COMPARISON OF SHORT-TERM AND LONG-TERM
NASALANCE SCORE VARIABILITY IN CHILDREN

A Thesis

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Rebecca Van Der Volgen

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Date
Student: Rebecca Van Der Volgen

I certify that this student has met the requirements for format contained in the University format manual, and that this thesis is suitable for shelving in the Library and credit is to be awarded for the thesis.

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Robert Pieretti, Ph.D., CCC-SLP

Department of Speech Pathology and Audiology
Abstract

of

COMPARISON OF SHORT-TERM AND LONG-TERM NASALANCE SCORE VARIABILITY IN CHILDREN

by

Rebecca Van Der Volgen

Statement of Problem

Nasalance score variability can be attributed to the Nasometer, to variance in the test procedures, between-subject variability, and subject performance variability (Lewis et al., 2008). Of particular importance with nasalance scores is subject performance variability. This can be due to the inconsistency with which subjects repeat the same stimulus, the degree of nasal patency, or timing of velopharyngeal (VP) closure.

Since nasalance scores are sensitive to the degree of nasal patency, test procedure variances, the changeable timing of closure for the VP mechanism, and developmental changes in children, then the degree of variation over time with children should be greater than that of adults. The specific research questions are as follows: (1) What is the degree of nasalance score variation associated with short-term variability in a group of normal children?; and (2) What is the degree of nasalance score variation associated with long-term variability in a group of normal children?
Sources of Data

Participants consisted of 14 speakers between the ages of 14 through 15 years. Nasalance score data was collected twice per day, in the AM and PM, for 4 days, and then once per week for 3 weeks afterward. Participants read the Turtle Passage and Mouse Passage three times each during the AM sessions. Each passage was read twice in succession without changing the headgear (NCHG). Then, the headgear was removed and replaced before participants read the passages for the third time (CHG). This allowed for analyses of short-term variability under the two conditions, NCHG and CHG.

Conclusions Reached

Nasalance score data revealed great variability across all five conditions, but in general, a difference of 8 points or less accounted for 86% to 100% of the variation. Data showed greater long-term variability in nasalance scores than in adults.

_______________, Committee Chair
Ann Blanton, Ph.D., CCC-SLP

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Date
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Chapter 1

INTRODUCTION

Purpose

Normal variability in nasalance scores—a computer-assisted instrumental means of objectively assessing resonance—can be attributed to several factors: The Nasometer itself; variance in the test procedures; between-subject variability; and subject performance variability (Lewis et al., 2008). Of particular importance to nasalance scores is subject performance variability. This variability can be due to the inconsistency with which subjects repeat the same stimulus, or to the degree of nasal patency, or opening.

However, another important cause of variability is the timing of velopharyngeal (VP) closure. In normal VP function, the velum lifts to close off the nasal cavity from the oral cavity for oral sounds, and lowers to allow airflow through both the oral and nasal cavities.

The timing of this velopharyngeal closure does not appear to be the same in children as it is in adults. In a study conducted by Zajac and Hackett (2002), the temporal characteristics of the /mp/ phoneme sequence in the word “hamper” were assessed in 46 children aged 6 to 8 years, 41 older children between 11 and 12 years, and 41 adults between 18 to 37 years of age. The researchers suspected that children and
adults differ “relative to the temporal aspects of VP aerodynamics during speech” (p. 433). Testing indicated significant differences between the age groups, specifically between the younger children and the older children, the younger children and the adults, and the older children and the adults. The duration and variability of the speech segments decreased as age increased.

Problem

If nasalance scores are not only sensitive to degree of nasal patency and test procedure variances, but also to changeable timing of closure for the VP mechanism and developmental changes in children, then the degree of variation over time with children should be greater than that of adults. In order to test this hypothesis, we will investigate changes in nasalance scores in a group of normal children over a 1-month period, closely reproducing the methodology of Lewis et al. (2008), in order to determine if there is a difference between nasalance scores over time for normal children as compared to normal adults. The specific research questions are as follows: (1) What is the degree of nasalance score variation associated with short-term variability in a group of normal children?; and (2) What is the degree of nasalance score variation associated with long-term variability in a group of normal children?
Chapter 2

BACKGROUND OF THE STUDY

Review of Research

The Nasometer is a computer-assisted instrument that measures the ratio of nasal energy over nasal plus oral energy, multiplied by 100, thus converting it to a percentage. The resulting number is called a Nasalance score and allows for Nalasance to be rated along a scale of 0 to 100. A score of 0 indicates that speech is being produced without any nasal sound energy, whereas a score of 100 indicates that all speech sound energy is coming through the nose (Fletcher, Adams, & McCutcheon, 1989, p.247).

Nasalance scores are a means of objectively assessing hypernasal resonance (Watterson, Hinton, McFarlane, 1996). When individuals with hypernasality are treated, nasalance scores obtained pre- and post-treatment are often used to measure the success of therapy or surgical intervention. It is the responsibility of the Speech Pathologist to determine if there is a clinically significant difference upon comparing the pre- and post-nasalance scores (Lewis, Watterson, Blanton, 2008). In making such a determination, the clinician needs to discern whether the change in the Nasalance score is due to normal variability or to an actual alteration in the client’s condition.

