

Silent Prosody

- or how to pronounce a
center-embedded sentence

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A doubly center-embedded relative clause construction (2CE-RC)

*The man the girl the cat scratched loved died.

[NP1 [NP2 [NP3 VP1] VP2] VP3]

* A main clause, containing a RC surrounded on both sides, with another RC surrounded on both sides inside it. (Like an onion.)

* Example from an expt by Gibson & Thomas (1999):

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

3 peculiarities of (English) 2CE-RC

- I. Unusually difficult comprehension – whether long or short.
More than twice as hard as a single embedding:
The man the girl loved died (and the cat scratched her).

- II. Easier if NP3 is a pronoun = “the pronoun effect” (Bever)
The man the girl I scratched loved died.

- III. Often perceived (wrongly!) as more grammatical if VP2 is absent = “the missing-VP illusion”
The man the girl the cat scratched died.

Many explanations over the years

- ✱ Parser can't recursively call the same sub-routine (Miller & Chomsky 1963).
- ✱ Misparsed on-line as coordination (Blumenthal 1966).
- ✱ Density of syntactic nodes per word is too high (J.A.Fodor & Garrett 1968).
- ✱ Can't assign both subject and object roles to NP2 (Bever 1970).
- ✱ Sausage Machine can't chunk word string correctly (Frazier & Fodor 1978).
- ✱ Disappearing syntactic nodes (Frazier 1985).
- ✱ Similarity of phrases causes interference (Lewis & Nakayama, 1999)
- ✱ Syntactic prediction locality theory (Gibson & Thomas 1999)

SPLT explanation (processing resources)

- * Syntactic Prediction Locality Theory (Gibson & Thomas) predicts:
- * High memory cost at NP3, to store predictions about still-needed constituents. Three incomplete clauses.
- * Very high integration cost at VP2: its subject and object are both non-local.

The patient who the nurse who the clinic had hired admitted met Jack.



But at CUNY, by the magic of prosody...

- ✱ We turn 2CE-RC monsters into normal-sounding English sentences.
- ✱ The rusty old ceiling pipes that the plumber my dad trained fixed continue to leak occasionally. 🔊



- ✱ But without the magic:
- ✱ The pipes that the unlicensed plumber the new janitor reluctantly assisted tried to repair burst. 🔊
- ✱ The plane that the transatlantic pilot my older cousin met on his vacation was flying to Portugal crashed. 🔊

What is the trick?

- * We claim: Prosody is a large part of the usual 2CE-RC problem.
- * A mismatch between the nested syntactic structure and the need for flat prosodic phrasing.
- * Prediction: If the prosody can be made natural, the syntactic structure will be easy to process. Three chunks! 😊
- * However, making the prosody natural is difficult. Typical phrase lengths discourage it. Need very short NP2 NP3 VP1 VP2. 😞
- * This can explain all 3 peculiarities of typical 2CE-RC:
 1. Unnatural or misleading prosody → incomprehension.
 2. Pronoun as NP3 is prosodically light, improves rhythm.
 3. VP2 should be prosodically grouped with its subject NP2, but difficult due to phrase lengths → parser suppresses VP2.

The importance of phrase lengths

* Effects of phrase lengths on sentence processing have been demonstrated at CUNY for Japanese (Inoue; Uehara; Hirose), Hebrew (Shaked; Webman), Turkish (Dinctopal), Bulgarian (Stoyneshka), Arabic (Abdelghany).....

* Encouraging phrase lengths for English 2CE-RC:

The rusty old ceiling pipes / that the plumber my dad trained fixed / continue to leak occasionally.

* Discouraging phrase lengths:

The pipes / that the unlicensed plumber the new janitor reluctantly assisted tried to repair / burst.

The pipes / that the unlicensed plumber / the new janitor reluctantly assisted / tried to repair / burst.

...while also satisfying prosodic constraints

* Least damage to syntactic tree = prosodic and syntactic phrases should be aligned, as far as possible.

