The Impact of Hearing Aid Use on the Nasalance Scores of Adults with Hearing Loss

Incidence de l'utilisation d'un appareil auditif sur les résultats de nasalance chez les adultes souffrant d'une perte de l'ouie

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Abstract

The purpose of this investigation was to examine the impact of a hearing aid on nasalance scores by evaluating nasalance in a prefitting condition and in a postfitting condition, and to determine in what way more accurate auditory feedback system and possible other sensory information may play with regard to the nasalance scores. An additional objective was to compare the obtained nasalance scores of hearing-impaired participants in the prefitting and postfitting conditions with the nasalance scores of normal hearing participants. Furthermore, the effects of hearing a hearing aid on nasalance with respect to the severity of hearing loss and age were examined. The study group consisted of 19 adults with no known physical impairment other than a sensorineural hearing loss, which could interfere with speech production. None of the participants ever wore a hearing aid. The participants were asked to read three passages, each containing a different proportion of nasal consonants. The Nasometer 6200 was used to investigate the nasalance differences between the unaided and aided conditions. In part, the results of the present study indicate significant nasalance differences between the prefitting and postfitting conditions. This suggests that velopharyngeal closure appears to be more accurate when auditory feedback is increased. Therefore, we can assume that the use of auditory feedback as a strategy to improve velopharyngeal function in patients with velopharyngeal disorders must be encouraged. In contrast, the hearing-impaired participants do not show either higher or lower nasalance values than normal hearing participants. In addition, nasalance, severity of hearing loss, and age were not positively related. Possible reasons for these findings are discussed.

Abstrait

Le but de l'enquête consiste à déterminer l'incidence d'un appareil auditif sur les résultats de nasalance. Pour ce faire, nous avons évalué la nasalance avant l'ajustement d'un appareil auditif et après. Nous avons aussi tenté de déterminer de quelle manière un système d'auto-écoute plus exact et de l'information sensorielle pourraient influencer les résultats de nasalance. Par ailleurs, nous avons comparé les scores de nasalance entre des adultes normaux et des personnes qui portent des appareils auditifs avant d'ajuster leur appareil auditif et après. Les scores des participants dont l'audition est normale. En outre, nous avons examiné l'effet de l'utilisation d'un appareil auditif sur la nasalance au plan de la gravité de la perte auditive et de l'âge. Le groupe d'études composé de 19 adultes n'ayant aucune déficience physique connue. Aucun des participants n'avait porté d'appareil auditif auparavant. Les résultats de notre étude indiquent des différences de nasalance importantes avant l'ajustement et après. Cela sous-entend que...
The speech of hearing-impaired and deaf speakers is often characterised by the presence of articulation, voice, and resonance abnormalities. The resonance disorders have been considered a consequence of the absence of acoustic regulation during voice and speech production and are not caused by the presence of a neuromuscular velopharyngeal dysfunction. Colton & Cooker, 1968; Fletcher & Daly, 1976; Sanchez & Vazquez, 1993. A number of authors have identified the resonance disorder as a cul-de-sac resonance (Bogue, 1983; Higgins, Carney & Schurte, 1994), hyponasality (Wilson, 1939), a nasality pattern comparable to that associated with cleft palate (Green, 1972), hypernasality (Swinsky, Jones, Osberger, & Miyamoto, 1998), and habitually nasalised (McClen, 1973). The information on these nasality disorders in hearing-impaired speakers was derived from perceptual assessment. Recently, reports from studies in which the use of objective instruments to evaluate nasalance in hearing-impaired participants have become available. Nasality is a major phonetic sign of the nasal consonants, as a vocal quality associated with the nasal consonants, as a vocal quality associated with cleft palate (Green, 1972), hypernasality (Swinsky, Jones, Osberger, & Miyamoto, 1998), and habitually nasalised (McClen, 1973). The term nasalance, on the contrary, reflects the relative proportion of sound emitted from the mouth and nose during speech (Baken & Orlikoff, 2000; Fletcher, 1976). The term nasalance, on the contrary, reflects the relative proportion of sound emitted from the mouth and nose during speech (Baken & Orlikoff, 2000; Fletcher, 1976). Nasalance has been found to correlate with perceived nasality (Fletcher, 1976; Dalston, Warren & Dalston, 1991a, 1991b; Dalston, Neiman & Gonzalez-Landa, 1993; Watterson, Lewis & Deutch, 1998). Fletcher and Daly (1976) compared nasalance measurements obtained by Tomor II (precedessor of the Nasometer) for 50 speakers with severe hearing impairment and 64 speakers with normal hearing. The results of this study revealed a statistically significant difference between the nasalance scores of the hearing-impaired and those of the normal hearing participants. This same difference was also reported by Lapine, Stewart, and Tatcchell (1991) who assessed 19 hearing-impaired children with the Nasometer 6200. Each hearing-impaired participant was asked to read or repeat the "Zoo Passage" (a passage without nasal consonants). Analysis of the trends for the mean nasalance scores in each speaking condition indicated that the hearing-impaired speakers presented nasalance scores above the norm for the Nasometer. In addition to the degree of hearing loss, the age at testing or the use of amplification (hearing aids or FM systems), did not yield a significant difference in nasalance scores. The authors concluded that the motor patterns for velopharyngeal control were established sufficiently and the neuromuscular patterns needed for speech were adequately retained even without any supplementary amplification.

