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Auditory and Acoustic Evidence for Palatalization of the Nasal Consonant in Cairene Arabic

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Abstract: This paper introduces the palatalized nasal [nʲ] as an allophonic realization of coronal /n/ in Cairene Arabic. The palatalized variants of the phonemes previously described in acoustic and sociolinguistic terms include the alveolar stops [t, d] and their pharyngealized counterparts [tˤ, dˤ] , which can be palatalized preceding the high, front vowel [i:]. While previous studies have anecdotally noted that the coronal nasal /n/ can undergo palatalization in the same environment, this variant has not been systematically investigated. Focusing on syllable-final /-ni:/ segments, I first use auditory measures to show that the palatalized variant occurs with some regularity (~50%) in the read speech of seven speakers of Cairene Arabic. Then, I provide acoustic evidence that this perceived difference significantly correlates with the difference in F2 values taken from the onset and midpoint of the vowel following the nasal consonant. There is also evidence of a lexical effect, such that borrowings exhibit less palatalization than non-borrowings. This study contributes data for the unexamined Cairene nasal and supports the likelihood of palatalization of coronals at the typological level.

Keywords: palatalization; nasal; Cairene Arabic; sociophonetics; acoustic phonetics

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1. Introduction

This paper presents an acoustic and auditory study of palatalization in the nasal consonant /n/ in Cairene Arabic (CA). While the mechanics of palatalization have not been widely studied across Arabic dialects, the few studies that have explored this phenomenon have centered on the sociolinguistics, phonology and phonetics of the palatalized stops, /t, d/ and the palatalization of their pharyngealized counterparts (Haeri 1996a; Youssef 2013). There exist some informal observations that the Cairene coronal nasal can undergo palatalization, but no work has systematically examined this sound.

Palatalization of coronals generally involves fronting and heightening articulatory gestures. Thus, a raised F2 and lowered F1 is expected due to the fronting and raising gestures associated with a shortened front cavity. Previous acoustic literature on palatalization have used F2-F1 as a possible cue in distinguishing between palatalized and non-palatalized consonants (Kochetov 2017; Iskarous and Kavitskaya 2010; Purcell 1979). However, this measure can be problematic when studying nasals, as antiformants are known to have an obscuring effect, rendering F1 measures unusable. Studies concerned with nasals have alternatively examined duration, intensity, or nasal murmurs, and have found F2 transition alone to be a highly effective cue for establishing palatalization (Recasens 1983; Harding and Meyer 2003; Kerdpol 2012). Upon examining palatalization in nasals, a linear relationship was established between the formant frequencies at the vowel onset and midpoint, in which F2 at vowel onset varies in relation to the coarticulatorily produced vowel (Sussman et al. 1991; following Lindblom 1963b). Due to F2's reliability in determining plain vs. palatalized nasals in particular, this paper utilizes two points along the F2 transition—one at vowel onset and the other at vowel midpoint/steady-state—and provides a method to establish palatalization in the CA nasal. Auditorily coded tokens are further analyzed in comparison to triangulate the acoustic findings, therefore providing two types of results:

one that indicates the strength/degree of palatalization measured in continuous terms, and the other in terms of frequency or proportions palatalized. This paper provides the first detailed phonetic descriptions of the Cairene [nʲ].

The participants in this study are seven native speakers from Cairo in their early 20 s, and the data include word-final /ni:/ segments elicited from word-list readings. Results show that using formant transition (F2Onset-F2Midvowel) as a measure effectively distinguishes between plain [n] and palatalized [nʲ]. By contributing new acoustic data for an unexamined variant in Arabic, my results provide a foundation for those interested in conducting further sociolinguistic and comparative work on palatalization across Arabic dialects.

1.1. Articulatory Gestures and the Phenomenon of Palatalization

The linguistic phenomenon of palatalization is not uncommon among the languages of the world, let alone within the dialects of Arabic. As a speech process involving the production of a secondary articulation, palatalization entails shifting the primary place of articulation towards the palatal region (Kochetov 2011), or the "superimposition of a raising of the front of the tongue toward a position similar to that for **i** on a primary gesture" (Ladefoged and Maddieson 1996, pp. 363–65). In coronal primary articulations, this involves a displacement of the tongue surface, which would have been realized to support movement of the tongue-tip in the non-palatalized production, to a slightly different primary constriction location (Ladefoged and Maddieson 1996, p. 365).

