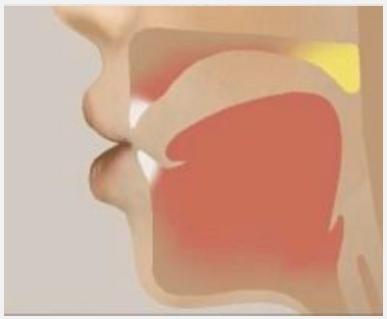
Review on Nasality Measurement Devices and Nasalance Factors

Edwina Dwi Sadika[1], Gradiyan Budi Pratama[1], Lei Chen[2], Xiaopeng Yang [1], Younggeun Choi[1], Boyoung Park[2], Minjung Yu[3], Myoung-Hwan Ko[3], Jongwan Park[3], Heecheon You[1]

[1] Dept. of Industrial & Management Engineering, POSTECH
[2] Humanopia, Inc.
[3] Medical Device Clinical Trial Center, Chonbuk National University Medical School

Agenda

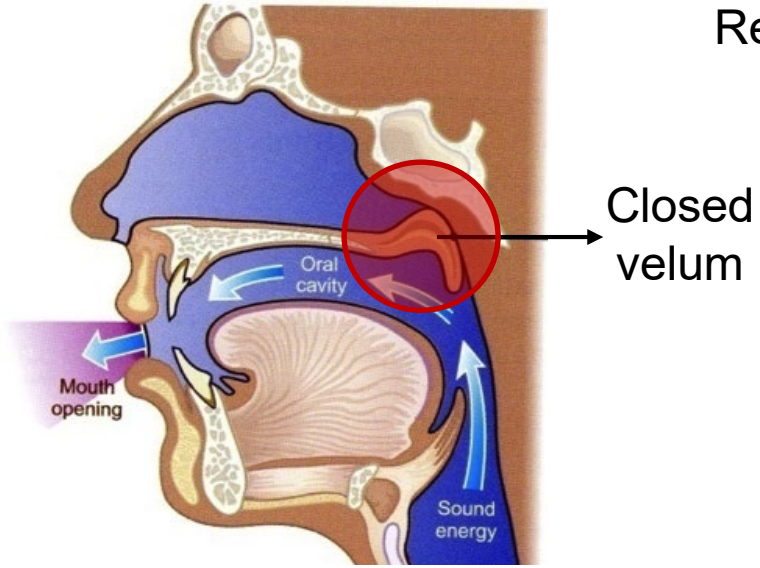
- Introduction
  - Background: Nasality & Resonance Disorder
  - Objective of the Study
- Nasalance Measurement Devices
- Nasalance Factors
- Discussion

Nasality

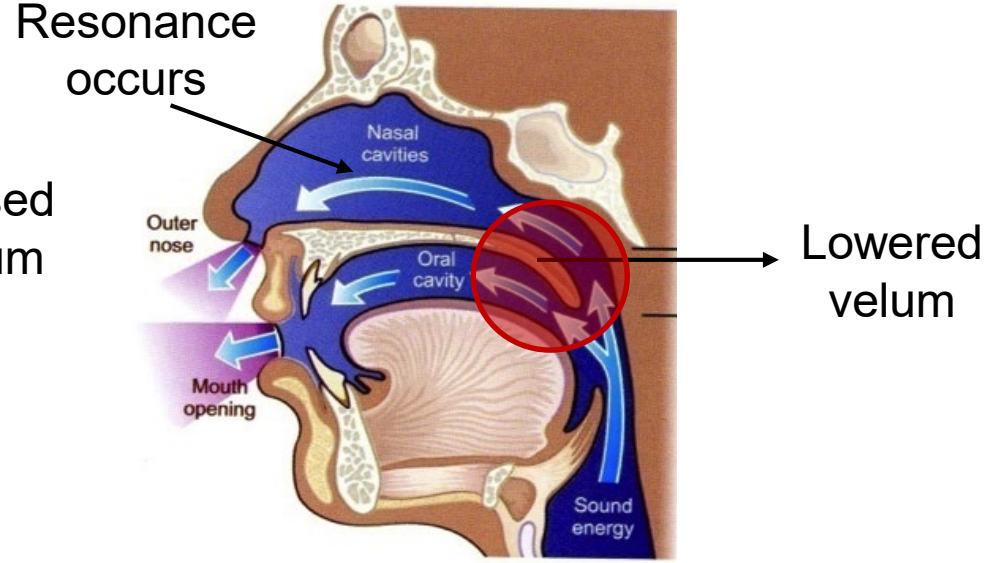
- Production of a sound while the velum is lowered → some air resonates in nasal cavities and escape through the nose

