IS SUBGLOTTAL PRESSURE A CONTRIBUTING FACTOR TO THE INTRINSIC F0 PHENOMENON?

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ABSTRACT

The hypothesis that compensation for lower loudness of high vowels (/i, u/) in speech might contribute to the higher intrinsic F0 of these vowels in comparison with low vowels (/a, æ/) was tested. F0, intensity and subglottal (oral) pressure were measured in two tasks. In the first the subjects (n=2) produced the test word /'pV:ppV/ (V=/i, u, æ, a/) embedded in a carrier phrase. The pressure measurements showed highest pressure values for the vowel /u/ for both two subjects. In the second task the subjects read a /pV:ppV/ word list and tried to maintain the same SPL of the long vowel through different vowels. The results showed that compensation for the SPL differences between vowels produced greater intrinsic F0 variation than in normal speech. However, the subglottal pressure differences were too small to explain the differences in the F0 values.

1. INTRODUCTION

The intrinsic F0 of vowels, a vowel-specific variation of F0 in comparable contexts, is a well-known phenomenon. The physiological background of this phenomenon remains partly unclear. Our earlier studies suggested that one important factor in this respect is the vowel-specific activity of the cricothyroid muscle activity. It does not, however, exclusively explain the vowel intrinsic F0 variation. Changes in the vertical tension of the vocal folds has been found to be one additional factor in the production of the intrinsic F0 phenomenon. Acoustical explanations have been rejected [1, 2].

Vowel intrinsic F0 variation has been reported to be present even in esophageal speech [3]. This might imply a sub(pseudo)glottal pressure-dependent control mechanism.

Subglottal pressure can affect the fundamental frequency in normal voice production [e.g. 4]. The present study is aimed at testing the hypothesis that compensation for lower loudness of high vowels (/i, u/) in speech might contribute to the higher intrinsic F0 of these vowels in comparison with low vowels (/a, æ/).

2. SUBJECTS AND METHODS

The subjects were two male native speakers (IR, OA) of Finnish without any known voice problems.

In the first task the subjects produced the test words in randomized order /'pV:ppV/ (V=/i, u, æ, a/) embedded in a carrier phrase (/sano 'pV:ppV ta:s/; "Say /pV:ppV/ again!")(n=25 for each vowel). In the second task the subjects tried to maintain the same sound pressure level (SPL) of the long vowel through different vowels by monitoring the display of an SPL meter (B & K 2209). Due to difficulties in adjusting SPL adequately the carrier phrase could not be used in the second experiment. /'pV:ppV/ words were read in the following order: V=/a, i, u, æ/ (n=30 for each vowel).

The acoustical samples were recorded using a microphone (JVC MD 247) (distance 30 cm) and a tape recorder (JVC CD 1635 MARK II). F0 peak values of the vowels of the first stressed syllable were analysed using a microcomputer-based analysis program (ISA). The subglottal pressure was estimated from the intraoral pressures (F-J Manophone) during /p/-consonants obtained from a tube (diametre about 3 mm) placed between the lips [a.m. Löfqvist et al. 5]. SPL peak values (F-J Intensity Meter) and subglottal (oral) pressure values were measured from calibrated plotted recordings (Siemens Oscillomink L). Pressure values were measured at two separate points: the peak for 1) the first /p/(point a) and 2) for /pp/(point b).

The results obtained are represented by arithmetic means (X) and standard deviations (SD). Statistical tests were carried out using Student's t-test.

3. RESULTS

The results for both experimental conditions are shown in Figs. 1 (subject IR) and 2. (subject OA).

The results of the first experiment with a carrier phrase showed a normal vowel intrinsic F0 pattern for both subjects (/i,u/>/æ, a/). Also the SPL values obtained showed expected patterns (/i, u/</æ, a/). The pressure values for the first measuring point (a in Figs.) showed significant vowel-specifity only for subject IR. In this case the pressure for the vowel /a/ tended to be lowest. However, the second measuring point (b in Figs.) showed statistically significantly higher pressure values for the vowel /u/ (IR: p=0.49 kPa; OA: p=0.60 kPa) than for other vowels /i, æ, a/ (respectively, IR: p=0.40 kPa, 0.39 kPa, 0.40 kPa; OA: p=0.55 kPa, 0.55 kPa, 0.55 kPa).

The pressure values in the second experiment showed more vowel-specifity for both subjects than in the first "normal" condition. The subglottal pressures measured at point b for the vowel /u/ (IR: 5.8 kPa; OA: 7.3 kPa) were significantly higher than for the vowels /i, æ, a/ (IR: 4.4 kPa, 3.3. kPa, 3.0 kPa; OA: 6.9 kPa, 5.8 kPa, 6.1 kPa, respectively).

As can be seen in Figs. 1 and 2 the equalization of the SPL level between the vowels was not a simple task. From the point of view of the present study, however, the fact that the SPL pattern could be changed (/i, u/≥ /æ, a/) is important. As compared to the first part of the study the range of intrinsic F0 variation grew in the second part. This was exclusively due to a drop in F0 values of /æ/ and /a/. For both subjects the F0 of vowels /i/ and /u/ did not change significantly even though both pressure and intensity values for these vowels were significantly higher.