Two general types of palatalization are often discussed: secondary palatalization (Bateman 2007; Hall 2000; Kochetov 2011) and full palatalization (Bateman 2007). Secondary palatalization, also referred to as "tongue-raising" (Bhat 1978), refers to the addition of a secondary, palatal articulation without changing the initial place of articulation, such as [t → tʲ] (Bateman 2011, p. 589). This type is extremely common in the labial, coronal and dorsal places in many languages of the world (Kochetov 2011). Full palatalization (Bateman 2007), can include palatalization to a posterior coronal and to an anterior coronal (Kochetov 2011). A shift to the posterior coronal may result in a non-sibilant sound, e.g., [t, k → c], or a sibilant sound, e.g., [t, k → t͡ʃ]. A shift to the anterior coronal can result in a non-sibilant sound, e.g., [p, k → t], or a sibilant, which is rare, e.g., [p, k → ts], and [t → ts], which is relatively more common (Kochetov 2011, p. 1671).

The most likely phonetic triggers of palatalization are the high front vowel /i/ and palatal glide /j/ (Chen 1973; Bhat 1978; Hall 2000; Hall and Hamann 2006; Hall et al. 2006; Bateman 2007, 2011, p. 596), followed 'at a considerable distance by mid front vowels' (Kochetov 2011, p. 1672). The acoustic similarities between the high front vowel and the palatal glide play a role, but it is also worth noting that different consonants in various languages have been found to have different triggers. At the typological level, however, Kochetov noted the dependencies between triggers and targets, in which coronals are commonly targeted by high vocoids and dorsals by /i/ and other front vowels (Kochetov 2011, p. 7). Bateman noted that if there were only one vowel trigger of palatalization in a language, that vowel should be /i/ due both to its high and front qualities (Kochetov 2011). These findings aid in better understanding palatalization in Cairene Arabic, as the triggers in this language variety follow the aforementioned pattern (discussed in the next section).

In describing the articulatory gesture of palatalization, it is recognized that co-articulation has to do with the occurrences of two different articulations at the same time. (Catford 1988, p. 106), and that palatalization thus occurs as a type of coarticulation. In CA, palatalization occurs as phonetic coarticulation, as opposed to a phonemic shift (Youssef 2013). We will thus henceforth treat palatalization of /n/ as a gradient, phonetic feature.

As the data analyzed in this study all contain /n/ in the syllable-final /ni/ position, the articulatory gestures involved are necessarily unpacked. First, to produce the nasal /n/, the soft palate is lowered, and there is a complete closure in the mouth: between tongue-tip and teeth or teeth-ridge for [n], so that all airflow is shunted through the nose (Catford 1988, p. 74). The realization can be apico- and lamino- articulations against the dental zone

and against the front and back of the alveolar zone (Catford 1988, p. 82). Secondly, on producing the high front [i, i:] vowel, the Jones' system of a "vowel limit" posits that since the tongue is tense and the dorsal surface is pushed close enough to the hard palate, there is a point at which the approximant [i] turns into a palatal fricative [j̝] (Catford 1988, p. 125). In other words, if the vowel is 'high enough,' it will ultimately result in a palatal-like production. Articulatorily speaking, [i] and [j] have an identical starting point, and "the highest point of the tongue in front vocoids lies on the front of the tongue, underneath the palatal zone" (Laver and John 1994, pp. 276–77). As the CA vowel [i:] is generally high and tense, it is feasible and likely for palatalization to occur as an assimilatory process (as documented in Youssef 2013, 2015).