In a study by Tatcchell, Stewart, and Lapine (1991), nasalance measurements using the Nasometer 6200 were obtained from 18 hearing-impaired children under three different speaking conditions. The children were asked to read or repeat the Zoo Passage with and without amplification, and with FM amplification. Percent nasalance in each condition was compared according to the degree of hearing loss and the age of the participant. The results of this study indicated that mean nasalance scores for hearing-impaired children did not significantly increase or decrease as a function of hearing loss, but showed a pattern of increasing nasalance scores for hearing impaired children did not significantly increase or decrease as a function of hearing loss, aided condition, and age. These authors suggest that the lack of differences between the device-on and device-off conditions can be explained by the continually retained neuromuscular control of the velopharyngeal mechanism, even in circumstances where the auditory feedback loop had been compromised.

In another study by Lapine, Stewart, Settle, and Brandon (1992) nasalance scores were obtained from 37 hearing-impaired children. Nasalance scores were measured during the reading of the Zoo Passage with (device-on) and without (device-off) personal amplification. Significant differences for nasalance in the device-off and device-on conditions were not evident although a high, positive correlation between these conditions was reported. Also nasalance, age, and gender were not positively related.

These researchers (Fletcher & Daly, 1976; Lapine et al., 1991) investigated the differences in nasalance scores between hearing-impaired participants and normal hearing participants. They concluded that speakers with hearing loss do have greater nasalance scores in comparison with normal hearing speakers due to the absence of acoustic regulation during voice and speech production. Lapine et al. (1991, 1992) and Tatcchell et al. (1991)
also investigated the nasalance differences in hearing impaired children in device-on-off experiments. From the reported studies it has become clear that nasalance scores of participants with hearing loss were not significantly different between the device-on and device-off condition, because of the retained neuromuscular control of the velopharyngeal mechanism during a short-term reduction of auditory feedback. Hearing seems to play a critical role in providing feedback about palatal function. Because participants are not able to "feel" the position of the velum during ongoing speech production, they must rely upon auditory feedback to achieve an oronasal resonance balance for normal speech production (Skolnick & Cohn, 1989). The importance of auditory feedback is well known. First, it plays a major role in different aspects of voice production (e.g., respiratory problems, loudness of voice, voice pitch, and resonance) (Boone & McFarlane, 1994). Secondly, auditory feedback is being used as a therapeutic strategy in the treatment of velopharyngeal disorders.

The previously reported studies investigated the immediate impact (device-on and device-off conditions) of a hearing aid on nasalance scores, whereas literature shows no information on the short-term impact of a hearing aid on nasalance scores. Thus, the primary goals of the present study are to delineate: a) the impact of a hearing-aid on nasalance scores by evaluating nasalance in two conditions: prefitting condition (period before the actual fitting of the hearing aid) and the postfitting condition (after a three-weeks constant use of a hearing aid), and b) to determine in what way more accurate auditory feedback, and possibly other sensory information, influences nasalance scores. Additional objectives of this study were to: a) compare the obtained nasalance scores of the hearing impaired participants in the preaided and aided conditions with the nasalance scores of normal hearing participants, and b) examine the effects of wearing a hearing aid on nasalance with respect to the severity of hearing loss and age.

