

THE NASOMETER:
A CLINICAL GADGET OR A POTENTIAL TECHNOLOGICAL BREAKTHROUGH?

Jan van Doorn and Alison Purcell

School of Communication Disorders
University of Sydney

ABSTRACT - The excessive nasal quality associated with some types of disordered speech is a perceptual speech feature which is exceptionally difficult to assess reliably. This has led to a search for objective measures of nasality by using the acoustic speech signal. One recent device which has been developed commercially for the clinical market measures the ratio of oral to nasal speech signal intensity, and this device is currently being assessed in various research and clinical settings around the world. To date, the focus of the assessment has been on the validity of Nasometer measures whereby the nasalance measures have been correlated with levels of perceived nasality as rated by clinicians specialising in nasality disorders of speech. This paper addresses the issue of establishing a measure of the reliability of nasalance measures in order to establish criteria for using the device in making clinical decisions.

INTRODUCTION.

The nasal quality which can be detected in some instances of disordered speech (e.g. in the case of cleft palate, and for some hearing impaired speakers) is caused by an incomplete closure of the velopharyngeal port during sounds which do not require the nasal cavity for their correct articulation (as opposed to the nasal consonants, where the velum is deliberately lowered to allow the nasal and oral cavities to be linked). Sounds produced with this incomplete closure have a distinct nasal quality associated with them, and the degree of "nasality" is determined by the amount of closure achieved at the velopharyngeal port - it may be partially closed or completely open, depending on the action of the velum. Attempts have been made in the speech pathology community to quantify the level of excess nasality in speech by using severity scales where the nasality is assigned a degree of severity by a skilled listener (Bradford, Brooks & Shelton, 1964). It is widely reported that the accurate assessment of the degree of nasality is an exceptionally difficult perceptual task (Philips, 1980; Pannbacker, Lass, Middleton, Crutchfield, Trapp & Scherbick, 1984).

The assessment of nasality has serious implications in several clinical settings: perhaps the most illustrative is the assessment of velopharyngeal competence in cleft palate because it is often the initial point in making decisions about whether speech therapy can improve the condition, or whether additional invasive procedures (e.g. nasendoscopy) or surgery may be required to assess and remediate the problem. An incorrect assessment of the speech quality can lead to unnecessary use of other procedures on a population of young children. Hence clinicians who work with the cleft palate population initiated the search for more objective means of assessing nasality in speech (Fletcher, Adams & McCutcheon, 1989; Kent, Liss & Philips, 1989).

The search for objective measures of nasality has been long standing. It has led to the development of devices which measure the airflow (i.e. volume velocity) from the nasal passages, the air pressure levels in nasal and oral cavities, and the spectral characteristics of the sound signal itself (McWilliams, Morris & Shelton, 1990). None of these measures has been found to necessarily correlate strongly with the resonance disorder of nasal speech.

One recent outcome of the search for an objective measure which correlates with perception of hypernasal speech is the commercial development of a device known as a Nasometer. The Nasometer measures the nasal/oral SPL ratio (referred to as "Nasalance") from two microphones separated by a sound baffle. The development of the Nasometer began with a device known as TONAR (Fletcher, 1970), and has been refined to become a PC linked device which has been marketed commercially since 1988.

nasal sentences also developed by Fletcher, 1972 which contain 35% of phonemes as nasal consonants, which is three times their usual frequency of occurrence in standard English. These two stimuli have been recommended by the developers of the Nasometer as suitable passages for assessing hyper- and hyponasality in speech.

Methodology

Experiment 1.

The Nasometer was fitted to one child, according to the instructions in the manual, and the child was asked to read one of the stimulus passages. At the completion of the reading, the recorded nasalance trace was stored in a computer file for later statistical analysis. Similarly, the nasalance trace for the second stimulus was recorded. Each stimulus was repeated two or three times, and the nasalance recorded and stored on each occasion before the Nasometer was taken off. The procedure was then repeated for the second child. This procedure was repeated on four different occasions during the day, until a total of thirteen repetitions of each stimulus had been recorded for each of the two children.

Experiment 2.