During consonant production of the /ni/ segment, the tongue dorsum height and dorsopalatal contact size in the nasal change as a function of the adjacent vowel in the progression [i] > [u] > [a] (Recasens 1999, p. 89; Recasens 1984). As such, on contact with /i/, which is a vowel that requires the raising and fronting of the tongue, /n/ shifts from a coronal to a lamino-alveolar consonant (Recasens 1999, pp. 88–89). This results in a larger contact surface between the tongue and the palate.

Similarly, during palatalization, dentoalveolars such as /n/ undergo tongue dorsum raising and fronting, causing the palatalized coronal to become lamino-alveolar. Thus, there appears to be some overlap in the coarticulatory gestures for producing both the plain and palatalized /ni/ segments. Given the explanation above on Jones' vowel limit, we recognize that the transition from a 'regular' coarticulatory effect of the following vowel to one that is palatalized is gradient, and this is reflected in the auditory coding process, which recognizes that what is counted as palatalized /n/ can be wide ranging (see Section 2.2).

While the displacement of the tongue can have many acoustic and auditory consequences, the observation of the data presented in this study is one of a /j/-like quality in the release of /n/ into /i/, suggesting palatalization, which is further demonstrated through F2-raising in the acoustic analyses.

On coarticulation in VCV contexts, there is evidence that vocalic anticipation is blocked when [i] contributes to the raising of the tongue dorsum in [n] (Recasens 1999, p. 99). Due to the increase in tongue-dorsum constraint when producing /n/, C-to-V carryover (left-to-right) effects are said to be more prominent for [ini] than for [ana] (Recasens 1999, p. 99). However, what is observed to be occurring in CA contradicts this, as it indicates anticipatory (right-to-left) coarticulation, with the influence of /i/ on the preceding consonants. Bladon and Al-Bamerni (1976, p. 148) note that anticipatory coarticulation occurs whenever an articulator is free to anticipate later segments (following Daniloff and Hammarberg 1973), implying a high-level encoding process of scanning ahead, or due to postulating the unit of speech encoding to be an articulatory syllable (consisting of a CV sequence). The triggering effect of /i/ in CA can thus be viewed as anticipatory coarticulation.

Additionally, relevant to our discussion of nasals is their observation by early Arab and Muslim phoneticians. According to Al-Khalil (d.175/791 in Darwish 1967)[1] and Sībawayhi (d.177/793)[2], the nasals /n, m/ were described as containing nasality (Bakalla 1981, p. 286) and as prone to assimilation, a phenomenon that is widely observed to be intrinsic to the nasal class (Bakalla 1981, p. 286). According to Sībawayhi, the Arabic nasal sounds are produced in a similar way to the modern phonetic description of the nasals, with the complete closure of the air in the oral cavity, and are further described as *munfatiḥ*, or non-velarized, while Ibn Jinni (Ibn Jinni 1954, d.392/1002 in Al Halabi) notes they are *munkhafiḍ*, or with lowering of the tongue body. Sībawayhi discusses *'ikhfā'* or hidden, *m* and *n*, referring to homorganic assimilation in place of articulation of n to the following consonant, e.g., *man jā'a* → *maɲjā'a* (Bakalla 1981, p. 290). This type of assimilation is also present in the observation on palatalization in cases where *n* is followed by the approximant *y* [j], observed by Al-Saqqaf (1999) and Haeri (1996a); below, see Table 1.

Table 1. Triggers of palatalization in Cairene (/t, d/ from Haeri 1996a, p. 51; Youssef 2015, pp. 25–27; /n/ from my own informal observations).

Environment	/t, d/	/n/
[j] glide	hadja 'quiet f.sg' → had^{j}ja	ha:n^{j}a 'female name' → ha:n^{j}ja
[i] (word-final)	fa:d^{ʕ}i 'empty m.sg' → fa:d^{j}i	tæ:ni 'again' → tæ:n^{j}i
[i:]	gidi:d 'new' → gid^{j}i:d	sini:n 'years' → si n^{j}i:n
[ɪ] epenthetic [a]	ruħt -ɪ- gibt '(I) went and bought' (lit. brought) → ruħt^{j} -ɪ- gibt	–
[i] (non-final) [a]	tiktib 'you write, masc.'	–
[ee] [a]	sanateen 'two years'	mine:n 'from where' → min^{j}e:n
low vowels [a]	uskutuu 'be quiet, plur.'	–
at word boundaries [a]	sitt ʔawi 'woman very'→ sitt^{j} ʔawi	–
near sibilants	wisti → 'my waist' wisʕt^{j}i	ħosni 'male name' → ħos n^{j}i

[a] While Haeri (1996a) found palatalization in these environments, Youssef (2015) found them to block or lack WP.