  ⇐ One of common problems in speech production is related to nasality

Oral sounding speech

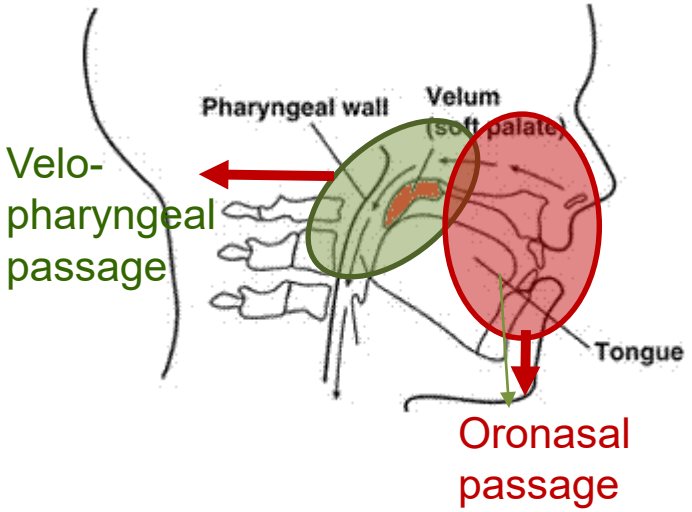


Nasal sounding speech



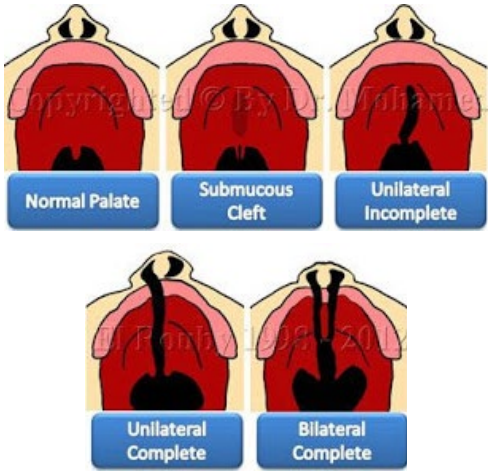
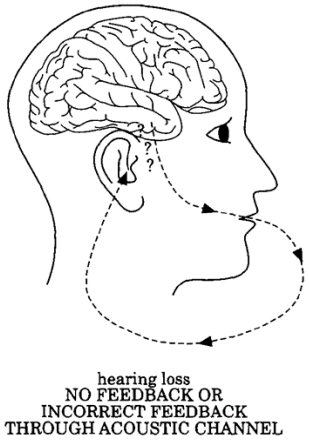
Resonance Disorder

- Difference in the amplified voice caused by structural anomaly or ineffective use of the structures of the velopharyngeal and oronasal passage way (ASHA, 2012)



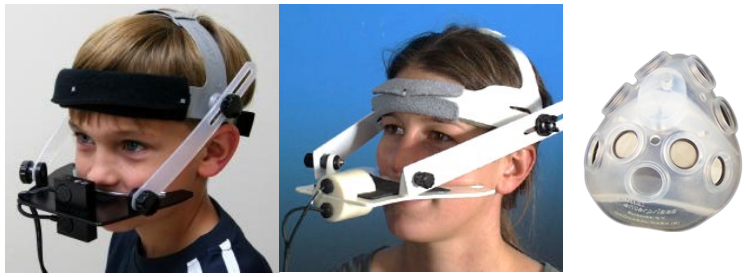
- **Types of symptom**
  - ✓ **Hypernasality**: Abnormal resonance in a human's voice due to increased airflow through the nose during speech
  - ✓ **Hyponasality**: Abnormal resonance in a human's voice due to decreased airflow through the nose
  - ✓ **Cul-de-sac resonance**: Sound resonates in speech cavity and cannot get out due to blockage in vocal tract