Normal variability in nasalance scores can be attributed to the Nasometer, to variance in the test procedures, between-subject variability, and subject performance.
variability (Lewis et al., 2008). Nasometer variability is of concern when comparing new data with previous scores obtained from a different type of measurement device or a different model of the Nasometer. Lewis and Watterson (2003) compared nasalance scores taken from the Nasometer and the NasalView. In comparing results of the stimuli, the authors found a weak association between the scores from the two machines and suggested that due to a qualitative and quantitative difference in the scores, the scores were not interchangeable (p.44). Furthermore, in a study comparing the nasalance scores taken with the Nasometer 6200 and the Nasometer II 6400, Watterson, Lewis, and Brancamp (2005) found that the machines introduced a new source of variation that needed to be considered when clinicians made clinical decisions. The authors proposed “that eight nasalance points should be considered normal variation when comparing nasalance scores from one machine to the other” (p.579).

Test procedure variability “involves intentional or unintentional differences in the placement of the headgear when obtaining repeated scores from the same person or when comparing one speaker from another speaker” (Lewis et al., 2008, p. 495). When positioning the headgear, a metal plate is placed between the nose and upper lip. This plate separates the nasal and oral signals that are transmitted to the two microphones supported by the plate. Any shift in the position of the metal plate could potentially cause an alteration in the signals filtered by the microphones (Fletcher et al., 1989, p.248).

Between-subject variability has been reported to be influenced by dialectal differences, sex, and age. Seaver, Dalston, Leeper, and Adams (1991) examined the
speech of 92 female subjects and 56 male subjects ranging in age from 16 to 63 years. The subjects had speech patterns consistent with one of four regional dialects—Mid-Atlantic, Southern, Mid-Western, and Ontario Canadian. Using the Nasometer 6200, data was collected for speech stimuli contained in three passages—the Rainbow Passage, which contains a proportionate amount of oral and nasal consonants found in everyday speech; the Zoo Passage, which lacks any nasal consonants; and the Nasal Sentences, which contain a plethora of nasal consonants. Results for the Nasal Sentences revealed significant differences in nasalance scores among the Mid-Atlantic and Ontario speakers, and the Mid-Atlantic and Southern speakers. For the Rainbow Passage, significant differences were found between the Mid-Atlantic and Mid-Western speakers, the Mid-Atlantic and Ontario speakers, and the Mid-Atlantic and Southern speakers. For the Zoo Passage, comparisons showed significant differences between the Mid-Atlantic speakers and each of the other three regional dialects. In short, the Mid-Atlantic speakers showed an increased degree of nasalance as compared to the other three dialects. With regards to any differences between the sexes, the nasalance scores for female subjects were significantly higher than for male subjects in the Nasal Sentences (p. 717).

In a study to investigate normal nasalance patterns for the gerontologic population, Hutchinson, Robinson, and Nerbonne (1978) assessed 60 subjects, 30 male and 30 female, varying in age from 50 to 80 years. Nasalance data was collected on four stimuli, the Zoo Passage, the Rainbow Passage, Nasal Sentences, and a sustained /a/. When compared to cumulative data collected from a previous study on young adults, the older subjects showed higher nasalance scores for all four types of stimuli (p. 473).
A particular issue with nasalance scores is subject variability. This can be due to the inconsistency with which subjects repeat the same stimulus, but also because of the degree of nasal patency, or opening. Fluctuations in nasal patency have been attributed to posture change, physical exercise, carbon dioxide in the blood, menstruation, fluctuations in hormones, cold, dry air, and air pollution (as cited in Lewis et al., 2008). Inversely, nasal congestion is also subject to change. According to Davis and Eccles (2004):

Nasal congestion is associated with inflammation of the nasal epithelium and the generation of inflammatory mediators that cause dilation of nasal blood vessels. Nasal congestion is a common presenting complaint of ‘rhinitis’ and as such the causative factors for rhinitis, e.g. allergens, viruses, bacteria and decongestant medication, are all potential causative factors for nasal congestion. (p. 660)

Should the nasal passages be congested, nasal airflow could be inhibited and potentially affect the amount of sound energy transmitted through the nose. Pegararo-Krook, Dutka-Souza, Williams, Tele Magahães, Cortez Rossetto, and Riski (2006) investigated the nasalance scores of 100 subjects, 59 of whom were hypernasal and 49 with normal speech and resonance. Scores obtained before and after the administration of a nasal decongestant were compared. The findings showed a statistically significant change between the nasalance scores for both the hypernasal and nonhypernasal groups. It was concluded that, due to the influence of the nasal decongestant on nasometric readings, use of a decongestant should be consistent when repeatedly obtaining scores from the Nasometer.
More recently, Watterson, Lewis, Ludlow and Ludlow (2008) assessed 20 adults with normal speech and resonance using nasometry and acoustic rhinometry before and after the use of a nasal decongestant. The results showed that, for the group as a whole, the degree of nasal patency was significantly different, with an increase in cross-sectional area from before decongestion to after decongestion. The group mean nasalance scores were also significantly different between pre- and post- nasal decongestion. However, for some subjects, changes in patency were small and changes in nasalance scores were minimal. This was probably because the subjects were already near maximum nasal patency before being administered the decongestant. Furthermore, “nasal decongestion did not cause normal nasalance scores to move into the abnormal range” and correlation analyses found a weak relationship between nasalance scores and nasal patency (p. 626). Watterson et al. concluded that the majority of change could not be attributed to the nasal decongestant, but instead to other variables, and that it is up to a knowledgeable clinician to interpret data and consider “circumstances and conditions that introduce variability” (p.626).