While nasality is an accompanying feature that, similar to palatalization, involves lowering of the soft palate so that the air stream passes through the nasal cavity as well as through the oral cavity (Ladefoged and Maddieson 1996, p. 131), the acoustic perception in this study is of palatalization: Coders, who were trained phoneticians, searched specifically for /j/-like qualities in the syllable-final /ni/ segment. Acoustically, while an F1 bandwidth increase is indicative of nasalization, the acoustic results are difficult to interpret (Pruthi and Espy-Wilson 2007) and aerodynamic measures (not employed in this study) are better at capturing these effects. While nasalization is worthy of further examination in a more detailed study of nasals in Arabic, it is not discussed further here, as our scope is limited to the process of palatalization on one of multiple CA coronals undergoing this phenomenon. This paper establishes a premise for further study of the potential spread of palatalization onto other consonants not previously discussed.

1.2. Palatalization in Cairene Arabic

In CA, the palatalization of /t, d/ stops and their pharyngealized counterparts have been examined by Bhat (1978), Haeri (1996a) and Youssef (2013). Haeri noted two types of palatalization in Cairene, one of which is termed weak palatalization (WP), which refers to the secondary palatalization described above. The other is termed strong palatalization (SP), and refers to full palatalization. In representing the auditory effects, WP in Cairene Arabic can be represented in IPA as [t, t^{ʕ} → t^{j}], and [d, d^{ʕ} → d^{j}], while SP can be described as affricates: [t, t^{ʕ} → t$\widehat{ʃ}$], and [d, d^{ʕ} → d$\widehat{ʒ}$].

Weak and strong palatalization in CA are triggered when stops are followed by the palatal glide /j/, long /i:/, word-final /i/, as well as by the phonetically lower word-internal or epenthetic short /i/or by the long mid vowel /ee/ (Haeri 1996a; Youssef 2013). The environments listed in Table 1 were described by Haeri and Youssef as the observed conditions for palatalization in Cairene.

In addition to the aforementioned coronal stops, Geenberg briefly observed in her study on palatalized stops that the Cairene coronal nasal may also undergo palatalization (Geenberg 2012, p. 21). Al-Saqqaf's descriptive work on Hadramawti Arabic (Al-Saqqaf 1999) again briefly mentioned the palatalized Cairene /n/ as a comparative point to Yemeni, and noted that the palatalized Hadramawti /n/ is not limited to the high-front vowel environment, unlike in Cairene. As he noted, "n, which escaped Haeri's attention (Haeri 1992, p. 171), is also among the consonants that become palatalized in the environment of i

or ī in, e.g., Ar. women's speech, e.g., inti [inɲtʃi] 'you' f.s., ya'ni [jæʕɲi] 'it means; I mean'" (Al-Saqqaf 1999, p. 95). However, neither Al-Saqqaf nor Geenberg undertook acoustic analyses of the palatalized nasal, despite its presence in multiple speech communities.

The triggers described for WP are relevant to that of the palatalized /n/, as it was observed that palatalized nasals occur in all of the environments for WP, but not necessarily for SP (Geenberg 2012). This is congruent with my own informal observations, although similar to Youssef, I did not observe palatalized [nʲ] in all environments listed by Haeri (see Table 1 for [nʲ] triggers). Grammatically, final [i] in Cairene has several roles: a noun-derived adjective (e.g., ʔamrikæ:n-i:, 'American'), and the first-person possessive or object pronoun (e.g., ʔibn-i, 'my son'; istannu:-ni, 'wait (2nd, pl.) for me!'). Word-final /ni:/ may also occur in names (e.g., hæ:ni, *ħ*osni), in other common words such as tæ:ni, 'again,' and extends to borrowed English words such as 'any,' and 'funny,' which commonly occur in the speech of educated Cairenes. Though a gradient, phonetic feature, the palatalization observed in CA is assimilatory and contains an anticipatory coarticulatory effect, since the consonants become more similar in place of articulation to the following vocoids (see Kochetov and Alderete 2011).