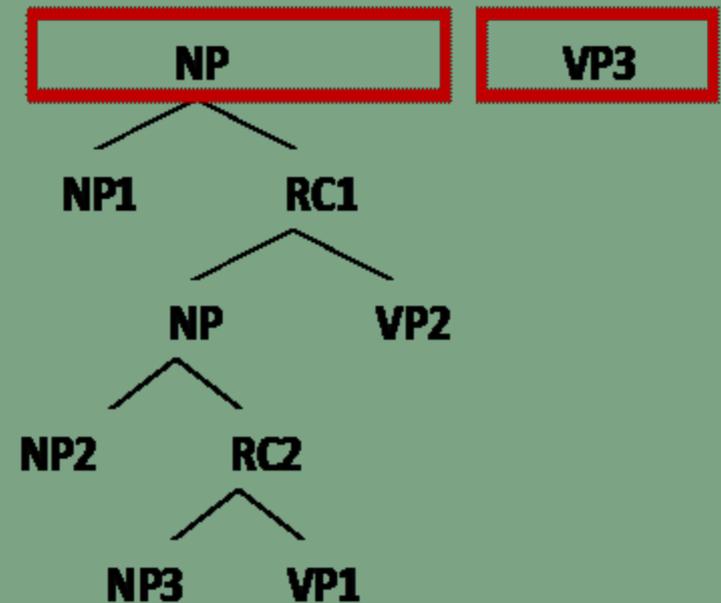
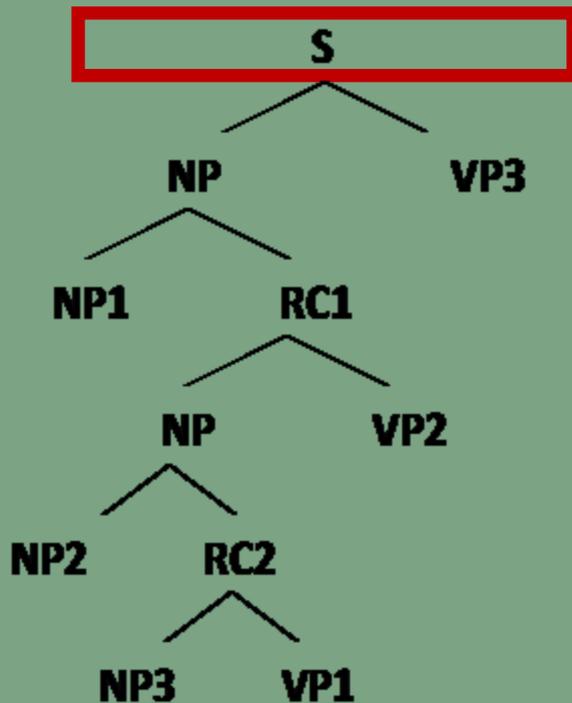
- Edge alignment: Align_R XP. Selkirk (2000)
- Wrap. Truckenbrodt (1999)
- The Sense Unit Condition. Selkirk (1984)

* Also optimal phrase length constraints:

- Binary Minimum ($ip \geq 2$ prosodic words). Selkirk (2000)
- Binary Maximum ($ip \leq 2$ prosodic words)
- Balance. Gee & Grosjean (1983)
- Uniformity. Ghini (1993)

Snip once - 2 prosodic phrases

The man the girl the cat scratched loved || died



But phrase lengths must cooperate

ENCouraging phrase lengths

😊 Balanced aligned prosody: $7+5 = 12$ words (4+4 stresses)
The girl the man I love met || died of cholera in 1960.

DISCouraging phrase lengths (typical)

😞 Unbalanced aligned prosody: $10+1 = 11$ words (6+1 stresses)
The little boy that the cat the dog chased bit || died.

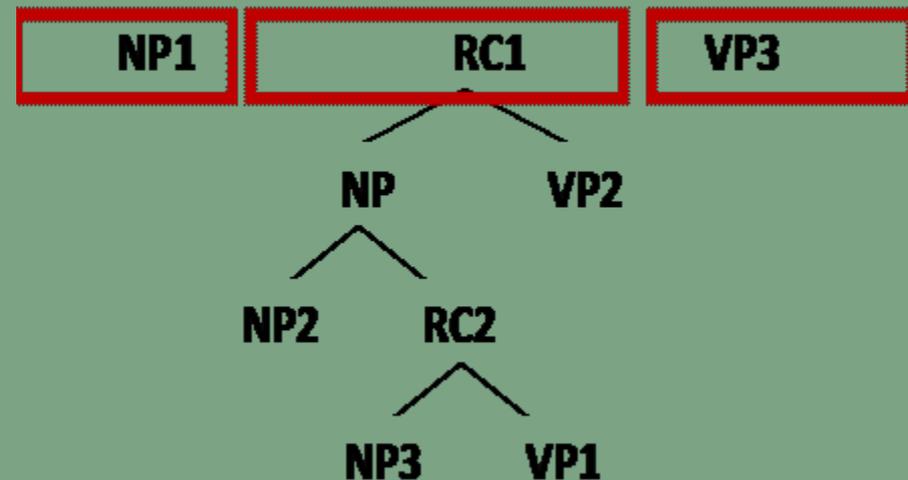
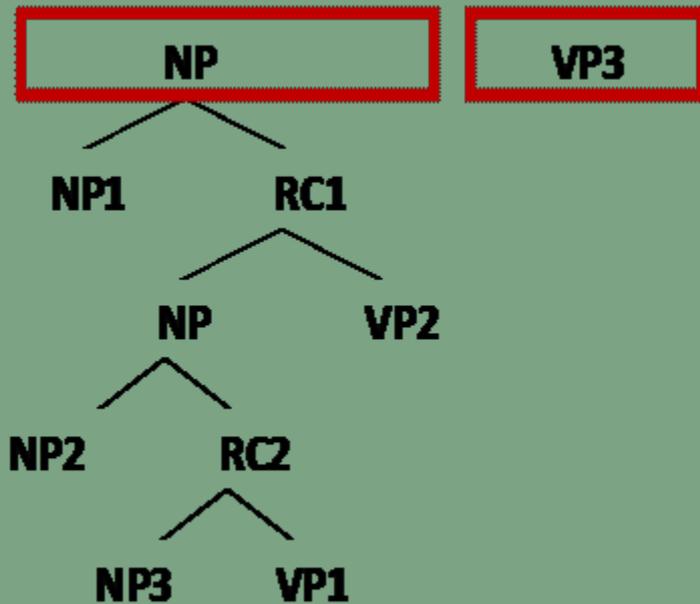
✳ **Syntactic phrase lengths typically are discouraging!**

