Effect of Co-Articulation on One Third Octave Spectral Amplitudes of Vowel /i/

A Navya, M Pushpavathi, Nikitha K
AlISH, India

Submission: November 07, 2017; Published: November 27, 2017
*Corresponding author: A Navya, AlISH, Mysore, 48, First Floor, Maruthi temple road, T.K. Layout, Kuvempunagar, Mysore, India, Tel: 9036377964; Email: navyaaslsp@gmail.com

Abstract

Hypernasality is one of the core speech characteristics observed in the speech of children with repaired cleft lip and palate. One-third-octave analysis has been considered as a potential tool to measure acoustic correlates of hypernasality in the speech of individuals with RCLP. However, the acoustic characteristics of speech are influenced by the contextual effects. Hence, the present study aimed to find out the difference in one third octave spectral amplitudes of vowel /i/ across various contexts in children with RCLP and typically developing children. A total of 24 participants (12-RCLP, 12-TDC) in the age range of 4-12 years were considered for the study. The speech sample recorded included repetition of isolated vowel /i/ and vowel /i/ in the phonetic context of /pit/ and /tip/. The one third octave spectral amplitudes were measured for all the stimuli and compared across the groups using MATLAB. The results indicated that energy concentration over one third octave spectrum was more in RCLP group for stimulus /i/, /pit/, & /tip/ as compared to control group. The spectral energy at low frequencies (97Hz, 125Hz and 157.5 Hz) of the isolated vowel /i/ demonstrated a significant increase in spectral energy in RCLP than the control group. The study also reported higher spectral amplitudes for vowel /i/ in the context of /pit/ and /tip/ across frequencies as compared to the spectral amplitudes of isolated vowel /i/ across the groups. The differences were attributed to the influence of phonetic context on the spectral amplitude of vowel /i/.

Introduction

Hypernasality is a perceptual quality associated with excessive nasal resonance because of velopharyngeal incompetence [1]. It is one of the major speech deviances exhibited by individuals with cleft lip and palate (CLP). The evaluation of hypernasal speech of children with repaired cleft lip and palate (RCLP) can be carried out using various methods. The acoustic analysis is one of the objective techniques which intend to directly study the speech production mechanism. Nasalization with its characteristic acoustic features affects the acoustic analysis of a speech signal. The speech signal gets influenced by dampening effect and by anti forms which will have a major impact on acoustic signal [1]. This technique is advantageous as it is non-invasive, cost effective, and since it can be applied to speakers with various age, gender and speech impairments with different etiologies [2].

Kent, Liss and Philips [3] and Chen [4] described the acoustic correlates of nasalized vowels in spectrograms. They reported an increase in formant bandwidths, the overall reduction in the amplitude of the vowel. They also noticed the low energy of the upper formants as a result of the presence of ant formants. Among the acoustic measures, one third octave spectral analysis is one of the spectral measures which is considered as a potential tool to measure acoustic correlates of hypernasality in the speech of individuals with RCLP. One third octave interval was chosen as it can be judged well against the critical bandwidth of ear’s analyzing mechanism [5]. The power spectrum extracted from digitized samples was analyzed at every one third octave band to calculate the mean power level of each band. These levels were then normalized relative to the amplitude of the band that contained the fundamental frequency [5]. This tool has been proved to quantify the degree of hypernasality [6]. The recent studies focusing on spectral features of hypernasal speech have been investigated hypernasality in the speech of children and young adults with cleft palate and cleft lip using one third octave analysis and in adults following maxillectomy.

Kataoka et al., [7] aimed at correlating the once third octave spectral evaluation with the perceived nasality in children with cleft palate and controls. When the two groups were compared, it was shown that the spectrum of hypernasality group was marked by increased spectral amplitudes between F1 and F2 and a reduction in spectral amplitudes around F2 region which differentiated the two groups. They obtained a highly significant correlation (r=0.84) between perceptual ratings and amplitudes of one third octave spectral bands (1k, 1.6k, & 2.5 kHz) using multiple regression analysis. In the same line of thought, Navya [7] measured one third octave band spectrum in vowels /a/ and /i/ and looked for its sensitivity and specificity in differentiating hypernasality group from the control group. The results indicated increase in amplitudes was observed for frequencies below 1000 Hz which demonstrated...
a significant difference between the two groups. Another major finding of the study was that the high sensitivity and specificity was found for the frequency region between 998Hz and 2663 Hz which shown to be better differentiating the two groups using 1/3rd octave spectra analysis. However, there are variations seen in the spectral characteristics with respect to speakers and phonetic contexts [8,9].

