The impact of stimulated vocal loudness on nasalance in dysarthria

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2 authors:

Monica Mchenry
New York Medical College

Julie M Liss
Arizona State University

The Impact of Stimulated Vocal Loudness on Nasalance in Dysarthria

Monica A. McHenry, Ph.D.

Department of Communication Sciences & Disorders
University of Houston, Texas

Julie M. Liss, Ph.D.

Department of Speech and Hearing Science
Arizona State University, Tempe

This study was designed to determine the effect of stimulated vocal loudness on nasalance in individuals with various dysarthria subtypes. Thirty participants produced three stimulated levels of vocal loudness while reading a nonnasal passage. Data included dysarthria classification, vocal sound pressure level, nasalance, and listener perception of nasality. There was not a predictable relationship between a change in vocal sound pressure level (SPL) and a change in nasalance, nor did these changes result in consistent perceptual results. There were, however, dysarthria-specific effects of stimulated vocal loudness on nasality. Further, the study highlighted the importance of corroborating objective data with perceptual findings.

A key component of dysarthria management is the behavioral manipulation of variables that may improve intelligibility. Because patients may have difficulty remembering and carrying out multiple cues to improve intelligibility (Yorkston, Beukelman, Strand, & Bell, 1999), it is ideal to find one feature that will dramatically impact all physiological systems. An example of this approach is the use of loud speech by individuals with hypokinetic dysarthria (Ramig, Countryman, Hoehn, & Thompson, 1996; Ramig, Sapir, Fox, & Countryman, 2001). Increasing vocal loudness has been shown to impact both segmental and suprasegmental aspects of speech production, as well as intelligibility, in some speakers with dysarthria (Ramig et al., 1996; Ramig et al., 2001). However, it remains to be determined whether such strategies differentially affect the various physiological subsystems of speech production. This question is of certain clinical import because occasionally specific problems may account for a large proportion of the intelligibility deficit in a given speaker (Duffy, 1995; McHenry & Wilson, 1994).

Hypernasality is common in various types of dysarthria, secondary to weakness and/or incoordination of the muscles responsible for velopharyngeal port modulation. Behavioral treatments for improving hypernasality have been shown to produce small or modest improvements, while more dramatic improvements can be obtained through surgical or prosthetic management (Duffy, 1995; Karnell, Hansen, Hardy, Lavelle, & Markt, 2004; Yorkston et al., 1999). Unfortunately, invasive procedures are appropriate in only a small proportion of patients; therefore, behavioral intervention is often the only option (Duffy, 1995; Kuehn et al., 2002).

An earlier study (McHenry, 1997) revealed that a stimulated increase in vocal loudness (e.g., verbally encouraging the production of louder-than-normal speech) resulted in reduced velopharyngeal orifice area in many individuals with motor speech disorders. In that work, 89% of 28 participants with traumatic brain injury decreased velopharyngeal orifice area when increased vocal loudness was stimulated. This finding has intuitive appeal with

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regard to dysarthria, wherein underlying muscular weakness contributes to inadequate velopharyngeal function. However, there were limitations to the earlier study that prevented a generalized interpretation of the results. First, participants were not classified according to dysarthria type. Because the hypernasality occurs in the setting of other dysarthria-specific speech symptoms, it is likely that increased vocal loudness is not uniformly beneficial across all dysarthria subtypes. Second, data in the original study did not include vocal sound pressure level, thus the precise relationship between loudness and velopharyngeal orifice area could not be determined. Although increasing vocal loudness is believed to be an essential feature for obtaining generalized physiologic changes that improve speech production, there is likely a nonlinear relationship between loudness level and speech production measures. Finally, while there is a good relationship between nasalance scores and perceptual judgments of nasality in both individuals with cleft palate (Hardin, Van Demark, Morris, & Payne, 1992) and those with neurogenic etiologies (McHenry, 1999), the relationship between perception of nasality and velopharyngeal orifice area is less clear (McHenry, 1999; Thompson & Murdoch, 1995).

This study was designed to determine the effect of varying vocal loudness on nasalance. Based on the previous investigation, it was predicted that, in general, increased vocal loudness would be associated with lower nasalance values, and the perceptual impression of less hypernasality, as compared with the normal loudness condition. However, it was anticipated that dysarthria-specific patterns might emerge, in which speaking softer than normal would result in lower nasalance values, and the perceptual impression of less hypernasality than in the normal or increased loudness conditions. If found, these results would highlight the need for judicious application of vocal loudness interventions and hint at their contraindications for the treatment of hypernasality in certain clinical scenarios.

