

Prosodic Balance

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Recent psycholinguistic experiments on prosody emphasize the role of syntax and semantics as necessary and sufficient influence factors on prosodic phrasing. The audience oriented, situationally dependent models stress the role ambiguity avoidance in prosodic phrasing (Snedeker and Trueswell, 2003). The model of situationally independent prosodic phrasing (Speer, Warren and Schafer, 2011) argues that break locations are tied to grammatical constraints (in particular the syntactic constraints) independent of the need to disambiguate. Finally, Breen, Watson and Gibson (2011) argue that intonational phrasing is constrained by meaning, not by balance.

In spite of these experimental results, phonological experience shows that speakers exhibit a tendency to produce prosodic phrases of comparable form and size (Fodor, 1998; Wang and Hirschberg, 1992). In cases of Neologistic Jargon Aphasia (Marshall, 2006), where neither structure, nor meaning, nor audience demands underlie prosodic choices, speakers produce fluent and almost perfectly balanced prosody. Recent computational simulations of prosodic phrasing (Tilsen, 2011) also predict strong preference for “regular” patterns in the planning of speech.

In this contribution we propose a computational definition of prosodic balance and we test it on a richly annotated speech corpus. The prosodically annotated part contains at the moment ca. 18000 words in ca. 1100 sentences, which have been parsed by a state-of-the-art LFG parser and manually annotated with labels for information status and prosody.

Prosodic, syntactic and semantic information were combined in a relational database, which links all the analyses at word level. We present the results of two simulations that we conducted on this database. The simulations were carried out on 34843 syllables of which 4002 were followed by a prosodic phrase boundary (ToBI labels X-, X%).

In our first simulation, a logistic regression model was fitted to predict the presence of a phrase boundary after each syllable. For examining prosodic balance, the number of pitch accents in each prosodic phrase was calculated and normalized by the number of syllables in the respective phrase (this is what we refer to as a **prosodic weight** of the phrase). For each consecutive syllable, the temporary prosodic weight (the prosodic weight the phrase would have if a boundary was realized immediately after the current syllable) was calculated. **Prosodic-weight-difference** was then defined as the difference between the weight of the preceding phrase (**prosodic-weight-previous**) and the temporary prosodic weight of the current phrase. The regression model controls several additional syntactic and phonological features, such as:

- number of syllables realized since the last prosodic boundary (syllables-in)
- number pitch-accents realized since the last prosodic boundary (accents-in)
- number of NP boundaries after the word containing the critical syllable (NP-ends)
- number of PP boundaries after the word containing the critical syllable (PP-ends)
- number of DP boundaries after the word containing the critical syllable (DP-ends)
- depth of syntactic embedding of a word containing the critical syllable (syntactic depth)

We found that both **prosodic-weight-previous** and **prosodic-weight-difference** were significant predictors for boundary placement, thus reflecting general balancing tendencies in the corpus.

In our second simulation, a linear regression model was fitted to predict the weight of each prosodic phrase. The model revealed the following significant predictors: **prosodic-weight-previous**, **syllables-in** and **syntactic depth**. The number of syllables and the weight of the prosodic phrase influences the weight of the

phrase to be produced; the greater the weight of the previous prosodic phrase, the greater the weight of the current one (Table 1). This subtle but significant correlation highlights the tendency of prosodic phrases to be balanced. Crucially, even when syntactic factors are controlled, prosodic balance still has a significant influence on intonational phrasing. This result runs against the hypotheses about prosodic phrasing drawn on recent experimental studies.

In order to disentangle the different results of a classical experiment (testing of behavior of native speakers in controlled production/perception experiments) and experience (computational models of behavior fitted to a richly annotated database) on prosodic balance, we designed a series of neurophysiological experiments. In particular, we recorded brain potentials from subjects processing temporarily ambiguous sentences that were prosodically balanced or non-balanced.

In these studies, we found that prosodic balance incrementally affects ambiguity processing: when an ideally balanced structure is not in accord with the intended reading, this conflict is reflected in a pronounced negativity on the disambiguating region. Crucially, this mismatch effect is able to override pure syntactic preferences as observed in experiments with prosodically neutral targets. These findings indicate that prosodic balance is immediately used for predicting the integration of upcoming constituents.

Taken together, our results add to previously conducted classical experiments in laboratory phonology by combining insights from computational modeling and neurophysiological studies. Our data suggest that prosodic balance is an important procedure to regulate propositionally organized language and speech.

Table 1: Coefficients of the linear regression model to predict the weight of a prosodic phrase.

	Estimate	Std. Error	Pr(> t)
(Intercept)	0.407	0.007	< 0.0001
<i>DP-end</i>	0.004	0.003	0.21
<i>PP-end</i>	-0.003	0.002	0.13
<i>NP-end</i>	-0.006	0.007	0.35
<i>prosodic weight prev</i>	0.050	0.014	< 0.0001
<i>syntactic depth</i>	-0.004	0.001	< 0.0001
<i>syllables-in</i>	-0.012	0.000	< 0.0001

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