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# Acoustic Analysis of Native (L1) Bengali Speakers' Phonological Realization of English Lexical Stress Contrast

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## Abstract

Acoustically, English lexical stress is multidimensional and involving manipulation of duration, intensity, fundamental frequency ($F_0$) and vowel quality. The current study investigates the acquisition of English lexical stress by L1 Bengali speakers at the phonological level in terms of the properties of acoustic cues. For this purpose, this study compares 20 L1 Bengali speakers' use of acoustic correlates for the production of English lexical stress in context sentence and neutral frame sentence. The result of this study showed that L1 Bengali speakers were not able to achieve neutral frame sentence like control over duration, intensity, $F_0$ and to a limited extent vowel quality in context sentence. As a result, unlike neutral frame sentence, L1 Bengali speakers were not sensitive to English lexical stress contrast in context sentence. This analysis reveals that, the difference between the neutral frame and context sentences in terms of L1 Bengali speakers' realization of phonology of English lexical stress contrast was probably due to the influence of Bengali phonology of lexical stress placement (restricted to the initial syllable of a word) on L1 Bengali speakers' English speech.

## 1 Introduction

Stress is one of the most important suprasegmental features in speech prosody. In linguistics, stress is the relative emphasis that may be given to certain syllables in a word, or to certain words in a phrase or sentence. English is a stress-accent language (Beckman, 1986) and English lexical stress is contrastive in nature and related to part-of-speech (Campbell and Beckman, 1997). At phonetic level, English lexical stress is acoustically related to combination of fundamental frequency ($F_0$), duration, intensity and vowel quality (Lieberman, 1960; Sluijter and Heuven, 1996). At phonological level, the location of English stressed syllable depends on factors such as syllable structure and lexical class. If a syllable has a long vowel, it is likely to receive primary stress, and in case of English disyllabic words, the location of stress on first or second syllable led the word to be identified as a noun or a verb respectively (Archibald, 2014; Major, 2001). As English continues to grow in importance as a language for international communication throughout the world, it is necessary for L1 Bengali speakers to acquire The English language properly. From the theory of second language acquisition, it is suggested that proper acquisition involves in correct production of one of the most important suprasegmental features that is lexical stress (Weinreich, 1979; Wode, 1978). Unlike English, word stress placement in Bengali is restricted to the initial syllable of a word (Hayes and Lahiri, 1991) and is not contrastive in nature (Chatterji, 1921). Bengali lexical stress is expressed by a combination of pitch, duration, and intensity; but stress does not affect vowel quality in Bengali (Chatterji, 1921; Emeneau, 1956). Although $F_0$, intensity, duration serve as cues to lexical stress in Bengali, the stress in a word is dominantly realized by a low rising pitch pattern, where the $F_0$ movement consists of a low $F_0$ valley followed by a rise (Hayes and Lahiri, 1991), and there is very little use of intensity to identify stress in Bengali (Khan, 2008).

There are fundamental differences in stress properties between English and Bengali languages at phonetic and phonological levels. At phonetic level, unlike English, vowel quality does not serve as the acoustic cue of Bengali lexical stress. Saha and Mandal (2015) previously showed that L1 Bengali speakers used the acoustic cues of vowel duration, intensity and $F_0$ in English like manner. Moreover, L1 Bengali speakers produced English like vowel quality in certain unstressed syllables,



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but in other cases, there were significant differences in vowel quality across groups. As a result, Bengali speakers produced significantly less English like stress patterns. This was due to interference from L1 to L2 (nonnative) at the phonetic level. At phonological level, Bengali differs from English in that Bengali is bound stressed language, but the occurrence of the strongest stress at the beginning of a word is not a phenomenon appearing very commonly in English. This leads to major problems with acquiring correct stress placement habits for L1 Bengali speakers in their English speech.

The current study concentrates on the acquisition of phonology of English lexical stress placement by L1 Bengali speakers. The objective of this study is to investigate the realization of the phonology of English lexical stress by L1 Bengali speakers who were fluent in English. For this purpose, examine the differences between the uses of acoustic correlates of English lexical stress by L1 Bengali speakers under the conditions, where the position of stress to be placed in the target words in context sentence was unknown and the position of stress to be placed in the target words in neutral frame sentence was known to L1 Bengali speakers.