1.3. Acoustics of Palatalization

Acoustically speaking, F2 formant transitions have been widely used as cues to determining nasal places of articulation. Palatalization in particular is often more apparent at the consonantal release than at the formation of the primary constriction, with a higher F2 value at the release (Ladefoged and Maddieson 1996, pp. 363–64). In a study comparing the interactive effects of nasal murmurs, transitions, and release as possible cues for place of articulation, Recasens (1983) noted that examining formant transitions proved useful in determining the palatal nasal's place of articulation, while the nasal murmur was not a useful cue for identifying this sound. It should be noted that the F2 transition may not provide a sufficient place cue for other types of nasal. Bilabial and velar nasals, for example, may rely on other features such as the nasal murmur or quality of the nasal release instead of, or in addition to, using F2 as a place cue (Recasens 1983). In examining formant transitions in the event of coarticulation, formant shapes will vary according to the surrounding vowels (Öhman 1966), but will generally be directed towards the same 'locus' or 'juncture' between the vowel and the sonorant, although F2 loci are not invariant in natural speech (Fant 1973; Kewley-Port 1982; Lehiste and Peterson 1961; Öhman 1966).

In describing the palatalized stops [t, d, tˤ, dˤ] in Cairene, the typical raising/fronting of F2 in these palatalized stops were seen in Youssef's acoustic data (Youssef 2015; from a 38-year-old female speaker), with F2 raising by approx. 390–460 Hz in the palatalized stops compared to their plain counterparts. Note that both the pharyngealized and plain stops can undergo palatalization in Cairene, and that the pharyngealized stops de-pharyngealize, or weaken in their pharyngealized quality, via fronting (Haeri 1996a; Youssef 2015).

Assuming that fronting is a necessary accompanying articulatory gesture for palatalization in CA, and for the above stated reasons which prevent the ability to use F1 as a measure for the nasal, this paper makes use of F2 as a cue for tracing palatalization in the presented data generated from word-list readings. The following sections define the auditory and acoustic measures used to triangulate the study of palatalized [nʲ] in CA, and proceeds with discussing the implications of the main findings and future directions on the study of this phenomenon.

2. Materials and Methods

2.1. Participants, Data Collection and Selection

Speech data gathered from 7 participants were used for the acoustic analyses in this section. They include three women and four men aged 20–27 who are native Egyptian colloquial speakers residing in the greater Cairo area at the time of data collection (month of July 2014; Due to the increasingly unstable political situation in Egypt, it became and

remains nearly impossible to do social science fieldwork in the country). All speakers were born, raised, and either attended or completed private or public university in Cairo.

For the purpose of eliciting controlled, comparable data that can be efficiently measured and analyzed, all speakers were given a wordlist written in Arabic script in dialectal spelling (e.g., تاني، بيحبوني). Of the 40 words, the 20 target words contained the coronal nasal preceding the high front vowel in the word-final /-ni:/ environment, which reflects the phonetic condition for palatalization in CA. A few tokens were noisy and produced unclear spectrograms, and were thus omitted. This yielded a total of 138 target tokens containing word-final /-ni:/ that were analyzed. The preceding vowel was not controlled for, but the words selected were items that I had informally observed to variably contain palatalization. To minimize overstressing/overemphasis of items containing the word-final /-ni:/ 20, other filler words that did not contain the /-ni:/ segment were included alongside the target items. Among the filler words, 6 tokens containing the nasal in the /-na/ word-final environment were produced, as well as 3 nasals in the word-medial /-ne-/ environment, while the rest contained no /n/ consonant at all. Although a small-scale study, this paper provides a detailed work to support the anecdotal evidence observed by the aforementioned scholars of variation in the variable (n).