METHODS

Participants

Participant demographic data are presented in Table 1. Participants were 22 males and 8 females. Patients were recruited from a pool of individuals referred for a motor speech evaluation. Criteria for selection to the current study included

1. presence of dysarthria,
2. nasalance score of > 28 when reading the *Zoo Passage* at typical loudness (Dalston, Nieman, & Gonzalez-Landa, 1994),
3. hearing within normal limits based on screening,
4. ability to attend to the task and follow simple directions.

Participants included in the perceptual portion of the study also met the criteria of greater than a 10 unit reduction in nasalance between the normal condition and either the soft or loud condition

The investigators established dysarthria type by independently viewing and judging videotaped conversational speech samples of the participants. Differential diagnosis was based on salient features established by Duffy (1995), as well as the participant's etiology. In the case of mixed dysarthrias, the participants were classified by the predominant dysarthria type. When the investigators did not agree on an initial classification, a consensus was reached. A consensus was required for 10% of the samples.

Cutoff values for normal nasalance vary somewhat across investigations, with reported values of 28 (Dalston et al., 1994), 30 (Karnell et al., 2004), and 26 (Hardin et al., 1992). In this investigation, a cut-off of 28 was selected because it is within the range of typical cutoff values. The criterion of difference in nasalance scores of at least 10 units between conditions was based on the typically reported difference between normal nasalance (around 15; Watterson, York, & McFarlane, 1994) and mild nasalance (above the mid-20s; Dalston et al., 1993). The correspondence between nasalance and severity ratings varies across investigations and clinics, and nasalance scores may reflect language or dialectal differences (Dalston et al., 1993). Unit differences between levels of severity are typically 10 to 15 (Dalston & Warren, 1986; Fletcher, 1976), although the initial crossover value from normal to mild may differ. There are no clear data indicating what difference in nasalance is required for listeners to perceive a change in resonance, and clinicians have been encouraged to consider a range of values when interpreting a nasalance score (Dalston et al., 1993).

The mean age of the male and female participants was 35 (*SD* = 14) and 28 (*SD* = 10) years, respectively. Twenty-four participants incurred a severe traumatic brain injury. The etiology for the remaining 6 participants included 2 with cerebrovascular accident, 3 with anoxic events, and 1 with

TABLE 1. Demographic, nasalance, and sound pressure level (SPL) data.

Dysarthria Type	Gender/ Number	Age	MPI	Nasalance Normal	Nasalance Soft	Nasalance Loud	dB SPL Normal	dB SPL Soft	dB SPL Loud
Spastic	M1	23	33	62	65	56	78	78	81
	M2	24	9	51	49	43	89	83	109
	M3	67	10	29	26	50	64	62	68
	M4	45	78	58	53	77	89	88	98
	M5	24	84	45	41	75	70	62	78
	M6	53	31	43	36	42	63	56	64
	M7	21	18	45	48	47	71	70	73
	M8	19	57	48	43	49	66	61	69
	M9	43	5	36	31	32	83	79	84
	M10	23	26	42	46	37	67	63	69
	M11	40	9	56	54	56	77	77	80
	F1	39	24	49	42	60	71	65	76
	F2	18	7	41	48	49	84	82	87
Flaccid	M12	54	11	53	53	53	66	63	68
	M13	27	26	58	37	32	69	65	72
	M14	40	9	31	42	26	67	59	71
	M15	22	4	45	49	43	70	65	75
	M16	37	9	52	54	52	72	67	84
	M17	20	4	29	41	22	65	64	73
	M18	35	7	31	28	18	59	59	64
	M19	32	7	57	62	47	66	62	77
	F3	42	13	68	69	54	70	65	76
Ataxic	M20	20	44	73	73	74	77	73	85
	M21	47	11	33	33	38	64	62	67
	M22	56	2	39	47	34	64	62	77
	F4	21	24	32	25	47	64	61	68
	F5	22	5	37	28	49	62	59	66
Hypokinetic	F6	19	3	52	53	52	72	65	78
	F7	37	10	33	34	35	59	51	63
	F8	27	4	46	34	36	64	63	66

Note: MPI = months post injury. Sp, Fl, At, and Hyp = spastic, flaccid, ataxic, and hypokinetic dysarthria, respectively.

angioma. Mean months postinjury/onset was 24 (*SD* = 30) and 41 (*SD* = 10) for males and females, respectively.

