The Acoustic Properties of Laryngeal Contrast in Najdi Arabic Initial Stops

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ABSTRACT

The aim of the present study is to investigate the acoustic properties of the laryngeal contrast in Najdi Arabic initial stops, with a particular focus on whether both voicing and aspiration are active features in the language. Temporal and spectral acoustic properties were investigated in /b, d, ɡ, t, k/ in word-initial position as produced by 12 native speakers of Najdi Arabic. The results revealed that Najdi Arabic contrasts prevoiced and aspirated stops, a rarely documented phenomenon. VOT and F0 onset were found to be robust acoustic correlates for the stop voicing contrast in the variety, showing tenseness for the voiceless set and active voicing for the voiced one. The implications of the acoustic details of laryngeal contrast in Najdi Arabic for the phonological representations are discussed, particularly in relation to the active distinctive features in the phonological system in Najdi Arabic.

Keywords: voicing, acoustics, Najdi Arabic, aerodynamics, laryngeal realism

1. BACKGROUND

Voicing in stops has been the focus of many studies due to its varied language-specific manifestations and the challenge these have posed for the phonological representation of voicing. Voicing involves different aerodynamic and articulatory events, with context-specific acoustic consequences. In word-initial stressed position, early studies have proposed that Voice Onset Time (VOT) is the main acoustic correlate that signals the distinction between voiced and voiceless stops [4, 22, 23]. The study of Lisker and Abramson [22] investigated VOT for initial stops in eleven languages and revealed that the voiced and voiceless stops in these languages fall into three main categories: voicing lead (median VOT: 100 ms), short lag (median VOT: 10 ms), and long lag (median VOT: 75 ms).

Languages differ in the implementation of laryngeal contrast with respect to the types and number of VOT categories that signal the distinction [4, 23]. Voicing languages such as French [3] contrast voicing lead with short lag. Aspirating languages such as English [22, 7] and German [15] typically contrast short lag with long lag. While a certain degree of variability and overlap in phonetic categories has been found within the same phonological category (e.g. both voicing lead and short lag were found for phonologically voiced stops in English by Docherty [7]), the main dichotomy between voicing and aspirating languages has dominated the literature. This has enabled researchers to claim qualitatively different laryngeal settings for the voicing contrast in each group, with one being based on the presence or absence of a spread glottis feature and the other on the presence or absence of voicing [11, 14, 16, 13]. In recent years, however, some languages have been found to have a unique pattern that is different from the above categorization in that they contrast prevoiced with aspirated stops, these include Swedish [1] Najdi Arabic [9] and Qatari Arabic [20].

These findings raise questions about the phonological representations that specify voicing contrast among languages. The traditional view postulates that the binary feature [+/-voice] represents the voicing contrast in the phonology regardless of the phonetic details. The laryngeal realism view, however, proposes mapping between phonological representations and phonetic detail, in which the acoustic characteristics reflect the privative distinctive features that specify the laryngeal contrast in the phonology [1]. Accordingly, it assumes that the laryngeal contrast in aspirating languages is specified by the [spread glottis] feature while it is specified by the [voice] feature in voicing languages.

Amongst the acoustic characteristics which define these features, the fundamental frequency and the first formant at the onset of a vowel following a stop have been found to be robustly related to the presence of prevoicing or aspiration, and to contribute to the identification of stops as voiced or voiceless [25, 18, 15]. F0 and F1 onset have been reported to be higher after voiceless stops than after voiced ones in many languages. This is a by-product of the opening of the vocal cords and the airflow at the release stage in the case of voiceless stops and the tension of the vocal cords in the case of voiced ones. [24, 26]. It has also been proposed that F0 and F1 onset are phonological properties that signal the laryngeal distinction regardless of the acoustic characteristics [6, 19].

The case of laryngeal contrast in Najdi and Qatari Arabic is interesting, as aspirated and prevoiced stops require both the [spread glottis] and [voice] features, something that is contradictory to what has been generally proposed in the literature about Arabic as a true voicing language. Importantly, it raises the question of whether the laryngeal contrast in one language can be based on two active features rather than one, something that phonological accounts based on binary contrasts and under-specification might disfavour [13, 14].

2. THE CURRENT STUDY

In the present paper, we investigated the VOT patterns of the voicing contrast in Najdi Arabic initial stops and looked at temporal and spectral acoustic correlates that have been reported in the literature as cues for the distinction between phonologically voiced and voiceless stops. As Flege's [9] study was small scale and with a focus on second language acquisition, this study allowed us to 1) extend the investigation of VOT patterns in Najdi Arabic initial stops by considering different places of articulation and different qualities of the following vowels, 2) explore the robust acoustic correlates that differentiate between phonologically voiced and voiceless stops in Najdi Arabic, and 3) draw conclusions regarding the phonological representation of voicing in Najdi Arabic and by doing so contribute to research on phonetics-phonology interface.