The majority of the studies incorporated vowels as the stimulus for carrying out an acoustic analysis of hypernasal speech. Among vowels, vowel /i/ was chosen as the optimal stimulus to determine nasality owing to the fact that high vowels are produced with greater velar height and it demands relatively less nasal coupling for it to be perceived as nasal, compared with low vowels [10-12]. However, it is observed that the acoustic property of a vowel gets influenced by coarticulatory effects. Coarticulation is regarded as a process whereby the properties of a segment are altered due to the influences exerted on it by neighbouring segments. Several studies have documented the variation in the acoustic features of vowels that were seen as a function of consonantal context. Lindblom [13] had observed the effect of three consonants (/bVb/, /dVd/) on eight Swedish vowels and compared the production of the same vowels in isolation. The results revealed that in the context of consonants, the formant frequency of a given vowel fails to achieve its target values than in a neutral context. Therefore, it was concluded that the vowel varied as a function of consonantal context and this effect was termed it as a formant undershoot. Hence, the present study aimed to evaluate the difference in one third octave spectral amplitudes of vowel /i/ across various contexts in children with RCLP and typically developing children.

Aim of the study: To evaluate one third octave spectral amplitudes of isolated vowel /i/ and also in the context of /pit/ and /tip/ in children with RCLP and typically developing children.

Method

Participants

The present study considered 24 children in the age range of six to ten years. Among 24 children, 12 children with repaired cleft lip and palate having no associated anomalies and 12 age and gender matched typically developing children served as controls. The control subjects had no history of ear, nose, and throat infections and all the participants in both the groups were screened for hearing loss prior to the inclusion. The informed consent was provided to the parents/caretakers of the participants.

Results

Descriptive and non-parametric statistical test results

Table 1: Mean and SD of one-third octave spectral amplitudes across frequencies, stimuli, and groups.

| Frequencies (Hz) | RCLP group /i/ | RCLP group /pit/ | RCLP group /tip/ | TDC group /i/ | TDC group /pit/ | TDC group /tip/ |
|------------------|-----------------|-----------------|-----------------|---------------|-----------------|-----------------|
|                  | Mean (dB)       | Mean (dB)       | Mean (dB)       | Mean (dB)     | Mean (dB)       | Mean (dB)       |
| Mean SD          | 12.4 8.39 3.54  | 12.12 4.80      | 5.01            | 14.73         | 14.02           | 12.50           |

How to cite this article: A Navya, M Pushpavathi, Nikitha K. Effect of Co-Articulation on One Third Octave Spectral Amplitudes of Vowel /i/. Glob J Oto 2017; 11(5): 555821. DOI: 10.19080/GJO.2017.11.555821.
The descriptive statistical analysis of the data was performed. The table 1 and figure 1 depicts the mean and standard deviation for isolated vowel /i/, /i/ in the context of /pit/ and /tip/ across the frequencies and groups. Figure 1 describes the variations in energy concentration with respect to frequencies across RCLP and normal groups for different stimuli. In general, it can be depicted that as the frequencies increased, there was a rise in amplitudes for both the groups across the stimuli. It is observed that frequencies from 12.4Hz to 31.3Hz showed an overall increase in the amplitudes across all the groups for all the stimuli. However, at 39.4Hz, there is a sudden drop in amplitudes for both the groups and also a gradual rise of amplitudes was observed from 49.6Hz to 198.4Hz. Later, again there is a significant increase in energy concentration for frequencies 250Hz and 315Hz.

One more major finding of the study is that, across frequencies, for both the groups of RCLP and TDC, mean amplitude values of /pit/ and /tip/ were higher when compared to the isolated /i/ stimulus which explains the effect phonetic context on spectral features of /i/. From figure 1, it was apparent that the relative differences in spectral amplitudes across the groups were higher for the isolated vowel /i/ than vowel /i/ in the context of /pit/ and /tip/. The isolated vowel /i/ exhibited increased spectral amplitudes in the RCLP group compared to the normals. The one-third-octave spectral amplitudes between the two groups for the vowel /i/ in /pit/ and /tip/ context were overlapping, which failed to stand as a differentiating factor.