An NP containing an RC isn't usually only 2 or 3 words long!

✳ Unless NP3 is a pronoun, this 2-phrase prosodic phrasing is hard to achieve. So let's try snipping again.

Snip again - 3 prosodic phrases

The man || the girl the cat scratched loved || died



But again, phrase lengths matter

ENCouraging phrase lengths

😊 Balanced aligned prosody: $3+6+3 = 12$

The elegant woman || that the man I love met || lives in Barcelona.

DISCouraging phrase lengths

😞 Unbalanced aligned prosody: $2+8+1 = 11$

The girl || that the young man I love met in Barcelona || died.

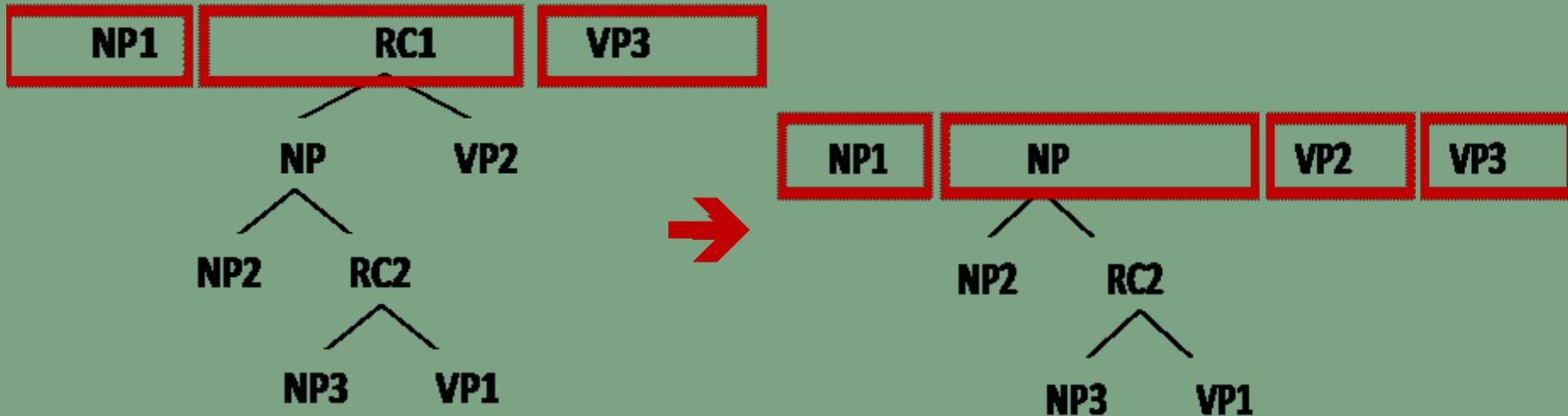
✳ How to make 2CE-RC pronounceable?

Encourage phrasing **NP1 RC1 VP3**, by lengthening NP1 and VP3 on the outside, and shortening RC1 in the middle.

✳ What if RC1 can't be shortened? Cut again?

4 prosodic phrases

The man || the girl the cat scratched || loved || died



But now, no very natural phrase lengths

* Expand VP2 to achieve balanced aligned prosody: $2+4+3+2=11$

The actor || that someone I love || met in Barcelona || died yesterday.

* But not an improvement! The sentence is beginning to break up.
The 'shopping list' effect.

* SUMMARY OF INTUITIONS:

- The 4-way prosodic phrasing splits up the complex middle constituent. This ought to help by easing the crush in RC1.
- But intuitively, it is less helpful than the 3-way phrasing.

* Let's put these intuitions to experimental test.

