A TEMPORAL INVESTIGATION OF NASALIZATION AND VELOPHARYNGEAL PORT OPENING

Youkyung Bae1, David Kuehn2, Charles Conway3, & Bradley Sutton3

1 Department of Special Education/Communication Disorders, New Mexico State University
2 Department of Speech and Hearing Science, University of Illinois at Urbana-Champaign
3 Department of Bioengineering, University of Illinois at Urbana-Champaign

INTRODUCTION

Although perceptual salience of oral-nasal resonance imbalance is influenced strongly by the amplitude domain of nasalization (Jones, 2000), literature has shown that the temporal domain of nasalization can also present unique features in relation to hypernasal speech. For example, Kuehn (1976) suggested that uncoordinated timing of the velopharyngeal closure in relation to other articulators may result in hypernasal speech. The timing features would become more critical when individuals cannot achieve normal resonance with adequate velopharyngeal closure (Zajac & Hackett, 2002). Given that approximately 20% of individuals with repaired cleft palate suffer from residual velopharyngeal incompetence (VPI) (Furlow, 1986), a thorough understanding of the timing patterns of the velopharyngeal mechanism is needed. Previous temporal investigations using aerodynamic and acoustic methods suggested that hypernasal speech may be overall characterized by prolonged nasal airflow and lengthened nasalized duration (e.g., Warren et al., 1993; Jones, 2000; Dotevall et al., 2001; Ha et al., 2004). As indirect measures do not provide direct visualization of the velopharyngeal region, however, many physiologic assumptions and inferences had to be made to interpret aerodynamic and acoustic phenomena in relation to the velopharyngeal status. Thus, there is a strong need to bridge physiologic timing information with findings obtained through the indirect measures.

Magnetic Resonance Imaging (MRI) techniques have recently become popular in speech research, providing information on vocal tract geometry and specific muscle configurations. MRI techniques, however, have been confined to imaging relatively static postures due to the slow speed of image acquisition. In addition, most MRI speech studies largely lack simultaneous speech recordings and subsequent acoustic analyses due to the intense noise generated by the MRI scanner. A successful fast MRI application in conjunction with acoustic analysis was reported by Bae, Kuehn, Conway, and Sutton (2008) in examining the acoustic and physiologic relationships of the velopharyngeal mechanism. That study showed that the acoustic parameters of nasalization including F1 peak amplitude and F1 bandwidth could be reliably predicted by velar and tongue positional variables.

The present study focused on the temporal aspects of the velopharyngeal mechanism. More specifically, the relationships between the acoustic representation of nasalized durations and the physiologic representation of the midsagittal velopharyngeal port opening period were examined using fast MRI with the acoustic analysis method in normal individuals.

METHOD

A total of ten normal adult individuals participated in the study. Dynamic midsagittal MR images including a full view of the oral cavity and velopharyngeal region were obtained using a 3T Siemens Magnetom Allegra MR Headscanner (Siemens AG, Erlangen, Germany). The present study used the level of an effective sampling rate at 30 images per second, which is equivalent to the standard video frame rate and promising to trace articulatory transitional movements. The spatial resolution of the dynamic MR images was 1.875 ×1.875 mm.

While acquiring dynamic MRI data, speech signals were simultaneously recorded using a fiber optic microphone (Dual Channel-FOMRI, Optoacoustics Ltd., Or Yehuda, Israel). Speech samples consisted of repetitions of two nonsense syllables including /za na za/ and /zu nu zu/, which differed only in terms of their vowel compositions. From the collected speech signals, acoustic information (F1 peak amplitude and F1 bandwidth) was derived using the linear predictive coding analysis in the Matlab software (The MathWorks™, Natick, MA) at the rate of 30 sets per second.

All temporal variables were reported in the unit of frames as both acoustic and MRI data were anchored in the same sampling rate of 30 frames per second. Based on the changes detected in F1 peak amplitude and bandwidth traces, four acoustic temporal variables were measured in frames including nasal onset interval, nasal murmur duration, nasal offset interval, and total nasalization duration (sum of nasal onset interval, nasal murmur duration, and nasal offset interval). In a similar manner, four physiologic temporal variables were measured in frames including velar lowering interval, complete oral closure duration, velar elevating interval, and velopharyngeal port opening period (sum of velar lowering interval, complete oral closure duration, and velar elevating interval) based on the changes detected in velar
and tongue movements. Thus, a total of four acoustic-physiologic temporal pairs were compared in two different vowel contexts.

RESULTS

Results from a series of mixed model analyses with repeated measures showed that there were no significant differences found in all four acoustic-physiologic temporal pairs. Across all pairs, however, a significant main effect was found for the vowel context, in which low vowels yielded significantly lengthened durations in the velopharyngeal port opening period and nasalized duration compared to the high vowel context ($F_{(1, 25)} = 49.03; p < .05$). A similar pattern of lengthened duration in the low vowel context relative to the high vowel context was found in the other acoustic-physiologic pairs except for the pair of nasal murmur duration and complete oral closure interval. The pair of nasal murmur duration and complete oral closure interval exhibited an opposite pattern, in which high vowel context yielded longer durations than the low vowel context. No significant interactions were found between the vowel context and the type of measure (i.e., physiologic or acoustic); however, velopharyngeal port opening periods were longer than acoustically nasalized durations in nine out of ten participants for the low vowel context.

DISCUSSION

The present study demonstrated the feasibility of fast MRI applications in studying the spatio-temporal aspects of the velopharyngeal mechanism along with acoustic analysis. Findings from the study suggested that the acoustic phenomenon of nasalization is very likely associated with the midsagittal physiologic phenomenon of velopharyngeal port opening in the temporal domain. Significantly lengthened timings of the velopharyngeal port opening and nasalized duration were observed in the low vowel context, which is consistent with previous temporal investigations (Bae, Kuehn, & Ha, 2007; Engelke, Bruns, Striebeck, & Hoch, 1996; Kuehn, 1976). It appeared that the low vowel context would require greater amount of velar excursion and longer velopharyngeal port opening period to achieve acoustic nasalization. It is likely, however, that the acoustic output of nasalization for the low vowel context would not reflect the greater physiologic efforts, partly due to the relatively reduced oral impedance present. A more parsimonious control of the velopharyngeal mechanism, on the other hand, may be present in the high vowel context, in which the acoustic output of nasalization would be more efficiently yielded by introducing subtle changes in the velopharyngeal port opening with shorter duration. Further studies are needed to examine how structural or functional deviations of the palatal region in the spatio-temporal domains are related to their acoustic consequences in individuals with varying degrees of velopharyngeal incompetence.

REFERENCES


