# A COMPARISON OF THE ACOUSTICS OF NONSENSE AND REAL WORD STIMULI: CORONAL STOPS IN BENGALI

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## ABSTRACT

Research suggests that nonsense and real words often exhibit differences in their acoustic properties. Despite this, the use of nonsense stimuli is prevalent in acoustic analyses of a range of phenomena and in experimental studies of segmental perception. The present study examined stop duration and preceding vowel formant transitions for two Bengali coronal stops produced in real and nonsense word stimuli. Firstly, significant differences were observed based on the stimulus type. Nonsense word production showed more distinct dental-retroflex differentiation. Secondly, the results revealed that F3 was a more reliable cue to place of articulation than closure duration and voice onset time.

**Keywords**: acoustics of nonsense words, coronal consonants, Bangladeshi Bengali.

## 1. INTRODUCTION

The use of nonsense stimuli is common in phonetic research [7,17,20], and has formed the basis of many classic acoustic phonetics studies dating from the 50s (e.g. [14]). It allows the creation of symmetrical contrasts/contexts that do not always exist in the real lexemes of a particular language. However, nonsense stimuli often have different acoustic characteristics from real words, and conclusions drawn exclusively on the basis of analyses of nonsense datasets may thus not reflect the characteristics of the phenomena in question in real word datasets [19]. A full understanding of the differences between nonsense and real word stimuli is thus crucial to our interpretation of past and present acoustic research, and additionally, may have significant impact on the design and interpretation of segmental speech perception research. Segmental perception tasks are often constructed using nonsense stimuli to avoid, for instance, word frequency effects skewing performance, and indeed, the use of nonsense vs. real words has been shown to induce different results in participants [7].

In order to address the present gap in research, this paper examines coronal place of articulation differences for the dental and the retroflex stops in Bengali in nonsense and real words. The focus is on stop duration as well as vowel formant transitions of the preceding vowels /a/ and /i/.

It has been shown for a number of languages that vowels can exhibit coarticulatory effects on the realisation of retroflex stops [5,11,12]. In the context of high front vowels, the retroflex can be produced with a more anterior place of articulation [5,11,12]. Bengali is of interest in this connection because this process has been observed in several languages spoken in South Asia [1,5,10,11,12], including two Indo-Aryan languages, Nepalese [10] and Hindi [12,17]. It is possible that vowel coarticulation will also have an affect on the acoustic properties of the retroflex in Bengali. In this case, there may be no distinction between the dental and the retroflex stop following /i/ in the real word stimuli. Since nonsense words are claimed to involve hyper-articulation [19], this raises the possibility that coarticulation effects might be suspended in nonsense words, leading to distinct outputs for the retroflex in each context (nonsense vs. real).

### 1.1 Background

Few production studies have looked at the acoustic properties of Bengali coronal stops (e.g. [15,16]), and this previous research has focussed mostly on temporal cues, ignoring a fuller range of acoustic parameters that may distinguish different places of articulation. Bengali contrasts bilabial, dental, retroflex and velar stops [4,9,15,16], but also has palato-alveolar [15,16] or post-alveolar [9] affricates. Additionally, stops contrast in terms of voicing, aspiration, and quantity [4,9,15,16]. There is considerable disagreement, however, with respect to descriptions of the retroflex stop which is, depending on the source, described as retroflex alveolar, apico-alveolar or apical post-alveolar (see [9] for more discussion).

According to [15,16], the closure duration of Bengali dentals and retroflexes is similar, however retroflexes have shorter VOTs than dentals. It remains to be seen whether additional cues (e.g. vowel transitions) contribute to the distinction of these coronal stops.

## 2. METHOD

### 2.1. Speakers

Four female and three male speakers of Bangladeshi Bengali, aged between 23 and 37, participated in the study. All speakers were bilingual in Bengali and English, three also spoke Hindi and two could read and understand Arabic. All speakers went to a Bengali-medium school and learned English as an L2. The age of onset for learning English varied between 4 and 6 years. The participants were living in Melbourne at the time of data collection and reported using Bengali with family and in social contexts. The variety of Bengali analysed here, Bangladeshi Bengali, is the standard variety spoken in Dhaka and other urban areas [9].

### 2.2. Materials

The stimuli consisted of four real words and four nonsense words that contained /t̪ʰ/ or /ʈʰ/ (see Table 1). The words were embedded in a carrier phrase /ami _____ bɔllam/ ("I said ________"). The target consonants of all tokens were produced in a VCV environment with the vowel contexts restricted to /a/ and /i/. In nonsense words, the structure and segmental composition were constant (/aCa/ and /iCi/). The segmental contexts of real words were chosen to be as similar as possible. The words were selected on the basis of target consonant position in the word (medial), and the type of the surrounding vowel. Lexical stress in Bengali is on the initial syllable [8,9].