Elicited prosody expts test these intuitions

* **Experiment 1** (Fodor & Nickels, AMLaP 2011)

Task: Read the sentences first silently, then aloud for recording, followed by judgments of **pronounceability** and **comprehensibility**.

Familiarization pre-procedure to increase parsability.

* **Experiment 2** (Schott & Fodor, AMLaP 2013)

Task: Read the sentences first silently, then aloud for recording, followed by **grammaticality** judgment.

A more objective measure of parsability.

* **Experiments 3 and 4 methods: Recall; Double Reading**

Expt 1 materials: Phrase length manipulation

- * Pairs of 2CE-RC sentences, same total length. Phrase lengths either **ENCourage** or **DISCourage** the 3-phrase prosody.

ENC: The rusty old ceiling pipes that the plumber my dad trained fixed continue to leak occasionally.

DISC: The pipes that the unlicensed plumber the new janitor reluctantly assisted tried to repair burst

- * Typical items from a previous study (Gibson & Thomas, 1999), uniformly long constituents. We regard as **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.

- * Filler items with mild parsing challenges: *if not because*, early/late closure, NP/clause complement, parenthetical Adverbial clauses.

Familiarization protocol in Expt 1

(aim: to avoid a floor effect)

Displayed one sentence at a time, in turn.
Read each sentence silently, then aloud.

My dad trained a plumber.

Here is the plumber my dad trained.

The plumber my dad trained fixed the rusty old ceiling pipes.

Here are the rusty old ceiling pipes that the plumber my dad trained fixed.

The rusty old ceiling pipes that the plumber my dad trained fixed continue to leak occasionally.

Judge the yellow one:

How easy to pronounce? 1 - 5

How easy to understand? 1 - 5

Examples from Expt 1 reading study

1. Example pronunciations of items with length variations

ENC

The rusty old ceiling pipes that the plumber my dad trained fixed continue to leak occasionally.

Examples:



DISC

The pipes that the unlicensed plumber the new janitor reluctantly assisted tried to repair burst.

Examples:



G&T

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

Examples:



2. Example pronunciations of separated-VP2

separate
VP2s

The shirt that the seamstress the immigration officer had investigated last week was carefully mending needed to be dry-cleaned.

Examples:



Item: G&T (DISC)

The plane that the transatlantic pilot my older cousin met on his vacation was flying to Portugal crashed.

Examples:



Item: Length_DISC

The prayer that the monk the religious fanatic had persecuted relentlessly was chanting every day was echoing in the empty church.

Examples:



Item: G&T (DISC)

Some curiosities

split
VP2s

The ancient manuscript that the grad student the new card catalog had confused a great deal was studying in the library was missing a page. Examples:   Item: G&T (DISC)

The song that the grunge rock drummer Elisabeth MacIntyre used to date submitted to a competition won. Example:  Item: Length_DISC

The plane that the transatlantic pilot my older cousin met on his vacation was flying to Portugal crashed. Example:  Item: Length_DISC

lists

“Listers” tended to pronounce almost every phrase separately, so the sentence sounds like a list.

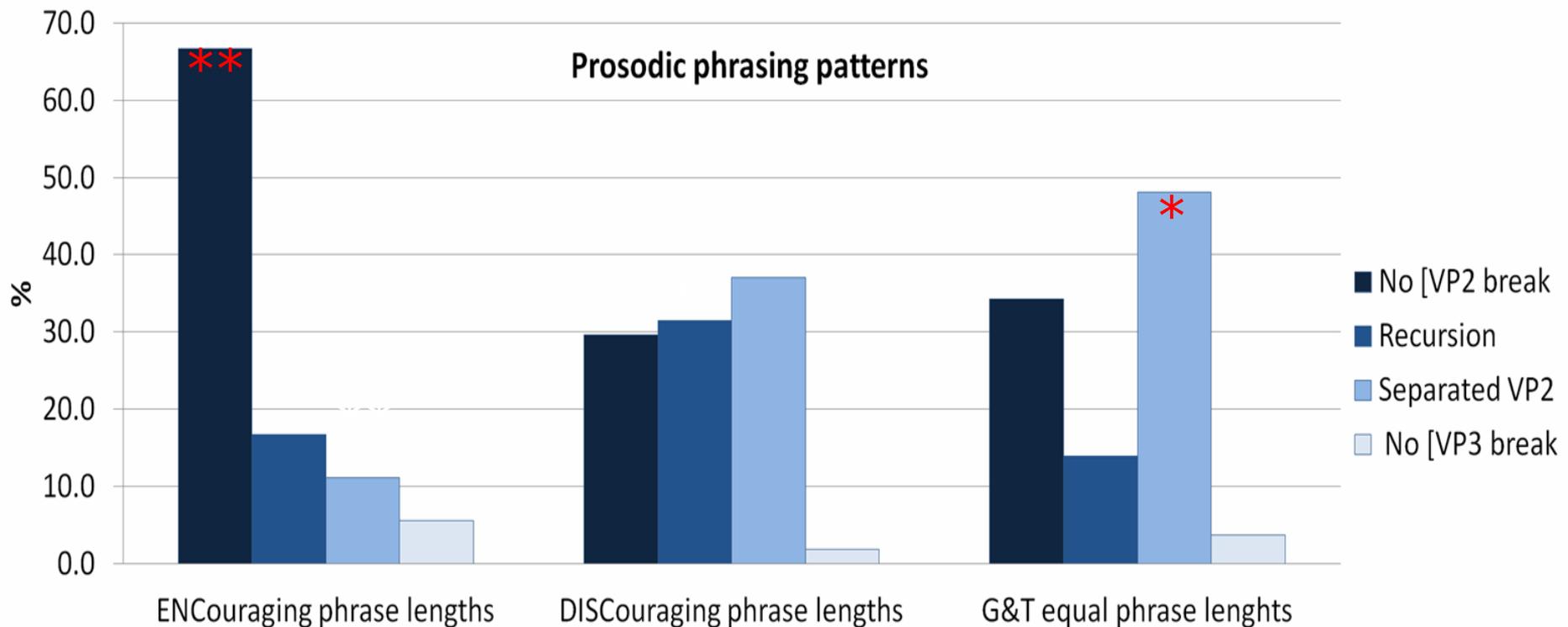
The barricades that the boys the cop arrested kicked disintegrated. Examples:  Item: weight_ENC