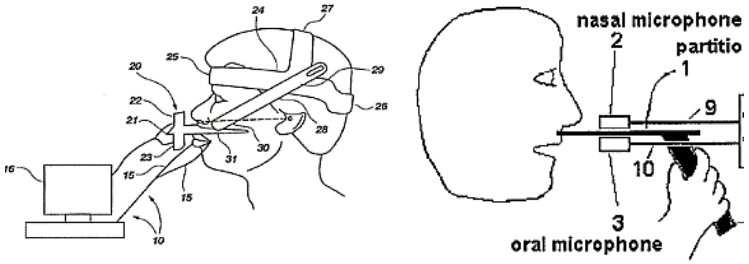
Causes of Resonance Disorder

	Causes		
	Insufficiency	**Incompetence**	**Mislearning**
Cause	Anatomy (structure)	Physiology (movement)	Learning (articulation)
Example	Cleft palate (main cause), submucous cleft, or short velum	Neurologic disorder or injury (e.g. stroke, dysarthria, cerebral palsy, traumatic brain injury)	Hearing loss/problem, improper speech learning (usually in children)
Types of Symptom	Hypernasality	Hypernasality & hyponasality	Hypernasality, hyponasality, cul-de-sac resonance
Patients	Mainly children	Children & Adults	Children & Adults
Figures		Brain trauma which affects speech muscles 	
Incidence	0.14% (1 of every 700 births)	25%-40% stroke victims	10% of US population

Objectives of the Study

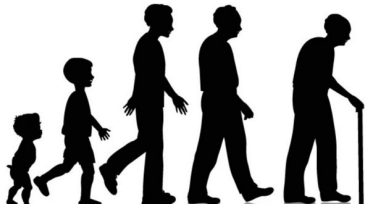
Nasalance Measurement Devices



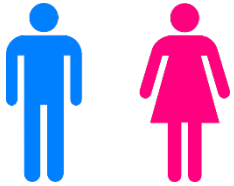


Nasalance Factors

Age



Gender



Dialect & Language

Procedure of Literature Review

Steps	Patent	Paper

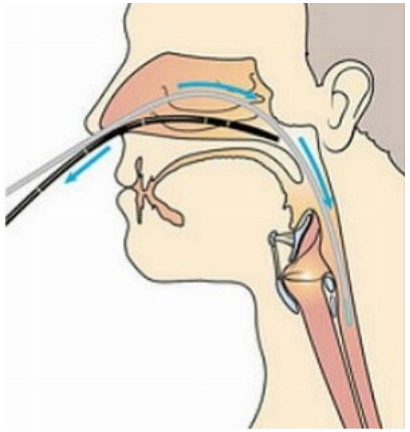
S1. Keyword combination search	• Source: wipson, google.patents
	• Criteria: title, abstract, keyword
	• Search equation
	  ○ (Nasality OR Nasalance) AND measure
	  ○ (Nasality OR Nasalance) AND (method OR apparatus OR tool OR device)
	
	Result: 65 patents
		• Source: Science Direct
		• Criteria: title, abstract, keyword
		• Search equation: (hypernasal OR hyponasal OR nasality OR nasalance) AND (measurement OR evaluation OR analysis OR technique OR algorithm OR tool)
		
		Result: 114 papers

S2. Title screening	25 patents	38 paper
S3. Abstract screening	• High: 10 abstracts • Medium: 2 abstracts	• High: 21 abstracts • Medium: 9 abstracts
S4. Review	12 patents	30 papers