**Table 1**: List of real Bengali words.

| /t̪ʰ/ | | /ʈʰ/ | |
|---|---|---|---|
| /mat̪ʰa/ | *head* | /aʈʰa/ | *glue* |
| /pɹit̪ʰibi/ | *earth* | /tɕiʈʰi/ | *letter* |

### 2.3. Procedure, annotation, and analysis

All recordings were made in the University of Melbourne recording studio. Each speaker was given a list of the sentences in Bengali script and was asked to read both real and nonsense sets, five times at normal speed. Due to an extra repetition produced by one male speaker, the data include a total of 281 tokens.

Stimuli segmentation and annotation was performed in *Praat* [2] by the first author and included the following acoustic landmarks associated with the target coronal stop and the adjacent vowels: a) onset of the preceding vowel (V1); b) onset of stop closure duration (CD); c) release of constriction; and d) onset of the following vowel (V2).

Durational measures for CD and VOT were extracted using the EMU-R interface [6]. F1, F2 and F3 values at 25%, 50% and 75% of the preceding vowel were extracted in *Praat*, and subsequently checked by hand for any points of data that appeared to be outside the expected range.

Linear mixed-effects (LME) models were applied in the analyses by using the lme4 package in the statistical package R [18]. The independent variables included the durational measures of CD and VOT. A model was fit for each variable with *place* of articulation (dental or retroflex), *stimulus type* (real or nonsense) and *vowel* type (/i/ or /a/) as fixed factors and *speaker* as a random factor. The LME analyses for the preceding vowel formants were performed separately for /a/ and /i/, with fixed factors for *stimulus type* and *place*, and a random factor for *speaker*.

## 3. RESULTS

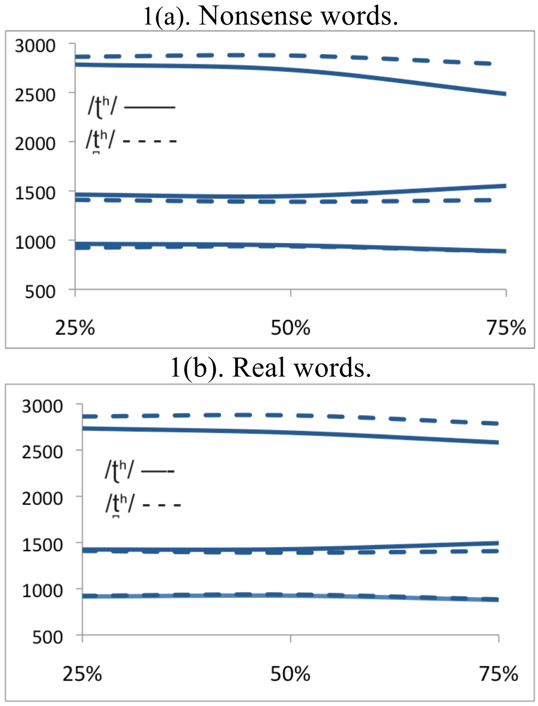
### 3.1. Formant measures

*3.1.1. Vowel /a/ at 25%, 50% and 75%*

Figure 1 illustrates the vowel formant trajectories for the vowel /a/ preceding the two stops in nonsense and real words.

**Figure 1**: Mean F1, F2 and F3 trajectories for /a/ preceding /ʈʰ/ and /t̪ʰ/ at 25%, 50% and 75% of the vowel in nonsense words (1a) and real words (1b).

1(a). Nonsense words.




As shown, consonant type had a significant effect on F2 movement at 25%, 50% and 75% into the preceding vowel. The vowel before the retroflex had higher F2 compared to the vowel preceding the dental regardless of the *stimulus type* (*t*=2.389, *p*=.02; 50%: *t*=3.616, *p*=.0003; 75%: *t*=5.24, *p*<.00001). The F1 results did not show significant effects for *stimulus type* or *place.*

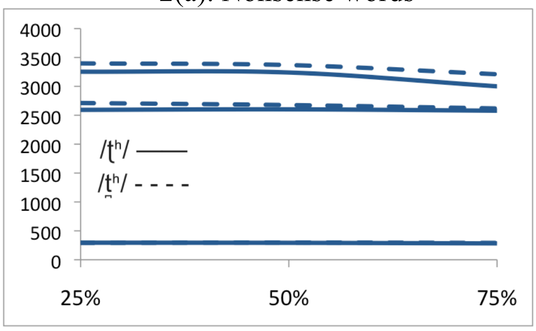
There was also a significant main effect of consonant type on F3 movement at 50% and 75% into the preceding vowel, clearly reflecting F3 lowering in the vowel preceding the retroflex (50%: *t*=2.7, *p*=.007; 75%: *t*=3.95, *p*<.0001). The results failed to show any effect of *stimulus type* on the F3 trajectory, with no evidence of an interaction between *stimulus type* and *place* for any of the three measuring points. On the whole, nonsense words showed greater inter- and intra-speaker variation in the realisation of the vowel.