Another issue regarding variability is the timing of velopharyngeal (VP) closure. Keuhn and Moon (1998) describe the function of the VP mechanism “as a valve during speech to direct the airstream through the oral cavity, the nasal passage, or both” (p.52). In normal VP function, the velum lifts to close off the nasal cavity from the oral cavity for oral sounds, and lowers to allow airflow through the nasal cavities for nasal sounds. Additionally, the mechanism has been shown to have more than just th binary function of opening and closing depending on the nasality of the segment. In fact, “it is likely that
VP control for vowels and probably also for sonorants, such as /w/ and /l/, involves a specified position or positions different from that of either nasal consonants or nonnasal obstruent consonants,” and variations seem to be specific to the language (Keuhn & Moon, 1998, p. 52).

However, the timing of velopharyngeal closure does not appear to be the same in children as it is in adults. In a study conducted by Zajac and Hackett (2002), the temporal characteristics of the /mp/ phoneme sequence in the word “hamper” were assessed in 46 children aged 6 to 8 years, 41 older children between 11 and 12 years, and 41 adults between 18 to 37 years of age. The researchers suspected that children and adults differ “relative to the temporal aspects of VP aerodynamics during speech” (p. 433). Testing indicated significant differences between the age groups, specifically between the younger children and the older children, the younger children and the adults, and the older children and the adults. The duration and variability of the speech segments decreased as age increased. The authors concluded that due to increased segment duration for young children, “the perceptual consequences of nasal air escape or hypernasality may be more salient than in older children and adults” (p. 437). Therefore, it is essential for a clinician to consider variability due to age-specific aspects of VP function when assessing a client.

Clinicians also need to consider the developmental changes that are occurring during the growth of a child. Van Lierde, Wuyts, De Bodt, and Van Cauwenberge (2003) studied the age-related nasal resonance patterns in Flemish children and young adults with normal speech and resonance. Using the Nasometer 6200, data was collected for
three vowels, /a/, /i/, and /u/, one nasal consonant, /m/, and three Dutch passages, two of which were comparable to the English Zoo Passage, which excludes nasal consonants, and the Rainbow Passage, which contains 11.7% nasal consonants. The third passage, the nasal text, contained an ample amount of nasals. The mean nasalance scores obtained for the three passages were 11.3%, 31.9%, and 51.6%, respectively. In addition, results revealed significant age-related effects on /a/, /i/, /m/, the Dutch Rainbow Passage, and the nasal text. Higher nasal resonance scores increased as a function of increase in age. However, the authors did not attribute their findings to changes in VP function, but instead to “developmental changes in speech mechanisms and differences in speech programming” (p. 348).

Further support showing the effect of developmental changes on VP function came from Prathanee, Thanaviratananich, Pongjunyakul, and Rengpatanakij (2003), who conducted a pilot study that assessed the nasalance scores of 64 Thai school children with normal speech and resonance. Due to the “different components of nasal consonants in the Thai language” (p. 37), the researchers created three passages that the children could easily read. The first passage is similar to the English Rainbow Passage in content, but devoid of any nasal consonants. The second passage contained 16% of Thai nasal consonants, and the third passage contained three times the number of normal nasal consonants found in everyday Thai conversation. The mean nasalance scores for the first, second, and third passages were 14.3%, 35.6%, and 51.1%, respectively. When the data was grouped by age, results were consistent with the work of Hutchinson et al. (1978) and Van Lierde et al. (2003). Nasalance scores increased as a function of an
increase in age. The authors suggested that with age, VP function can be affected by changes in the craniofacial structure and an increase in the cross-sectional area of the nose (p. 353).

However, if variations in VP function are language-specific, then it is reasonable to suspect that normative data for English speaking children may differ slightly. Fletcher et al. (1989) collected normative data from a group of 117 Alabama elementary school children, ranging in age from 5 years, 70 months to 12 years, 8 months. The children produced the Zoo Passage and Rainbow Passage once, and the Nasal Sentences twice. The mean nasalance scores for the Zoo Passage, Rainbow Passage, and Nasal Sentences were 15.5%, 35.7%, and 61.1%, respectively, which is very similar to the Thai and Flemish-speaking children.

More recently, Sweeney, Sell, and O’Regan (2004) assessed 70 English-speaking Irish children, 36 girls and 34 boys, ranging in age from 4 years 11 months to 13 years. All the children had normal speech, resonance, and voice. Nasalance scores were obtained for 16 test sentences that corresponded with 4 sentence types: (1) those with high pressure consonants, but devoid of nasal consonants, (2) sentences with low-pressure consonants, and devoid of high-pressure and nasal consonants, (3) sentences containing 55% nasal consonants, and (4) mixed consonant sentences, which included high and low pressure consonants and 11% nasals. Results revealed a mean nasalance score of 26%, with a range of 17% to 35%, for all 16 sentences. For the high-pressure consonant sentences, the mean nasalance score was 14%, with a range of 7% to 25%. The means nasalance score for low-pressure consonants was 16%, with a range of 7% to
30%, and for the nasal sentences, the mean was 51%, with a range of 33% to 68%. Results did not show a significant difference between the group means for females, at 27%, and for males, at 26% (p.171).

