Prosodic Phrasing as a Source of Center-embedding Difficulty

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1 INTRODUCTION

DOUBLY CENTER-EMBEDDED RELATIVE CLAUSES (2CE-RC): The man the girl the cat scratched kicked died.
NP1 NP2 NP3 VP1 VP2 VP3

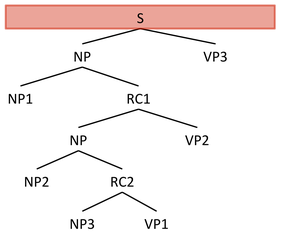
3 peculiarities:
I. Unusually difficult comprehension
II. Improved if NP3 is a pronoun = "the pronoun effect"
III. Perceived (wrongly!) as more grammatical if VP2 is absent = "the missing-VP effect"

Many explanations have been proposed for these phenomena. Without disproving the relevance of the proposed factors, we point to **prosodic phrasing** as a powerful influence on 2CE-RC comprehensibility.

OUR EXPLANATION OF THE DIFFICULTY: A mismatch between the syntactic structure and the prosodic phrasing typically assigned.

- Prosodic phrasing is influenced by phrase lengths/balance as well as syntactic alignment (Selkirk, 2000 in Horne (ed.); Sandalo & Truckenbrodt, 2002 MIT:WPL).
- Prosodic phrasing is typically flat (though not necessarily); a succession of phrases at the same level.
- But 2CE-RC syntax cannot easily be divided into successive phrases that meet prosodic criteria.

This explains all three peculiarities. If the prosody is natural, the syntax is comprehensible. Unnatural prosody → incomprehension.

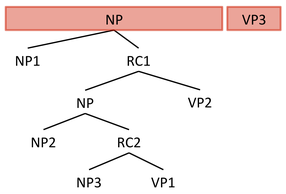


SYNTACTIC TREE OF 2CE-RC SENTENCES

Now, how to assign prosodic structure to this syntactic tree?

Snip it apart at natural syntactic breaks , starting from the top.

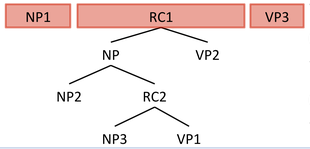
Into 2 units, 3 units, 4 units or … ?



TREE DIAGRAM SHOWING 2 PROSODIC UNITS

☺ **Balanced aligned prosody:** 7+5 = 12
The girl the man I love met || died of cholera in 1962.

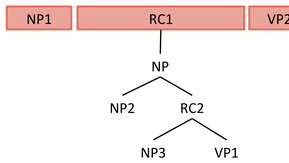
☹ **Unbalanced prosody:** 10 + 1 = 11
The little boy that the cat the dog chased bit || died.



TREE DIAGRAM SHOWING 3 PROSODIC UNITS

☺ **Balanced aligned prosody:** 3+6+3 = 12
The elegant woman || that the man I love met || lives in Barcelona.

☹ **Unbalanced prosody:** 2+8+1 = 11
The girl || that the young man I love met in Barcelona || died.



TREE DIAGRAM SHOWING 4 PROSODIC UNITS

☹ **Balanced aligned prosody:** 2+4+4+2=12
The actor || that someone I love || met in South Carolina || died yesterday.

Try reading the sentence yourself. Do you agree that the 4-way prosodic phrasing is less helpful than the 3-way phrasing?

Intuitively, it seems to be bad because it isolates VP2. See our

INTUITIONS support the ☺ 3-way, versus ☹ 4-way, prosodic phrasing:
Even a triple-embedded example (from Tom Bever) is parsable. No coincidence – its phrase lengths permit 3-way prosody (with effort!)

☺ The pictures || that the reporter everyone I met trusts took || showed that the fire was set by an arsonist. 2+8+9

By contrast, prosodically unfriendly examples are hard to comprehend even when the interpretation is tightly constrained by selection restrictions. (See Gibson & Thomas items in section 2.2 DESIGN.)