For each of the five children in the group, the Nasometer was fitted to the child, and the child read one of the two stimulus passages (except the youngest child who repeated the passage after the experimenter) and the nasalance trace for the utterance was recorded and stored. In a similar manner the nasalance trace was stored for the second stimulus. Both stimuli were then repeated. The Nasometer headset was then removed for a short period (5 - 10 minutes) and after that the entire procedure was repeated. The procedure was repeated for three consecutive days for Subjects 4 and 5, and for four consecutive days for Subjects 1 - 3.

Thus data for a total of either 12 (three days) or 16 (4 days) repetitions of each of the two stimulus passages was obtained for each of the subjects. The variables which may have affected the measures in this experiment were (1) variations in the child's speech pattern (2) variations caused by the placement of the headset, and (3) variations over time.

Experiment 3.

The procedure of using two repetitions of each stimulus for recording and saving nasalance traces once the headset was correctly positioned on each child (as described in Experiment 2) was also used in this experiment, but in this case the procedures were carried out at various intervals over a period of three months, initially at weekly intervals, and then less frequently.

Data Analysis.

For each of the utterances, the mean and standard deviation for the nasalance traces was calculated using the Nasometer's own software package. The degree of variability shown by the means of the nasalance values for both stimuli under the various experimental conditions described in the methodology was investigated by calculating the mean, standard deviation, maximum and minimum of the mean nasalance values for each subject in each of the experimental conditions. In order to establish a measure of the reliability of nasalance levels which would take into account the variations which are likely to be encountered in clinical situations, a regression analysis on the maximum and minimum values against the corresponding mean was performed. The regression coefficients were then used to predict the maximum and minimum from a given mean reading, and the predicted and actual ranges of values for each subject in the various experimental conditions were compared.

RESULTS

A summary of the mean nasalance values, and the maxima and minima of the ranges associated with the means are summarised for all the subjects in all experimental conditions in

Because the Nasometer grew out of the need to have an objective measures which would correlate with perceptual measures, its validity has been assessed on the strength of its correlation with perceived levels of nasality in speech (Fletcher, 1976; Dalston & Warren, 1986). This has led to a circular argument, in that it is generally agreed that perception itself is unreliable, and it would appear illogical to argue that the Nasometer's validity can be based on its correlation with perceptual judgement. In order to break away from this circle a better question to ask would be "What are the perceptual measures of hypernasality being used to achieve, and is it possible for the Nasometer to achieve these same results in a more reliable manner?" Clinically, nasality measures are used to assist in establishing the reasons for unacceptable levels of nasality in speech, and to shape the nature of the intervention to alleviate the problem, and to assess the success of the intervention. In essence this requires reliable assessment across clients, and over time with the same client. Can, then, the Nasometer be used to provide a more reliable means of achieving the clinical aims?

The issue of the Nasometer's reliability seems to have been virtually ignored in the arguments about how well its measures correlate with perceptual measures. In the literature there is a notable absence of any studies on the reliability of the Nasometer for repeated measures using the same speaker, and the same speech sample. The reliability of the instrument has fundamental implications in the clinical settings in which it is used. For instance, if norms are to be used as a means of assessing abnormal levels of nasalance, or if treatment efficacy is going to be assessed using nasalance measures, then it is essential that the reliability of the Nasometer measures be strongly established. Thus the purpose of this study was to investigate the reliability of nasalance measures by investigating the variability of repeated measures of nasalance for each subject in a small group of children, using two speech samples which are commonly used in clinical nasalance assessments.

METHOD

Introduction

Experiments were conducted to assess the degree of variability of nasalance measures using repeated measures on two different reading passages with a small group of children for three different sets of conditions:

Experiment 1: Repeated nasalance measures were made over the course of a single day using two subjects.

Experiment 2: Repeated nasalance measures on each day over a period of four consecutive days using five subjects.

Experiment 3: A longitudinal study taking nasalance measures at various intervals over a period of 85 days using two subjects.

Instrumentation

A system was used whereby the Kay Nasometer was linked to a Toshiba Notebook 2100 computer attached to a deskstation (into which the circuit board for the Nasometer was fitted) to provide a portable unit which could be transported to clinical and field settings as required for data collection and storage.