Although normative data is necessary in considering whether a client may have abnormal nasal resonance, when measuring for the success of treatment or surgical intervention, it is important to distinguish whether any changes in nasalance scores are actually due to intervention or are within the range of normal variability. In order to determine normal variability, Lewis, Watterson, and Blanton (2008) assessed twenty-six adults with normal speech and resonance over the short-term and long-term. Nasalance scores were obtained for two types of stimuli: The Turtle Passage, which does not contain any nasal consonants; and the Mouse Passage, which contains 11% nasal consonants. In order to account for subject performance and test procedure variability in the short-term, the researchers performed tests and immediate retests with a change of headgear (CHG) and without a change of headgear (NCHG). Long-term variability was tested over three different time spans: (1) AM versus PM over the course of 5 days, (2) 1 day separation, and (3) 1 week separation. There was an inherent procedure variability associated with the removal of the headgear in the long-term assessments. Analyses of the short-term data showed 93% of nasalance scores with the Turtle Passage varied within five points in the NCHG condition, and 92% were within five points in the CHG condition. For the Mouse Passage, nasalance scores differed by five points for 97% of the NCHG condition and 88% for the CHG condition. Long-term analyses showed that for the Turtle Passage, the mean of the difference in nasalance scores was 2.96 for the AM/PM and DAY conditions,
and 2.37 for the WEEK condition. “For the Mouse Passage, the means and standard deviations of the nasalance difference scores for the AM/PM, DAY, and WEEK conditions were 3.14 (SD, 1.21), 3.30 (SD, 2.34), and 3.30 (SD, 2.31), respectively” (p.498). From these findings, Lewis et al. concluded that typical variability for most people would be a difference of about five nasalance points.

Since nasalance scores are sensitive to degree of nasal patency, test procedure variances, variability over the short- and long-term, and to changeable timing of closure for the VP mechanism and developmental changes in children, the purpose of the current study was to investigate changes in nasalace scores in a group of normal children over a 1-month period, in order to determine if there is a difference between nasalance scores over time for normal children as compared to normal adults. The specific research questions are as follows: (1) What is the degree of nasalance score variation associated with short-term variability in a group of normal children?; and (2) What is the degree of nasalance score variation associated with long-term variability in a group of normal children?
Chapter 3

METHODOLOGY

Participants

Participants consisted of 14 speakers between the ages of 14 through 15 years. For the purposes of this study, participants only went up to 15 years, as opposed to 16 years, because studies “indicate that nasal cross-sectional size at the nasal valve does not increase much after age 15,” and furthermore, “nasal area may influence nasal resonance balance” (Warren, Dalston, & Mayo, 1994, p. 260).

Participants were recruited from one public school within the Sacramento, California metropolitan region. Eight of the 14 participants reportedly spoke English as a first language; five of 6 students whose first language was not English reportedly began academic English instruction beginning in Kindergarten or 1st grade; and the sixth English Language Learner (ELL) reportedly began academic English instruction in the 3rd grade. Approximately 7% of participants (n=1) were Caucasian, 21% Asian (n=3), 50% African American (n=7), and 21% Hispanic (n=3). Mayo, Floyd, Warren, Dalston, & Mayo (1996) conducted a cross-racial study comparing the nasalance scores of 40 African American and 40 white Americans. No significant differences were found for the Zoo passage. Data regarding the nasalance scores for Asian and Hispanic speakers of English could not be obtained. However, Gildersleeve-Neumann and Dalston (2001)
concluded that “there is no apparent reason to suggest that their [Hispanic] scores would differ from those of African American or European speakers of English,” and thus they treated data from all subjects as homogeneous (p.107). For the purposes of this study, cross-racial analyses were not conducted and data from all 14 subjects were also treated as homogeneous.

None of the speakers had a history of cleft palate, speech or resonance disorders, or hearing loss. Speakers were excluded if they had undergone a tonsillectomy or adenoidectomy within a year of the study. At the time of recruitment, none of the participants had an upper respiratory infection or allergies, nor were they using antihistamines, decongestants, or nose sprays. Over the course of the study, 1 participant reported having a cold. Data was still obtained for that participant, but excluded from the analysis during those time periods in which s/he experienced a cold or allergies.

Once permission was granted by the school district overseeing the one public school, two notices were sent home to parents: an initial notice and a follow-up notice for parental approval. Parents then received a formal letter of invitation and signed an informed consent approved by the university’s Institutional Review Board. After parental consent was obtained, assent was gained from the children who agreed to participate.
Stimuli

While previous studies of nasalance have used the Zoo Passage and Rainbow Passage as stimuli, Watterson, Wright, and McFarlane (1993) found that young children had too much difficulty reading or reciting the passages fluently. Thus, Watterson, Hinton, and McFarlane (1993) compared nasalance scores obtained from the Zoo Passage and Rainbow Passage to two novel stimuli, the Turtle Passage and the Mouse Passage. The Turtle Passage is 29 syllables in length and, similar to the Zoo Passage, does not contain any nasal consonants. The Mouse Passage is 40 syllables long and contains 11% nasal consonants, similar to the Rainbow Passage. The authors found that nasalance scores for the Turtle Passage and Mouse Passage were comparable to those of the Zoo Passage and Rainbow Passage, respectively. Thus, the Turtle Passage and Mouse Passage were used as stimuli.

Instrumentation

The Nasometer II, model 6400, version 2.6 (KayPENTAX, Lincoln Park, NJ) was used to collect data.
Procedures

Procedures for this study followed those of Lewis et al. (2008, p. 497). The Nasometer was calibrated before each data collection period according to the manufacturer’s specifications. Data was collected in a quiet room provided by the school. Each participant was seated in a comfortable chair and was facing away from the Nasometer video monitor, which was shielded to prevent any influence from visual feedback. The same examiner collected data and placed the headgear for a given participant throughout all sessions to limit between-examiner variability. The plate separating the oral and nasal openings was placed perpendicular to the facial plane and rested firmly against the upper lip. To secure the headgear, the examiner used the same sequence each time it was placed by first securing the strap at the back of the head, then adjusting the screws at the temple, and lastly, securing the screws at the sound separation plate. Nasalance scores collected for each reading of each passage were recorded on the given participant’s data sheet and subsequently transferred to an Excel (version 2013) data file for statistical analyses (Microsoft Corp., Seattle, WA).