## 2 Method

### 2.1 Speakers

In this study, 20 L1 speakers (8 male, 12 female) of Standard Colloquial Bengali (SCB) were participated. L1 Bengali speakers were in the age group between 20 to 35 years. They were all originally from Kolkata in West Bengal and had either completed undergraduate degree studies or were continuing their postgraduate degree studies. Moreover, the L1 Bengali speakers had studied English as a second language for a minimum of ten years and were fluent in English.

### 2.2 Materials and Procedure

Seven pairs of disyllabic words given in Table 1 were selected following the methodology of Beckman (1986) and Fry (1955). Each word pair consisted of a noun and a verb that had identical spelling forms and differed only regarding stress placement. The words were randomly presented and were pronounced three times each by L1 Bengali speakers at their normal speech rate in the neutral frame sentence 'I said test word this time'. The stressed syllable of each target word in neutral frame sentence was marked on the reading text for speakers.

| Noun | IPA Notation | Verb | IPA Notation |
|---|---|---|---|
| `contract | `kɑ:ntrækt | con`tract | kən`trækt |
| `desert | `dezɚt | de`sert | dI`zɚt |
| `object | `abʤekt | ob`ject | əb`ʤekt |
| `permit | `pɝmIt | per`mit | pɚ`mIt |
| `rebel | `rebəl | re`bel | rI`bel |
| `record | `rekərd | re`cord | rI`kɔ:rd |
| `subject | `sʌbʤekt | sub`ject | səb`ʤekt |

Table 1: Disyllabic words with contrasting stress positions.

Furthermore, each disyllabic target word was placed in context sentences which were shown in Table 2.

| Target Word | Noun/ Verb | Context Sentence |
|---|---|---|
| contract | noun | Mr. Smith has finally agreed to sign the new contract. |
| contract | verb | Will steel contract when it is cooled? |
| desert | noun | They got lost in the desert. |
| desert | verb | Will he desert his team? |
| object | noun | What is the object on the table? |
| object | verb | They won't object to your decision. |
| permit | noun | In order to park here, you need a permit. |
| permit | verb | Would you permit her request? |
| rebel | noun | The rebel army did this. |
| rebel | verb | They rebelled at this unwelcome suggestion. |
| record | noun | Can I get a copy of my health record? |
| record | verb | She recorded all songs her daughter sang yesterday. |
| subject | noun | What is the subject of this sentence? |
| subject | verb | Must you subject me to this boring twaddle? |

Table 2: Disyllabic words in context sentences with contrasting stress positions.

But stressed syllable of each target word in context sentence was not marked; i.e., speakers were not informed about the proper location of stress in the target words. The target words were randomly presented and were pronounced three times each by L1 Bengali speakers at their normal speech rate in the context sentences (Fry, 1958). The speech was recorded by using AESOP's (Visceglia et al., 2009) recording toolkit with

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AESOP's specified recording platform. For the fluency of reading, the speakers were instructed to read out the text several times before recording and read the material aloud. The speech was digitized at a sampling rate 16 kHz with an accuracy of 16 bits/sample.

### 2.3 Measurements

Using Praat acoustic analysis software (Boersma and Weenink, 2004), stressed and unstressed vowels of each test word were examined acoustically for duration; the average, peak and lowest $F_0$; average and peak intensity. The intensity measure was calculated as the mean of multiple intensity values extracted and smoothed over the number of time points. $F_0$ measures were measured as the average value over entire vowel, where the pitch range for female speakers was set to 100-500 Hz and 75-300 Hz for male speakers. F1 and F2 of all vowels were measured at the middle point of their steady state and these computed formant frequencies were then averaged across the each entire vowel. The statistical analysis was done by SPSS, where two way mixed factorial analysis of variance (ANOVA) was performed with sentence type (neutral frame or context) as between subjects variable and stress position (1st syllable or 2nd syllable) as the within subjects variable for the originally measured values of each acoustic variable. All post-hoc tests (LSD) were performed with critical p value of 0.05.