Subjects

The subjects were a group of five children (one male and four female) with age range 5-11 yrs, who were not suffering from any conditions such as colds or sinus infections which could affect the nasal passages. Two of the subjects (Subjects 1 and 2) participated in each of the three experiments, and the three additional children participated in Experiment 2 only.

Stimuli.

Two speech stimuli were used to make nasalance measures: the Zoo Passage, which is a speech sample designed by Fletcher, 1972 which contains no nasal consonants, and a set of

Figure 1. It can be seen from the figure that for all three experimental conditions there was a substantial degree of variability in the repeated nasalance measures for each subject.

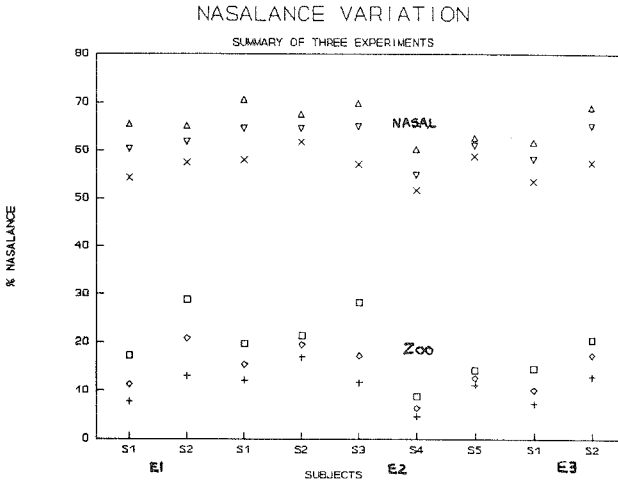


Figure 1. Summary of nasalance means and ranges for all experiments.

The regression analysis, whereby the maximum and minimum nasalance values were regressed against the corresponding mean values for each stimulus, using all subjects in all experimental conditions gave the following regression equations for each of the speech stimuli.

Zoo Passage: $M = 1.23x + 1.35$ M: Maximum
 $m = 0.72x + 0.44$ m: Minimum

Nasal Sentences: $M = 0.97x + 5.92$ x: mean
 $m = 0.69x + 14.22$

Figures 2a & 2b shows the actual (solid lines) and estimated (dotted lines) ranges for each subject in each of the experimental conditions. It can be seen from this figure that for the subjects in this study at least that it is possible to predict the range of values from the mean nasalance for the two speech stimuli used in the experiments.

DISCUSSION

The aim of this project was to examine the amount of variability which occurred on repeated nasalance measures for a particular subject using the same speech sample, and hence establish estimates of reliability levels for mean nasalance measures for any one subject. The experimental conditions in this project have incorporated the type of variation which might reasonably be expected to occur when the Nasometer is used in clinical settings: repeated measurements a single occasion of service, or on more than one occasion on the same day, measurements over a series of consecutive days (in, say, an intensive therapy program) and measurements over a longer time span (regular assessments at weekly or monthly intervals, or assessments pre- and post-surgery). From the results it is clear that all these factors have affected the mean nasalance levels of each of the speakers.

The prediction of the range of variability for a particular mean nasalance level by using the coefficients from the linear regression of the maximum and minimum values with the means shows good agreement between the actual and predicted values for the maxima and minima of the range of nasalance values for all subjects included in this study (see Figure 2). It would seem reasonable, therefore, to make a similar prediction for the range of expected values from a single recording (or possibly the average of two repeated recordings) in a clinical situation.

One of the anticipated clinical advantages of the objective nasalance measurements provided by the Nasometer would be in assessing improvements over time, or after surgery, whereby the perceptual rating factor could be eliminated. In light of the degree of variability found in repeated nasalance measures found in this study, comparison of two assessments on the same subject taken at different times would need to be made with cautious regard to the reliability of each measure. From the results of this study it would seem that it is possible to estimate a measure of the error associated with a single measurement by using an

appropriate regression equation for the speech sample being used. Interpretation of any differences between two measurements taken, say, pre- and post- surgery could then be interpreted in the light of the range of values which have been estimated as the expected normal variation. Additionally, it would be preferable to incorporate repeated measurements into the assessment routine where possible, in order to improve the estimate of the mean nasalance value, and hence the estimation of the nasalance range associated with the measurement.