The table 2 and figure 2 represents the amplitudes of frequencies from 396Hz to 8KHz for the stimulus /i/, /pit/ and /tip/ across the two groups. From figure 2, it can be noticed that there is a gradual reduction in the spectral amplitudes from 793Hz to 2519Hz across the groups. Then for 3174Hz and 4000Hz, there is a rise in the spectral amplitudes followed by gradual reduction while reaching to 8000Hz. The frequencies 1000Hz, 1259.9 Hz, 1587.4Hz and 2000 Hz demonstrated a significant increase in amplitudes of the isolated vowel /i/ across the groups. For vowel /i/ in the context of /pit/ and /tip/, the spectral energy in the frequency bands between 630Hz to 2519Hz demonstrated higher amplitudes for RCLP group than TDC. To check the normality, Shapiro-Wilk test of
normality was applied. Review of the S-W test for normality of one third-octave spectral amplitudes for RCLP and TDC group indicated the skewed distribution of the data. Followed by the normality test, the data was subjected to non-parametric statistical test i.e., Mann-Whitney U test. The Mann-Whitney U test was conducted to evaluate the null hypothesis that there is no change in participant’s amplitude scores when measured across the stimuli and between the groups (Table 3).

![Figure 2: The amplitudes of one third octave frequencies (396 Hz to 8000 Hz) across stimuli and groups.](image)

| Frequencies (Hz) | RCLP group | Normal group |
|------------------|------------|--------------|
|                  | /i/ Mean (dB) | SD | /pit/ Mean (dB) | SD | /tip/ Mean (dB) | SD | /i/ Mean (dB) | SD | /pit/ Mean (dB) | SD | /tip/ Mean (dB) | SD |
| 396              | 33.09      | 12.01 | 42.22 | 5.95 | 44.80 | 9.82 | 29.95 | 9.43 | 41.10 | 8.33 | 42.60 | 10.67 |
| 500              | 46.08      | 10.14 | 38.34 | 8.69 | 37.20 | 7.07 | 40.33 | 10.8 | 36.60 | 5.60 | 40.32 | 5.22 |
| 630              | 39.70      | 9.76  | 44.35 | 8.74 | 44.49 | 4.81 | 41.67 | 6.94 | 46.32 | 6.93 | 42.11 | 7.61 |
| 793              | 36.75      | 6.78  | 40.32 | 5.99 | 41.31 | 8.69 | 32.74 | 6.99 | 35.42 | 5.22 | 36.23 | 7.48 |
| 1000             | 28.98      | 8.09  | 40.32 | 7.17 | 37.44 | 4.29 | 27.30 | 9.18 | 30.17 | 6.81 | 29.50 | 5.07 |
| 1259             | 27.13      | 6.77  | 36.76 | 9.74 | 32.94 | 7.54 | 21.22 | 11.11 | 26.75 | 4.39 | 26.05 | 4.77 |
| 1587             | 25.86      | 7.54  | 34.27 | 8.19 | 33.96 | 8.50 | 17.19 | 9.98 | 25.45 | 5.68 | 24.26 | 4.34 |
| 2000             | 27.25      | 6.08  | 34.70 | 5.72 | 34.25 | 5.20 | 19.22 | 10.82 | 26.95 | 9.01 | 24.99 | 4.36 |
| 2519             | 28.85      | 6.04  | 39.47 | 7.97 | 39.18 | 8.28 | 27.90 | 8.28 | 37.55 | 8.31 | 33.30 | 4.59 |
| 3174             | 36.31      | 6.34  | 40.92 | 7.42 | 40.61 | 6.74 | 39.44 | 3.99 | 44 | 6.17 | 42.01 | 6.63 |
| 4000             | 36.68      | 5.66  | 40.59 | 7.53 | 40.15 | 7.43 | 39.55 | 4.05 | 39.50 | 6.59 | 39.07 | 6.70 |
| 5039             | 33.36      | 6.61  | 35.33 | 9.21 | 34.58 | 7.40 | 32.50 | 5.27 | 32.54 | 7.25 | 34.35 | 6.55 |
| 6349             | 26.59      | 9.64  | 27.55 | 8.16 | 25.75 | 9.59 | 22.05 | 7.56 | 23.90 | 8.22 | 26.85 | 8.01 |
| 8000             | 23.99      | 5.75  | 22.86 | 7.18 | 24.15 | 6.00 | 20.05 | 8.67 | 15.94 | 4.64 | 19.71 | 4.93 |

Table 3: Mann-Whitney U test results describing frequencies showing significant differences.

