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The relationship between the Nasality Severity Index 2.0 and perceptual judgments of hypernasality

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ABSTRACT

Purpose: The Nasality Severity Index 2.0 (NSI 2.0) forms a new, multiparametric approach in the identification of hypernasality. The present study aimed to investigate the correlation between the NSI 2.0 scores and the perceptual assessment of hypernasality.
Method: Speech samples of 35 patients, representing a range of nasality from normal to severely hypernasal, were rated by four expert speech-language pathologists using visual analogue scaling (VAS) judging the degree of hypernasality, audible nasal airflow (ANA) and speech intelligibility. Inter- and intra-listener reliability was verified using intraclass correlation coefficients. Correlations between NSI 2.0 scores and its parameters (i.e. nasalance score of an oral text and vowel /u/, voice low tone to high tone ratio of the vowel /i/) and the degree of hypernasality were determined using Pearson correlation coefficients. Multiple linear regression analysis was used to investigate the possible influence of ANA and speech intelligibility on the NSI 2.0 scores.
Results: Overall good to excellent inter- and intra-listener reliability was found for the perceptual ratings. A moderate, but significant negative correlation between NSI 2.0 scores and perceived hypernasality ($r = -0.64$) was found, in which a more negative NSI 2.0 score indicates the presence of more severe hypernasality. No significant influence of ANA or intelligibility on the NSI 2.0 was observed based on the regression analysis.
Conclusion: Because the NSI 2.0 correlates significantly with perceived hypernasality, it provides an easy-to-interpret severity score of hypernasality which will facilitate the evaluation of therapy outcomes, communication to the patient and other clinicians, and decisions for treatment planning, based on a multiparametric approach. However, research is still necessary to further explore the instrumental correlates of perceived hypernasality.
Learning outcomes: The reader will be able to (1) describe and discuss current issues and influencing variables regarding perceptual ratings of hypernasality; (2) describe and discuss the relationship between the Nasality Severity Index 2.0, a new multiparametric approach to hypernasality, and perceptual judgments of hypernasality based on visual analogue scale ratings; (3) compare these results with the correlations based on a single

Abbreviations: EAI, equal appearing interval; VAS, visual analogue scale; DME, direct magnitude estimation; NSI 2.0, Nasality Severity Index 2.0; VLHR, voice low tone to high tone ratio; ANA, audible nasal airflow; ICC, inraclass correlation coefficient.

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parameter approach and (4) describe and discuss the possible influence of audible nasal airflow and speech intelligibility on the NSI 2.0 scores.

1. Introduction

During communication, speech productions are perceived by the listener which results in a fundamental interaction between production and perception. A speech disorder only exists when it is recognized by the patient and/or others in the patient's environment. Perceptual assessments of speech disorders by clinicians are based on this principle and remain the currently most utilitarian procedure during diagnosis and evaluation of speech therapy and/or surgical intervention because it cannot be replaced yet by any instrumental assessment. Moreover, several authors consider perceptual assessments as the standard against which instrumental measurements must be validated (Kent, 1996; Keuning, Wieneke, & Dejonckere, 2004; Moll, 1964; Vogel, Ibrahim, Reilly, & Kilpatrick, 2009). However, several variables can influence listeners' perception of speech which may limit the reliability and validity of perceptual judgments. Kreiman, Gerratt, Kempster, Erman, and Berke (1993) provide an overview of these factors. More specifically, *individual differences* due to experience, persons' perceptual habits, biases, etc. which determine the listener's internal standard can influence perceptual judgments. Additionally, *task factors* such as definitions of rating scales, listeners' familiarity with the used scale and perceptual context (i.e. the 'listener drift' in which listeners rate speech as more severely disturbed when a moderately impaired speech sample follows a series of mildly impaired samples) may have a potential influence. Lastly, *interaction between listeners' and task factors*, such as differences in the interpretation of the rating points of the used scale, can also influence listeners' decisions. Furthermore, the discussion continues about the type of rating scale that has to be applied (Baylis, Chapman, Whitehill, & Group, 2015; Brancamp, Lewis, & Watterson, 2010; Schiavetti, Sacco, Metz, & Sitler, 1983; Whitehill, Lee, & Chun, 2002; Wuyts, De Bodt, & Van de Heyning, 1999; Yiu & Ng, 2004; Zraick & Liss, 2000). Equal appearing interval (EAI) scales with clear description of the different grades are recommended in different perceptual assessment protocols for resonance disorders in patients with cleft palate (Henningsson et al., 2008; John, Sell, Sweeney, Harding-Bell, & Williams, 2006; Sell, 2005; Sell, Harding, & Grunwell, 1994; Sell, Harding, & Grunwell, 1999; Sweeney & Sell, 2008). Moreover, EAI scaling was applied in 74% of the studies that included a perceptual assessment of cleft palate speech, as reported by Lohmander and Olsson (2004). However, recent studies suggested that resonance can be rated more reliably and validly by using ratio scales such as direct magnitude estimation (DME) or visual analogue scaling (VAS) (Baylis, Munson, & Moller, 2011; Baylis et al., 2015; Whitehill et al., 2002; Zraick & Liss, 2000). Brancamp et al. (2010), on the other hand, reported no statistically significant differences between ratings of nasality based on EAI and DME scales. Nevertheless, listeners need adequate information about the terminology to describe nasality reliably (Kent, Weismer, Kent, Vorperian, & Duffy, 1999; Whitehill, 2002). Additionally, inclusion of reference samples and training sessions may improve consistency because the instable internal standard of the listener is then replaced by perceptual references (Kreiman et al., 1993).