*3.1.2. Vowel /i/ at 25%, 50% and 75%*

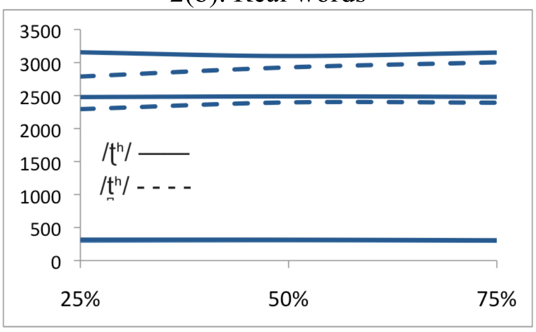
Figure 2 illustrates the vowel formant trajectories for the vowel /i/ preceding the two stops in nonsense and real words. Clearly, the formant trajectories for /i/ exhibit a different pattern from those presented for the vowel /a/.

**Figure 2**: Mean F1, F2 and F3 trajectories for /i/ preceding /ʈʰ/ and /t̪ʰ/ at 25%, 50% and 75% of the vowel in nonsense words (2a) and real words (2b).

2(a). Nonsense words




2(b). Real words




First, *stimulus type* had a significant effect on F2 movement at 25%, 50% and 75% into the preceding vowel (25%: *t*=2.435, *p*<.02; 50%: *t*=2.695, *p*<.007; 75%: *t*=2.252, *p*<.02), revealing lower F2 values for this vowel in the real word stimuli. The difference in F2 between the two types of stops did not reach significance (*p*=.07).

Second, there was a significant effect of *stimulus type* on F3 at 25% and 50% of the vowel (25%: *t*=3.09, *p*=.002; 50%: *t*=3.09, *p*=.002). *Place* also showed a significant effect on F3 at 25% into the vowel and at vowel midpoint (25%: *t*=3.25, *p*<.002; 50%: *t*=2.76, *p*<.006). However, a further examination of the interaction between *stimulus type* and *place* (25%: *t*=7.2, *p*<.001; 50%: *t*=2.9, *p*<.004), confirmed F3 lowering for the vowel preceding the retroflex in nonsense words. In the real word stimuli, lower F3 was found for the vowel preceding the dental.

For the F1 results, neither *place* nor *stimulus type* had any significant effect. An interaction between *place* and *stimulus type* for F1 at 25% of the vowel confirmed higher F1 for the vowel in the dental context produced in the real word (*t*=3.155, *p*=.002).

**3.2. Stop duration**

Figure 3 illustrates the distribution of closure duration for real and nonsense words, grouped by vowel type and place of articulation. *Stimulus type* had a strong effect on stop closure duration, with significantly shorter values produced in real words (*t*=3.69, *p*=.0003). There was also an interaction between *stimulus type* and *vowel* context (*t*=5.83, *p*<.00001), reflecting greater closure duration for the /i/ tokens in general. *Place* of articulation had no effect on this parameter. As shown, there is no consistent pattern for the retroflex-dental stop contrast and a greater variability in the production of nonsense words.

The results for voice onset time (Figure 4) show a strong main effect of *stimulus type* on the duration of voice onset (*t*=3.77, *p*=.0002), with longer VOT in nonsense words. The effect of *place* only approached significance (*p*=.06) and VOT was longer following /i/ (*t*=3.203, *p*=.002). An interaction between *stimulus type* and *place* (*t*=2.433, *p*=.015) was suggestive of the retroflex-dental contrast in real words; however, the contrast was only maintained in the /i/ vowel context. Similar to the stop closure results, the productions of nonsense words were more variable.

Consistent with the findings on stop closure and VOT, combined durations of stop closure and VOT (Figure 5) revealed greater duration for nonsense words (*t*=5.730, *p*<.0001), with no significant effect of *vowel* on the overall stop duration (*p*>.05). Despite *place* of articulation having a significant effect on stop duration (*t*=2.572, *p*=.0101), durational differences between two stops worked in the opposite direction for each *stimulus type* (*stimulus type* * *place*: t=3.659, $p$<.0002).

