THE INTERACTION OF SIBILANTS AND IP BOUNDARIES IN EGYPTIAN ARABIC

Andre Schwab, Kevin Samejon, Teddy Manning, Miriam Yifach

ABSTRACT

This paper presents data demonstrating that in Egyptian Arabic (Central Semitic), a tonal contrast in boundary tones can be spelled through fricative manipulation. The boundary tone contrast is a prosodic distinction between H-H% in yes-no questions, and L-L% in declarative statements. The sibilants /s sˤ/ in a variety of contexts appear to behave in similar ways to each other, yet somewhat differently to previous literature. Segment-final center of gravity falling is universal, even in underlyingly rising contours. High tonal targets in questions seem to be systematically realized instead through fricative-initial raising, which should be articulatorily marked given current phonetic theory on sibilants. Center of gravity in questions seems to be higher in all matched environments, except segment-finally where no clear distinction is made.

Keywords: tone perception, F0 correlates, sibilant acoustics

1. INTRODUCTION

Within the Autosegmental-Metrical tradition, scaling and timing of tonal targets are orthogonal dimensions of phonological representation. The tonal target model (Pierrehumbert & Beckman 1988) typically includes boundary tones which are spelled out phrase-finally and carry prosodic meaning. A proposed universal has been that a rising boundary tone is interpreted as questions (Henriksen 2012), but ample evidence shows that in many linguistic regions, this does not hold true (Rialland 2007). Illustrated below is one of the other uses of rising boundary tone in English, the "incredulity contour" (Ladd 2008).

(1) The English Incredulity Contour

L+H* L-H%		L+H*	L-H%
Sue?!	A	driving	instructor?

The realization of a tonal target on a vowel is relatively straightforward through F0 manipulation, but the actual acoustic cues and processes used in the realization of prosodic targets and movements on voiceless consonants is less well understood. One of the most revealing studies thus far concerns fricatives in an utterance-final position (Niehbur 2012), in which manipulation of fricative spectral energy appears to carry much of the perceptual load in question/declarative phrase-final signaling in German. The correlates of higher tonal targets on fricatives include higher center of gravity, larger range, and higher intensity than in low tonal targets.

1.1 F0 Articulation and Fricative Noise

Fricative spectra are complicated and can be manipulated for a variety of factors (Koenig et al. 2013). These include articulator movement into and out of sibilant position, in which the highest frequencies will be mid-fricative; varying degrees of labialization where more labialization lowers the fricative sound through increase in frontal space; and airstream manipulation, where higher airstream power (i.e. through excited speech) leads to higher spectral noise (Shadle 2012). Moreover, word-internal differences in placement may motivate their own differences in sibilant acoustics, where word-initial fricatives have lower center of gravity than word-final fricatives, while also having higher center of gravity at the very end of frication (Welby & Niehbur 2019). Given multiple different manners of fricative manipulation, surrounding environment is likely a strong influencer of the phonetic realization in-context, but multiple articulatory correlates likewise are conducive for manipulation of spectral noise into a controllable signal.

1.2. Case study: Fricatives in Egyptian Arabic

The voiceless sibilant system of Egyptian Arabic (Central Semitic, Egypt) is comprised of strong contrasts between /s sˤ/ among others. These are contrastive in all phonotactic constructions of the language. The acoustic distinction between them is debated (Shosted et al. 2018), but appears to involve lower center of gravity in the pharyngealized token (Abu-Al-Makarem 2005). The actual articulatory mechanism behind Cairene Arabic's emphatic consonant series has been argued to be to be true pharyngealization, which is not true of all dialects (Lehn 1963).

1.2. Tonal contours in Egyptian Arabic

The tonology of Egyptian Arabic has, unlike many languages, been described (Chahal & Hellmuth

2014). Declarative sentences are argued to have an L-L% falling contour, while Yes-No questions (YNQ) are argued to have a H-H% rising intonation phrase-finally. The schema for several attested boundary tones is reproduced below in figure 1.

Figure 1. Chahal & Hellmuth 2014, Egyptian Arabic F0 trendlines.

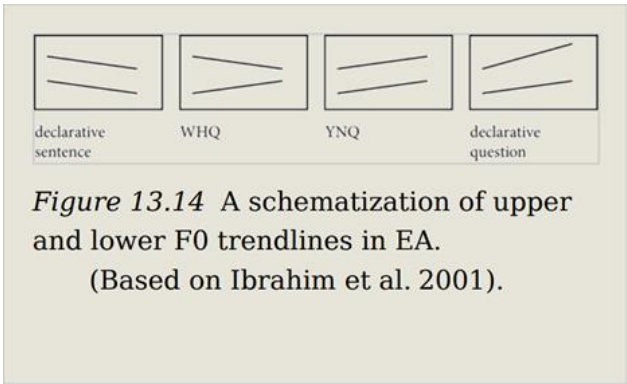


Figure 13.14 A schematization of upper and lower F0 trendlines in EA. (Based on Ibrahim et al. 2001).

