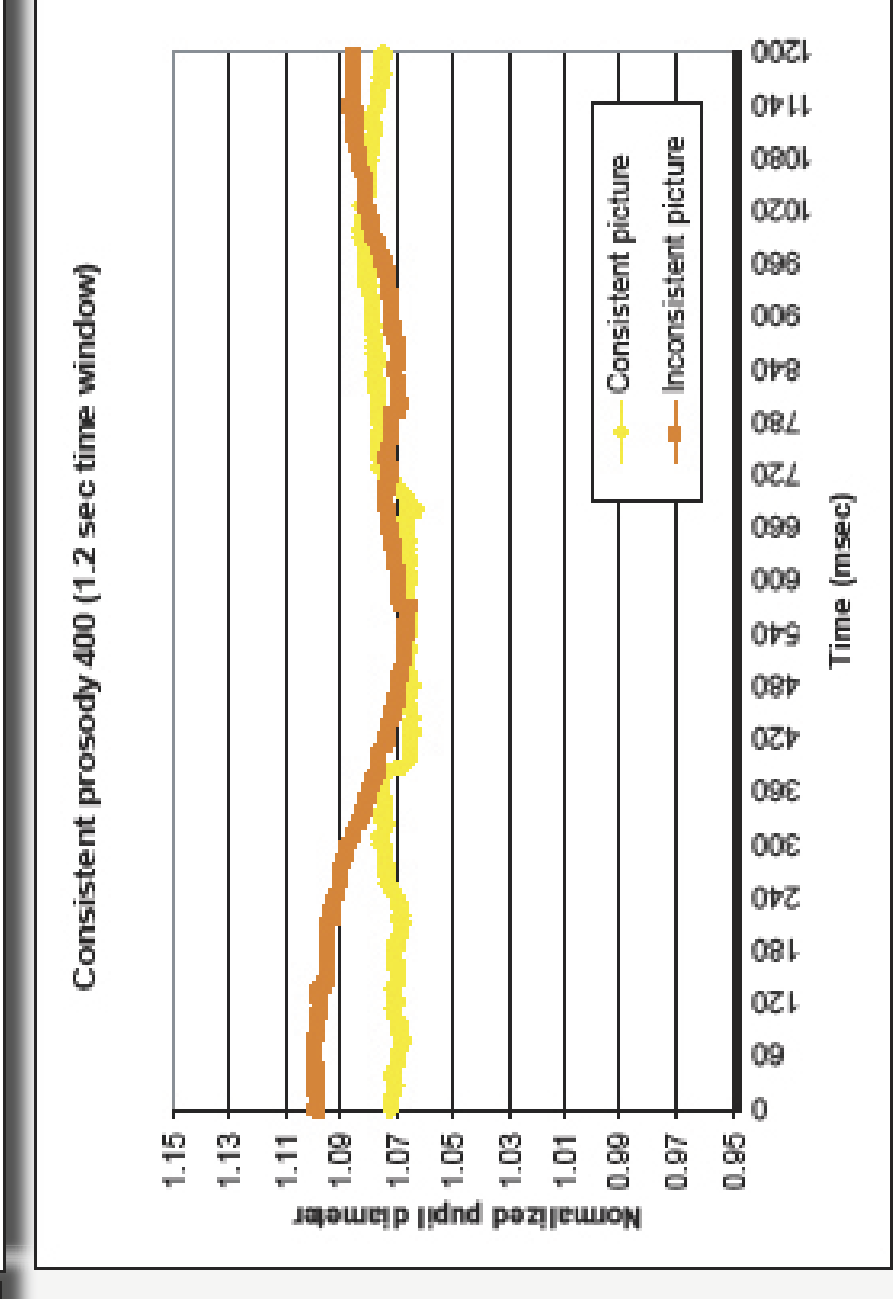


Figure 4c.