Nasality Assessment Methods

Invasive

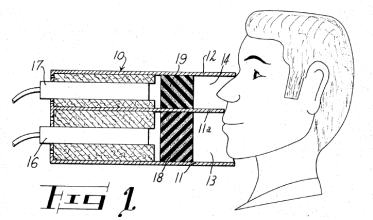
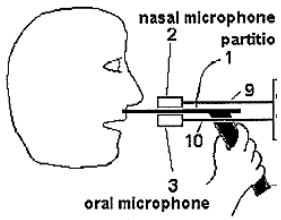
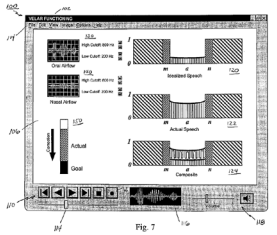
- Direct observation of velopharyngeal movements during speech (nasendoscopy)
- Limitations
  - ✓ Uncomfortable
  - ✓ Interfered
  - ✓ Qualitative



Non-Invasive

- Indirect assessment using digital signal processing-based techniques while providing quantitative result
- Limitations
  - ✓ Uncomfortable
  - ✓ Interfered speech

Non-Invasive Methods: Commercialized

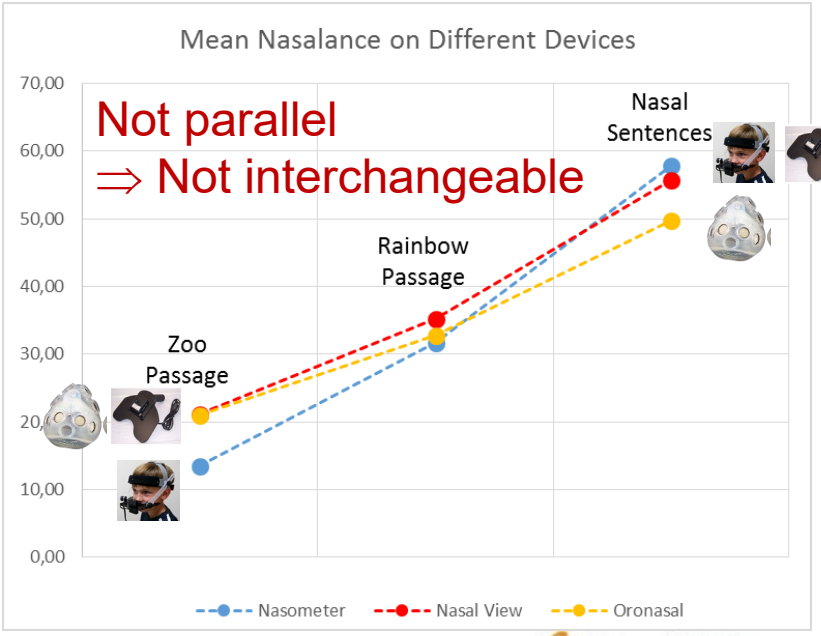
	Fletcher (1973)	Rothenberg (2010)	Rothenberg (2005)
Images	**Nasometer**  	**Nasalance System**  	**Oronasal Mask**  
Hardware	• Head gear • Separator plate • Oral and nasal microphones	• Hand-held tool • Separator plate • Oral and nasal microphones	• Circumferentially-vented mask • Air chamber • Oral and nasal airflow sensors
Nasalance Calculation	$\frac{\text{Nasal Energy (dB)}}{\text{Nasal Energy (dB)} + \text{Oral Energy (dB)}}$		$\frac{\text{Nasal Airflow (volt)}}{\text{Nasal Airflow (volt)} + \text{Oral Airflow (volt)}}$

Comparison: Nasometer, Nasal View, Oronasal Mask

- Bressmann (2005): Statistically significant differences between instruments
  - ✓ Zoo passage: Nasometer score were significantly lower
  - ✓ Rainbow passage: NasalView score were significantly higher
  - ✓ Nasal sentence: OroNasal score were significantly lower
- Nasalance scores from three systems are NOT interchangeable
- Nasometer remains the gold standard for the clinical diagnosis of resonance disorders

	Zoo Passage	*Rainbow Passage*	*Nasal Sentences*
Nasometer 	13.45 Lower SD 5.9 ✓ NV* $p < .001$ ✓ ON* $p < .001$	31.69 SD 5.47 ✓ NV* $p < .001$ ON n.s.	57.9 SD 6.69 NV n.s. ✓ ON* $p < .001$
NasalView 	21.1 SD 4.78 ✓ NM* $p < .001$ ON n.s.	35.2 Higher SD 4.7 ✓ NM* $p < .001$ ✓ ON* $p < .001$	55.74 SD 5.01 NM n.s. ✓ ON* $p < .001$
OroNasal System 	20.97SD 6.15 ✓ NM* $p < .001$ NV n.s.	32.74 SD 6.05 NM n.s. ✓ NV* $p < .001$	49.72 Lower SD 6.12 ✓ NM* $p < .001$ ✓ NV* $p < .001$

* Statistically significant. NM = Nasometer; NV = NasalView; ON = OroNasal System.