**Figure 3**: Closure duration for /ʈʰ/ and /t̪ʰ/ (in ms), presented for nonsense (N) and real (R) words, and plotted separately for each vowel context.

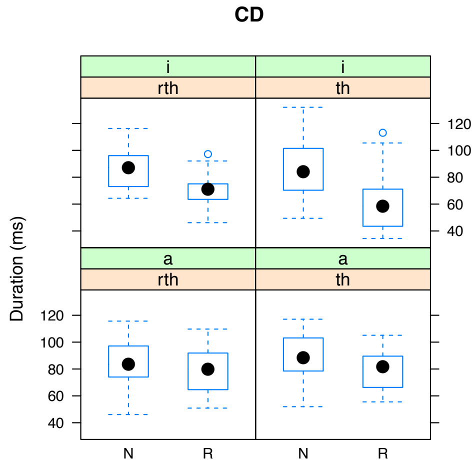



**Figure 4**: Voice onset time for /ʈʰ/ and /t̪ʰ/ (in ms), presented for nonsense (N) and real (R) words, and plotted separately for each vowel context.

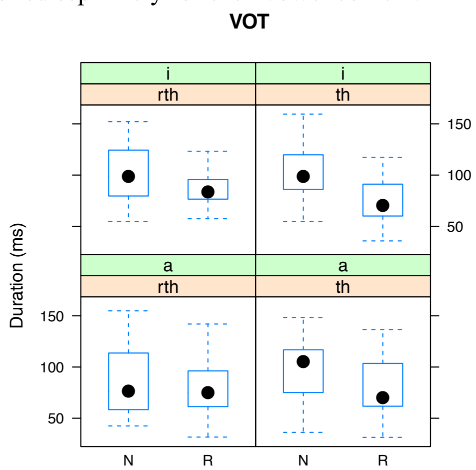
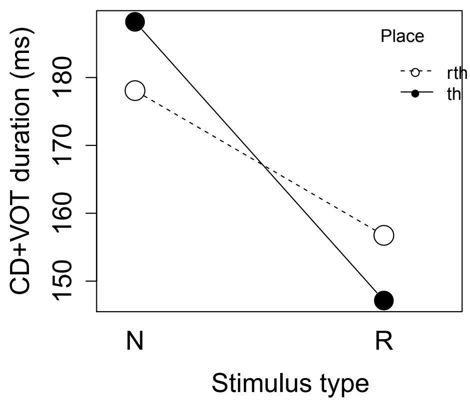



**Figure 5**: Interaction between the combined CD and VOT durations for /ʈʰ/ and /t̪ʰ/ (in ms) and stimulus type (N – nonsense, R – real).




## 4. DISCUSSION

The aims of this study were to examine the dental-retroflex contrast in Bengali and to determine whether the acoustic characteristics of these stops differ depending on whether they are produced in real or nonsense words. The results show that this is indeed the case: the stops have greater durational values across all three durational measures and exhibit a greater span in the distribution of means compared to the stops in real words. In terms of the retroflex-dental contrast, no distinction was made between /ʈʰ/ and /t̪ʰ/ on the basis of closure duration, consistent with [15,16]. The findings also failed to present a clear place distinction for the voice onset timing parameter, consistent with the findings for Hindi [3] and contrary to previous findings for Bengali [15,16]. The combined stop closure and voice onset durations showed a reverse effect of coronal place of articulation in nonsense vs. real words, which could be due to hyper-articulation. However, this could also be the influence of the word length of the real word with the dental stop.

With respect to the vowel formant measurements, F3 and F2 were reliable cues to the retroflex-dental contrast, however, the patterns showed considerable differences depending on the vowel and stimulus type. For the /a/ vowel, F3 showed lowering concomitant with F2 raising at 50% and 75% of the vowel in both types of stimuli. While the effect of F3 on the coronal place distinction is consistent with the current literature [5,13], the F2 movement needs to be examined further, given substantial differences in the acoustics of retroflexes cross-linguistically [13].

For the /i/ vowel produced in real words, there was no distinction of stop place based on F3: the speakers almost merged these two stop categories. The data is suggestive of what has been reported in other Indo-Aryan and Dravidian languages [1,5,10,11,12], but needs further investigation. As hypothesised, the nonsense word productions showed a significant dental-retroflex contrast for F3, suggesting that the speakers make these two categories more distinct than they are in the pronunciation of real words.

To conclude, the findings of the current study support previous research that a) the productions of nonsense word are more hyper-articulated than the productions of real words, and b) despite stronger articulation, nonsense word productions affect the investigated phenomena differently from real words [7,19], questioning the reliability of segmental perception tasks based solely on nonsense stimuli.

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