Participants were recorded in spaces with as minimal noise as possible, and took place in either my home or the participant's home, or in a rented meeting room at a local cafe. However, some street noises that permeate the bustling city of Cairo could not be entirely avoided. This is a common challenge for fieldworkers in greater Cairo, where quiet, soundproof recording studios belonging to institutions, if available, have restricted access and are not always practical or possible to use. The speakers were recorded in wav format using a Zoom H1 Recorder (48 kHz) with an external cardioid lavalier microphone (SP-CMC-2), which they were instructed to hold 5–10 inches from their mouths.

2.2. Auditory Coding and Acoustic Measurements

An auditory coding method was first employed by the author, and 75% of the data was coded by two other linguists: a sociophonetician who is not a speaker of Arabic and a linguist who is a speaker of Cairene Arabic with familiarity of phonetic variation in Arabic dialects. The tokens are coded as 'n' for the plain, unpalatalized nasal, or 'nj' for tokens that contained any degree of palatalization (from lighter to stronger degrees of palatalization). Recognizing that palatalization is a gradient, phonetic feature in CA, the coding originally allowed for three categories: 'non-palatalized,' 'somewhat palatalized,' and 'strongly palatalized,' but the last two categories were collapsed into a larger 'palatalized' category for analysis. The two speakers of Arabic coded the data with 61% agreement, a point further discussed later in this paper. When these two coders did not agree on a token, the coding of the third, non-Arabic speaking phonetician was used in a tie-breaker system to code that token. These auditorily coded items are labeled Auditory Code in the statistical model.

The acoustic measurements used to determine the cue to palatalization of the nasal in this study are performed by obtaining the frequency value of F2 by hand, in Praat, measured in hertz (Hz), at two points in the word-final /-ni:/ segment: one point at the release of the nasal murmur into the following vowel (coded: F2Onset), and another at the midpoint of the same vowel (coded: F2Midpoint). For each word, the F2Midpoint was subtracted from F2Onset, and the resulting value is henceforth referred to as "F2Diff". This follows Lindblom (1963a, 1963b), Gibson and Ohde (2007) and Sussman et al. (1991), who found that comparing the formant transition between these two points served as a useful cue in distinguishing between palatal/palatalized and plain alveolars. A larger, negative F2Diff value indicates a steeper, upward CV transition, while a smaller value indicates a flatter, upward transition. To visually illustrate this, the two points measured (F2Onset and F2Midpoint) are marked in each spectrogram in Figure 1, which shows spectrograms from two speakers: one non-palatalizer (left), and one palatalizer (right), saying [hæ:ni:] 'name, *Hanny*'. The left, non-palatalized spectrogram shows F2 coming out of the 'n' closure at a lower point and heightening rapidly and into the steady-state/midpoint of the [i:] vowel.

The right, palatalized spectrogram, however, shows F2 starting at a higher point at [i:] onset, and shows little to no upward transition into the vowel midpoint. In the acoustic analysis, taking the difference between the two points measured in each vowel allows for an alternative way of normalizing between vocal tract length, so no additional vowel normalization techniques were employed.

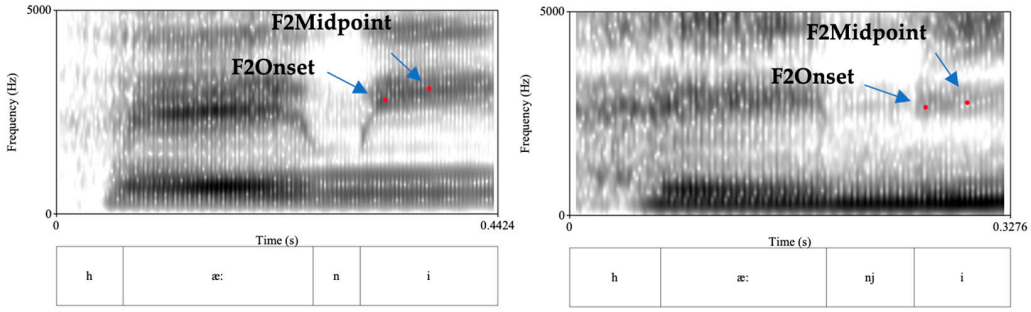

Figure 1. Spectrograms from two women: one non-palatalizer (**left**), showing a lower F2 at the 'i' vowel onset, and one palatalizer (**right**), showing higher F2 at onset, saying [hæ:ni] 'male name, Hanny'.