## 3 Results and Discussions

### 3.1 Duration

In this study, durations of first syllable's vowel (V1) and second syllable's vowel (V2) of each test word in the neutral frame and context sentences were measured (in ms), and the results are shown in Table 3 and Table 4 and Figure 1 and Figure 2. From these results, it is observed that stressed vowels were longer than unstressed vowels in neutral frame sentence; but in the case of context sentence, L1 Bengali speakers produced stressed vowel and its unstressed counterpart with almost equal duration. Results of the analysis of vowel duration showed that there were significant main effect of sentence type [for V1: $F(1,38) = 21.34$, $p < 0.001$; for V2: $F(1,38) = 33.31$, $p < 0.001$], significant main effect of stress position [for V1: $F(1,38) = 238.82$, $p < 0.001$; for V2 : $F(1,38) = 228.27$, $p < 0.001$], as well as significant interaction between sentence type and stress position [for V1: $F(1,38) = 165.49$, $p < 0.001$; for V2 : $F(1,38) = 157.98$, $p < 0.001$]. This result indicates that there was a significant difference in the effect of stress on vowel duration between neutral frame and context sentences.

| Neutral Frame Sentence | | Context Sentence | |
|---|---|---|---|
| 1st syllable stressed | 2nd syllable stressed | 1st syllable stressed | 2nd syllable stressed |
| 92.71 | 71.31 | 68.81 | 66.86 |

Table 3: Average duration of V1 (ms) in differing stress locations.

| Neutral Frame Sentence | | Context Sentence | |
|---|---|---|---|
| 1st syllable stressed | 2nd syllable stressed | 1st syllable stressed | 2nd syllable stressed |
| 74.18 | 99.42 | 64.63 | 66.95 |

Table 4: Average duration of V2 (ms) in differing stress locations.

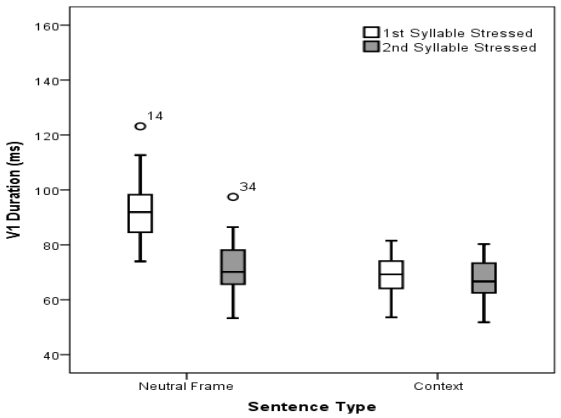


Figure 1: Average duration of V1 (ms) in differing stress locations of neutral frame and context sentences by L1 Bengali speakers.

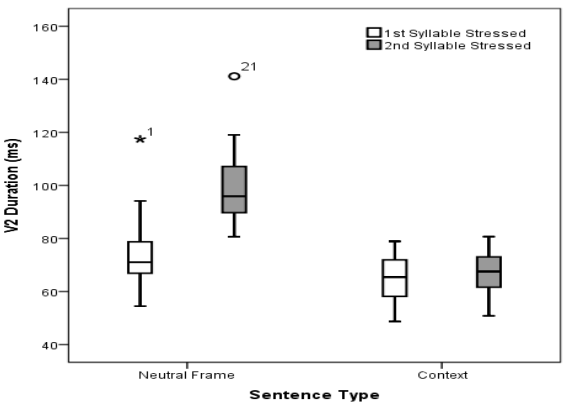


Figure 2: Average duration of V2 (ms) in differing stress locations of neutral frame and context sentences by L1 Bengali speakers.

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The interaction effect and post-hoc test (based on sentence type) showed that there was significant difference between duration of stressed vowel and its unstressed counterpart for neutral frame sentence [V1: p = 0.000000000087, p < 0.05; V2: p = 0.00000000019, p < 0.05]; that means stressed V1 or stressed V2 was longer than unstressed V1 or unstressed V2 respectively. But in case of context sentence, there was not statistically significant difference between duration of stressed vowel and its unstressed counterpart [V1: p= 0.075, p > 0.05; V2: p = 0.08, p > 0.05]; this indicates that L1 Bengali speakers produced stressed vowel and its unstressed version of target words in context sentence with almost equal duration unlike neutral frame sentence. This was due to the influence of Bengali phonology, where the first syllable of a word is always stressed; as a result, L1 Bengali speakers' tendency was to put stress on the first syllable of each disyllabic target word in context sentence regardless of English lexical stress contrast.