3. METHODS

3.1. Materials and speakers

The data reported here are based on recordings of natural sentences produced by twelve monolingual native speakers of Najdi Arabic (6 males, 6 females) aged 25-35 years, living in Riyadh and of mid to high socio-economic level. We created a list of 80 real Najdi Arabic monosyllabic (CVC) words. The test words started with voiced or voiceless stops that differed in place of articulation (bilabial, alveolar, velar), followed by one of eight Najdi Arabic vowels (/a:/, /a/, /i:/, /i/, /u:/, /u/, /e:/, /o:/). The test words were preceded by the carrier phrase [ʔana ʔagool] 'I say'. The participants were seated in a quiet room in their homes and were asked to read the sentences from a computer screen, with a sentence on each slide and at a steady pace. Each target word was repeated three times but the sentences were semi-randomized so that the same word never appeared twice in a row. The participants were instructed to read the sentences aloud in their native dialect. Their production was recorded using a microphone (Klim USB FR. 100Hz-10Kh), which was placed 25 cm in front of their mouths. The recording was made at a sampling frequency of 44,100 Hz, 16 bits quantisation and in mono channel. The total number of target sentences was 240 (80 words x 3 repetitions). The total number of tokens was 2880 (240 sentences x 12 participants).

3.2. Acoustic analysis

Acoustic analysis was carried out using Praat [2]. All tokens were manually transcribed and segmented in TextGrids through interpreting the waveforms and the spectrograms (Figure 1 and 2). For each stop, VOT, stop closure, and F0 and F1 at the onset of the following vowel were measured. VOT was measured as the period between the beginning of the release burst of the stop and the onset of the glottal vibration [22]. For closure duration, the onset was determined as the end of the final sound of the carrier phrase to the onset of the stops release. The release of the stop was observed as a burst of noise on the waveform and the spectrogram. In terms of F0 and F1, they were measured at the voicing onset of the following vowel. The voicing onset was determined at the beginning of the first cycle of the glottal vibration [10].

Figure 1: The segmentation and labelling of the word *ba:t* 'slept'.

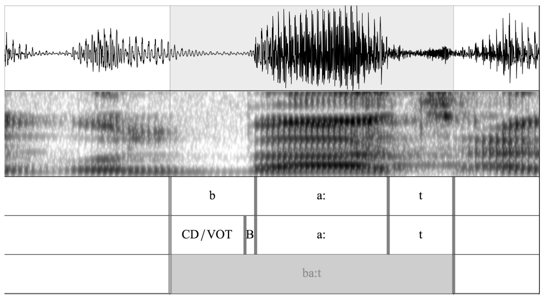
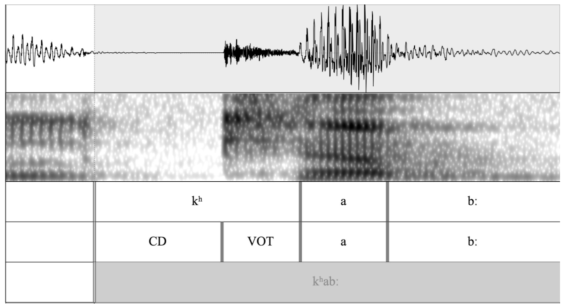


Figure 2: The segmentation and labelling of the word *kabb* 'spill'.



3.3. Statistical analysis

A one-way analysis of variance (ANOVA) was conducted to test the effect of the linguistic factors on VOT, with a place of articulation as a factor with three levels (bilabial, alveolar, velar) and with the type of the following vowel as a factor with eight levels (/a:/, /a/, /i:/, /i/, /u:/, /u/, /e:/, /o:/). A post-hoc test (Tukey's HSD) was performed to test the pairwise differences among the levels of each of the linguistic factors. Additionally, each of the acoustic correlates in voiced and voiceless stops were separately investigated using one way ANOVA with closure duration (CD), F0 onset, and F1 onset as dependent variables and voicing status as independent variable (voiced/ voiceless).

4. RESULTS

As shown in Figure 3 and Tables 1 and 2, voiceless stops in Najdi Arabic are aspirated word-initially while voiced stops are produced with prevoicing throughout the closure for 98% of the tokens. Mean VOT was 76.2 ms (SD= 14.36) for voiceless stops and -75.13 ms for voiced stops (SD= 27.01).