2.3. Statistical Analyses

Using the package AFEX, a wrapper for lmer in R (Singmann et al. 2015; R Core Team 2013), the data were first fitted with the following linear mixed effects regression model: F2Diff~AuditoryCode*Word+(1 | speaker). The dependent variable F2Diff is the subtracted value of F2Onset-F2Midpoint, and is expressed as a continuous variable (Hz). The fixed effects are the auditorily coded tokens, coded as AuditoryCode (categorically coded: n/nj) and word (categorically coded: 20 levels). The variable speaker was included as a random intercept to account for individual variation.

3. Results

3.1. Auditory Results

The total number of auditorily coded tokens include 66 tokens coded as palatalized [nʲ], and 72 tokens coded as plain [n], yielding a total of 47.8% palatalized tokens (Table 2). This is evidence in itself that the palatalized variant is a robust realization of /n/ before /i:/ in CA. Table 2 shows the breakdown of (nj) versus (n) codes by individual speaker. While two of the women show categorical realizations (interestingly, in different directions), most participants produce both variants, and averaging across participants, there is not a compelling difference based on speaker gender (41.67% for women compared to 53.63% for men) in this data pool.

Table 2. Token count and percent palatalized by speaker and gender.

Speaker	Gender	[nʲ]	[n]	Total	% Palatalized	Speaker	Gender	[nʲ]	[n]	Total	% Palatalized
1	F	19	0	19	100%	4	M	17	3	20	85%
2	F	0	19	20	0%	5	M	6	14	20	30%
3	F	5	15	20	25%	6	M	2	18	20	10%
						7	M	17	2	19	89.5%

Some of the intra-speaker variation may be driven by lexical effects. Table 3 contains the proportion of palatalization in five of the seven speakers (two speakers were omitted as they were categorically either a palatalizer or non-palatalizer, revealing no by-word variation). The table and visualized data in Figure 2 show that the words produced with the fewest palatalized tokens—i.e., only 1 instance of (nj) code in each—were *ya3ni* [jaˤni], 'I mean/meaning,' which contains the voiced pharyngeal fricative known to have a formant-lowering effect, and the borrowed words (from English) *funny* and *any.* The word with the

highest proportion of palatalized tokens is *kallimiini* 'call me, 2nd, f.sg,' (80%; Table 3). This is unusual, as other words with final /i:ni/ syllables should have had similar coarticulatory patterns, but this is not the case in the current findings. It is otherwise not immediately clear what unites the words that were or were not frequently palatalized, but English borrowings certainly seem to be among the least palatalized.