Speech Stimuli

- Types of passage
  - Oral passage: Including NO nasal consonants
  - Oro-nasal passage: Balanced oral & nasal voice
  - Nasal sentences: Heavily loaded with nasal consonants

- Nasal consonant rate = $\frac{\text{Number of nasal consonant}}{\text{Number of phonemes}} \times 100\%$
  - Nasal consonant: /n/, /m/, /ng/

Languages	Nasal Consonant Rate		
	Oral Passage	Oro-nasal Passage	Nasal Sentences
English*	0%	11.0%	35.0%
Korean		17.0%	55.0%
Cantonese		17.2%	40.1%
Mid-west Japanese		-	-
Flemish		11.0%	35.0%
Irish English		11.0%	51.0%
Puerto Rican Spanish		11.0%	49.1%
Mexican Spanish		-	20.0%

***English Speech Stimuli**

Oral passage: Zoo passage 0%

Look at this book with us. It's a story about a zoo. That is where bears go. Today it's very cold out of doors, but we see a cloud overhead that's a pretty white fluffy shape.

Oro-nasal passage: Rainbow passage 11%

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon.

Nasal sentences 35%

Mama made some lemon jam.
Ten men came in when Jane rang.
Dan's gang changed my mind.
Ben can't plan on a lengthy rain.
Amanda came from Bounding, Maine

Nasal consonant rate calculation
- Number of nasal consonant = 35
- Number of phonemes = 100
- Nasal consonant rate = 35%

Comparison: Nasometer 6200 vs. Nasometer II 6400

- Awan and Virani (2013): Nasalance - **Nasometer 6200 >** Nasometer II 6400 on the **Zoo and Rainbow passages**

  ⇐ Normative data need to be established for each device

Nasometer 6200

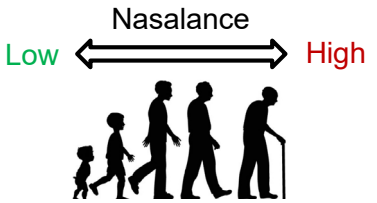
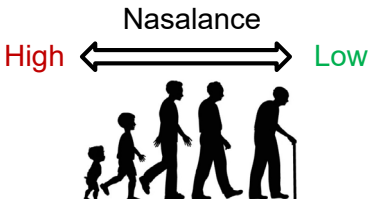
Nasometer II 6400

Passage	*Nasometer 6200*		*Nasometer II 6400*	*Mean Difference*	*Pearson's r Correlation*
Zoo Passage*	17.64 (5.05) Range: 7.87 to 31.10	>	10.49 (4.04) Range: 4.67 to 24.67	+7.15 (3.51) Range: +14.77 to −4.90	$r = .72$†
Rainbow Passage*	34.78 (5.00) Range: 21.30 to 44.50	>	31.73 (6.82) Range: 21.67 to 56.33	+3.05 (5.41) Range: +10.17 to −15.4	$r = .62$†
Nasal Sentences	60.31 (4.66) Range: 49.97 to 69.50		59.54 (7.13) Range: 47.33 to 80.67	+0.77 (5.20) Range: +10.00 to −19.47	$r = .68$†

* System differences are significant at $P < .01$.
† All correlations are significant at $P < .01$.