Given these facts, a follow up to Niehbur 2012 is in order, to look at the behavior of fricatives in word-final position when affected by these contours.

2. METHODOLOGY

Three Egyptian Arabic speakers of various backgrounds currently living in Boston, MA, were recruited for a speech production study, and compensated for their time. All were between ages 20-25, and had been in the United States at least two years. One had exposure to French and German in education, but all have two Arabic-monolingual parents.

The recording session occurred at the phonology lab of Boston University using a MacBook Air and a provided microphone and sound booth. A constant distance from the microphone to the lips was ensured. Participants were given one test run, followed by three recording blocks of around six minutes, each separated by an optional two-minute break.

The stimuli consisted of a slide presentation with text in Modern Standard Arabic. The tokens were utterance-final words with word-final /s sˤ/ in three contexts: preceded by /i a ʔ/. The utterances were alternated between YNQs and declarative sentences in order to alternate the boundary tones between L-L% and H-H%, following the analysis of Chahal & Hellmuth 2014.

Each speaker produced 48 sentences (8 sentences, question vs declarative, three repetitions), 18 of which contained target words. Within each target sentence, the utterance-final fricative was manually isolated and bounded in order to be further analysed.

The recordings were then analysed using Praat and Praat scripts in order to take measurements of the center of gravity of the target fricatives, as well as the center of gravity in three separate points of the segment (beginning, middle, end). Intensity and duration of the segments was also measured but was found to have no substantial differences and so will be omitted from the analysis. Likewise, non-final fricatives (e.g. at the onset of the syllable) were found to have no difference between question and declarative intonations, as they appeared to be too far from the phrase boundary to be affected.

2. DATA ANALYSIS

The results for /s/ are reproduced below in Fig. 2. The declarative intonation is altogether lower than the question intonation at all stages of the segment by at least 400Hz. Interestingly, the question intonation begins as high as the middle of the sound (6800 Hz) indicating that the H-H% acoustic spell-out may rely on high energy at all stages of the segment. These findings were consistent for all three speakers and all preceding contexts. The absence of difference between the beginning and middle portion of the /s/ in questions runs against articulatory predictions (Shadle 2012) where the middle section is highest, and is thus likely a marked, deliberate articulatory distinction. The fricative center of gravity consistently falls in the end of the segment in all tokens save one.

Figure 2. Mean center of gravity for the 8 tokens of utterance-final /s/ from all the speakers in three different locations of the segment in both declaratives and YNQs, rounded to the nearest 20Hz.

		Beginning	Middle	End
S	Dec	4800	6400	4800
S	Que	6800	6800	6080

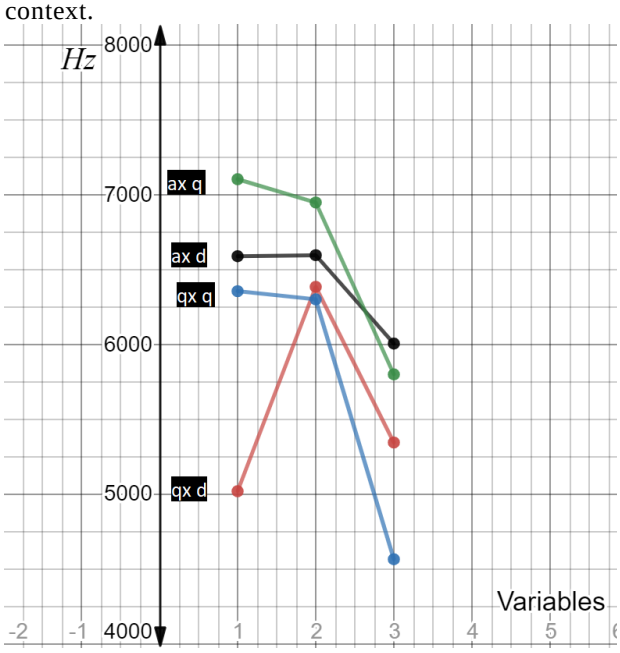
These findings are more complicated for the pharyngealized /sˤ/, which was produced in four contexts. One set of targets was produced with a preceding [a], one with a preceding glottal stop; one set was in a falling declarative L-L% intonation and one was in a YNQ H-H% rising intonation. A summary of the findings is presented below in figure 3, in which a continuation of trends from before can be found, yet some new trends are found as well. As before, the end of all sibilant segments seems to fall from the middle portion fairly drastically by at least 600Hz.

Figure 3. Mean center of gravity for 16 tokens each, for beginning, middle, and end of segment, in Hz. <X> here stands for [sˤ] for the ease of data processing. All measurement means are rounded to the nearest 50Hz at the end of analysis.