One-way ANOVA results showed that there was a significant effect of place of articulation on VOT (P=0.0016). For voiceless stops, mean VOT for /k/ (83.9 ms) was significantly longer than for /t/ (68.4 ms, p = 0.001), as was reported in previous studies [22, 4]. For voiced stops, on the other hand, post-hoc test (Tukey's HSD) revealed that VOT values increased in the order /b/ > /d/> /g/, with significant differences between all the pairs. This is due to the difficulty of maintaining voicing the further back the place of articulation [22, 24].

Though not presented here, one-way ANOVA results also showed a significant effect of the following vowel type on VOT (P=0.00553), with high vowels having longer VOT than low ones.

Figure 3: VOT patterns for phonologically voiced and voiceless stops.

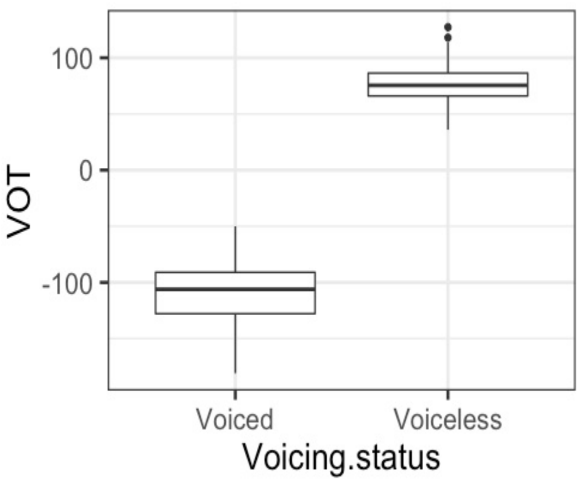


Figure 4: Closure duration patterns for phonologically voiced and voiceless stops.

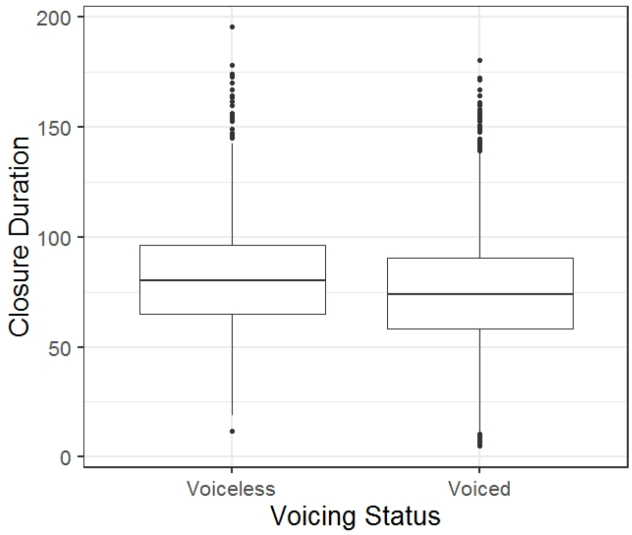


Figure 5: F0 onset patterns for phonologically voiced and voiceless stops.

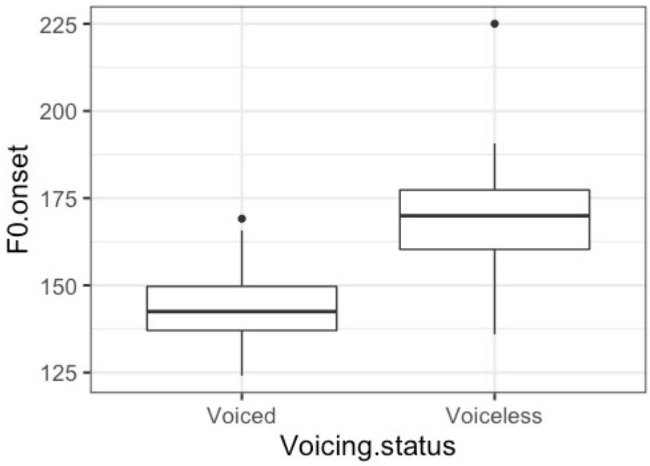


Figure 6: F0 onset patterns as a function of vowel quality.