Methods

Participants

Nineteen participants (13 men and 6 women) participated in this study. Participants ranged in age from 32.2 to 82.10 years with a mean age of 65.3 years (Figure 1). Patients were included if they had no history of craniofacial anomalies or velopharyngeal impairment and if there were no rhinological, articulation, or voice disorders at the time of the study. Each participant was assessed by an otorhinolaryngologist performing a complete ear, nose and throat examination to exclude voice disorders, palatal, velopharyngeal and nasal pathologies. For the traditional nasopharyngeal and laryngeal examination the laryngologist used indirect laryngoscopy and macroscopic otoscopy. A Thudicum spring speculum was used for inspection of the nose. This ear, nose and throat examination combined with a detailed history was used to determine the presence or absence of a hearing handicap.

Figure 1

Age and sex distribution of the study population

Figure 2

Age and sex distribution of the study population
Figure 2
Distribution of hearing thresholds in dB (HL) in the study population at low, middle, and high frequencies. Each diagram shows the distribution for ears from the study group. The bars show the number of ears per 10-dB HL hearing loss.

- **Distribution of low-frequency hearing status**
  (Average of 125-250-500 Hz)

- **Distribution of pure-tone average thresholds**
  (Average of 500, 1kHz and 2kHz)

- **Distribution of high-frequency hearing status**
  (Average of 4kHz and 8kHz)

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All participants exhibited a sensorineural hearing loss with a pure-tone average (PTA) (500, 1kHz, 2kHz), low frequency hearing loss (LOW) which is the mean of air conduction thresholds (AC) at 125, 250 and 500 Hz, and the average high frequency hearing loss (HIGH), the mean of AC thresholds at 4000 and 8000 Hz. These data are presented in Figure 2. In addition, audiometric data were described as a function of age (Figure 3).
Table 1
Mean nasalance scores in percentages (as provided by the Nasometer), Sds, and 95% prediction intervals (PI) of the three reading passages. The prediction interval comprises 95% of the normal cases (Van Lierde et al., 2001).

<table>
<thead>
<tr>
<th>Passage</th>
<th>Percentage of Mean ± Se</th>
<th>SD</th>
<th>95% PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal consonants</td>
<td>17.4% (29/171)</td>
<td>33.8</td>
<td>5.5</td>
</tr>
<tr>
<td>Oral text</td>
<td>0%</td>
<td>10.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Nasal text</td>
<td>57% (86/152)</td>
<td>55.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

The Nasometer (Model 6200) developed by Fletcher and Bishop (1973) and manufactured by Kay Elemetrics (1994) was used for data collection. The Nasometer is based on an earlier instrument called Tonar (The Oral Nasal Acoustic Ratio). The Nasometer is slightly different in structure, function, and practical features from its predecessors Tonar and Tonar II. The Nasometer is known as an indirect and objective assessment instrument. With this microcomputer-based device, the oral and nasal components of a participant's speech are sensed by microphones mounted on either side of an efficient sound separator plate, which rests on the participant's upper lip. The signal from each of the microphones is individually filtered and digitized by custom electronic modules. The resultant signal is a ratio of nasal to nasal-plus-oral acoustic energy. This ratio is multiplied by 100 and expressed as a nasalance score (Kay Elemetrics, 1994).
Comparison of nasalance scores in the preaided versus aided condition, as a function of age, obtained using an oronasal, oral, and nasal text. Text 1 is an oronasal text, Text 2 is an oral text, and Text 3 is a nasal text.

Table 2

<table>
<thead>
<tr>
<th>Passage</th>
<th>Normative nasalance data (N = 33)</th>
<th>Nasalance scores in the preaided condition (N = 19)</th>
<th>Nasalance scores in the aided condition (N = 19)</th>
<th>Nasalance scores preaided versus nasalance scores aided condition</th>
<th>Nasalance scores preaided condition versus normative nasalance scores</th>
<th>Nasalance scores aided condition versus normative nasalance scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral text</td>
<td>33.7±1.3 (5.5)</td>
<td>35.7±1.5 (7.6)</td>
<td>31.7±1.3 (4.6)</td>
<td>0.005*</td>
<td>0.4</td>
<td>0.01*</td>
</tr>
<tr>
<td>Nasal text</td>
<td>55.8±0.9 (6.1)</td>
<td>56.0±1.7 (5.2)</td>
<td>54.2±1.5 (5.1)</td>
<td>0.005*</td>
<td>0.2</td>
<td>0.05*</td>
</tr>
</tbody>
</table>