Nasalance score data were intended to be collected twice per day, in the AM and PM, for 5 consecutive days, and then once per week for 3 weeks afterward. Due to examiner illness, data were collected on the Monday, Wednesday, Thursday, and Friday of the first week of data collection, thus totaling 4 days the first week, 3 of which were consecutive. Also, due to a shortened school day on the Friday of the 1st week, PM data were not collected. The Turtle Passage and Mouse Passage were read three times each
during the AM sessions. Each passage was read twice in succession without changing the headgear (NCHG). Then, the headgear was removed and replaced before participants read the passages for the third time (CHG). This allowed for analyses of short-term variability under the two conditions, NCHG and CHG. In order to limit any sequencing effects, the order in which the passages were read was randomly assigned for each subject. A given participant read the passages in that assigned order across all data collection sessions.

Each passage was read one time in the PM sessions and in three subsequent sessions, each separated by 1 week. This allowed for analyses of long-term nasalance score variability under three conditions: (1) scores from AM versus PM of the same day, (2) scores collected 1 day apart, and (3) scores collected 1 week apart over a 1 month period.

Therefore, three scores were obtained in the AM sessions for 4 days and one in the PM sessions for 3 days. Additionally, one score was obtained per week for the 3 weeks thereafter. Thus, 18 nasalance scores were obtained per passage from each participant. In total, 36 nasalance scores (18 scores x 2 passages) were obtained from each participant who attended all data collection sessions throughout the 1-month period.

Data Analysis

To assess short-term variability in nasalance scores obtained in the AM, separate analyses were made for the NCHG condition and the CHG condition for each passage.
Five comparisons of scores in the NCGH condition were obtained by comparing scores from each day’s first and second readings of each passage. For the CHG condition, five comparisons were obtained by comparing scores from each day’s first and third readings of each passage.

Long-term variability was assessed under three conditions: (1) AM versus PM nasalance scores, (2) scores 1 day apart, and (3) scores 1 week apart. Variability between the AM and PM scores was assessed by comparing each day’s first AM reading of the passage and the same day’s PM reading. This provided 3 comparisons for each passage. Variability in scores obtained 1 day apart was assessed by comparing AM scores from days 3 and 4, and 4 and 5. This provided 2 comparisons for each passage. Variability in nasalance scores obtained one week apart was assessed by comparing the first AM score from week 1 to the score from week 2, as well as comparing scores obtained for week 2 to those of week 3, and week 3 to week 4. This provided 3 comparisons for each passage.

For all readings of each passage, means and standard deviations were computed.
Over the course of the study, nasalance score data points were collected from each participant, resulting in a total of 504 data points (14 participants x 18 nasalance scores x 2 passages). However, data from 1 participants had to be excluded due to a cold, and 10 participants did not attend 1 or more of the subsequent weeks’ data sessions. This accounted for a total of 26 missing data points.

Short-term variability in nasalance scores is shown in two test-retest conditions: (1) NCHG, in which the headgear of the Nasometer was not removed and replaced; and (2) CHG, in which the headgear was removed and replaced. Long-term variability is seen in three conditions: (1) AM/PM, in which nasalance scores obtained in the morning are compared with those obtained in the afternoon of the same day; (2) DAY, in which nasalance scores obtained one day apart are compared; and (3) WEEK, in which comparisons between nasalance scores obtained a week apart are made. The hours of separation between the AM and PM sessions varied. The minimum AM/PM separation was 3 hours and the maximum was 5 hours across all 4 days of data collection.
Table 1 Means and Standard Deviations of Nasalance Score Differences for No Headgear Change (NCHG), Change Headgear (CHG), Moring to Afternoon (AM/PM), Separated by 1 Day (DAY), and Separated by 1 week (WEEK) conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Stimulus</th>
<th>Turtle</th>
<th>Mouse</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
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<td>NCHG</td>
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</tr>
<tr>
<td>CHG</td>
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<td>WEEK</td>
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<td>4.59</td>
<td>3.79</td>
</tr>
</tbody>
</table>

Short-Term Variability

Table 1 shows the means and standard deviations of nasalance scores in the NCHG and CHG conditions for both the Turtle Passage and Mouse Passage. The mean of the nasalance score differences for the Turtle Passage in the NCHG condition was 1.71 (SD, 1.62). In the CHG condition, the mean of the Turtle Passage nasalance score differences was 3.18 (SD, 3.67). The means and standard deviations of the nasalance score differences for the Mouse Passage in the NCHG and CHG conditions were 2.02 (SD, 1.60) and 2.63 (SD, 2.48), respectively.

For the Turtle Passage and Mouse Passage, Tables 2 and 3 show the short-term variability in the NCHG and CHG conditions. Table 2 shows that a difference of six or less nasalance score points accounted for 100% of the variability in the NCHG condition and 88% of the variability in the CHG condition. For the Mouse Passage (Table 3), it can
be seen that a difference of six or less nasalance points accounted for 98% of the variability in the NCHG condition and 89% in the CHG condition. These findings differ by one nasalance point from those of Lewis et al. (2008), who suggested “a difference of five nasalance points should account for typical variability in most [adults]” (p. 500).