The pipes that the unlicensed plumber the new janitor reluctantly assisted tried to repair burst. Example:  Item: Length_DISC

The box of chicken nuggets that the drummer Beth dates bought fell apart on his way home. Example:  Item: Length_ENC

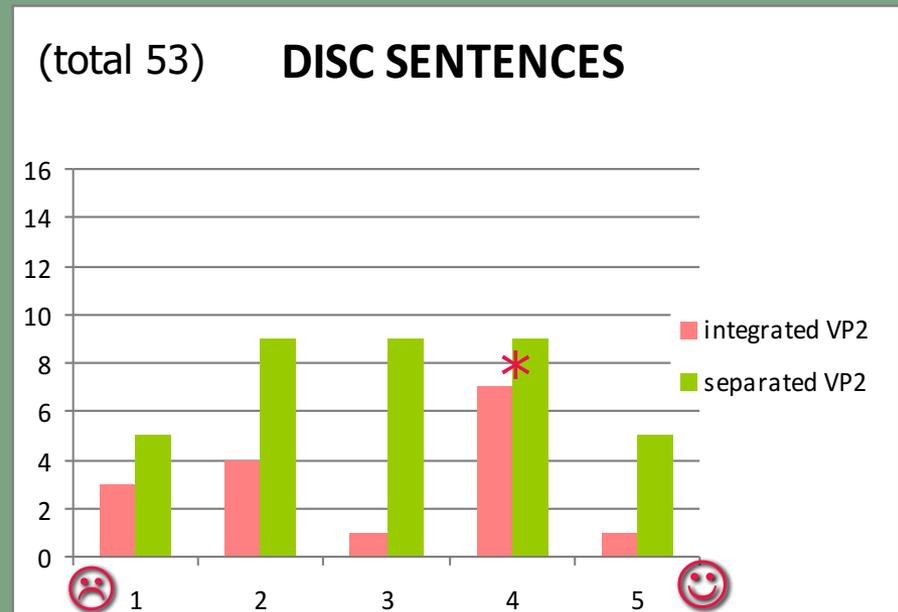
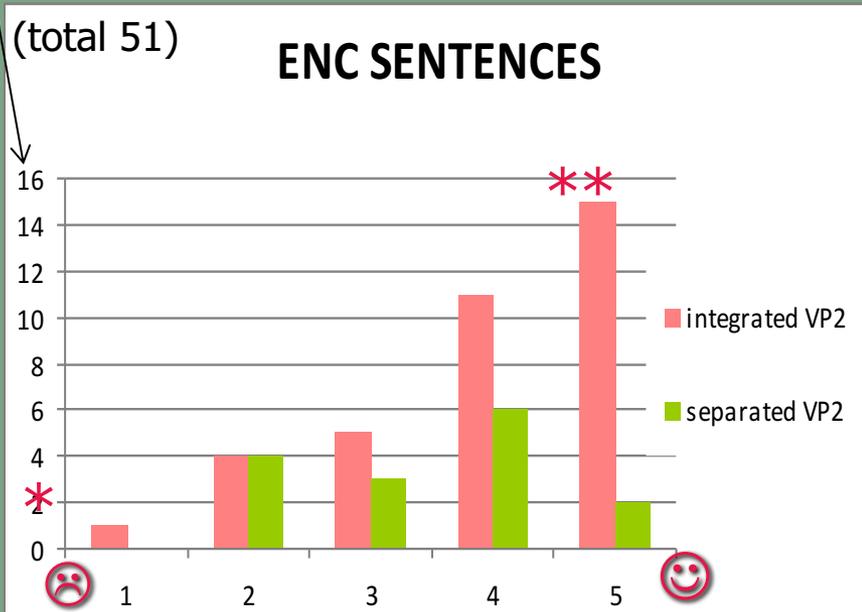
Phrase lengths influenced produced prosody (expert-coded) especially in the VP region