Task and Instrumentation

Data were obtained during a comprehensive motor speech evaluation. While wearing the Nasometer II headset (Model 6400, Kay Elemetrics), the participants repeated the *Zoo Passage* after the examiner at one habitual and two stimulated loudness levels: soft and loud. For the habitual soft and loud conditions, respectively, the participants were instructed to repeat the passage "about as loud as you usually talk," "about half as loud as you usually talk," and "about twice as loud as you usually talk." The examiner modeled the target loudness level as the participant repeated the passage. If the participant did not demonstrate a perceptible change in loudness in the soft or loud conditions, respectively, they were instructed to repeat the passage "as soft as you can without whispering" or "as loud as you can without shouting, like this" (examiner model). Data were recorded on digital audiotape (Sony DCD-D3) using separate oral and nasal channels. DAT input settings were adjusted to allow maximum deflection for each loudness level. Sound pressure level was calibrated after data acquisition at 65, 70, and 75 dB SPL. If there were multiple settings per participant to allow for maximum deflection, calibration was performed at each setting. Data were edited using the Computerized Speech Laboratory (CSL 4300B, Kay Elemetrics) to delete the examiner's voice and pauses. Sound pressure level was calculated by inputting the calibration tones to CSL. At each dB value, the energy calculation function was applied. From the three values a linear regression was completed. The coefficient and constant were applied to the edited nonnasal passage to obtain the sound pressure level at each stimulated loudness level. The CSL was only used for editing (required because of examiner modeling) and calculation of dB SPL. The edited data were then input into separate oral and nasal channels of the nasometer for nasalance calculation.

Listener Perception

Audiotapes were made of the participants saying the first three sentences of the *Zoo Passage* (Kay Elemetrics, 1994). These sentences do not contain nasal consonants, which, when present, may serve to diminish the strength of correlation between nasalance and the perception of nasality (Watterson, McFarlane, & Wright, 1993). The normal condition and the condition in which the speaker produced greatest reduction in nasalance were selected for listener judgments. The conditions were paired randomly, and speakers were randomized as well. Presentation volume was constant within and across paired sentences. The listening session lasted approximately 30 minutes.

Listeners were 28 graduate students in the communication disorders program at the University of Houston. Stimuli were presented through speakers in a quiet classroom, with 30 seconds between the presentation of the stimulus pairs. Using a forced-choice response format, the listeners were instructed as follows: "You will hear paired samples of sentences. Circle the set you perceive as being *more* nasal." Intra-judge reliability was determined by replaying 20% of the sample, with the repeated sentences randomly inserted in the listening set. Intra-judge reliability was considered adequate for inclusion if at least 75% of the repeated sentences were judged the same. Thirteen of 28 judges achieved this level of reliability. The judgments from the remaining listeners were excluded.

RESULTS

Nasalance/SPL Change

Because of the very wide range of nasalance values within and across loudness conditions, averaged data are not meaningful. Further, statistical analyses are not appropriate because of the small and unequal number of participants in each disordered group. Tables 1 and 2 illustrate each participant's demographic data, as well as nasalance values and respective dB SPL for the three stimulated loudness conditions. As can be seen in these tables, the extent to which speakers modified their vocal loudness across the three conditions varied considerably. In many cases, the dB values in the loud or soft conditions were identical to or negligibly different from normal, particularly for the male speakers.

Dysarthria Type

Table 2 shows the percent change in dB SPL and nasalance values compared with the normal condition. For individuals with spastic dysarthria, increased SPL had a primarily deleterious impact on nasalance, with 7 of 13 participants demonstrating negative effects. It was anticipated that the reduction of loudness would improve nasalance. Although it did so for 9 of 13 participants, the improvement was not as large as in the flaccid dysarthric group's improvement with increased SPL.

Seven of nine participants with flaccid dysarthria demonstrated reduced nasalance with increased vocal SPL. Two showed decreased nasalance in both loud and soft conditions, but with greater improvement in the loud condition. By contrast, six of nine participants with flaccid dysarthria demonstrated increased nasalance in the soft condition.

Data for the five participants with ataxic dysarthria show a consistent trend. Increased SPL had a negative effect on four of five individuals, with reduced SPL yielding marked improvement for two of the five.

The least consistent findings occurred in for individuals with hypokinetic dysarthria. For two participants, SPL manipulation in either direction increased or induced no change in nasalance. In

TABLE 2. Percent dB SPL and nasalance change from normal to loud and normal to soft conditions.