### 3.2 Intensity

In this study, the peak and average intensity of all vowels in the disyllabic target words in the neutral frame and context sentences were measured (in dB). The ratio between V1 and V2 vowels within the same word was obtained, and the results are shown in Table 5 and Table 6 and Figure 3 and Figure 4.

| Neutral Frame Sentence | | Context Sentence | |
|---|---|---|---|
| 1st syllable stressed | 2nd syllable stressed | 1st syllable stressed | 2nd syllable stressed |
| 105.05 | 94.62 | 105.03 | 103.25 |

Table 5: Average intensity ratio of V1/V2 (%) in differing stress locations.

| Neutral Frame Sentence | | Context Sentence | |
|---|---|---|---|
| 1st syllable stressed | 2nd syllable stressed | 1st syllable stressed | 2nd syllable stressed |
| 104.98 | 94.56 | 105.23 | 103.44 |

Table 6: Peak intensity ratio of V1/V2 (%) in differing stress locations.

From these results, it is observed that stressed vowels were longer than unstressed vowels in neutral frame sentence; but in the case of context sentence, L1 Bengali speakers produced stressed vowel and its unstressed counterpart with almost equal duration.

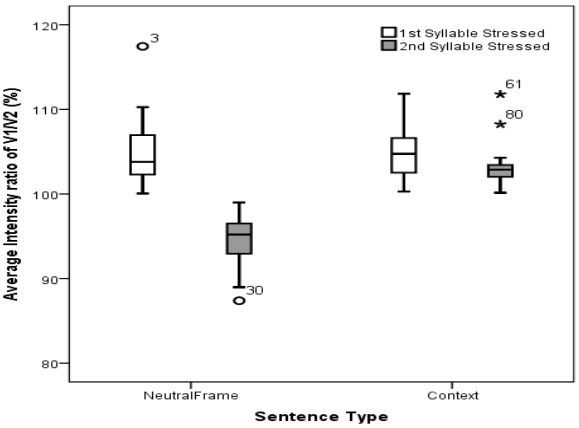


Figure 3: Average intensity ratio of V1/V2 (%) in differing stress locations of neutral frame and context sentences by L1 Bengali speakers.

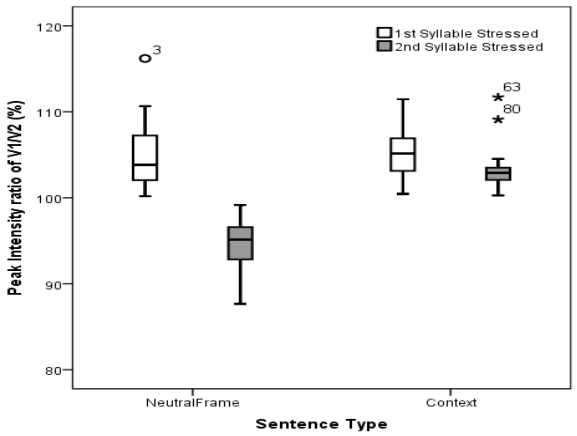


Figure 4: Peak intensity ratio of V1/V2 (%) in differing stress locations of neutral frame and context sentences by L1 Bengali speakers.

Results of the analysis of vowel duration showed that there were significant main effect of sentence type [for V1: F(1,38) = 21.34, p < 0.001; for V2: F(1,38) = 33.31,p < 0.001], significant main effect of stress position [for V1: F(1,38) = 238.82, p < 0.001; for V2 : F(1,38) = 228.27, p < 0.001], as well as significant interaction between sentence type and stress position [for V1: F(1,38) = 165.49, p < 0.001; for V2 : F(1,38) = 157.98, p < 0.001]. This result indicates that there was a significant difference in the effect of stress on vowel duration between neutral frame and context sentences. The interaction effect and post-hoc test (based on sentence type) showed that there was significant difference between duration of stressed vowel and its unstressed counterpart for neutral frame sentence [V1: p = 0.000000000087, p < 0.05; V2: p = 0.00000000019, p < 0.05]; that means

