Boundary Strength Scaling

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Duration and Boundary Strength

(1) a. ((Steve or Sam) and Bob) will come.
b. (Steve or (Sam and Bob)) will come.

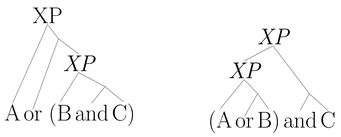
- Lehiste (1973, 117) found that duration (among other correlates) disambiguates (1a,b).
- Prosody often disambiguates attachment ambiguities (Wightman et al., 1992; Price et al., 1991; Schafer et al., 2000; Carlson et al., 2001; Snedeker and Trueswell, 2003; Kraljic and Brennan, 2005, ...)

(2) Cues for Boundary Strength:
a. Initial Strengthening (Keating, to appear, and references therein)
b. Pitch Accent Scaling (Ladd, 1988)
c. Presence/Absence of intonational boundary (Watson and Gibson, 2005, and references therein)
d. **Final Lengthening**

Boundary Strength and Syntax

Perceived boundary strength relates to syntax:

(3) Right-Branching vs. Left-Branching
a. Right-Branching b. Left-Branching



Price et al. (1991); Carlson et al. (2001); Clifton et al. (2002); Keating (to appear); Wagner (2005a,b): prosodic disambiguation by making boundaries *relatively* stronger or weaker.

(4) **Anti-Attachment (Watson and Gibson, 2005):** Listeners prefer not to attach an incoming word to a lexical head that is immediately followed by an intonational boundary.

This can be generalized (cf. Wagner, 2005a):

(5) **Hypothesis about Attachment and Prosody (HAP)**: In a sequence $A \prec B \prec C$, if the boundary separating A and B is weaker than the one separating B and C, then $[AB]C]$, if it is is stronger, then $[A[BC]]$.

What is the exact model that predicts the correct lengthening effects?

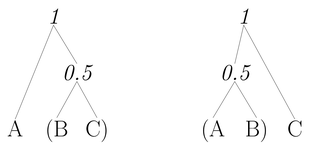
Modeling Relative Duration

Intuition: Proportional Model

Within a coordinate structure, all coordinates are prosodically on a par. Idea: Relative Duration reflects proportional ratio of entire structure.

Simple Proportional Model

(6) Coordinate Structures
a. Right-Branching b. Left-Branching



(7) Predictions for Coordinate Structures

							A	B	C	D
1	A	or	B	or	C	or	D	1/4	1/4	1/4	1
2	A	or	(B	and	C)	or	D	1/3	1/6	1/6	1/6
3	A	or	B	or	(C	and	D)	1/3	1/3	1/6	1/6
4	(A	and	B)	or	C	or	D	1/6	1/6	1/3	1/3
5	(A	and	B)	or	(C	or	D)	1/4	1/4	1/4	1/4
6	(A	and	B	and	C)	or	D	1/6	1/6	1/6	1/2
7	A	or	(B	and	C	and	D)	1/2	1/6	1/6	1/6
8	((A	or	B)	and	C)	or	D)	1/8	1/8	1/4	1/2
9	(A	and	(B	or	C))	or	D	1/4	1/8	1/8	1/2
10	A	or	((B	or	C)	and	D)	1/2	1/8	1/8	1/4
11	A	or	(B	and	(C	or	D))	1/2	1/4	1/8	1/8

Where the Simple Model Fails

(8) Same ratios, but different prosodies:

A or B or C or D
1/4 1/4 1/4 1/4

vs.

(A and B) or (C and D)
1/4 1/4 1/4 1/4

→ Conjunct B has ratio 1/4, but in fact it is lengthened more than A or C.

Idea:

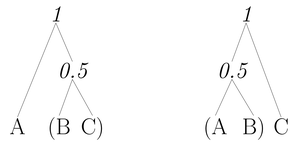
More lengthening after B since the boundary **ends/precedes** a constituent of ratio 1/2

→*Boundary-Based Proportional Model.*

Boundary-Based Proportional Model

Boundary reflects ratio of biggest constituent that ends/begins at that boundary.

