Velum-oral timing and its variability in Korean nasal consonants

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Introduction. Previous studies on intergestural timing have generally focused on its systematic variability across contextual variations [1, 2]. However, when it comes to timing between gestural units that comprise a segment, we hypothesize that such intergestural timing exhibits largely fixed timing relations due to its tight coupling structures, i.e., that it is less malleable due to prosodic variations. To investigate this, we examine how the velum and oral gestures in nasal consonants are temporally coordinated. Variability in intergestural timing can be induced by contextual influences including focus, phrase boundaries, or speech rate; yet types of syllable structure and the temporal constraints on the formation of nasal consonants—requiring nasal airflow during oral closure—can render intergestural timing of nasals inelastic to a certain degree. For example, intergestural lag is more stable within a segment than the lag between similar gestural sequences across segments [3]. Moreover, intergestural timing may vary systematically in its temporal alignment when that timing is the basis of segmental contrast [4]. We evaluate this multi-faceted temporal coordination of gestures in several Korean nasal sequences.

Method. Real-time Magnetic Resonance Imaging speech production data of the midsagittal vocal tract (with a temporal resolution of 12ms/frame) was acquired from five Korean speakers. Target items were syllable-onset nasals (/#n/), coda nasals (/n#p/, /n#t/), and juncture geminate nasals (/n#n/) across three boundary/focus conditions (Wd, AP, & AP+focus; 7/8 reps each). Gestural landmarks (onset, target, & release) for the Velum (VEL) gesture were computed from the kinematics of velum centroids using tangential velocity (Fig 1) [5]. Tongue Tip (TT) gestural actions were determined by region-of-interest image sequence analysis [6]. Velum-to-Tongue-Tip intergestural lags are indexed as intervals between the two gestures' temporal landmarks: i) the interval from the VEL lowering onset to the TT onset (onset lag) and ii) the interval from TT onset to VEL raising onset (o-r lag). The former indicates how the two gestures are phased relative to each other, and the latter serves as an articulatory index of nasality. Results for gestural lags were analyzed using linear mixed effects models, and Levene's tests were used for comparing variances.

Results & Discussion. Initial data analysis for four speakers indicates that onset lags in coda (including concatenated nasals at a morpheme juncture) and singleton onset nasals are similar—the velum lowers before TT constriction formation begins (Fig 2a), with onset nasals showing greater timing variability overall (Fig 2c). On the other hand, singleton onset nasals have shorter o-r lags (near-zero lag) than coda and geminate nasals (Fig 2b,d). There is also large individual variation in the o-r lag for onset nasals. In addition, while onset nasals have shorter and smaller velum lowering than coda nasals, no such distinction is found between coda nasals and geminate nasals. Findings on velum actions in nasals suggest that the nasality is weakened in the onset position, and the process of nasal weakening may create comcomitant greater variability. This study of intergestural timing under prosodic variations reveals articulatory grounding for phonological phenomena commonly observed in Korean such as denasalization or nasal weakening. In sum, intergestural timing is not merely a function of contextual overlap and variation, but rather intrinsic to the representational specification for these segment-sized gestural molecules combined with their syllabic structural properties.

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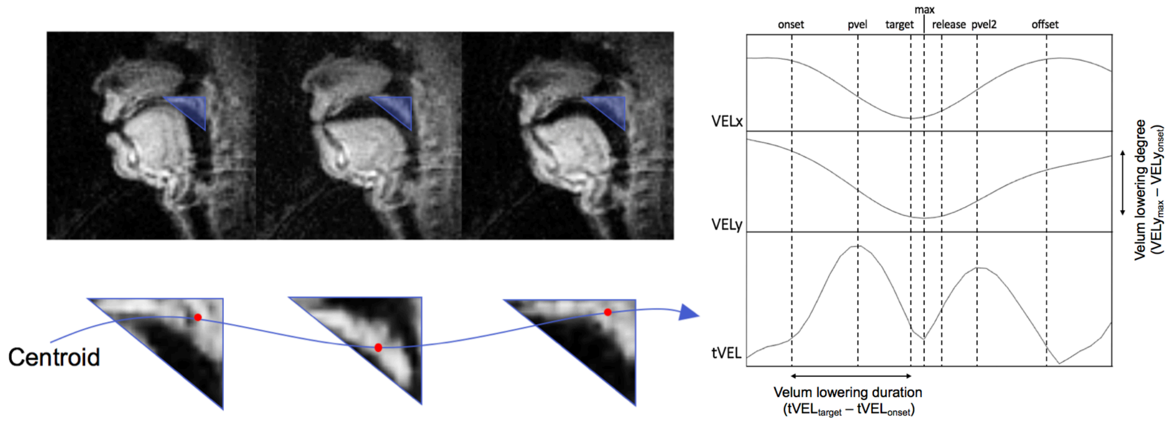