CONCLUSION

The studies carried out in this project have established that nasalance measures for the same person repeating the same speech sample show significant variation. For the subjects in this study it was possible to estimate the range of nasalance values if the mean nasalance was known. It has been suggested that the same estimation method could be used in a clinical

ESTIMATED AND ACTUAL NASALANCE RANGES

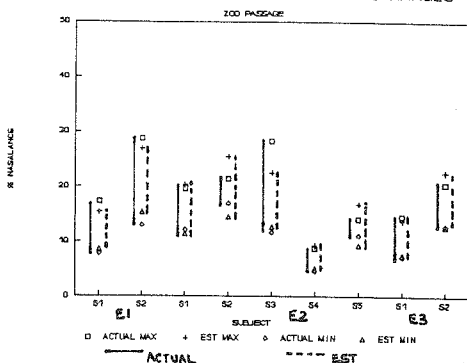


Figure 2a: Actual and estimated ranges for Zoo Passage.

ESTIMATED AND ACTUAL NASALANCE RANGES

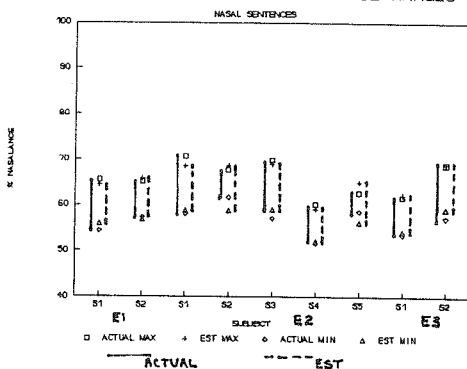


Figure 2b. Actual and estimated ranges for nasal sentences.

situation where a single measurement has been made so that an estimate of the expected range of nasalance values could be established. This estimate would assist clinicians in making decisions where comparisons of different nasalance measures were involved.

REFERENCES

- Bradford, L.J., Brooks, A.R., & Shelton, R.L. (1964) *Clinical Judgement of Hypernasality in Cleft Palate Children*, *Cleft Palate Journal*, 1, 329- 335.
- Dalston, R.M. & Warren, D.W. (1986) *Comparison of TONAR II, Pressure-Flow and Listener Judgements of Hypernasality in the Assessment of Velopharyngeal Function*, *Cleft Palate Journal*, 23, 109-115.
- Fletcher, S.G. (1970) *Theory and Instrumentation for Quantitative Measurement of Nasality*, *Cleft Palate Journal*, 7, 601-609.
- Fletcher, S.G. (1972) *Contingencies for Bioelectric modification of Nasality*. *Journal of Speech and Hearing Disorders*, 37, 329-346.
- Fletcher, S.G. (1976) *"Nasalance" versus Listener Judgements of Nasality*. *Cleft Palate Journal*, 13, 31-44.
- Fletcher, S.G., Adams, L.E., & McCutcheon, M.J. (1989) *Cleft Palate Assessment through oral-nasal Acoustic Measures*. In Bzoch, K.R. (Ed.), *Communicative Disorders Related to Cleft Lip and Palate*, (Little, Brown & Co: Boston).
- Kent, R.D., Liss, J.M., & Phillips, B.S. (1989) *Acoustic Analysis of Velopharyngeal Dysfunction in Speech*. In Bzoch, K.R. (Ed.), *Communicative Disorders Related To Cleft Lip and Palate*. (Little, Brown & Co: Boston).
- McWilliams, S.B., Morris, H. and Shelton, R. (1990) *Cleft Palate Speech*. 2nd ed. (Decker Inc: Philadelphia).
- Pannbacker, M., Lass, N., Middleton, G., Crutchfield, E., Trapp, D., & Scherbick, K. (1984) *Current Clinical Practices in the Assessment of Velopharyngeal Closure*. *Cleft Palate Journal*, 21, 33-37.
- Philips, B.J. (1980) *Perceptual Evaluation of Velopharyngeal Competency*. *Annals of Otology, Rhinology and Laryngology (Supplement)*, 89, 153-157.