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stressed V1 or stressed V2 was longer than unstressed V1 or unstressed V2 respectively. But in case of context sentence, there was not statistically significant difference between duration of stressed vowel and its unstressed counterpart [V1: $p = 0.075$, $p > 0.05$; V2: $p = 0.08$, $p > 0.05$]; this result indicates that L1 Bengali speakers produced stressed vowel and its unstressed version of target words in context sentence with almost equal duration unlike neutral frame sentence. This was due to the influence of Bengali phonology, where the first syllable of a word is always stressed; as a result, L1 Bengali speakers' tendency was to put stress on the first syllable of each disyllabic target word in context sentence regardless of English lexical stress contrast.

### 3.3 Fundamental Frequency ($F_0$)

The average $F_0$ of all vowels, peak $F_0$ of stressed vowels and lowest $F_0$ of unstressed vowels in target words were measured (in Hz) for both types of sentences. The ratio between stressed and unstressed vowels within the same disyllabic word for average $F_0$ and peak and lowest $F_0$ was obtained, and the results are shown in Table 7 and Table 8 and Figure 5 and Figure 6. From these results, it is observed that V1/V2 ratios were over 100% for average $F_0$ and peak/lowest $F_0$ when V1 or V2 was stressed for both sentence types. This result suggests that when vowels were stressed, $F_0$s were increased for both sentence types. Results of the analysis of average and peak/lowest $F_0$ ratios showed significant main effect of sentence type [for average $F_0$ ratio: $F(1,38) = 41.84$, $p < 0.001$; for peak $F_0$/lowest $F_0$ ratio: $F(1, 38) = 83.42$, $p < 0.001$], significant main effect of stress position [for average $F_0$ ratio: $F(1,38) = 43.98$, $p < 0.001$; for peak $F_0$/lowest $F_0$ ratio: $F(1,38) = 51.01$, $p < 0.001$] and significant interaction between sentence type and stress position [for average $F_0$ ratio: $F(1,38) = 30.93$, $p < 0.001$; for peak $F_0$/lowest $F_0$ ratio: $F(1,38) = 21.34$, $p < 0.001$]. This result implies that there was a significant difference in the effect of stress position on $F_0$ of vowels in disyllabic target words between the neutral frame and context sentences for L1 Bengali speakers. The interaction effect and post-hoc test (based on sentence type) showed that there was significant difference between average $F_0$ ratio of V1/V2 [$p = 0.00000000018$, $p < 0.05$] as well as the ratio between peak and lowest $F_0$s [$p = 0.00000000044$, $p < 0.05$] in differing stress locations for neutral frame sentence. This result indicates that, for neutral frame sentence, the average $F_0$ ratio of V1/V2 and peak and the lowest $F_0$ ratio of V1/V2 were significantly higher when V1 was stressed compared to V2 was stressed. But there was not statistically significant difference between average $F_0$ ratio of V1/V2 [$p = 0.45$, $p > 0.05$] as well as the ratio between peak and lowest $F_0$s [$p = 0.083$, $p > 0.05$] in differing stress locations for context sentence. This result implies that V1/V2 ratio was almost equal in differing stress locations for average $F_0$ ratio as well as peak and lowest $F_0$ ratio for context sentence, unlike neutral frame sentence.

| **Neutral Frame Sentence** | | **Context Sentence** | |
|---|---|---|---|
| **1st syllable stressed** | **2nd syllable stressed** | **1st syllable stressed** | **2nd syllable stressed** |
| 117.4 | 109.65 | 105.6 | 104.92 |

Table 7: Average $F_0$ ratio of V1/V2 (%) in differing stress locations.

| **Neutral Frame Sentence** | | **Context Sentence** | |
|---|---|---|---|
| **1st syllable stressed** | **2nd syllable stressed** | **1st syllable stressed** | **2nd syllable stressed** |
| 122.1 | 112.22 | 106.57 | 104.46 |

Table 8: Peak & lowest $F_0$ ratio of V1/V2 (%) in differing stress locations.

That means the increase in $F_0$ of V1 was significantly higher than that of V2 in the same disyllabic target word of context sentence in differing stress locations. From this result, it is revealed that, due to the interference of Bengali phonology, V1 was always stressed instead of V2 of the same disyllabic target word in context sentence by L1 Bengali speakers regardless of recognizing English lexical stress contrast.

