Perception of Differences in Tonal Alignment Depends on Location Relative to the Nucleus-Coda Boundary

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Tonal alignment is the timing of f0-contours in relation to speech segments. Although tonal alignment was long thought not be the primary correlate for any linguistic contrast (*e.g.* Yip 2002), recent research shows that systematic variation in tonal alignment is contrastive in some languages (*e.g.* Remijsen 2013, DiCanio *et al.* 2014). Perceptual studies indicate that the minimum perceptible difference in alignment may be about 50 ms (House 1999). Production data from some languages that use tonal alignment for phonemic contrasts, namely Dinka (Remijsen 2013) and Shilluk (Remijsen & Ayoker 2014), indicate that the differences in alignment can be smaller: around 40 ms for category means. How can listeners perceive such small differences in phonetic implementation? How perceptually sensitive to differences in tonal alignment are listeners? We hypothesized that listeners of Shilluk would be very sensitive to differences in tonal alignment, and that they would demonstrate *categorical* perception, while listeners of control language Spanish would demonstrate *continuous* perception. A first forced-choice discrimination experiment contained pairs of synthesized stimuli, all with falling contours on the same CVC nonsense word. Each stimulus within a pair diverged equally from a given anchor point, at the start of the vowel (0 ms), slightly into the vowel (30 ms), or towards the end (80 ms) of the vowel with a duration of 150 ms (Figure 1). Crucially, the middle anchor point is at the estimated phonemic boundary between the Shilluk *early*-aligned high-to-low falling contour, and the *late*-aligned high-to-low fall.

This first experiment shows, firstly, neither L1 Spanish, nor L1 Shilluk listeners are very sensitive to differences in tonal alignment: only gaps as large as 80 and 90 ms could be reliably perceived. Such poor discrimination is unexpected for the Shilluk listeners, given the smaller alignment differences in speech production and the reliable identification reported by Remijsen & Ayoker (2014). Secondly, perceptual sensitivity to differences in tonal alignment is found to increase the later the location of the alignment in the nucleus/vowel. On average, Spanish and Shilluk listeners both perceive differences in tonal alignment *continuously* if only the alignment of the fall is manipulated (Figure 2). This result was unexpected for the Shilluk listeners: the presence of contrastive tonal alignment in their L1 phonology suggests it would be categorical. This might be explained by hypothesizing the loss of this feature in the variety of Shilluk spoken in Khartoum, but there is no independent evidence for this.

A second forced-choice discrimination experiment was conducted to test whether the presence of a nucleus-coda boundary would yield a different perception pattern for L1 Shilluk participants. The nonsense word in Experiment 2 had a short vowel of 70 ms, resulting in the late anchor point at 80 ms occurring in the coda (Figure 3). While the anchor point at 80 ms into the rhyme had been *most* sensitive when it occurred during the nucleus/vowel in Experiment 1, it was found to be *least* sensitive when it extends into the coda (Figure 4). These findings are in line with the Spectral Constraints Hypothesis (House 1990), which states that perceptual sensitivity to tonal alignment is lowest right after segment boundaries, as the spectral changes temporarily impede perceptibility of tone movement. Although questions remain regarding the exact definition of alignment (*cf.* Schepman *et al.* 2006, section 5), the present study clearly demonstrates that the presence of the nucleus-coda boundary changes the perceptibility of the stimulus pairs of the late anchor point condition. These findings suggest that defining tonal alignment simply in relation to the onset of the vowel does not accurately reflect the way it is perceived.

References

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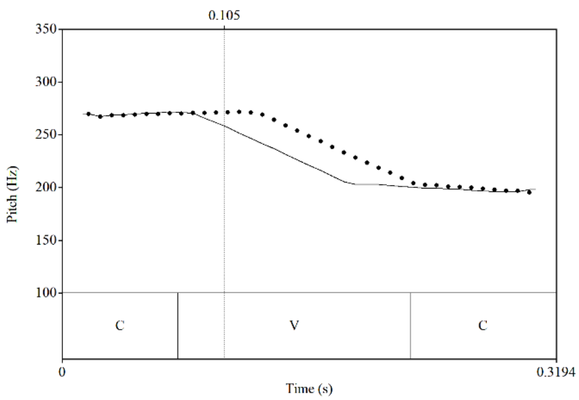

Figure 1: Example of a stimulus pair with a gap of 40 ms in the middle anchor point condition (30 ms into the vowel) of a word with a long vowel of 150 ms as in Experiment 1.

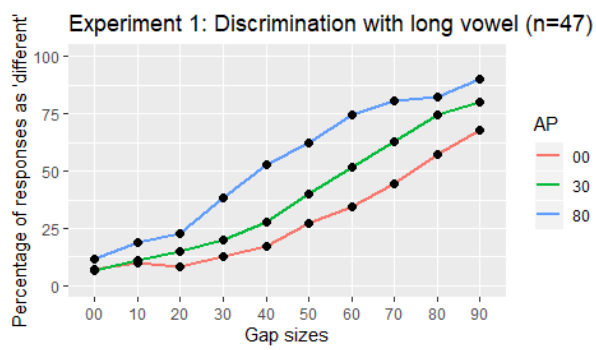

Figure 2: Percentage of responses as 'different' per gap and anchor point (AP) condition for a nucleus duration of 150 ms (n=47).

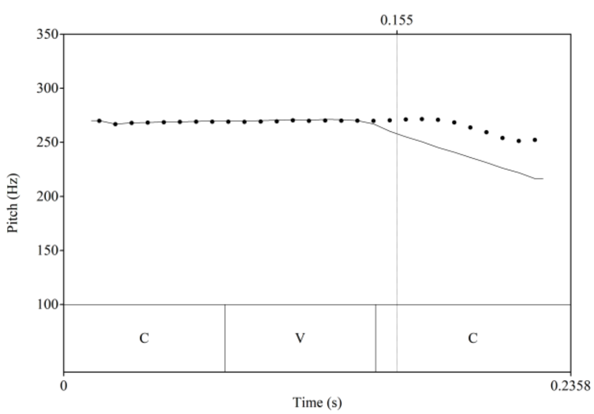

Figure 3: Example of a stimulus pair with gap 40 ms in the late anchor point condition (80 ms into the vowel) of a word with a short vowel of 70 ms as in Experiment 2.

Figure 4: Percentage of responses as 'different' per gap and anchor point (AP) condition for a nucleus duration of 70 ms (n=22).