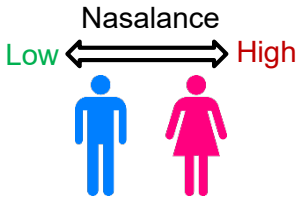
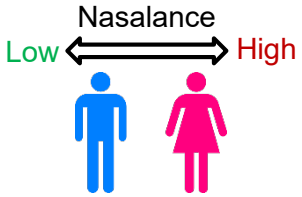
Age on Nasalance

- Age-related lengthening of the vocal tract, physiological changes, soft tissue, bony tissue, and muscle changes (Rochet et al. 1998)

Studies	Language	Result				
		Age group	Nasalance			Illustration
			Oral	Oro-nasal	Nasal	
Rochet et al., 1998	English	9-13	9.30 SD: 3.20	31.00 SD: 4.20	59.50 SD: 5.70	
		14-19	10.80 SD: 5.00	32.90 SD: 4.50	62.10 SD: 6.40	
		20-44	11.90 SD: 6.00	33.60 SD: 6.00	62.80 SD: 7.40	
		45-64	12.60 SD: 5.10	34.10 SD: 5.70	62.40 SD: 6.60	
		65-85	12.60 SD: 4.60	33.00 SD: 6.00	60.70 SD: 7.20	
		Mean difference	3.30	3.10	3.30	
Park et al, 2014	Korean	Child (7 – 11 years)	11.44 SD: 3.07	33.35 SD: 4.90	65.43 SD: 6.02	
		Adult (18 – 32 years)	11.94 SD: 4.21	34.73 SD: 4.79	62.02 SD: 5.67	
		Mean difference	0.50	1.38	3.41	

Gender on Nasalance

- Difference in velum length and velopharyngeal closure pattern (Zajac & Mayo, 1996; Rochet et al., 1998)

Studies	Language	Result				
		Gender	Nasalance			Illustration
			Oral	Oro-nasal	Nasal	
Park et al, 2014	Korean (7-32 years)	Female	12.18 SD: 3.88	35.56 SD: 3.88	64.84 SD: 5.68	
		Male	11.20 SD: 3.42	32.53 SD: 4.68	62.60 SD: 6.28	
		Mean difference	0.98	3.03	2.24	
Van Lierde, 2001	Flemish (19-27 years)	Female	11.60 SD: 4.40	36.10 SD: 5.40	57.40 SD: 6.10	
		Male	10.20 SD: 4.00	31.50 SD: 4.60	54.20 SD: 5.80	
		Mean difference	1.40	4.60	3.20	
Van Doorn and Purcell, 1998	English (children 4-9 years)	Female	12.60 SD:5.60	-	58.60 SD:8.60	
		Male	13.60 SD:6.20	-	59.60 SD:8.10	
		Mean difference	1.00	-	1.00	

Dialect on Nasalance

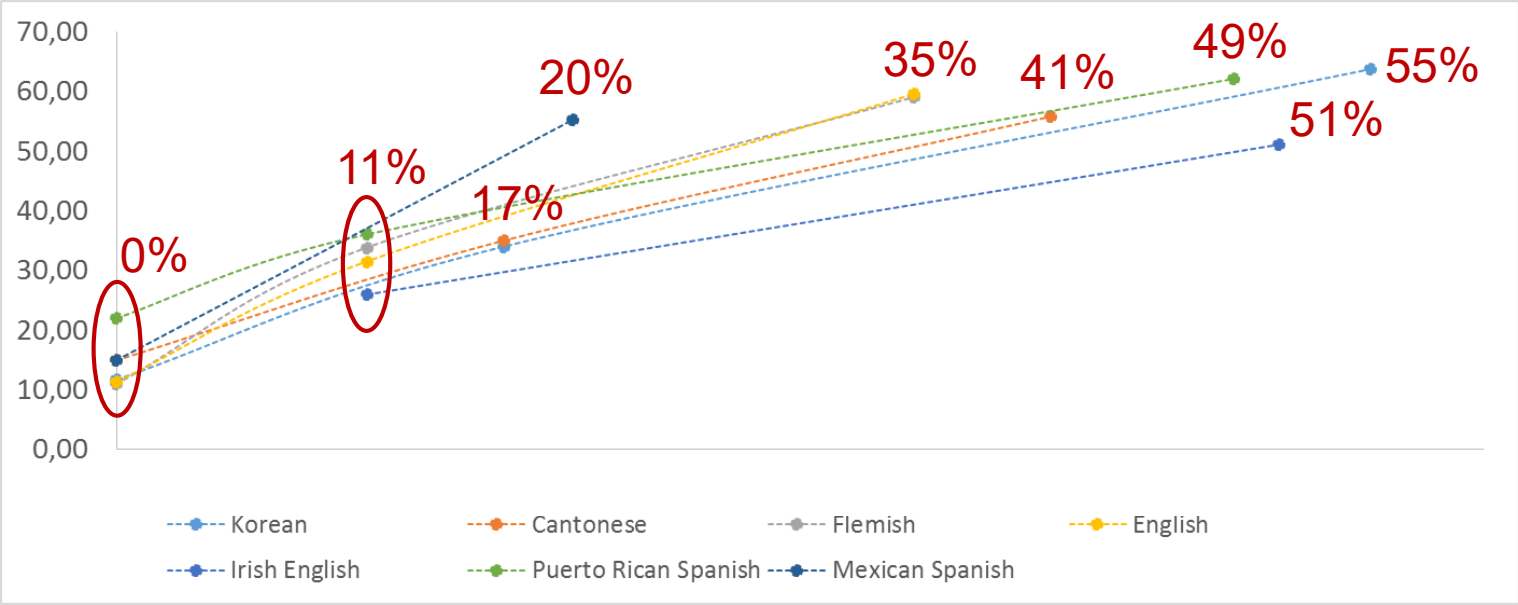
- Kummer (2008): Dialects or languages that use more high vowels (higher tongue position) might be expected to have higher nasalance as compared to those with low vowels or a lower tongue position
- Mayo, Floyd, Warren, Dalston, and Mayo (1996): Hypothesized that across dialects, there may be differences in the timing of VP closure when transitions are made between nasal consonants and vowels