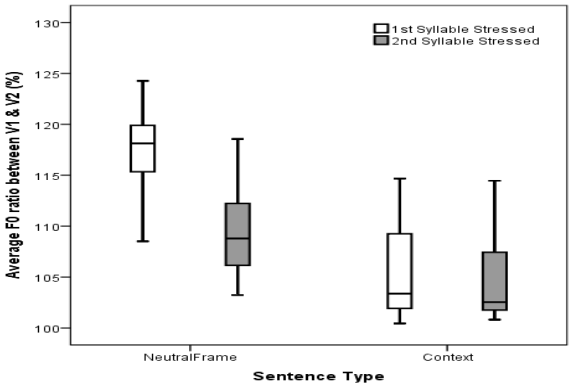


Figure 5: Average $F_0$ ratio of V1/V2 (%) in differing stress locations of neutral frame and context sentences by L1 Bengali speakers.

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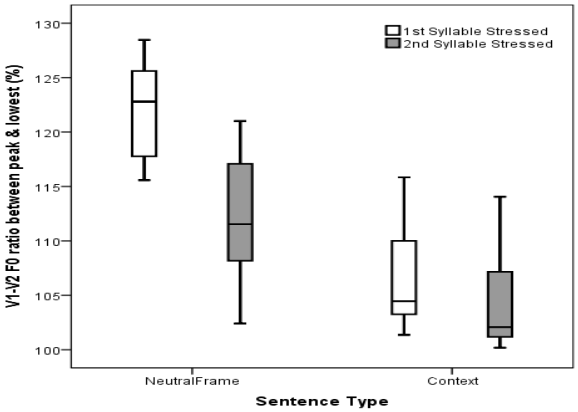


Figure 6: Peak and lowest $F_0$ ratio of V1/V2 (%) in differing stress locations of neutral frame and context sentences by L1 Bengali speakers.

### 3.4 Vowel Quality

Vowel quality is defined in terms of first (F1) and second (F2) formant frequencies (Kul, 2010). In this study, formant spacing was used to quantify the property of vowel quality, where two measures are derived from the center frequencies of F1 and F2 (Blomgren et al., 1998; Amir and Amir, 2007). The compact-diffuse (C-D), calculated as the difference between F1 and F2 (F2-F1), is correlated with the phonetic property of tongue height. The grave-acute (G-A) feature, calculated as the arithmetic mean of F1 and F2 [(F1+F2)/2], is correlated with the phonetic dimension of the tongue advancement. For each syllable in each word, separate ANOVAs were performed for both C-D and G-A variables with two factors – sentence type (between subjects variable) and stress position (within-subjects variable). Results of post-hoc test (LSD) at level $p < 0.05$ are shown in Table 9, where S refers to stressed syllables, U to unstressed syllables, NF to production of neutral frame sentence and C to production of context sentence by L1 Bengali speakers. NF < C (NF > C) indicates that Bengali speakers' productions of a given syllable in neutral frame sentence showed smaller (higher) mean values of a given acoustic feature than did context sentence.

Similarly, S < U (S > U) indicates smaller (higher) mean values of a given acoustic feature for stressed syllable compared to that of unstressed syllable for the corresponding type of sentence. From the result of analysis (shown in Table 9), it is observed that Bengali speakers did not show statistically significant difference in their production of most of the stressed as well as unstressed syllables between the neutral frame and context sentences. Only exceptions were for the syllables *-tract* (*contract*), *-ject* (*object*), *-mit* (*permit*) and *–re* (*record*), in which the stressed or unstressed or both versions did show the significant difference between the neutral frame and context sentences in terms of C-D or G-A or both features. Overall five general patterns were found from this analysis:

**Type 1. Correct non-reduction:** L1 Bengali speakers did not reduce the vowel in the following unstressed syllables of both neutral frame and context sentences (no significant differences were found for either C-D or G-A): *de-* (*desert*), *ob-*(*object*), *-cord* (*record*).