*p indicates a statistically significant difference at a probability level of 95% (p = 0.05).
1994). The result of this computation may be displayed as a statistical table, time history display, or nasogram (which shows nasalance for time periods from two through 100 seconds) and a bar graph showing moment-to-moment nasalance peaks for feedback purposes. Prior to initiating data collection, the Nasometer was calibrated on a sound treated booth following the procedures outlined in the manual (Kay Elemetrics, 1994). The position of the Nasometer headset was adjusted in accordance to the manufacturer's specifications. The Nasometer was selected for this study because it corresponds highly with the criteria pointed out by Etzioni (1980) who stated that the ideal technique for the evaluation of the physical correlates of nasality is psychologically and physically noninvasive, capable of assessing velopharyngeal function during speech while not disrupting articulatory, phonatory, or ventilatory processes. Moreover, the technique should have no limitations for sensory feedback of speech activity and the results should be easily interpretable and correlate with perceived nasality.

**Stimulus Material**

The Dutch stimuli designed and used by Van de Weijer and Sis (1991) in their normative study were chosen as reading stimuli because they were comparable to the type of English passage that are designed specifically for use with the Nasometer (see Table 2).

The first passage, an "oronasal text" corresponds exactly with the English "Rainbow Passage" (Fairbanks, 1960) containing the same percentage of nasal consonants found in standard Dutch speech (11.63%) (Van den Broecke, 1988). The second passage, an "oral text" is similar with the "Zoo Passage" (Fletcher, 1972) and is normally used to detect hypomenhality in a participant's speech. The last passage, a "nasal text," is designed to detect hypomanhality in a participant's speech. However, the use of the collected Dutch nasalance data as cut-off limits to assess clinical levels of abnormal nasality must be interpreted cautiously (Van Lierde, Wuyts, De Bodt, & Van Cauwenberge, 2001). The Dutch stimuli designed and used by Van de Weijer and Sis (1991) in their normative study were chosen as reading stimuli because they were comparable to the type of English passage that are designed specifically for use with the Nasometer (see Table 2).

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The participants were instructed to perform each reading task at a comfortable vocal pitch and loudness level. Each participant was asked to read the experimental stimuli in the prefitting, as well as postfitting conditions. If the participants made a reading error, they were asked to read the passage again. The specific passages used are presented in the Appendix.

**Statistical analysis**

Statistica for Windows (version 5.1) was used for the statistical analysis of the nasalance data. For the comparison of the nasalance data in the preaided and aided condition Wilcoxon test was applied. A Kruskal-Wallis ANOVA was employed where the participant's ages were divided in three groups (Group 1: 22-25 years, group 2: 56-70 years and group 3: 71-82 years) to investigate the contribution of age between the preaided and aided condition. The student t-test was applied for the comparison of the nasalance values in the preaided and aided condition with the normative nasalance values (Van Lierde et al., 2001). ANOVA was also employed to investigate the contribution of hearing loss (PTA data) to nasalance scores between the preaided and aided condition.

**Results**

**Influence of Hearing Aid Use on Nasalance Scores**

Group data on mean nasalance in the preaided and aided condition for each reading passage are presented in Table 2. In addition, the standard error and the standard deviation for the three reading passages are shown. The mean nasalance score for all hearing-impaired participants in the preaided condition for the oronasal text was 35.5%, for the oral text 12.9% and for the nasal text 56.8%. The mean nasalance score for all hearing-impaired participants in the aided condition after wearing the hearing aid for three weeks was 31.7% for the oronasal text, 11.2% for the oral text, and 54.2% for the nasal text. The Wilcoxon test showed statistically significant differences in nasalance between the preaided and aided conditions for the three reading passages (see Table 2).

**Comparison of Nasalance Scores of Hearing Impaired Participants in the Preaided and Aided Conditions with Normative Nasalance Scores**

Normative nasalance scores for each reading passage (Van Lierde et al., 2001) are also presented in Table 2. In addition, the standard error and the 95% prediction interval (mean ± 2s) for the three reading passages are provided. This interval comprises 95% of the normal cases. All the mean nasalance scores of the hearing-impaired participants in the preaided and aided conditions were found within the 95% confidence interval. The student t-test showed a significant modification of the nasalance values between the oronasal text (p = 0.01) and the nasal text (p = 0.05) in the aided condition and the normative nasalance values of the oronasal and the nasal text.