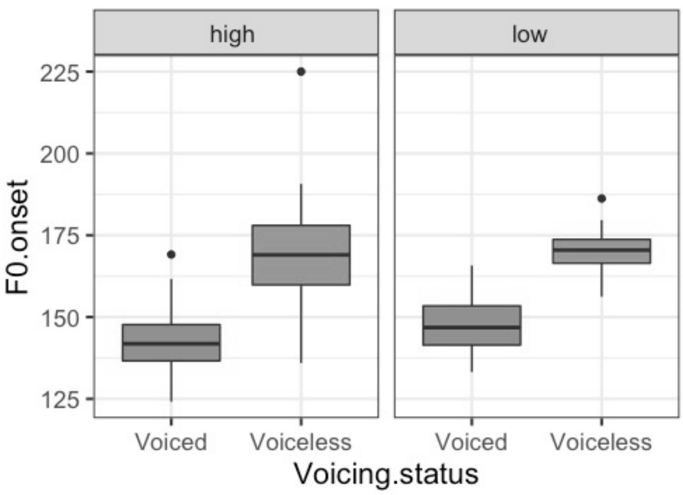


Table 1: mean VOT values for /b, d, g/, N= number of tokens, SD= standard deviation.

Place	Stop	mean VOT (ms)	N	SD
Bilabial	/b/	-82.18	576	20.64
Alveolar	/d/	-74.73	576	23.68
Velar	/g/	-68.3	576	31.87
Total mean		75.13		27.01

Table 2: mean VOT values for /t,k /, N= number of tokens, SD= standard deviation.

Place	Stop	mean VOT (ms)	N	SD
Alveolar	/t/	68.49	576	12.44
Velar	/k/	83.92	576	16.28
Total mean		76.2		14.36

In terms of closure duration, voiceless stops were significantly longer than voiced stops (P=0.0433). The mean closure duration was 83.2 ms (SD=24.8) for voiceless stops and 75.1 ms (SD=27.01) for voiced stops. However, the results showed overlap between the closure duration values of the two categories.

F0 onset values were found significantly higher following voiceless than voiced stops in high and low vowels, which concurs with findings from other languages [8, 25] and demonstrates a tenser setting following voiceless stops. F0 onset ranged from 140.56 Hz to 188.87 Hz for voiceless stops and from 125 Hz to 173.4 Hz for voiced stops. F1 onset values for phonologically voiced and voiceless stops showed no significant difference (P=0.62) and are not presented here due to lack of space.

5. DISCUSSION

The aim of the present study was to investigate the phonetic realization of phonologically voiced and voiceless initial stops in Najdi Arabic with the aim to investigate which phonetic categories they occupy along the VOT continuum and what implications this has for their phonological representations. As discussed in the background to the study, the laryngeal contrast in languages has typically been thought of as being represented by one set of distinctive features, often assumed to be binary (e.g. [+/- voicing] or [+/-spread glottis]. Results from this study showed that phonologically voiced and voiceless stops can be identified by the presence of negative VOT in case of voiced stops and positive VOT in case of voiceless stops, with no contradiction or overlap between the two categories. The presence of prevoicing in voiced stops and long lag VOT in voiceless stops in all tokens of the present study indicate that VOT is a strong and effective acoustic correlate in the description of voicing contrast in Najdi Arabic. The results are consistent with Flege's [9] conclusion that Najdi Arabic has aspirated and prevoiced stops. In the present study, F0 emerged as another acoustic correlate that differentiates between voiced and voiceless initial stops, once again concurring with results from languages with fortis stops which show tenseness following the voiceless set [12, 27].

The presence of prevoiced and aspirated stops in the laryngeal system in Najdi Arabic generates questions about the nature of the phonological representations that specify such contrast. By considering the laryngeal realism approach, it could be suggested that laryngeal contrast in Najdi Arabic, like in Qatari Arabic and Swedish, is over-specified in the phonology with [voice] for voiced stops and [spread glottis] for voiceless stops. Such assumption contradicts the economy principle proposed by Chomsky and Halle [5] which highlights that voicing contrast between segments is specified by one distinctive feature.

6. FUTURE REASERCH

A follow-up study is being carried out by the authors to investigate the phonetic realization of laryngeal contrast in Najdi Arabic by considering different positions within the word and the sentence to test the quality and the quantity of the VOT patterns in different phonetic contexts. VOT in utterance-initial context is specifically being examined in voiced stops based on the assumption that it reflects the presence or absence of [voice] due to the difficulty in initiating and maintaining voicing in such a position [15]

Additionally, we are using different tools that are proposed in the realm of laryngeal realism to extend our understanding of the interactions between the acoustic signals and the active distinctive features in the phonological systems. These tools include testing the effect of speech rate on the temporal acoustic correlates and their implications for the presence or absence of the phonological features. They also include examining the passive and active voicing patterns in the intervocalic position as another way to address the synergy between the acoustic cues and the phonological representations.

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