**Long-term Variability**

Table 1 shows the means and standard deviations of nasalance score differences for each passage in the AM/PM, DAY, and WEEK conditions. For the Turtle Passage, the means and standard deviations in the AM/PM, DAY, and WEEK conditions were 2.98 (SD, 2.75), 3.21 (SD, 2.51), and 4.59 (SD, 3.79), respectively. The means for the Mouse passage in the AM/PM, DAY, and WEEK conditions were 3.49 (SD, 2.98), 3.43 (SD, 2.87), and 5.32 (SD, 3.83), respectively.

It can be seen from Table 2 that a difference of eight or less nasalance score points accounted for 93% of the variability in the AM/PM condition, 96% for the DAY condition, and 86% of the variability in the WEEK condition for the Turtle Passage.
Table 2 Cumulative Frequencies (Raw/%) of Absolute Differences in Nasalance Scores in NCHG, CHG, AM/PM, DAY, and WEEK conditions for the Turtle Passage

<table>
<thead>
<tr>
<th>Nasalance Score Difference</th>
<th>Comparison</th>
<th>NCHG*</th>
<th>CHG*</th>
<th>AM/PM †</th>
<th>Day ‡</th>
<th>Weeks §</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>14/25</td>
<td>8/14</td>
<td>-</td>
<td>2/5</td>
<td>1/4</td>
<td>0/0</td>
</tr>
<tr>
<td>≤ 1</td>
<td>31/55</td>
<td>24/43</td>
<td>12/29</td>
<td>2/5</td>
<td>7/25</td>
<td>3/14</td>
</tr>
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<td>≤ 2</td>
<td>42/75</td>
<td>31/55</td>
<td>12/29</td>
<td>22/54</td>
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<td>8/36</td>
</tr>
<tr>
<td>≤ 3</td>
<td>48/86</td>
<td>40/71</td>
<td>33/80</td>
<td>19/68</td>
<td>11/50</td>
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<tr>
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<td>46/82</td>
<td>34/83</td>
<td>22/79</td>
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<tr>
<td>≤ 5</td>
<td>54/96</td>
<td>48/86</td>
<td>37/90</td>
<td>22/79</td>
<td>18/82</td>
<td></td>
</tr>
<tr>
<td>≤ 6</td>
<td>56/100</td>
<td>49/88</td>
<td>38/93</td>
<td>23/82</td>
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<tr>
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<td>50/89</td>
<td>38/93</td>
<td>28/100</td>
<td>19/86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤ 10</td>
<td>52/93</td>
<td>39/95</td>
<td>-</td>
<td>19/86</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>40/98</td>
<td>-</td>
<td></td>
<td>1986</td>
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<td>-</td>
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<td>20/91</td>
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<tr>
<td>≤ 13</td>
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<td>-</td>
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</tr>
<tr>
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<td>-</td>
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</tr>
<tr>
<td>≤ 17</td>
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<td>-</td>
<td></td>
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<td></td>
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<tr>
<td>≤ 19</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
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<tr>
<td>≤ 20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Total number of comparisons made across 5 consecutive days = 56

† Total number of comparison made across 5 consecutive days = 41

‡ Total number of comparisons made 1-day apart = 28

§ Total number of comparisons made 1-week apart = 22

Table 3 shows that for the Mouse Passage, a difference of eight or less nasalance score points also accounted for 93% of the variability in the AM/PM and DAY conditions, and 86% in the WEEK condition.
Table 3 Cumulative Frequencies (Raw/%) of Absolute Differences in Nasalance Scores in NCHG, CHG, AM/PM, DAY, and WEEK conditions for the Mouse Passage

<table>
<thead>
<tr>
<th>Nasalance Score Difference</th>
<th>Comparison</th>
<th>NCHG*</th>
<th>CHG*</th>
<th>AM/PM †</th>
<th>Day ‡</th>
<th>Weeks §</th>
</tr>
</thead>
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<tr>
<td>0</td>
<td></td>
<td>7/13</td>
<td>13/23</td>
<td>6/15</td>
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<tr>
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<td>24/43</td>
<td>23/41</td>
<td>10/24</td>
<td>9/32</td>
<td>6/27</td>
<td></td>
</tr>
<tr>
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<td>32/57</td>
<td>18/44</td>
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<td>6/27</td>
<td></td>
</tr>
<tr>
<td>≤ 3</td>
<td>50/89</td>
<td>39/70</td>
<td>24/59</td>
<td>16/57</td>
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<td></td>
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<tr>
<td>≤ 4</td>
<td>52/93</td>
<td>45/80</td>
<td>30/73</td>
<td>18/64</td>
<td>9/41</td>
<td></td>
</tr>
<tr>
<td>≤ 5</td>
<td>53/95</td>
<td>48/86</td>
<td>33/80</td>
<td>23/82</td>
<td>11/50</td>
<td></td>
</tr>
<tr>
<td>≤ 6</td>
<td>55/98</td>
<td>50/89</td>
<td>36/88</td>
<td>24/86</td>
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<tr>
<td>≤ 7</td>
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<td>36/88</td>
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</tr>
<tr>
<td>≤ 8</td>
<td>56/100</td>
<td>54/96</td>
<td>38/93</td>
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<td>27/96</td>
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<td></td>
</tr>
<tr>
<td>≤ 10</td>
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<td>40/98</td>
<td>27/96</td>
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<tr>
<td>≤ 11</td>
<td></td>
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<td>21/95</td>
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<tr>
<td>≤ 12</td>
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<td>21/95</td>
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<tr>
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<td>41/100</td>
<td>21/95</td>
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<tr>
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<td>41/100</td>
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<tr>
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<td>41/100</td>
<td>21/95</td>
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<tr>
<td>≤ 18</td>
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<td>41/100</td>
<td>21/95</td>
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<tr>
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<td>21/95</td>
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<tr>
<td>≤ 20</td>
<td></td>
<td>41/100</td>
<td>21/95</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Total number of comparisons made across 5 consecutive days = 56