2 EXPERIMENT

2.1 PROCEDURE

Participants:
- 28 English native speakers (19f/9m)
- Mean age 30.9 (10.1)

Stimuli:
2CE-RC sentences either to ENCourage or DISCourage 3-phrase prosody:
- 8 varying in phrase length (see examples in 2.2)
- 4 varying in phrase weight : Varied were word frequency and default stress. ENC sentences contained low frequency/heavily stressed words at the edges. DISC sentences had those words in the inner part.
  - ENC: **The soufflé** that the waitress the boss hired brought **disintegrated**.
  - DISC: The drink **that the hostess the nightclub employed stirred** spilled.
- 16 fillers: *if not because*, early/late closure, NP/clause complement, parenthetical Adverbial clauses

Sums of frequencies were matched across sentences.

Dependent Measures:
- by subjects, after reading aloud: Pronounceablility and Comprehensibility
- by expert judges: Appropriateness of global prosodic contour and positions of prosodic breaks

Task: Reading sentences first silently, then aloud, followed by pronounceablility and comprehensibility judgments.

Familiarization Protocol (excerpt from the instructions): Sentences are grouped in sets of five, starting simple and becoming progressively more complex. After the 5th sentence you will see a screen with a scale from 1 to 5, with 1 meaning really difficult to read aloud. Then the next screen will show a similar scale for judging how difficult it was to grasp the meaning of the sentence. The first four sentences in a set are designed to be helpful to you in reading and understanding the 5th one, so that you can pronounce it in the clearest possible way. When you judge how difficult a sentence was to understand, don't worry about whether the meaning (the event it describes) is plausible in real life. The question is: Could you tell what its meaning is?

2.2 DESIGN

HYPOTHESIS: 2CE-RC sentences are more difficult to understand when VP2 is prosodically isolated (the ☹ 4-way analysis).
Technique: Use phrase lengths to induce prosodic phrasing which either ENCourages or DISCourages the ☺ 3-way analysis.
Compare with standard experimental items, which are DISCouraging: uniformly long or uniformly short constituents.
Protocol: Complete sentence presentation (not SPR). After familiarization sequence, read aloud (reveals prosody). Judge (reveals pronounceability and comprehensibility).

ENC: ☺ The rusty old ceiling pipes | that the plumber | my dad | trained | fixed | continue to leak occasionally. (5+7+4 = **16**)

DISC: ☹ The pipes | that the unlicensed plumber | the new janitor | reluctantly assisted | tried to repair | burst (2+12+1 = **15**)

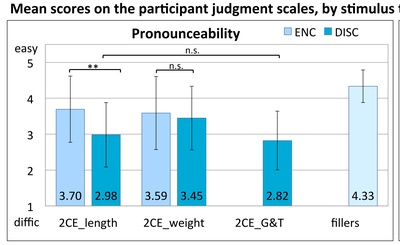
But matched for total sentence length (in words)!

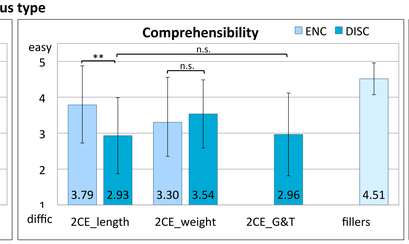
4 typical items from a previous study (Gibson & Thomas, 1999) with uniformly long constituents were included (2CE_G&T). They must be considered to be DISCouraging :

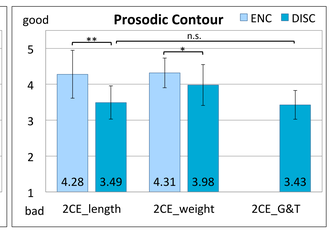
The ancient manuscript | that the grad student | who the new card catalog | had confused a great deal | was studying in the library | was missing a page.

2.3 RESULTS

Mean scores on the participant judgment scales, by stimulus type







Percentage of separate VP2s

	ENC	DISC
2CE_length	33.3	70.4
2CE_weight	44.4	53.7
2CE_G&T		65.7

(** between ENC 33.3 and DISC 70.4; n.s. between ENC 44.4 and DISC 53.7; n.s. between DISC 53.7 and DISC 65.7)

Correlation with separate VP2 (negative correlation indicates worse scores)

	Pronounceablility	Comprehensibility	Prosodic Contour
2CE_length	-.312**	-.210*	-.591**
2CE_weight	-.008	.082	-.309
2CE_G&T	.084	.156	-.273**