Dysarthria Type	Gender/ Number	dB SPL Normal to Loud	Nasalance Normal to Loud	dB SPL Normal to Soft	Nasalance Normal to Soft
Spastic	M1	4% ↑	10% ↓	0%	5% ↑
	M2	19% ↑	16% ↓	7% ↓	4% ↓
	M3	6% ↑	42% ↑	3% ↓	10% ↓
	M4	9% ↑	25% ↑	1% ↓	9% ↓
	M5	10% ↑	40% ↑	10% ↓	9% ↓
	M6	2% ↑	2% ↓	11% ↓	16% ↓
	M7	3% ↑	4% ↑	1% ↓	6% ↑
	M8	5% ↑	3% ↑	8% ↓	11% ↓
	M9	1% ↑	11% ↓	5% ↓	14% ↓
	M10	3% ↑	12% ↓	6% ↓	9% ↑
	M11	4% ↑	0	0	4% ↓
	F1	7% ↑	18% ↑	8% ↓	14% ↓
	F2	3% ↑	16% ↑	2% ↓	15% ↑
Flaccid	M12	5% ↑	0	5% ↓	0
	M13	4% ↑	45% ↓	6% ↓	37% ↓
	M14	6% ↑	16% ↓	12% ↓	26% ↑
	M15	7% ↑	4% ↓	7% ↓	8% ↑
	M16	14% ↑	0	7% ↓	4% ↑
	M17	11% ↑	24% ↓	2% ↓	29% ↑
	M18	8% ↑	42% ↓	0	10% ↓
	M19	14% ↑	18% ↓	6% ↓	8% ↑
	F3	8% ↑	21% ↓	8% ↓	2% ↑
Ataxic	M20	9% ↑	1% ↑	5% ↓	0
	M21	4% ↑	13% ↑	3% ↓	0
	M22	17% ↑	13% ↓	3% ↓	17% ↑
	F4	6% ↑	32% ↑	5% ↓	22% ↓
	F5	9% ↑	24% ↑	7% ↓	24% ↓
Hypokinetic	F6	8% ↑	0	10% ↓	2% ↑
	F7	2% ↑	6% ↑	14% ↓	6% ↑
	F8	4% ↑	22% ↓	2% ↓	26% ↓

marked contrast, relatively small changes in SPL in either direction markedly improved nasalance for the third participant.

Perceptual Judgment of Nasality

Eleven of the 22 participants who showed nasalance reductions in the soft or loud conditions met the 10 unit difference criterion for perceptual judgments. The data for these individuals are presented in Table 3. The perceptual data represent how many of the 13 listeners perceived productions in either the soft or loud conditions to be either more or less nasal than those in the normal condition. The most consistent finding is the perceptible reduction of nasalance in the soft condition for three of four individuals with spastic dysarthria. A parallel finding is the perceptible reduction of nasalance in the loud condition for three of four individuals with flaccid dysarthria. The relationship between nasalance and listener perception is less clear for individuals with an ataxic component or hypokinetic dysarthria. Perceptual judgments corresponded to nasalance changes in only one of four participants with these differential diagnoses.

Closer inspection of the relationships among dB SPL changes, nasalance changes, and listener perceptions reveals that the patterns are neither sim-

TABLE 3. Decibel and nasalance changes between Normal and Loud conditions (N → L) and Normal and Soft (N → S) conditions.