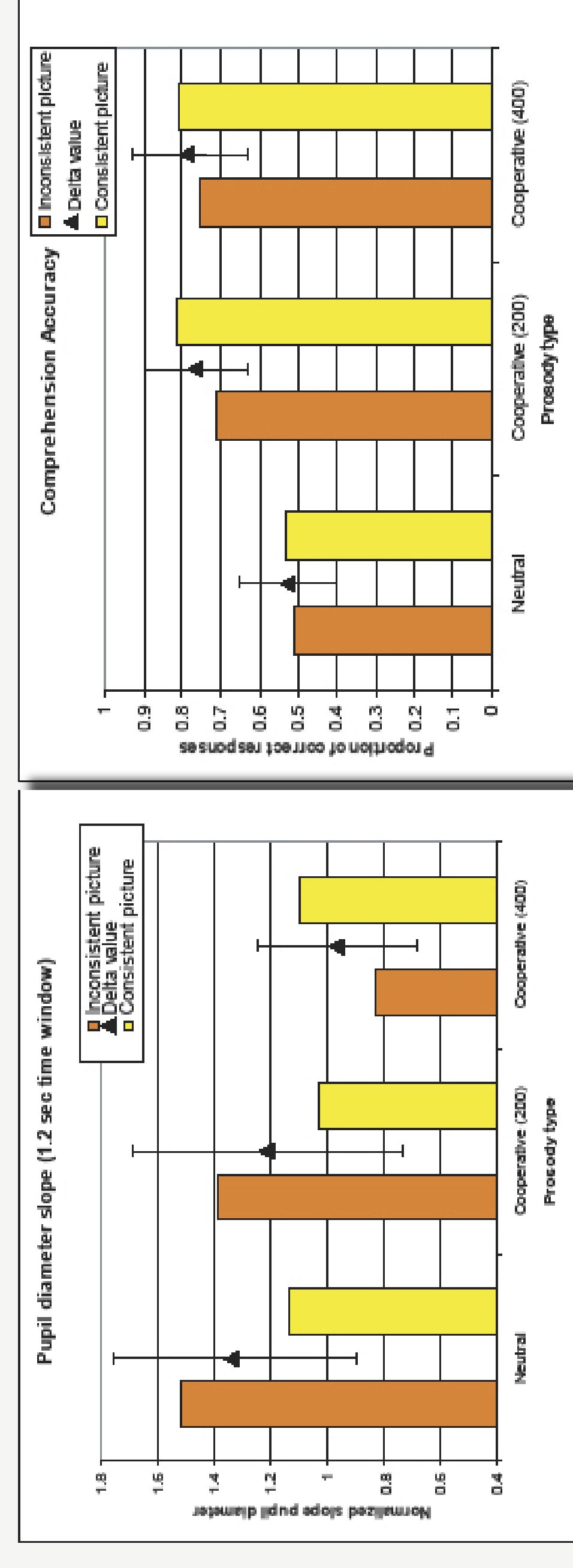


## Results

- Pupil slope showed a main effect of Prosody  $F(2,34) = 3.81, p < .05$ , and a significant interaction  $F(2,34) = 3.19, p = .05$ .
- Accuracy showed a significant main effect of Prosody  $F(2,34) = 13.41, p < .01$ , and a marginal effect of Visual context  $F(1,17) = 3.56, p = .08$ . The interaction was not significant (see Figure 5b).

- Summary: Pupil slope indicates greater processing effort with the Inconsistent picture in both the Neutral and 200 ms prosody conditions. Comprehension accuracy was more influenced by prosody.

Figures 5a & 5b.



## CONCLUSIONS

- Prosody type showed a robust main effect for each DV indicating that Cooperative prosody can immediately prevent the garden-path. However, pupil slope in the Cooperative (200) prosody/Inconsistent picture condition was quite high suggesting that Inconsistent visual context impairs comprehension.
- Consistent visual context seemed to reduce the online processing effort in the Neutral prosody condition; however the reduction in processing effort is not reflected in the accuracy score. Pupil slope and comprehension accuracy dissociate, and only the online measure shows the critical interaction between visual and prosodic information (see also Engelhardt et al., 2006).
- Pupil slope revealed a significant interaction which is consistent with the assumptions of unrestricted processing models. These data suggest that visual context does influence online parsing.
- In follow-up experiments, we will examine other features of prosody besides pause length, and we will vary the timing of the presentation of the visual stimulus relative to the utterance.