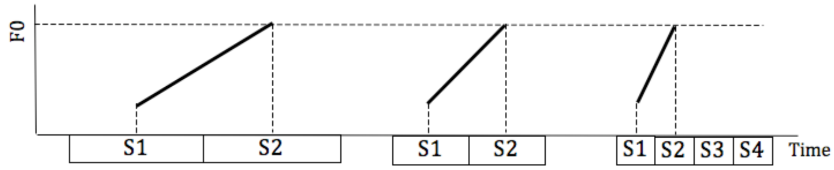
Cross-linguistic applications of a weighted constraint model of F0 movements

This paper investigates the question of what determines F0 movements: pitch targets, or shape of a rise or fall, or some combinations of these. In the level-target approaches, the F0 movements are described with level targets such as L and H (e.g. Pierrehumbert and Beckman 1988). Under this view, shapes of F0 movements (i.e. slope, duration, excursion size) are the results of interpolating between these level targets. The targets are aligned with segmental landmarks ("the anchors"), and the alignment is stable and not affected by speech rate or syllable structure ("Segmental Anchoring Hypothesis (SAH)", Arvaniti et al. 1998, Ladd et al. 1999). On the other hand, F0 movements have also been described in terms of their shape. If shape is the primary determinant of intonation, shape must be relatively stable under changes in other conditions ("Constant Shape Hypothesis (CSH)"). The two views seem inconsistent, because under changes in speech conditions such as speech rate, if segmental alignment is to be kept, the shape will change (Fg.1); as speech rate increases, rise time decreases and slope gets steeper. If shape is to be kept, the alignment will be violated (Fg.2); the peaks are found later relative to the anchor at a fast rate, and earlier than the anchor at a slow rate.

In Cho (2007), we tested the two hypotheses with Seoul Korean. Seoul Korean is a good language to test conflicting hypotheses that make contradictory predictions on F0 peak alignment patterns because it does not have lexical tones, and thus peak alignment is relatively flexible. We found both effects of the SAH and CSH on the timing of the initial rise peak in the Seoul Korean LHLH intonation pattern. Timing of peaks ("H") was linearly correlated with timing of segmental anchors ("A"), which is the effect of the SAH (Fg.3). There was also evidence for the existence of a target *rise time* ("R", the time that it takes to complete a rise from L to H). That is, when speech rate was fast, the peaks were found later than the anchor; when speech rate was slow, the peaks were found earlier than the anchor (Fg.4), as the CSH predicts. Since effects of both the SAH and the CSH are observed, the proposed model of peak timing takes these two factors as interactive terms. Instead of treating the two hypotheses as inviolable principles, we treat the two factors as interacting terms in the proposed model of F0 peak timing, by using weighted constraints (Flemming 2001) ([1]). Conflicting constraints require that the H peak be aligned to the anchor (H=A), and that the rise from L to H occupy a target duration (H=R). The actual H peak timing is the time that minimizes the summed cost of violations of the alignment target and the rise time target. In the current study, we also include the alignment constraint on L in the model.

Building on this finding, we test the hypothesis that both alignment constraint and shape constraint exist in a language and cross-linguistic differences can be captured by relative weights on the alignment and shape constraints. We conducted experimental studies of Mandarin (lexical tone language), Tokyo Japanese (pitch accent language), English (lexical stress language), in addition to Seoul Korean (phrasal tone only). In all these languages, the timing of the word-initial rise peak with regard to a segmental position was examined. We observed a cross-linguistic tendency that H peaks occurred relatively later at faster rates than at slower rates, which supports the existence of both shape and alignment constraints. However, the amount of variations in peak timing varied in different languages, e.g. Mandarin showed a more consistent alignment pattern than Korean. Such cross-linguistic differences can be explicable in terms of the weights of the alignment constraint across languages.

Figure 1. The prediction of the SAH (Segmental Anchoring Hypothesis)
(a) Slow (b) Normal (c) Fast



*The anchor is assumed to be in the middle of the associated syllables.

Figure 2. The prediction of the CSH (Constant Shape Hypothesis)
(a) Slow (b) Normal (c) Fast

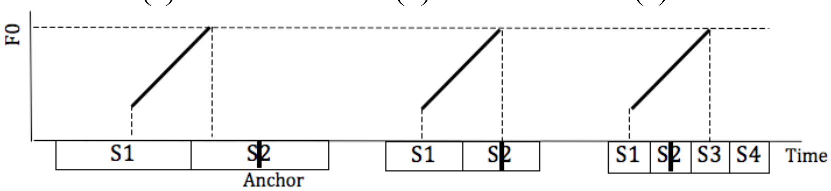


Figure 3. The effect of the SAH

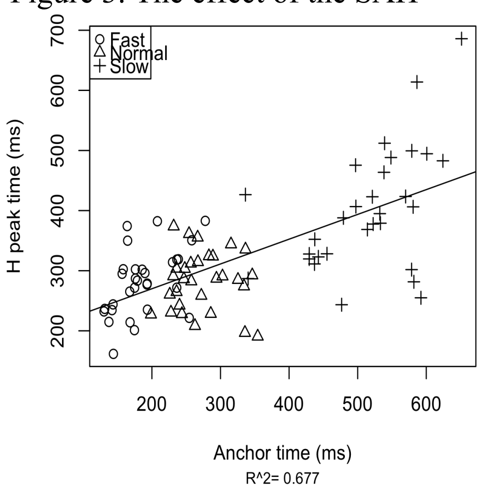
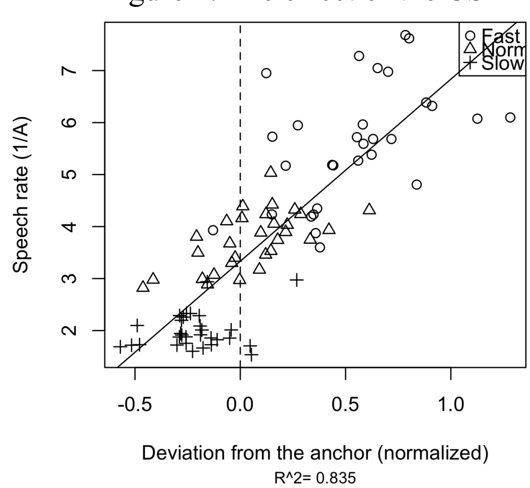


Figure 4. The effect of the CSH



(1) $H_0=\text{ArgMin}[w_A(H-A)^2+w_R(H-R)^2, H]$

H_0: actual timing of H, given A and R
A: the anchor, alignment target
R: the rise time target
w_A,w_R: positive weights

H: timing of H
H-A: Deviation from A
H-R: Deviation from R

Selected References

Arvaniti, A., R. Ladd, and I. Mennen (1998) Stability of tonal alignment: the case of Greek prenuclear accents. *Journal of Phonetics*, 26, 3-25.

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