(9) Coordinate Structures
a. Right-Branching b. Left-Branching



(10) Predictions for Coordinate Structures

							A	B	C	D
1	A	or	B	or	C	or	D	1/4	1/4	1/4	?
2	A	or	(B	and	C)	or	D	1/3	1/6	1/3	?
3	A	or	B	or	(C	and	D)	1/3	1/3	1/6	?
4	(A	and	B)	or	C	or	D	1/6	1/3	1/3	?
5	(A	and	B)	or	(C	or	D)	1/4	1/2	1/4	?
6	(A	and	B	and	C)	or	D	1/6	1/6	1/2	?
7	A	or	(B	and	C	and	D)	1/2	1/6	1/6	?
8	((A	or	B)	and	C)	or	D)	1/8	1/4	1/2	?
9	(A	and	(B	or	C))	or	D	1/4	1/8	1/2	?
10	A	or	((B	or	C)	and	D)	1/2	1/8	1/4	?
11	A	or	(B	and	(C	or	D))	1/2	1/4	1/8	?

Predictions for Last Constituent

- If lengthening reflects ratio of constituent *preceding* boundary, then factor should always be 1—¿ last constituent should always be extremely long.
- If lengthening reflects ratio of constituent *following* boundary, then no prediction.

Experiment

Experiment 1: 4 subjects (all linguists) recorded in dialogue between subject and experimenter:

(11) Recorded Dialogue:
Who will solve the problem first?
Morgan and Joey are working together.
Norman is working on his own. and so is Ronny. So one of the following will solve it first:
Morgan and Joey or Norman or Ronny.

Dependent Variable:
$log(\frac{duration}{normalized\ average\ duration})$.

Simple vs. Boundary Model

Regression Analysis:

- Simple Model: $R^2 = 0.32$, $p < 0.001$
- Boundary Model: $R^2 = 0.73$, $p < 0.001$; (no additional effect by simple model)

[Experiment II on subset of 6/11 structures, dialogue between naive subjects, much lower N by item and subject, $R^2 = 0.03$ (simple model) *vs.* $R^2 = .10$ (Boundary model), $p < 0.001$ for both]

- Unsurprisingly, the Boundary model outperforms the simple model.
- How about non-proportional model like LRB?

Boundary Model *vs.* LRB

LRB Model (Watson and Gibson, 2005): Probability of Boundary depends on size of constituents adjacent to boundary.

Model adapted to make quantitative predictions: Adding together the size of adjacent constituents gives estimate of boundary strength. (size: number of phonological phrases, in our experiment 1 for each proper name)

Variation in length of first three conjuncts:

- LRB Model: $R^2 = 0.69$, $p < 0.001$.
- Boundary Ratio Model: $R^2 = 0.73$, $p < 0.001$; (marginal additional effect of LRB model)

- Boundary also outperforms non-proportional LRB Model, the combined model (multiple variation) has $R^2 = 0.81$. (More Discussion of LRB see Wagner (2005b)

Boundary Strength Scaling

- A proportional model means that boundaries are scaled relate to each other (Price et al., 1991; Carlson et al., 2001; Clifton et al., 2002; Keating, to appear; Wagner, 2005a,b).
- This makes predictions about production/perception about boundary strength if the relative lengthening of constituents is manipulated.
- Testing these predictions is part of a on-going research project.

The Last Constituent

Predictions:

- LRB Model: No variation, length is always = 4, i.e. high degree of lengthening.
- Boundary Ratio Model: At least under one version, always high degree of lengthening.
- Simple Model: Variation according to ratio of constituent.

Results

- Simple Model: $R^2 = .53$, $p < 0.001$

- For final constituent, simple model works best
- Maybe because final constituent length redundant since there is a one-to-one mapping between ratios and syntactic trees excluding the ratio of last constituent.

Further Question on Last Constituent

- We tested *duration* of the actual names, but not the duration of a following pause.
- In fact, after the last constituent, we could not measure the length pause.
- Question: Does Pause after final constituent reflect stronger boundary?
- ...so are duration and pause, although often otherwise contributing to the same percept, really different, at least in final position?

Further Question on Proportional Model

- Does incremental production (e.g. time pressure vs. no time pressure) give evidence for relative boundary strength scaling?
- Does manipulation of relative duration change perception of boundary strength in the predicted way?
- What about acoustic parameters other than duration?

We are currently building a parser based on proportional model, together with John Kraemer (MIT), (Wagner et al., 2006).

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