| Stimuli | Frequencies | M-W U” | Z value | Significance |
|---------|-------------|---------|---------|--------------|
| /i/     | 99Hz        | 36      | -2.09   | 0.038        |
|         | 125Hz       | 37      | -2.02   | 0.043        |
|         | 157.5Hz     | 29.5    | -2.45   | 0.014        |
|         | 1259Hz      | 27      | -2.6    | 0.009        |
|         | 1587Hz      | 27      | -2.59   | 0.009        |
|         | 2000Hz      | 25      | -2.71   | 0.007        |
In the present study, overall the energy concentration over the one third octave spectrum for stimulus /i/, /pit/, & /tip/ were more in RCLP group as compared to TDC group. From table 3, it can be interpreted that one-third octave spectral amplitudes at frequencies 1259 Hz, 1587 Hz and 2000 Hz showed a significant difference between normal and RCLP groups in all the three stimuli (/i/, /pit/ & /tip/). It shows that irrespective of the context, these mid frequencies were sensitive enough to discriminate the two groups. For isolated vowel /i/, significant differences in spectral energies between RCLP and control group was found at lower frequencies (97Hz, 125Hz, and 157.5 Hz). However, the significant difference in spectral energies was not found for the same frequencies for vowel /i/ in the presence of a context (pit, tip). For /pit/, /tip/, such as 793.7Hz, 1000Hz, 1259Hz, 1587Hz and 8000Hz differentiated the normal from RCLP group. The significant difference was exhibited at frequencies 1000Hz, 1259Hz, 2519Hz, 1587Hz and 8000Hz for the stimulus /tip/.

Discussion

The present study aimed to find out the differences in spectral amplitudes between children with RCLP and typically developing children (TDC) across stimuli. One of the major findings of the study is that the energy concentration over the one third octave spectrum was found to be more in RCLP group for across the stimulus compared to TDC group. This result is in consensus with the findings of a previous study conducted by Navya et al. [13,14] who reported higher spectral amplitudes at all the one-third octave spectral frequencies for the vowel /a/ and /i/ in RCLP than in normals. The result was also supported by Kataoka et al., [10] who also found increased amplitudes for the hypernasal group of isolated vowels compared to control group. The possible explanation for increased spectral energy in the vowel production of children with RCLP is due to the presence of reinforced harmonics at frequencies where the energy is not normally expected. However, the contradictory findings were found in majority of the studies who have reported reduction in the amplitude of all formants in hypernasal speech [4,14,11].

Another finding of the current study is that, the spectral amplitudes of vowel /i/ in the context of /pit/ and /tip/ differentiated the normal from RCLP group at 793.7Hz, 1000Hz, 1259Hz, 2519Hz and 8000Hz by exhibiting increased amplitudes for RCLP group. Similar results were obtained by Lee, Ciocca, & Whitehill [16] who also used non nasal words in consonant-vowel-consonant (CVC) combinations (e.g., /pit/, /tip/) and found that participants with hypernasal speech tended to have higher intensity levels at bands centered at 630 Hz, 800 Hz, and 1000 Hz, as well as lower intensity levels for the band centered at 2.5 KHz compared to speakers with normal resonance. However, the justification for the findings obtained and explanation about the contextual effect was not provided by the authors in their work.

The study also reported higher amplitudes for /pit/ and /tip/ across frequencies compared to the isolated vowel /i/, for both the groups of RCLP and TDC. This finding can be correlated well with coarticulatory studies [13,11,17-22]. These studies focused on consonantal context effect on spectral and temporal characteristics of vowels and have shown that the vowels undergo phonetic reduction owing to the influence of consonantal context. The phonetic reduction of a vowel entails a reduction in the acoustic duration of the vowel and formant undershoots (i.e, a change in formant frequencies from their ideal target values). As a result, it can be decoded that these potential spectral modifications in a vowel due to the effect of phonetic context might alter the amplitude related information and frequency specific differences can be described on the same basis. Thus the study concluded that coarticulation results in higher spectral amplitudes in vowel /i/ in the context of /pit/ and /tip/ compared to isolated vowel /i/ and were attributed to the phonetic reduction of vowel /i/. Overall, the RCLP group exhibited higher one third octave spectral amplitudes than control group.

| Stimulus | Frequency | Amplitude | p-value |
|----------|-----------|-----------|---------|
| /pit/    | 793.7Hz   | 38        | -1.96   | 0.50    |
|          | 1000Hz    | 27        | -2.59   | 0.09    |
|          | 1259Hz    | 25        | -2.71   | 0.07    |
|          | 1587Hz    | 27        | -2.59   | 0.09    |
|          | 8000Hz    | 34.5      | -2.16   | 0.03    |
| /tip/    | 1000Hz    | 15.5      | -3.26   | 0.01    |
|          | 1259Hz    | 30.5      | -2.39   | 0.17    |
|          | 1587Hz    | 34        | -2.83   | 0.05    |
|          | 2519Hz    | 34        | -2.19   | 0.02    |
|          | 8000Hz    | 36        | -2.07   | 0.03    |