Studies	Dialect	Passage			Result
		Oral	Oro-Nasal	Nasal	
Seaver, Dalston, Leeper, and Adams (1991) (United States and Ontario, Canada)	Mid-Atlantic	21.0	39.0	65.0	Mid-Atlantic: higher nasalance scores
	Southern	13.0	34.0	61.0	
	Mid-western	15.0	35.0	62.0	
	Mean difference	8.0	5.0	4.0	
Van Doorn and Purcell (1998)	Australia	13.0	-	59.6	Australia: lower than American (nasal & zoo passage) and higher than Canadian (zoo passage)
	American	15.5	-	61.1	
	Canadian	9.3	-	59.5	
	Mean difference	6.2	-	1.6	

Language on Nasalance

- Nasalance differ among languages according to pronunciation characteristics

Languages	Oral Passage (nasal consonant rate)	Nasalance	Oro-nasal Passage (nasal consonant rate)	Nasalance	Nasal Sentences (nasal consonant rate)	Nasalance
Korean	0%	11.7	17%	34.0	55%	63.7
Cantonese		15	17%	35.5	41%	55.7
Flemish		10.9	11%	33.8	35%	59
English		11.2	11%	36.0	35%	59.5
Irish English		-	11%	26.0	51%	51
Puerto Rican Spanish		21.9	11%	36.0	49%	62.1
Mexican Spanish		15	-	-	20%	55.3



Discussion

- Three nasality measurement devices: Nasometer (gold standard), Nasal View, and Oronasal Mask
  - ✓ The majority of the nasalance normative data (72%) were obtained from the Nasometer 6200. (Mayo & Mayo, 2011)
- Nasalance can be influenced by
  - ✓ Device
    - ➢ Nasometer 6200 > Nasometer II 6400 for Zoo and Rainbow passages
    - ➢ Nasometer, Nasal View, and Oronasal Mask nasalance are NOT interchangeable
  - ✓ Age (mean difference: 3.41), gender (mean difference: 4.60), dialect (mean difference: 8.00)
    - ➢ Dialect is the most important factor to consider since it has the largest mean nasalance difference

  ⇒ Normative data should be customized to a specific device for various age groups, gender groups, dialects, and languages.
- Future study
  - ✓ Establish a normative nasalance database by surveying existing nasalance studies
  - ✓ Develop an ergonomic nasometer with better comfort and reliability

Acknowledgement

This study was supported by the Biomedical Research Institute Fund,

Chonbuk National University Hospital.