**Type 2. Lack of reduction:** Unlike neutral frame sentence, there was not found a significant change in either C-D or G-A features from stressed to unstressed versions of the following syllables of context sentence: *con-* (*contract*), *-mit* (*permit*), *re-* (*rebel*).

**Type 3. Unexpected reduction:** Unlike neutral frame sentence, L1 Bengali speakers significantly reduced unstressed vowel (in terms of either C-D or G-A or both) in the following syllables of context sentence: *per-* (*permit*), *re-* (*record*).

**Type 4. Incorrect reduction:** In these syllables of both neutral frame and context sentences, there were significant differences between stressed and unstressed vowels, but the unstressed vowel of context sentence was in each case significantly different (in terms of either C-D or G-A, or both)from its neutral frame counterpart. These syllables include: *-tract (contract), -ject (object)*.

**Type 5. Correct reduction:** Syllables in which both neutral frame and context sentences show the significant difference between stressed and unstressed vowels. Moreover, there was not statistically significant difference between unstressed vowels of the neutral frame and context sentences (in terms of either C-D or G-A or both). These syllables include: *-sert (desert), -bel (rebel), sub- (subject), -ject (subject)*.

Based on these comparisons, it reveals that L1 Bengali speakers showed lots of similarity between the neutral frame and context sentences regarding stressed and to a limited extent unstressed vowel productions.

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| Syllable | Stressed / Unstressed | | | | Neutral Frame Sentence/Context Sentence | | | |
|---|---|---|---|---|---|---|---|---|
| | Neutral Frame Sentence | | Context Sentence | | Stressed | | Unstressed | |
| | C-D | G-A | C-D | G-A | C-D | G-A | C-D | G-A |
| con- | S < U | | | | | | | |
| -tract | S < U | S > U | | S > U | NF < C | | NF < C | |
| de- | | | | | | | | |
| -sert | S < U | S < U | S < U | | | | | |
| ob- | | | | | | | | |
| -ject | S < U | | S > U | | | | NF > C | |
| per- | | | | S < U | | | | |
| -mit | | S > U | | | | NF > C | | |
| re- | S < U | | | | | | | |
| -bel | | S > U | | S > U | | | | |
| re- | | | S < U | S < U | NF > C | NF > C | | |
| -cord | | | | | | | | |
| sub- | S < U | | S < U | S > U | | | | |
| -ject | | S > U | S > U | | | | | |

Table 9: Results of pair wise comparisons between formant measures for stressed and unstressed vowels by syllable.

For most syllables, stressed vowels did not show a significant difference between the neutral frame and context sentences (Table 9, fifth and sixth columns); the exceptions were *-tract (contract)*, *-mit (permit)*, and *re- (record)*. This means that, for the majority of vowels used in the stressed syllable, L1 Bengali speakers employed approximately the similar quality and category of vowels in both neutral frame and context sentences. Furthermore, there was not statistically significant difference in unstressed vowels of most syllables between the neutral frame and context sentences (Table 9, seventh and eighth columns), with the exceptions of *–tract (contract)* and *–ject (object)*. This observation indicates that L1 Bengali speakers produced similar degree and quality of reduced vowels in most of the syllables of both neutral frame and context sentences.

## 4 Conclusions

From the results of this study, it appears that L1 Bengali speakers showed a substantial difference in use of the acoustic correlates of vowel duration, intensity, and $F_0$ of English lexical stress between the neutral frame and context sentences. But, L1 Bengali speakers did not show the significant difference in vowel quality of stressed syllable between the neutral frame and context sentences and L1 Bengali speakers reduced vowel in the unstressed syllable with a similar degree and quality in both types of sentences. This acoustic analysis reveals that L1 Bengali speakers were not able to achieve neutral frame sentence like control over duration, intensity, $F_0$ and to some extent quality of stressed and unstressed vowels in context sentence. This difference between both types of sentences was probably due to the interference from Bengali phonology of lexical stress placement on L2 English, where L1 Bengali speakers' tendency was to put stress on the first syllable of each disyllabic target word in context sentence without recognizing its lexical stress contrast. Hence, results of this acoustic analysis suggest that, although L1 Bengali speakers were able to produce lexical stress contrast in neutral frame sentence in an English-like manner, they were not sensitive to English lexical stress contrast in context sentence.

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