Legend:
- Asterisks indicate significance levels:
  * meaning p≤.05 and
  ** meaning p≤.01 (two-tailed).
- Lower scores indicate negative assessments on the scale (e.g. for pronounceablility "1"= "very difficult to read", "5" = "very easy to read")
- Separate VP2 is defined by a prosodic break before and after VP2

3 SUMMARY OF FINDINGS

- Subjects' judgments (**Pronounceability** and **Comprehensibility**) and expert judgments (**Prosodic Contour**):
  - 2CE-RC sentences with **length manipulations (2CE_length and 2CE_G&T)**: DISC sentences were judged harder to pronounce (by ≈0,7 points out of 5), harder to understand (by ≈0,9) and were spoken with a less appropriate overall prosodic contour (by ≈0,8)
  - 2CE-RC sentences with **weight manipulations**: this variation did not show the expected differences except for the Prosodic Contour scale, where ENC sentences were judged to have a more appropriate prosodic contour (by ≈0,3)
- **Percentage of separate VP2s:**
  - **length manipulations:** ENC sentences indeed encouraged a ☺3-way prosodic phrasing, whereas DISC sentences more often received a ☹4-way prosodic phrasing (meaning that VP2 has been phrased separately)
  - again, the **weight manipulation** did not lead to the expected differences between ENC and DISC versions
- **Correlations:**
  - for **length variations**: correlations show that - when VP2 was separate - sentences were harder to read, harder to understand and had a less appropriate overall prosodic contour; missing correlations for the **G&T sentences** must be attributed to a limited variance (only DISC items) in that category
  - for **weight variations:** as usual, no significant results on this category

4 EXPLANATION

Wagner (2009, NLLT) proposes that syntax-prosody alignment is achieved not by ignoring some syntactic boundaries (the edge-alignment approach; Selkirk & others), but by readjustment of syntactic structure (Chomsky & Halle, 1968; Langendoen, 1975) – subject to syntactic constraints.

A constituent can be separately phrased prosodically only if it can be raised to a high syntactic position, as sister to the previous prosodic phrase.

This applies to 2CE-RC:

3-phrase prosodic phrasing is possible because an RC can be extraposed from the nominal it modifies and adjoined to a higher node.

RC Extraposition:

✓The woman *e* wept $_{RC}$[who the policeman had harassed].

4-phrase prosodic phrasing would require raising finite VP2 out of RC1. But this is syntactically illegitimate; RC is an extraction island.

No finite VP Extraposition:

*The woman $_{RC}$[who the policeman *e* yesterday] $_{VP}$[had harassed] wept.

5 CONCLUSION

What is special about 2CE-RC?

Syntax-prosody misalignment.

In typical examples, phrase lengths induce a prosodic structure that mismatches the syntactic structure.

Other side of the coin: Where phrase lengths cooperate with syntactic alignment, there's no mismatch, and no problem with comprehension.

Two requirements for a good match:
- The heavily nested syntactic structure of 2CE-RC can be adjusted to create a flat structure for prosody -- in some respects but not all; syntactic constraints must be respected.
- Where syntactic adjustment is possible, prosodic phrase lengths must be appropriate to encourage that structure in reading (aloud, or silently with implicit prosody).

This suggests a productive interaction between syntax and prosody on-line:
- low-level syntax identifies possible low-level syntactic phrases;
- rhythmic properties (phrase length/balance) determine whether those low-level syntactic phrases need to be combined or separated;
- the resulting prosodic phrasing feeds back into syntactic parsing so that only syntactic analyses congruent with it are computed

This explains all 3 peculiarities of 2E-RC processing:

I. Unusually difficult comprehension. Standard experimental examples typically have overweight RC1.
II. Improvement if NP3 is a pronoun. Pronoun is short and unstressed; helps to slim down the RC1.
III. Apparent improvement if VP2 is absent = "the missing-VP effect".
Why is VP2 often suppressed by the parser?
Assume the parser attempts to relate successive prosodic phrases as syntactic sisters.
It cannot (legitimately) do so when VP2 is a separate prosodic unit.
VP2 can be a sister only if (mis-) attached as the matrix VP.
But then it is ousted by the real matrix VP3 which follows.