† Total number of comparison made across 5 consecutive days = 41

‡ Total number of comparisons made 1-day apart = 28

§ Total number of comparisons made 1-week apart = 22

These results reflect variability as a result of headgear removal and replacement and from changes over time. A review of Tables 2 and 3 show that variability in the long-term conditions was greater to that found in the short-term NCHG condition for both the Turtle and Mouse passages. Within the long-term conditions, variability in the WEEK condition was slightly greater than the AM/PM and DAY conditions for both passages. This is contrary to the findings of Lewis et al. (2008), who did not find an
increased pattern of variability in nasalance scores as the time between data collection sessions increased.
It is necessary to note that normal nasalance score variability can be attributed to the Nasometer, to variance in test procedures, between-subject variability, and subject performance variability. Nasometer variability occurs from the use of a different type of measurement device or a different model of the Nasometer. Test procedure variance can occur due to differences in placement in the headgear. Between-subject variability can be influenced by dialectal differences, sex, and age. Lastly, subject performance variability can occur due to the inconsistency with which subjects repeat the same stimulus, fluctuations in nasal patency, and developmental age differences effecting VP timing and closure.

The purpose of this study was to examine the degree of nasalance score variation associated with short-term and long-term variability in a group of normally-developing children. Short-term variability was assessed under two immediate test-retest conditions, one without a change in headgear (NCGH) and one with a change in headgear (CHG). Long-term variability was assessed under three conditions: (1) AM scores versus PM scores, (2) scores taken 1 day apart, and (3) scores taken 1 week apart.

Short-term variability data, as seen in Table 1, shows that the least amount of variability occurred in the NCHG condition (1.71 and 2.02). The means of the NCHG and CHG conditions for the Turtle Passage (1.71 and 3.18, respectively) found a
variability of greater than one nasalance point, as compared to a difference of less than one nasalance point between the NCHG and CHG conditions for the Mouse Passage (2.02 and 2.63, respectively). This suggests that although removal and replacement of the headgear is a variable to consider, consistent closure of the VP mechanism and coordination between the respiratory and articulatory functions of speech may not be as accurate as adults. Comparisons between the means of the AM/PM and DAY conditions for both the Turtle and Mouse Passages suggest that variations in nasal patency are relatively limited when compared to the WEEK conditions.

Overall, long-term variability did increase over time. For example, for the Turtle Passage, 93% of the nasalance scores in the AM/PM condition were within six nasalance points compared to 82% in the DAY and WEEK conditions. For the Mouse Passage, 88% of the nasalance scores in the AM/PM condition and 86% in the DAY condition were within six nasalance points, compared to only 59% of the nasalance scores for the WEEK condition.

The present study sought to determine whether the degree of nasalance variation over time is greater in children than in adults. Nasalance score data revealed great variability across all five conditions, but in general, a difference of 8 points or less accounted for 86% to 100% of the variation. This is indeed different from the findings of Lewis et al. (2008), who determined that in adults, “a difference of about five nasalance points should account for typical variability in most people,” (p. 500). Therefore, these participants between the ages of 14 and 15 did not show the same degree of agility in VP closure timing as adults. This could potentially be attributed to the developmental
changes suggested by Van Lierde et al. (2003), hormone fluctuations as cited in Lewis et al. (2008), or changes in the craniofacial structure and an increase in the cross-sectional area of the nose as suggested by Prathanee et al. (2003), or a combination of the three. Thus further research is needed to determine at approximately what age do VP timing and variability in patterns of closure become adult-like.

There are several limitations to this study that should be considered. First, only one type of Nasometer or measurement device was used to collect data. Results from the present study can only be applied when collecting scores from the Nasometer II, Model 6400, as scores from the NasalView are not comparable (Lewis & Watterson, 2003), and clinicians would have to consider an additional variance of eight points with the use of the Nasometer 6200 (Watterson et al., 2005).

A second limitation, particularly pertaining to between-subject variability, is that the results of this study cannot be applied to those clients outside the ages of 14 to 15. Many craniofacial surgeries occur before the age of 6 and after the age of 15. Therefore, in order for clinicians to discern whether changes in nasalance scores are due to normal variability or to an alteration in the client’s conditions after therapy or surgical intervention, further research is needed to look at normal variability in nasalance scores for children outside this study’s age range.

Third, the present study lacked data from different dialectal regions. Results from a study conducted by Seaver et al. (1991) showed significant differences in nasalance scores between Mid-Atlantic, Mid-Western, Southern, and Ontario Canadian speakers. It could be assumed that clients from different dialectal regions could have discrepancies in
the amount of variability between nasalance scores. Until research can account for the variability that occurs across regional dialects, clinicians need to consider such potential discrepancies when making clinical decisions.

Fourth, analyses of the data did not compare nasalance score variability in children of the opposite sex. Seaver et al. (1991) found significantly higher nasalance scores for female participants than for male participants. It is possible that the normal variability within the higher scores for females could be similar to that of the lower scores of the male participants. However, normal variability could be different considering the developmental changes in the speech mechanism that occur for both sexes, but are particularly noted in males. Thus, further analyses of the data are warranted to determine if such differences exist.

Lastly, the number of comparisons that were made was limited by the low number of participants and the missing data points from missed data collection sessions. In order to make a potentially more valid determination of the differences between nasalance scores over time for normal children and normal adults, a larger number of participants and data for everyday of the first week is needed.