How to cite this article: A Navya, M Pushpavathi, Nikitha K. Effect of Co-Articulation on One Third Octave Spectral Amplitudes of Vowel /i/. Glob J Oto 2017; 11(5): 555821. DOI: 10.19080/GJO.2017.11.555821.
References

1. Kent R, Read C (2002) Acoustic Analysis of Speech, 2nd edn (San Diego, California: Singular, Thomas Learning).
2. Kim RD, Kim YJ (2003) Toward an acoustic typology of motor speech disorders. Clinical linguistics & phonetics 17(6): 427-445.
3. Kent RD, Liss J, Philips BJ (1989) Acoustic analysis of velopharyngeal dysfunction in speech. In K R Bzoch (Eds.) Communicative disorders related to cleft lip and palate. Boston Little Brown, Bostan, US, pp. 258-270.
4. Chen, Marilyn Y (1996) Acoustic correlates of nasality in speech (Doctoral dissertation, Massachusetts Institute of Technology).
5. Kataoka R, Michi K, Okabe K, Miura T, Yoshida H (1996) Spectral Properties and Quantitative Evaluation of Hypernasality in Vowels. The Cleft Palate-Craniofacial Journal 33(1): 43-50.
6. Navya A, Pushpavathi M (2013) One third octave analysis: a diagnostic tool to measure nasality in conjunction with nasalance in children with repaired cleft lip and palate. Journal of the All India Institute of Speech & Hearing 32: 36-44.
7. Navya A (2015) Construction of nasality severity index (Unpublished master’s thesis). University of Mysore, Mysore, India.
8. Kent RD, Weismer G, Kent JF, Vorperian HK, Duffy JR (1999) Acoustic studies of dysarthric speech: Methods, progress, and potential. Journal of communication disorders 32(3): 141-189.
9. Watterson T, Emanuel F (1981) Observed effects of velopharyngeal orifice size on vowel identification and vowel nasality. The Cleft Palate journal 18(4): 271-278.
10. Hajek J, Maeda S (2000) Vowel height and duration on the development of distinctive nasalization. Papers in Laboratory Phonology V: Acquisition and the lexicon 52-69.
11. House A, Stevens KN (1956) Analog studies of the nasalization of vowels. Journal of Speech and Hearing Disorders 21(2): 218-232.
12. Moll KL (1964) Objective measures of nasality. The Cleft palate journal 35: 371-374.
13. Lindblom B (1963) Spectrographic study of vowel reduction. The journal of the Acoustical society of America 35(11): 1773-1781.
14. Hattori S, Yamamoto K, Fujimura O (1958) Nasalization of vowels in relation to nasals. The Journal of the Acoustical Society of America 30(4): 267-274.
15. Glass J, Zue V (1985) Detection of nasalized vowels in American English. In Acoustics, Speech, and Signal Processing, IEEE International Conference on ICASSP’85 10: 1569-1572.
16. Lee ASY, Gocca V, Whitehill TL (2003) Acoustic correlates of hypernasality. Clinical Linguistics & Phonetics 17(4-5): 259-264.
17. Strange W, Verbrugge RR, Shankweiler DP, Edman TR (1976) Consonant environment specifies vowel identity. The Journal of the Acoustical Society of America 60(1): 213-224.
18. Schouten MEH, Pols LC (1979) Vowel segment in consonantal contexts: a spectral study of coarticulation. Part I Journal of Phonetics 7: 1-23.
19. Andruski JE, Nearey TM (1992) On the sufficiency of compound target specification of isolated vowels and vowels in/bVb/syllables. The Journal of the Acoustical Society of America 91(1): 390-410.
20. Strange W, Bohn OS (1998) Dynamic specification of coarticulated German vowels: Perceptual and acoustical studies. The Journal of the Acoustical Society of America 104(1): 488-504.
21. Hillenbrand JM, Clark MJ, Nearey TM (2001) Effects of consonant environment on vowel formant patterns. The Journal of the Acoustical Society of America 109(2): 748-763.
22. Ohde RN, Sharf DJ (1998) Coarticulatory effects of voiced stops on the reduction of acoustic vowel targets. The Journal of the Acoustical Society of America 58(4): 923-927.

Your next submission with Juniper Publishers will reach you the below assets

- Quality Editorial service
- Swift Peer Review
- Reprints availability
- E-prints Service
- Manuscript Podcast for convenient understanding
- Global attainment for your research
- Manuscript accessibility in different formats (Pdf, E-pub, Full Text, Audio)
- Unceasing customer service

Track the below URL for one-step submission
https://juniperpublishers.com/online-submission.php