

# Prosody induced by phrase lengths facilitates syntactic processing in reading

## Severe difficulty of doubly-center-embedded relative clauses

The boy the dog the cat chased bit died.  
[ NP1 [ NP2 [ NP3 VP1 ] VP2 ] VP3 ]

- Very difficult to understand.
- Often judged to be ungrammatical.
- Typically pronounced with 'list intonation', strongly suggesting that the nested syntactic structure has not been computed.

We maintain :

- that there is one prosodic contour (in English) that is compatible with the nested structure: NP1 / NP2 NP3 VP1 VP2 / VP3 (" / " marks prosodic boundary)
- that when phrase lengths permit this prosody, 2CE-RC sentences are quite easy to parse.

**ENCOURAGING PHRASE LENGTHS** (short inner phrases):

The newly-installed lamp post that the car a cop chased had rammed was totally ruined.

**DISCOURAGING PHRASE LENGTHS** (long inner phrases):

The wall that the limousine the police vehicle had been chasing crashed into was ruined.

A pilot study (Fodor & Nickels 2011) obtained self-reported judgments on a 5-point scale.

ENC items were judged more pronounceable & more comprehensible than DISC items.

Our study employed the "Missing-VP illusion" as an objective test of accurate parsing.

Illusion: 2CE-RC sentences with VP2 omitted are often judged to be grammatical.

(Gibson and Thomas, 1999)

## Method

### Materials

16 ENC/DISC sentence pairs

Same total number of words and characters (+/-2).

Each in 2 versions: **Complete**; **Missing VP2**

Counterbalanced across four lists

25 filler sentences of varied syntactic structure, 13 ungrammatical due to a missing element

### Procedure

Participants read a sentence silently first, then aloud while recording themselves.

After recording, they answered the question: "Is something missing from this sentence?"

We used a web-based experiment platform : a Java applet (<http://gong.ust.hk/nanogong/>)

integrated into a web-based survey platform (www.limesurvey.org).



Figure 1. User interface for web-based experiment

### Participants

Unexpectedly, 23 out of 47 responders who successfully completed the questionnaire judged more than half of the Complete target items to have something missing. Possibly these participants found all 2CE-RC sentences unacceptable, without a clear sense of what was wrong with them. These 'CE-rejectors' were excluded from subsequent analyses, leaving 24 participants in the data pool.

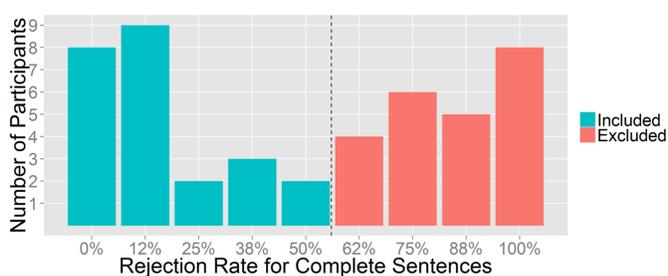


Figure 2. Bimodal distribution of rejection rates for complete sentences for each subject

### Prosodic break judgments

Two trained judges listened to the recordings and noted locations of prosodic boundaries. Each judged independently. In case of disagreement, they discussed until they reached a consensus.

## Results

### Phrase lengths and prosodic boundaries

- Phrase lengths predicted prosodic contours significantly, especially in the NP region. ENC items were pronounced with more breaks after NP1 ( $z=4.5$ ,  $p < .001$ ), and with fewer breaks after NP2 ( $z = -6.1$ ,  $p < .001$ ), compared to DISC items.
- There was a tendency for DISC items to break after both NP1 and NP2 – in the manner of 'list intonation' ( $X^2 = 38.1$ ,  $p < .001$ ).

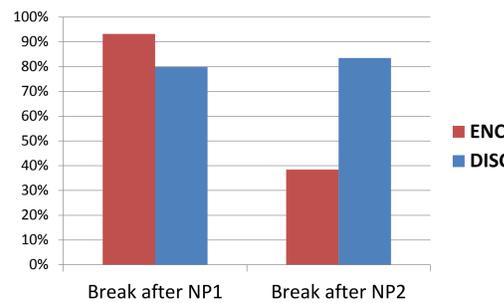


Figure 2. Likelihood of prosodic break at NP1 / NP2 for ENC and DISC phrase lengths

	ENC	DISC
Break after NP1 AND NP2	35% (66/190)	67% (126/188)

Table 2. Likelihood of prosodic break after both NP1 & NP2 for ENC and DISC phrase lengths

### Accuracy by phrase length

- Sentence judgments ("Something missing?") were less accurate for DISC items. Confirmed in a simple mixed effects linear regression model, but only for Complete items.
- Little sign of any Missing-VP2 effect: accuracy was surprisingly high for both ENC and DISC.

	ENC	DISC	Contrast	Estimate	SE	z-Value	p-Value
Complete	90%	79%	<b>ENC vs DISC (Complete)</b>	<b>1.11</b>	<b>0.49</b>	<b>2.29</b>	<b>.02 *</b>
Missing VP2	95%	89%	ENC vs DISC (Missing VP2)	0.68	0.48	1.42	.15

Table 3. Mean accuracy in the four conditions

Table 4. Results from simple mixed-effects modeling with only phrase lengths as predictor

### Accuracy by prosodic contour

- The best predictor of judgment accuracy was the **produced prosody**, regardless of whether the sentence was associated with phrase lengths pre-classified as ENC or DISC.
- When participants produced a sentence with a break after NP2 (preventing the optimal prosodic phrasing; see above) their judgment of the sentence was less accurate.

Contrast	Estimate	SE	z-Value	p-Value
ENC vs DISC (Complete)	1.11	0.49	1.61	.106
ENC vs DISC (Missing VP2)	0.68	0.48	0.90	.371
Break after NP1	0.10	0.53	0.19	.853
<b>Break after NP2</b>	<b>-1.54</b>	<b>0.77</b>	<b>-2.00</b>	<b>.046 *</b>
Break before VP3	0.23	0.55	0.43	.672

Table 5. Results from extended mixed-effects modeling with phrase lengths and prosodic break locations as predictors

## Discussion

- ▶ Note that **prosody was not directly provided** in the stimuli.
- ▶ Manipulation of phrase lengths reliably influenced the produced prosodic contour.
- ▶ Phrase lengths predicted judgment accuracy, but this effect disappeared when the location of prosodic breaks was taken into account → prosodic phrasing was a better predictor.
- ▶ This indicates that the phrase length effect is mediated by prosodic phrasing.



- ▶ Support for the proposed optimal prosodic phrasing (see above): When the optimal grouping of NP2 NP3 VP1 VP2 into a single phrase was not possible (specifically, when speakers paused after NP2), judgment accuracy was reduced.
- ▶ Contrast with Nickels & Fodor: Their best predictor of comprehension difficulty was a **break before VP2**. This also prevents the optimal prosodic phrasing. With their 'familiarization' technique to make reading easier, trouble arose only later in the sentence.

## References

- Fodor, J. D., & Nickels, S. (2011). Center-embedded sentences: Phrase length, prosody and comprehension. Poster presented at AMLaP conference.
- Gibson, E., & Thomas, J. (1999). Memory limitations and structural forgetting: The perception of complex ungrammatical sentences as grammatical. *Language and Cognitive Processes*, 14(3), 225-248.

Get a copy!