Gender/Number	Loudness Change	dB Change	Nasalance Change	Listener Perception Number/13
Spastic				
M3	N → L	+ 4 (64 → 68)	+ 22 (28 → 50)	10 perceived soft less nasal than normal
	N → S	– 2 (64 → 62)	– 2 (28 → 26)	
M4	N → L	+ 9 (89 → 98)	+ 19 (58 → 77)	6 perceived soft less nasal than normal
	N → S	– 1 (89 → 88)	– 5 (58 → 53)	
M5	N → L	+ 8 (70 → 78)	+ 30 (45 → 75)	8 perceived soft less nasal than normal
	N → S	– 8 (70 → 62)	– 4 (45 → 41)	
F1	N → L	+ 5 (71 → 76)	+ 11 (49 → 60)	8 perceived soft more nasal than normal*
	N → S	– 6 (71 → 65)	– 7 (49 → 42)	
Flaccid				
M19	N → L	+11(66 → 77)	– 10 (57 → 47)	8 perceived loud less nasal than normal
	N → S	– 4 (66 → 62)	+ 5 (57 → 62)	
F3	N → L	+ 6 (70 → 76)	– 14 (68 → 54)	7 perceived loud less nasal than normal
	N → S	– 5 (70 → 65)	+ 1 (68 → 69)	
M18	N → L	+ 5 (59 → 64)	– 13 (31 → 18)	7 perceived loud less nasal than normal
	N → S	0 (59 → 59)	– 3 (31 → 28)	
M13	N → L	+ 3 (69 → 72)	– 26 (58 → 32)	6 perceived normal less nasal than loud *
	N → S	– 4 (69 → 65)	– 21 (58 à 37)	
Ataxic				
F4	N → L	+ 4 (64 → 68)	+ 15 (32 → 47)	8 perceived soft less nasal than normal
	N → S	– 3 (64 → 61)	– 7 (32 → 25)	
F5	N → L	+ 4 (62 → 66)	+ 12 (37 → 49)	8 perceived soft less nasal than normal
	N → S	– 3 (62 → 59)	– 9 (37 → 28)	
Hypokinetic				
F8	N → L	+ 2 (64 → 66)	– 10 (46 → 36)	8 perceived normal less nasal than loud*
	N → S	– 1 (64 → 63)	– 8 (46 → 34)	

Note: * indicates listener perception not congruent with nasalance data.

ple nor consistent. Among the speakers with spastic dysarthria who demonstrated reduced nasalance in the soft speech condition, the actual changes in average vocal SPL were only 1, 2, 3, 6, and 8 dB less than in the normal condition. Nasalance values also were only minimally less than in the normal condition (2, 4, 5, and 7 units). Nonetheless, with the exception of speaker F1, these corresponded with relatively strong agreement of reduced hypernasality among listeners. It is of note that similar vocal SPL and nasalance change values were obtained in the one instance in which the soft speech was deemed more hypernasal than the normal loudness speech, such that small differences had strong perceptual consequences.

The vocal SPL and nasalance difference values for the speakers with flaccid dysarthria were greater in magnitude than those for the speakers with spastic dysarthria. Loud condition values were 5, 6, and 11 dB SPL greater in intensity than in normal condition, and 10, 13, and 14 units less in nasalance. Again, this corresponded with relatively strong agreement among the listeners that the loud speech was less hypernasal than that produced in the normal condition.

Considering the data for the spastic and flaccid speech, it appears that reductions in nasalance, irrespective of the magnitude of vocal SPL change, were associated with the perceptual impression of reduced hypernasality. This observation, however, is not upheld in the data for the ataxic or hypokinetic speech. Similar to the data for spastic dysarthric speech, the absolute SPL differences from the normal condition were small (0–5 dB), and the nasalance absolute differences ranged from 0 to 26 units. However, in two of three cases, speech in the normal condition was perceived as less hypernasal than that in the loud condition, even when nasalance values in the loud condition were reduced relative to normal. In each of these cases, the absolute vocal SPL differences between normal and loud conditions were negligible.

DISCUSSION

There are several clinical implications of the present findings. First, contrary to clinical intuition, there is not a predictable relationship between a change in dB SPL and a change in nasalance, at least in the context of the motor speech disorders evaluated herein. Furthermore, these changes in dB SPL and nasalance did not result in consistent and predictable perceptual results. Finally, these results differ from earlier work in which 89% of subjects with motor speech disorders evidenced reduced velopharyngeal orifice area with increased vocal effort (McHenry, 1997). Here we found different patterns of results for the different subtypes of dysarthria, with various possible explanations for the discrepant patterns.

The perceptual consequences of nasalance and SPL changes defied a predictable relationship. Some participants demonstrated a perceptible change in nasality with a very small change in dB SPL or nasalance, whereas others demonstrated minimal change in perceived nasality with relatively large changes in either dB SPL or nasalance. The former are more interesting from a clinical perspective. For some individuals, there may be a threshold for vocal SPL (either increased or decreased) that is worth exploring during diagnostic therapy. Participant M3 (spastic dysarthria) demonstrated that a small reduction in SPL (–2 dB) leading to a minimal reduction in nasalance (28–26) yielded a large difference perceptually, with 76% of listeners judging the soft condition to be less nasal than the normal condition. Participant F4 (ataxic dysarthria) also crossed the threshold into normalcy. With a reduction of only 3 dB, nasalance decreased from 32 to 25, a change that 62% of listeners perceived. For these individuals with borderline velopharyngeal incompetence, the exploration of vocal loudness changes may yield immediate therapeutic benefits.