ENC lengths avoid a separated VP2 (the *4-phrase prosody)



Prosodically integrated VP2 is associated with good (self-rated) comprehension

of judgments at that scale value

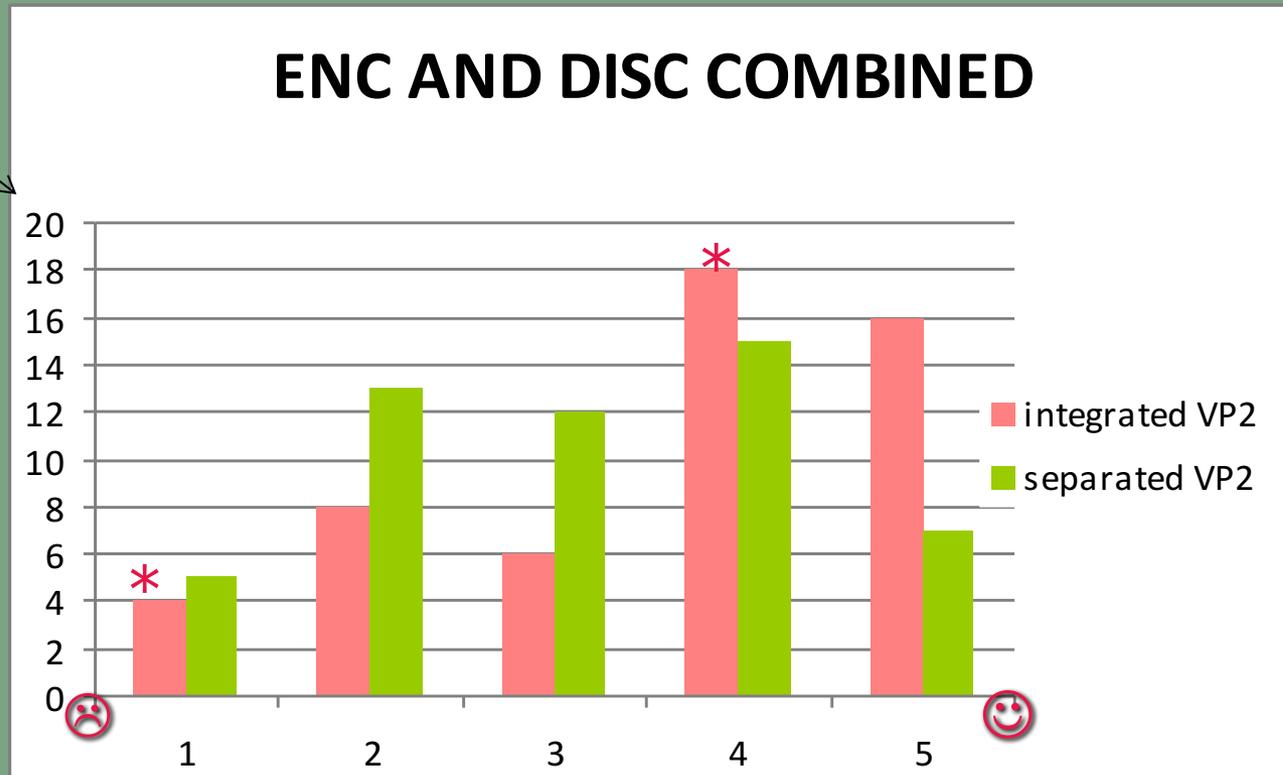


5-point scale, self-rated comprehensibility (5 is good)

χ^2 : departure from equal frequency of the five comprehension scores for that prosody type.