To supplement perceptual evaluations of resonance disorders, several instrumental techniques are available (Bettens, Wuyts, & Van Lierde, 2014). A recent instrumental approach to identify hypernasality is the Nasality Severity Index version 2.0 (NSI 2.0) (Bettens, Van Lierde, Corthals, Luyten, & Wuyts, 2015), based on the originally developed NSI by Van Lierde, Wuyts, Bonte, and Van Cauwenberge (2007). The NSI 2.0 includes different instrumental measurement techniques based on the optimal statistical discrimination of 35 children with perceived hypernasality and a control group of 50 children without resonance disorders, with sensitivity and specificity as the serving criteria. The index consists of a combination of three acoustic parameters: the nasalance value of the vowel /u/ and an oral text passage obtained by the Nasometer and the voice low tone to high tone ratio (VLHR) of a sustained vowel /i/ with a cutoff frequency of $4.47 \times F0$ Hz (originally described by Lee, Yang, and Kuo (2003)). The formula yields NSI $2.0 = 13.20 - (0.0824 \times$ nasalance /u/ (%)) $- (0.260 \times$ nasalance oral text (%)) $- (0.242 \times$ VLHR /i/ $4.47 \times F0$ Hz (dB)). A cutoff score of zero was determined to discriminate between children with and without resonance disorders, resulting in a sensitivity of 92% (i.e. % correct identification of children with hypernasality) and a specificity of 100% (i.e. % correct identification of children without hypernasality), in which a score below zero is considered pathological. Additionally, the validity of the NSI 2.0 was proven to be high by applying the parameter results of an independent patient and control group on the derived formula (sensitivity 88%, specificity 89%, cutoff zero). Although the NSI 2.0 can discriminate children with from children without hypernasality with a high sensitivity and specificity, only the presence or absence of hypernasality was used as the outcome variable in the binary logistic regression analysis. Hence, no correlation was yet determined between degree of hypernasality and the NSI 2.0 scores. Additionally, the absence or presence of hypernasality was only determined by two investigators in that study, which may be insufficient to obtain reliable judgments.

Two of the three parameters of the NSI 2.0 are obtained by a Nasometer. This device, originally developed by Fletcher and Bishop (1973) and manufactured by KayPentax (NJ, Lincoln Park), measures the amount of nasalance by capturing the oral and nasal signal using two microphones on a sound separation plate which is placed under the nose of the patient. After bandpass filtering, the nasal signal is divided by the total signal of oral and nasal energy and multiplied by 100 to receive the nasalance score in percentage. This value represents an indirect measure of nasality. However, contradictory results have been reported about the correlation between the perceived degree of nasality and nasalance values. Correlation coefficients