Aside from the aforementioned research directions, future research is also needed to determine the normal variability of nasalance scores within hypernasal populations and in comparison to those with normal resonance. Should any overlap occur between the two populations, this could call into question the reliability of the Nasometer as an objective measure of hypernasality.
Conclusion

These data showed greater long-term variability in nasalance scores for children than for adults. When using the Nasometer II, Model 6400, to measure the success of therapy or intervention of clients between the ages of 14 to 15, a difference of eight nasalance points should be considered normal variation. This guideline can be applied to both types of stimuli, but clinicians should further consider variations arising from differences in sex and regional dialects.
Appendix A

Turtle and Mouse Passages

_Turtle Passage_

What could it be?

It has a head,

four feet with a tail.

It walks real slow,

cause it carries a house.

Could it be a turtle?

_Mouse Passage_

There was a young mouse,

that lived in my house,

who wanted to go to school.

He asked one day,

please show me the way.

I said yes! Follow me.

Mr. Mouse was going to school.
Appendix B

Letter of Invitation

Title of Study: Comparison of Short-term and Long-term Nasalance Score Variability in Children

Principal Investigator: Rebecca Van Der Volgen, B.A., Department of Speech-Language Pathology and Audiology, California State University, Sacramento

Faculty Supervisor: Ann Blanton, Ph.D., Department of Speech-Language Pathology and Audiology, California State University, Sacramento

I, Rebecca Van Der Volgen, B.A., from the Speech-Language Pathology and Audiology Department at California State University, Sacramento, invite your child to participate in a research project entitled Comparison of Short-term and Long-term Nasalance Score Variability in Children.

The purpose of this research project is obtain information on the normal variation in instrumental scores used to assess individuals with hypernasality. Each participant will be seated in a comfortable chair and facing away from the Nasometer video monitor, which will be shielded to prevent any influence from visual feedback. The same examiner will
collect data and place the headgear for a given participant throughout all sessions. The plate separating the oral and nasal openings will be placed perpendicular to the facial plane and rested firmly against the upper lip. To secure the headgear, the examiners will use the same sequence each time it is placed by first securing the strap at the back of the head, then adjusting the screws at the temple, and lastly, securing the screws at the sound separation plate. Nasalance scores collected for each reading of each passage will be recorded on the given participant’s data sheet and subsequently transferred to an SPSS (version 13.0) data file for statistical analyses (SPSS Inc., Chicago, IL).

The participants will recite two passages, the Turtle Passage and the Mouse Passage. The Turtle Passage is 29 syllables in length and does not contain any nasal consonants. The Mouse Passage is 40 syllables long and contains 11% nasal consonants.

If you agree to your child taking part in this study, your child’s involvement will last 1 month. Participating children will be asked to return to the data collection room 2 times per day for 5 consecutive days, and then once per week for 3 weeks afterward. Each visit will take approximately 20 minutes.

The discomforts and risks your child may experience by participating in this study are minimal. Any discomfort that may arise may be due to placement of the headgear.
Your child will not benefit from taking part in this research study. However, the results of this research may guide the future use of the Nasometer as an objective measurement in the treatment of those with hypernasality.

Research records that are reviewed, stored, and analyzed at California State University will be kept in a secured area in Dr. Blanton’s office. Scores collected for research purposes will be labeled with a code number and will be stored in a secured area in Dr. Blanton’s office.

In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

Health information about your child will be collected if you choose to be part of this research study. Health information is protected by law as explained in the California State University, Sacramento Privacy Notice. If you have not received this notice, please request a copy from the investigator. At California State University, Sacramento, your child’s information will only be used or shared as explained and authorized in this consent form or when required by law. It is possible that some of the other people/groups who receive your health information may not be required by Federal privacy laws to protect your information and may share it without your permission.
To participate in this research you must allow the study team to use your health information. If you do not want us to use your protected health information, you may not participate in this study.

Your permission for the use, retention, and sharing of your child’s identifiable health information will expire upon completion of the research study. At that time the research information not already in your medical record will be destroyed.

If you choose to participate, you are free to withdraw your permission for the use and sharing of your health information data scores at any time. You must do this in writing. Write to Dr. Blanton and let her know that you are withdrawing from the research study. Her mailing address is 6000 J St., Sacramento, CA 95819-6104.

If you withdraw your permission:

- We will no longer use or share medical information about you for this research study, except when the law allows us to do so.
- We are unable to take back anything we have already done or any information we have already shared with your permission.
- We may continue using and sharing the information obtained prior to your withdrawal if it is necessary for the soundness of the overall research.
- We will keep our records of the care that we provided to you as long as the law requires.
Your child does not have to participate in this research. If you and your child chooses to take part, you have the right to stop at any time. If you decide not to participate or if you decide to stop taking part in the research at a later date, there will be no penalty or loss of benefits to which you are otherwise entitled.

If you have any pertinent questions about your rights as a research participant, please contact the California State University, Sacramento Committee for the Protection of Human Subjects (916-278-7161, research@csus.edu)

If you have any questions, please feel free to contact me.

Thank you

Rebecca Van Der Volgen

Rebecca Van Der Volgen, B.A. Ann Blanton, Ph.D.
Principal Investigator Faculty Supervisor
(916) 712-2922 (916) 278-6679
Becky.vandervolgen@gmail.com blantona@saclink.csus.edu
This study has been reviewed and received ethics clearance through California State University, Sacramento Institutional Review Board.
References