Prosody assists (self-rated) comprehension – regardless of pre-classification as ENC/DISC

of judgments at that scale value (total 104)



5-point scale, self-rated comprehensibility (5 is good)

More experiments, different methods

- * Expt. 2: Missing-VP effect.
(visual input, grammaticality judgment)
- * Expt. 3: Auditory input.
(recall test)
- * Expt. 4: Double reading.
(on-line L-R problem or deeper)

Expt 2. Missing-VP: Grammaticality judgment. A less subjective indicator of parsability

- * Half of items had a word or phrase missing. Half were complete.
- * No pre-familiarization. Read once silently, then aloud, then judge (Is it a real English sentence?).
- The rusty old ceiling pipes that the plumber my dad trained fixed continue to leak occasionally. **<ENC Complete>**
- Admittedly, the rusty old ceiling pipes that the plumber my dad trained continue to leak occasionally. **<ENC Missing VP2>**
- The pipes that the unlicensed plumber the new janitor reluctantly assisted tried to repair burst. **<DISC Complete>**
- To no-one's surprise, the pipes that the unlicensed plumber the new janitor reluctantly assisted burst. **<DISC Missing VP2>**

Expt. 2 (Missing VP2) results

(excluding Ss who judged all CE sentences ungrammatical!)

- * High judgment accuracy on the 2CE-RC items. (Surprising!)
- * ENC phrase lengths facilitated acceptance of Complete items. 😊
- * ENC phrase lengths more often yielded the optimal 3-chunk prosodic grouping [NP1 [NP2 NP3 VP1 VP2] VP3]. 😊
- * In NP-region: DISC lengths increased breaks after NP2. 😞
- * In VP-region: DISC lengths increased no-break before VP3. Then syntactic judgment accuracy was at chance. 😞
- * These data support intuitions and Expt 1's self-judgments:
✓ **Phrase lengths influence prosody, which aids syntactic parsing.**
- * **!** No 'missing-VP2 illusion'. Little tendency to over-accept the Missing items, for either ENC or DISC. (I don't know why.)

Experiment 3: Auditory input - recall test

Fodor, Goldman & Thorne (2015)

- * **Items:** All sentences were grammatical;
all 6 phrases in a sentence were medium length.
- * **Auditory input**, recorded by a trained speaker. Prosody provided: 3 prosodic phrasings for the same word string.
- * **Task:** Listen to sentence (just once), then type out as much of it as you can.
- * **Recall accuracy** used as measure of success in structuring the word string (cf. George Miller 1956).

 **ENC:** NP 1 || NP2 NP3 VP1 VP2 || VP3

 **NP-DISC:** NP 1 NP2 || NP3 VP1 VP2 || VP3

 **VP-DISC:** NP 1 || NP2 NP3 VP1 || VP2 VP3

Audio input with written recall – some example responses!

The park ranger that the Dutch tourist that the snake bit had called for stayed calm. (ENC)

* The park rangers, that the Dutch tourist that the snake had called for, stayed calm.

The iced tea that the movie star that the barman kissed was drinking looked delicious. (ENC)

* The ice tea at the bar, that the movie star was kissing, looked refreshing.

The mailbox that the sports car the cops chased plowed into was crushed. (NP-DISC)

* The mailbox, that the sports car chased was crushed.

The rowdy kids that the scout leader that the bees stung had punished were misbehaving. (VP-DISC)

* The rowdy kids that the bees stung for misbehaving was punished.

Expt 3, auditory sentence recall: Results

- * Main clause usually recalled, regardless of the prosody.
- * More VPs omitted than NPs, regardless of the prosody.
- * Middle-level clause (upper RC) shows worst recall, mostly due to omission of VP2 (not attributable to omission of its subject NP2). A version of the **Missing-VP effect**. 😊
- * Overall, VP-DISC performed better than ENC. (Unexpected!) 😞

Why? We speculate: The pause between VP1 and VP2 is unnatural linguistically, but would have advantages for memory: Gives time to process VP1. Protects VP2 against any confusion with VP1. And VP3 is final, so very salient, so odd phrasing of VP3 does little damage.

- * In general, the data support the role of prosody in processing 2CE-RC sentences, but perhaps not the ideal task after all.