Fig 1. *Velum centroid tracking in real-time MRI image (left); Velum trajectories (VELx & VELy), tangential velocity (tVEL), and temporal landmarks (right)*

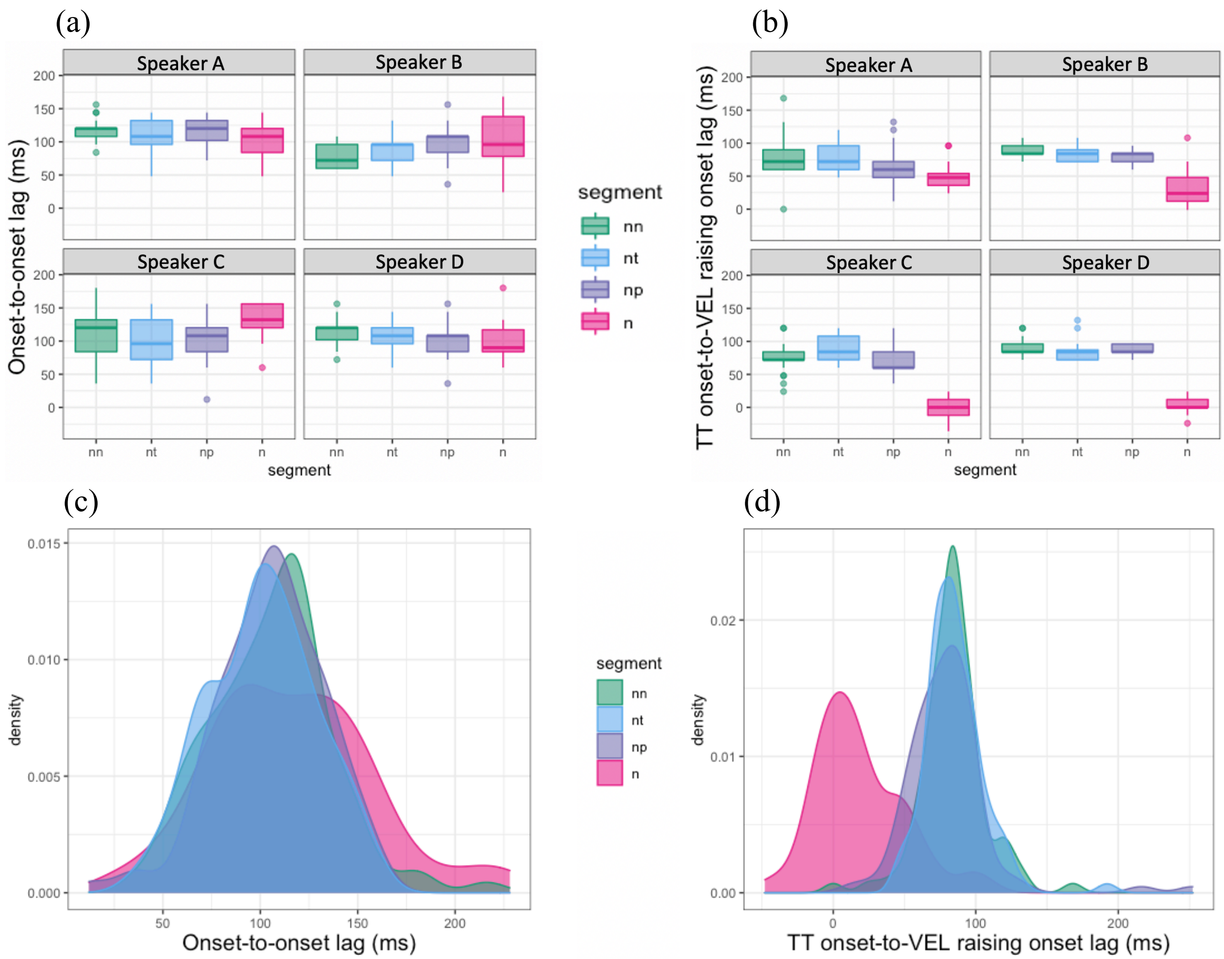

Fig 2. *Intergestural lags (onset lag (a) & o-r lag (b)) and their density plots (onset lag (c) & o-r lag (d))*

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