**Influence of Age on Nasalance Scores**

Nasalance scores as a function of age were compared between the aided versus preaided condition in the oronasal, oral, and nasal texts (see Figure 4). This figure
clearly shows a decrease in nasalance in the aided condition. However, there is no significant effect with respect to the age variable. The influence of age was evaluated through linear regression analysis by determining the coefficient of determination (R²). This value equals the proportion of variation in the nasalance scores that can be explained by the variation of the age variable. For the three reading passages this value was extremely low (< 10%), what indicates that in this small population, nasalance was not found to be related to age. Furthermore, a Kruskal-Wallis ANOVA analysis was employed to investigate the contribution of age between the preaided and aided condition. Chi-square values did not show any significant (p > 0.05) relationship.

**Influence of Severity of Hearing Loss on Nasalance Scores**

The results of the one-way ANOVA indicated no significant effect (p = 0.629) for the impact of the degree of hearing loss on the nasalance scores between the preaided and aided condition.

**Discussion**

The present study investigated the impact of hearing aid use on nasalance scores by comparing a preaided condition with a condition of three weeks, during which a hearing aid was worn. The short-term effects were observed during a three-week period, sufficient for demonstrating the emergence of short-term nasalance changes. However, this observation interval does not allow deducing nasalance changes over a longer period of time. All 19 participants were adults with no known physical impairment, other than a sensorineural hearing loss which could interfere with speech production. None of the participants were hearing impaired previously.

**Influence of Hearing Aid Use on Nasalance Scores**

Significant nasalance differences were found between the preaided and aided condition. The obtained nasalance data yielded significantly lower nasalance scores in the aided condition than in the normal group. The findings of this study support the physiological assessment of Higgins, Cartney, and Schuler (1994), who investigated the velopharyngeal function in eleven hearing-impaired adults. They concluded that velopharyngeal control was not a significant problem for most individuals with hearing loss. However, the results of the present study are in contradiction with the findings of previous researchers (Higgins & Daly, 1991) who found nasalance scores above the norm. A comparison to the Fletcher and Day (1976) study is difficult because the type of hearing impairment of the participants was not indicated. A possible explanation for the differences in the results of Lapine et al. (1991), might be due to the use of children with a sensorineural hearing loss as the study group.

In the present study the mean nasalance scores for the three reading passages were not significantly higher in the hearing-impaired speakers in the preaided condition than in the normal group. The findings of this study support the physiological assessment of Higgins, Cartney, and Schuler (1994), who investigated the velopharyngeal function in eleven hearing-impaired adults. They concluded that velopharyngeal control was not a significant problem for most individuals with hearing loss. However, the results of the present study are in contradiction with the findings of previous researchers (Higgins & Daly, 1991) who found nasalance scores above the norm. A comparison to the Fletcher and Day (1976) study is difficult because the type of hearing impairment of the participants was not indicated. A possible explanation for the differences in the results of Lapine et al. (1991), might be due to the use of children with a sensorineural hearing loss as the study group.

In the present study the mean nasalance scores for the three reading passages in the aided condition lies within the 95% prediction interval and can be regarded as normal. However, the mean nasalance scores for the oronasal and nasal conditions showed a significant modification in the hearing-impaired speakers in the aided condition compared to the normative nasalance values. This modification occurred when the reading passages included nasal consonants and when a coordinate opening and closing function of the velopharyngeal mechanism was required. Lower nasalance scores were also obtained when the reading passages included nasal consonants and when a coordinate opening and closing function of the velopharyngeal mechanism was required. Speech programming differences, in terms of differences in anticipatory nasal coarticulation, may be influenced by more accurate auditory control. Further research regarding speech programming differences in the unaided and aided condition should be considered.
Influence of Age and Hearing Loss on Nasalance Scores

The mean nasalance scores for hearing-impaired adults did not significantly increase or decrease as a function of hearing loss or age. However, in this study, there was no decrease in nasalance scores over the period of three weeks of hearing aid use for periods shorter than three weeks.

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References


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Appendix

Reading Stimuli

Oronasal Text

Oral Text
Het is zaterdag. Ets heeft vrij. Ze loopt door de stad. Het is prachtig weer, de lucht is blauw. Op straat ziet ze Bart op de fiets. Als Bart haar ziet, zwaait hij. Eis loopt verder. Bij de bakker koopt ze brood, bij de slager koopt ze vlees. Als het vijf uur is, gaat ze terug, zodat ze op tijd weer thuis is.

Nasal Text