Perhaps the most interesting result is that, at least for the flaccid and spastic speakers, there was a physiologically interpretable pattern of findings that corresponded with stimulated increases and decreases in vocal SPL. Presumably, speakers with flaccid dysarthria exhibit hypernasality because of profound muscular weakness prohibiting sufficient velopharyngeal port closure. It would be predicted that increasing overall vocal SPL would generate improved velopharyngeal closure, particularly for those with mild hypernasality, by maximizing motor unit recruitment. Thus, nasalance values and the perception of nasality should then decrease for these speakers when asked to speak louder than normal. Indeed, this was the case for the speakers with flaccid dysarthria in the present study whose data met the criteria for evaluation.

In spastic dysarthria, the physiologic explanation for hypernasality would be similar to flaccid, with inefficient velopharyngeal valving due to spastic paralysis creating weakness and ineffective movement of the velopharyngeal musculature. However, their pattern of results was opposite those of speakers with flaccid dysarthria, such that decreased vocal SPL was associated with a decrease in nasalance and a decrease in perceived nasality for the majority of speakers whose data met criteria. It is unlikely that the speakers' attempts to reduce vocal SPL resulted in a change in velopharyngeal closure. The most likely explanation for this finding is that the reduced nasalance may have been due to less airflow through the nasal passageway in the soft as compared with normal or loud conditions, and this was associated with perceived decreases in nasality. Alternatively, decreasing vocal SPL may have improved voice quality (i.e., reduced strained-strangled quality), which affected listeners' ratings of nasality (see Kreiman, Garratt, & Berke, 1994; Zraick et al., 2000). Another possible mechanistic explanation is that speakers decreased their rate of speech in the soft condition, which may have provided more time for velopharyngeal port closure to be achieved. Speaking rate was not considered in this investigation, although this possibility could be explored. In any case, the correspondence between reductions in nasalance and the perception of reduced nasality in the soft condition for spastic dysarthria points toward an explanation of reduced nasal energy.

Whereas the patterns of results for the majority of speakers with flaccid and spastic dysarthria have supportable physiological explanations, the findings for individuals with ataxic and hypokinetic dysarthria are much less clear, with little correspondence between listener judgments and changes in nasalance. As Karnell et al. (2004) noted, perceptual ratings of hypernasality include qualitative components that are not reflected by nasalance values. The speech production of both individuals with hypokinetic and ataxic dysarthria is characterized by temporal and spatial inconsistency (Caliguiri, 1989; Yorkston & Beukelman, 1981). It is possible that this inconsistency influenced listeners' perception more than the apparent reduction in nasalance.

Limitations

The focus of this investigation was hypernasality, and it should be stated explicitly that other aspects of production, such as intelligibility, articulatory integrity, speaking rate, or voice quality, were not evaluated. If the perception of reduced hypernasality corresponds to other measures of speech or voice characteristics, this study raises the possibility that a speaker's attempt to modify vocal loudness, irrespective of actual SPL changes, may improve overall speech production. It may also have been the case that more experienced listeners would have been able to separate the perception of nasality from other speech or voice differences (see Kreiman, Gerratt, & Precoda, 1990; Lewis, Watterson, & Houghton, 2003) or that a different perceptual task (e.g., direct magnitude estimation, see Whitehill, Lee, and Chun, 2002) may have generated different patterns of results. Furthermore, speaking rate, though not measured in the present investigation, has been shown to be related to nasal airflow and the perception of nasality among normal speakers (Goberman, Selby, & Gilbert, 2001). Future studies of the perception of nasality in dysarthria may choose to incorporate speech rate measures to reveal possible influences or interactions. Finally, the responses were elicited through a stimulated loudness paradigm. Not all speakers changed loudness even with modeling. It is possible that clearer results would be obtained by individuals matching a target dB SPL, eliminating those participants who were not able to vary loudness.

Stimulating loudness changes remains a variable worth exploring in the initial management of velopharyngeal incompetence. In some instances, relatively small changes in vocal SPL may result in perceptible changes in hypernasality. Because of the many variables affecting dysarthric speech production, the corroboration of objective findings with perceptual judgments is critical.

Address correspondence to Monica McHenry, 100 Clinical Research Center, University of Houston, Houston, TX 77204-6018 USA.
e-mail: mmchenry@uh.edu

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