		Beginning	Middle	End
aX	Dec	6600	6600	6000
aX	Que	7100	6950	5800
qX	Dec	5000	6400	5300
qX	Que	6300	6300	4550

However, unlike before, we see substantial difference in /-asˁ#/ declaratives in that the beginning of the sibilant is not lower than the middle, while in rising question intonations, -asˁ begins even higher than the middle of the segment, at 7100Hz versus 6950Hz. This is highly unusual and, again, not predicted by phonetic modeling of fricatives. A visualization of this is shown in Figure 4.

Figure 4. Mean center of gravity of /-sˁ/, in Hz, over the course of beginning, middle, and end of the segment. The different contexts are preceding /a/ versus a glottal stop, and in a YNQ versus declarative context.

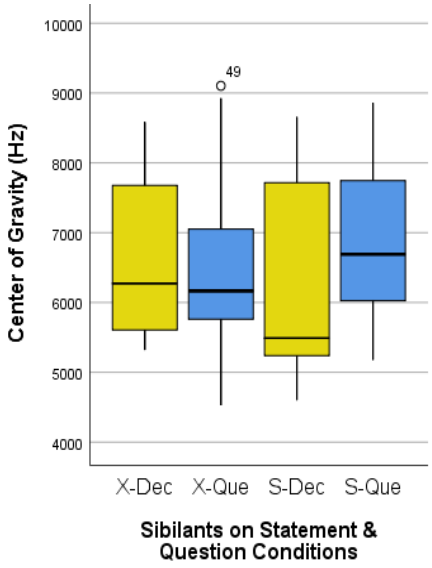


Here, the falling of center of gravity in question versus declarative contexts is severe in both cases, with question ends falling to even lower frequencies than declarative end-contexts. This suggests that there is little to no perceptual difference segment-finally, and that intonation spell-out (if it exists) must occur earlier.

Perhaps the most surprising finding here is the high frequency for the beginning of the /sˁ/ following /a/ in declarative intonations. An easy explanation would be that marking the boundary between vowel and fricative could be more difficult, and thus would be a methodological error rather than reflective of real data. However, this problem should have applied to the /s/ as well, were this the case, yet we find a very low beginning frequency in this context for that sound.

The sustained high frequency of the sibilants from their start until the middle, as found before for /s/, is compelling. This suggests some degree of regularity in this process, and sibilant-initial height might be instrumental in spelling out high and low tonal targets on fricatives. This is in contrast to the centers of gravity of the fricatives as a whole (not broken down into parts), which for /sˁ/ seem about even in questions versus declaratives, illustrated by Figure 5. Although the data for /s/ might compel us to measure the fricative segments as a whole (like Niehbur 2012), the obscurement of localized internal phenomena in /sˁ/ suggests that further breakdown beyond the segment level can be necessary to yield the correct results.

Figure 5. Centers of gravity segment-wide for /sˁ/ <X> and /s/ <S>, varied by intonation contour in questions versus declaratives.



These results are compelling as different sibilant segments in different contexts behave in similar ways: raising in question-intonation phrases seems to be spelled out sibilant-initially instead of sibilant-finally, showing a possible regular phonological correspondence between high F0 and high fricative center of gravity.

3. CONCLUSIONS

We have argued that the contrast between declarative falling intonation and YNQ rising intonation phrase-finally can be realized through sibilant manipulation for some speakers of Egyptian Arabic. Intensity and length of segment were not distinctive, but rather segment-internal progression of center of gravity (in

Hz) appeared to vary systematically between the two contexts. Specifically, fricative-onset was regularly raised in underlyingly H-H% contexts, suggesting some link between initial frequency of fricatives with tonal targets. The middle of the fricatives was sometimes, but not always, distinctive in the two contexts, and segment-final dropping is present in almost all tokens, rendering it likely non-contrastive and unimportant in spelling out the prosodic contrast.

A point of future study would be further investigation to what looks like a systematic fricative-final lowering of center of gravity regardless of prosodic boundary, countering the expectations set by previous literature (Welby & Niehbur 2019). Likewise, word-initial fricatives were found to have no significant difference between YNQ and declarative contrasts, calling into question Chahal & Hellmuth 2014, but this could be due to the smaller nature of this experiment.

Two future experiments are likely in order. The first would be a perception experiment with manual manipulation of the center of gravity of an utterance-final fricative in YNQ vs declarative contexts. The findings above predict that low fricative-initial center of gravity should entail a falling declarative contour, while high fricative-initial center of gravity should cue a rising interrogative contour. Manipulation of the end of the segment should be non-contrastive, while the middle might be predictive of interpretation, even if less than segment-initial sibilant height. The other experiment would be an expansion of the current production study with more participants of more variable ages and less daily exposure to English varieties.

This experiment importantly shows the importance in subdividing fricative segments, as the trajectory of center of gravity throughout the segment seems to be able to mirror the temporally-grounded raising and lowering of vowel formants, including F0. As we show that fricatives can hold prosodic features traditionally associated with vowels, perhaps application of vowel-like temporal analyses may shed light on fricative distinctions which on the whole may be difficult to measure without segment-internal analysis.

4. REFERENCES

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