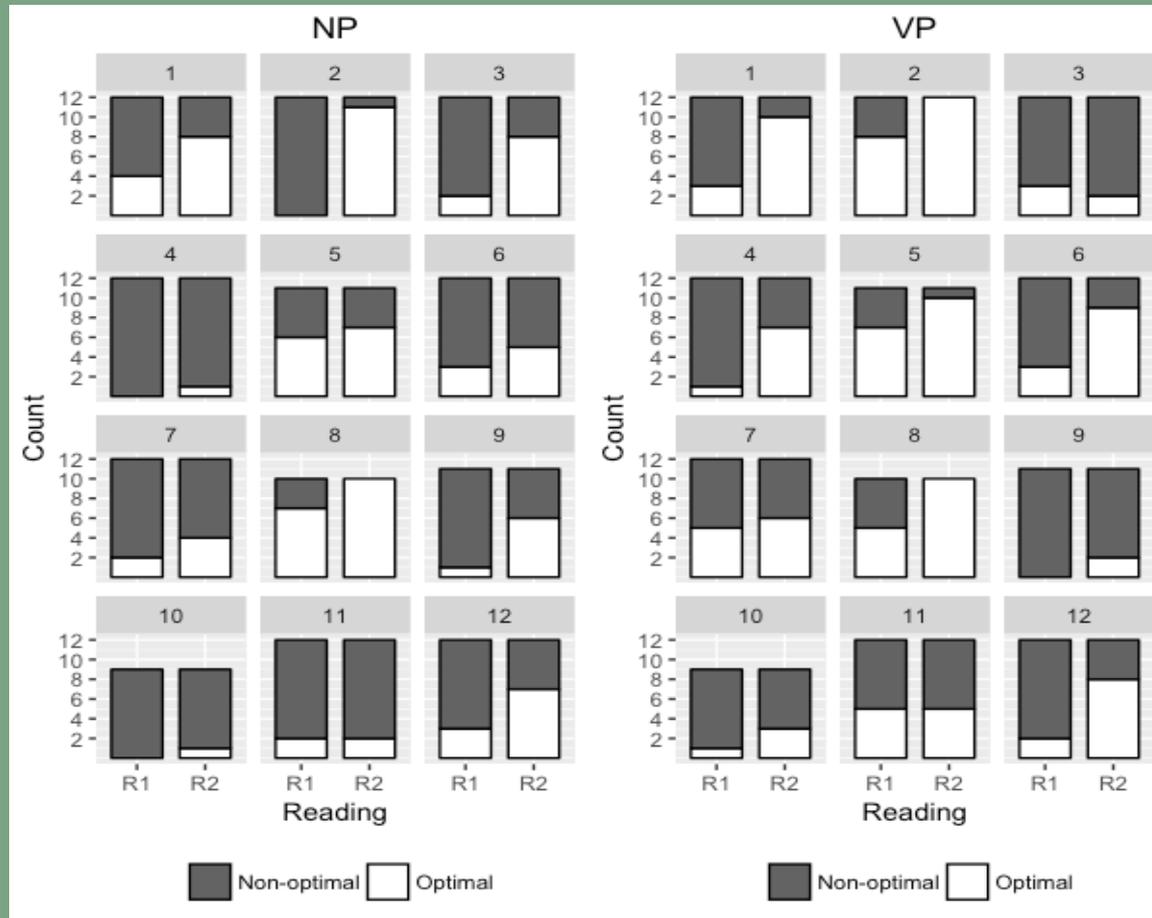
Experiment 4: Double reading methodology

- * Fodor, Macaulay, Ronkos, Callahan & Peckenpaugh (2019). Center-embedded sentences: An online problem or deeper?
- * Expert judgments of the naturalness of participants' reading pronunciation, with or without preview.
- * **Visual input:** All test sentences had 6 phrases of medium length.
- * **Task:** First, read aloud without preview. (A timer checks no cheating.) Instruction: "Don't worry if it doesn't come out right". Then read it a second time "the way you think it ought to be pronounced".
- * **Hypotheses:** Errors are likely in the first 'cold' reading. Would confirm that 2CE-RC phrasing is not typical of 'normal' prosody/syntax alignment.
- * This second reading might reveal that (some!) English speakers do have prosodic competence that facilitates 2CE-RC parsing.



Expt 4 (double reading) – results

Expert judgments of naturalness of reading pronunciation, for Reading-1 and Reading-2. By subject, 12 items.



Double reading - % natural produced prosody

* Means: NP sequence: R1 **22%** R2 **51%**

VP sequence: R1 **31%** R2 **69%**

So: preview does help.

* However: **Extreme individual differences**

Some Ss recognized the natural phrasing quickly.

Others barely arrived at it by 2nd reading, or not at all.

* E.g., participant 2: [NP] R1 **0** → R2 **92**

[VP] R1 **67** → R2 **100**

* But participant 11: [NP] R1 **17** → R2 **17**

[VP] R1 **42** → R2 **42**

Seeking explanation

- * The extreme (laughable!) awkwardness of 2CE-RC sentences disappears when prosody/syntax alignment is achievable.
- * So it is not attributable to the recursive syntactic structure.
- * Nor to excessive memory load. Nor to low corpus frequency....
- * Does it imply separate evolutionary paths for syntax and phonology?
- * Or just different practical needs for syntax (hierarchical) and phonology (linear)?
- * How do other languages cope with it? Is it peculiar to English?
In some other languages (French, German, Korean, Japanese, Turkish) 2CE-RC constructions have been described as complex, not typical of everyday chat, but also not out of bounds of normal comprehension. Can you confirm?
- * So –

OVER TO YOU !

Your ideas?

Your language?

Thank you!