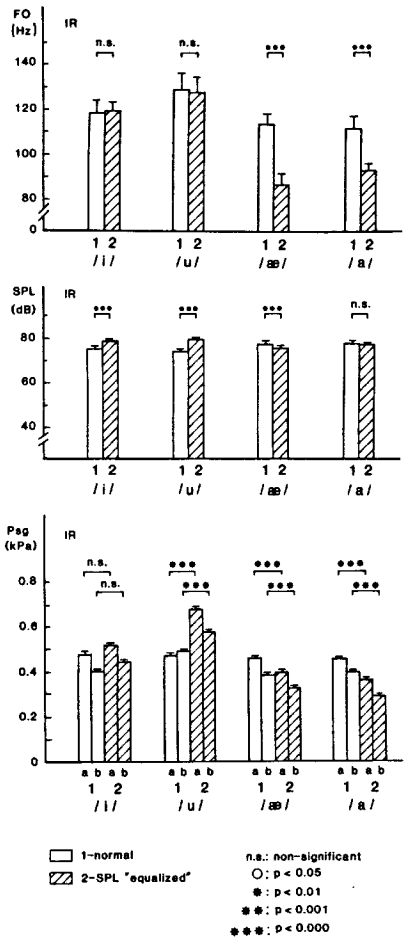

Figure 1. Average (X±SD) F0, SPL and subglottal pressure (p_{sg}) values for four vowels (subject IR).

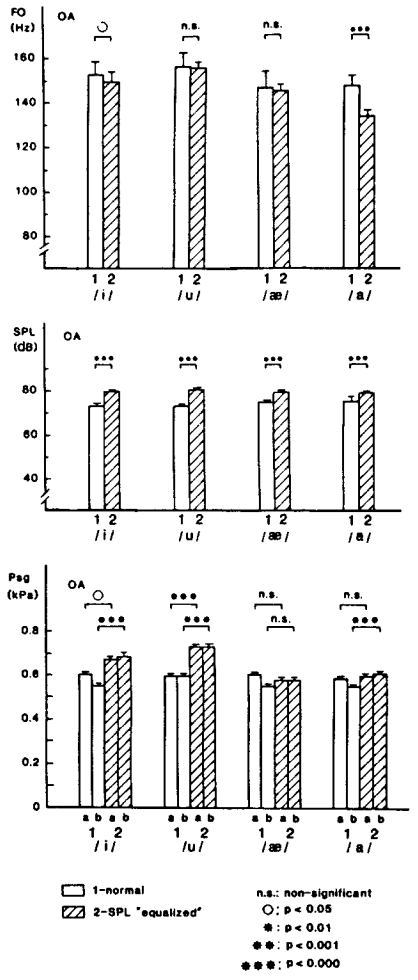

Figure 2. Average (X±SD) F0, SPL and subglottal pressure (p_{sg}) values for four vowels (subject OA).

4. DISCUSSION

The subglottal pressure for the highest vowel /u/ was significantly higher than that for the other vowels for both subjects in the experiment in which test words were embedded in a carrier phrase. This might imply a compensation for the low loudness of the vowel /u/. However, the estimated pressure difference between the average values for /u/ and /i, æ, a/ was only 0.05 kPa. From physiological studies it is known that in low chest register phonation a pressure rise of 0.1 kPa causes an F0 rise of 5 Hz (see e.g. [4] for a review). Thus, it seems that only a few hertz of intrinsic F0 variation could be explained by pressure differences.

In the second part of the present study in which the SPL of the long vowel of the word /pV:ppV) was kept as constant as possible the pressure differences were greater (approximately 0.1 kPa). However, even in this case the F0 difference between the vowels /u/ and /æ, a/ cannot be explained on this basis. It is obvious that a laryngeal contribution is necessary (c.f. [1]).

Usually F0 and intensity are known to be closely correlated (e.g. [4]). However, in the second condition of the present study the higher intensity and pressure values co-occurred with lower F0 than in the first part. Two tentative explanations can be suggested. Firstly, the intrinsic F0 phenomenon is under keen cortical control and the intrinsic F0 of /i/ and /u/ represent the "correct" values. Now that the SPL was not allowed to change deliberately the situation was unnatural from the point of view of the low vowels /æ/ and /a/, which caused a reduction in laryngeal activity and, consequently, a drop in F0. The second possibility is that the finding was caused by the difference in the test tasks. I.e. the reading style of a natural sentence is produced with a higher F0 than the list of separate and equally stressed words. In this case the F0 of /æ/ and /a/ would reflect the normal values of the task. Correspondingly the F0 of /i/ and /u/ would reflect the increased effort needed to reach the SPL in question. Thus the same F0 values for /i/ and /u/ in the two test conditions would be coincidental. Further studies are needed to distinguish between these two possibilities suggested by this preliminary study.

It can be concluded that equalization of the output SPL of vowels has an influence on the vowel intrinsic F0 variation. This is also reflected in the subglottal pressure level, but the difference in the F0 patterns can not be explained on the basis of subglottal pressure differences alone. A laryngeal contribution is necessary.

5. REFERENCES

[1] VILKMAN, E., AALTONEN, O., RAIMO, I., ARAJÄRVI, P., OKSANEN, H. (1989), "Articulatory hyoid-laryngeal changes vs. cricothyroid muscle activity in the control of intrinsic F0 of vowels." *J. Phonetics, 17,* 193-203.

[2] VILKMAN, E., AALTONEN, O., LAINE, I., RAIMO, I. (1991), "Intrinsic pitch of vowels - a complicated problem with an obvious solution". *Proc. of the 6th Vocal fold physiology Conference,* Stockholm 1989, Raven Press, in press.

[3] GANDOUR, J., WEINBERG, B. (1981), "On the relationship between vowel height and fundamental frequency: evidence from esophageal speech." *Phonetica, 37,* 11-22.

[4] TITZE, I.R. (1989), "On the relation between subglottal pressure and fundamental frequency in phonation." *J. Acoust. Soc. Am., 85,* 901-906.

[5] LÖFQVIST, A., CARLBORG, B., KITZING, P. (1982), "Initial validation of an indirect measure of subglottal pressure during vowels." *J. Acoust. Soc. Am. 72,* 633-635.