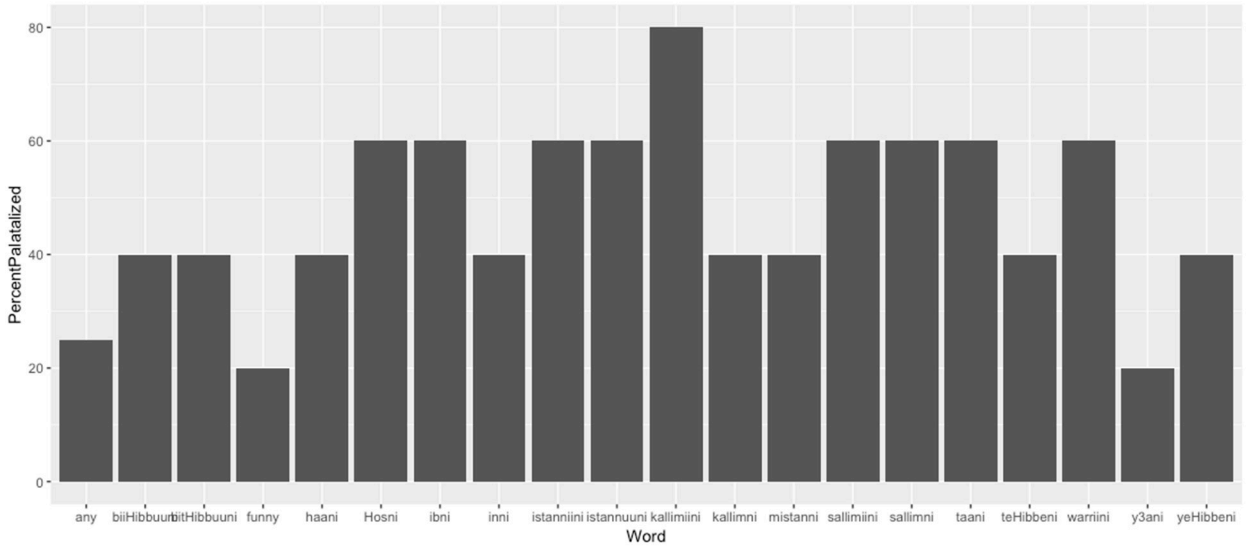

Figure 2. Visualization of proportion of palatalized tokens by word (based on Table 3).

Grouped by context, words ending in words ending in /i:ni/ (*kallimiini, istanniini, warriini, sallimiini*) are somewhat more likely to be palatalized (60–80%), compared to other contexts, such as the /u:ni/ (*istannuuni, bitHibbuuni, biiHibbuuni*), /ani/, /a:ni/ and /Cni/ environments (40–60%). The geminate /nn/ (*mistanni, inni*) and geminate + epenthetic /bb-ɪ/ groups (*teHibbeni, yeHibbeni*) are somewhat less likely to be palatalized (40%) than all other contexts.

3.2. Acoustic Results

Based on the raw token counts above and thus following the methodology from the auditory analysis, the two speakers who categorically produced either (n) or (nj) 100% of the time were omitted in the acoustic analysis. This controls for any influential points that would have caused errors when examining lexical variation.

Upon examining F2Diff, it is apparent that these values distinguish tokens we heard as plain (n) vs. palatalized (nj). This is displayed in Figure 3, which demonstrates less of a difference between the two points measured in (nj), since the F2Onset is starting very high and barely moves to reach the F2Midpoint height of the /i:/ vowel. Contrarily, in plain (n), F2Onset starts at a lower point and moves higher into the vowel midpoint, so there is a greater height difference. Thus, a main effect of Auditory Code (n, nj) on F2Diff is observed ($F = 4.06$, $df = 1, 112.67$, $p = 0.01$, $N = 99$). The distinguishing cue appears to be around the 100 Hz mark, indicating that if F2Diff is less than 100 Hz, the auditory quality is likely palatalized, while an F2Diff greater than 100 Hz covaries with an auditorily non-palatalized nasal. The average F2Diff is −62.4 Hz for palatalized codes, and −209.5 Hz for the non-palatalized ones.

Table 3. Token count and percent palatalized by word (includes five of seven speakers); see Appendix A for gloss.

Transliteration Note: H = ħ, 3 = ʕ, nj = n^{j}												
Word	kallimiini	Hosni	ʔibni	istanniini	istannuuni	sallimni	taani	warriini	sallimiini	biiHibbuuni		
% Palatalized	80.00% (5)	60.00% (5)	60.00% (5)	60.00% (5)	60.00% (5)	60.00% (5)	60.00% (5)	60.00% (5)	60.00% (5)	40.00% (5)		
Word	bitHibbuuni	haani	kallimni	mistanni	teHibbeni	yeHibbeni	inni	any	funny	Ya3ni	**Total**	
% Palatalized	40.00% (5)	40.00% (5)	40.00% (5)	40.00% (5)	40.00% (5)	40.00% (5)	40.00% (5)	25.00% (4)	20.00% (5)	20.00% (5)	47.40% (99)	

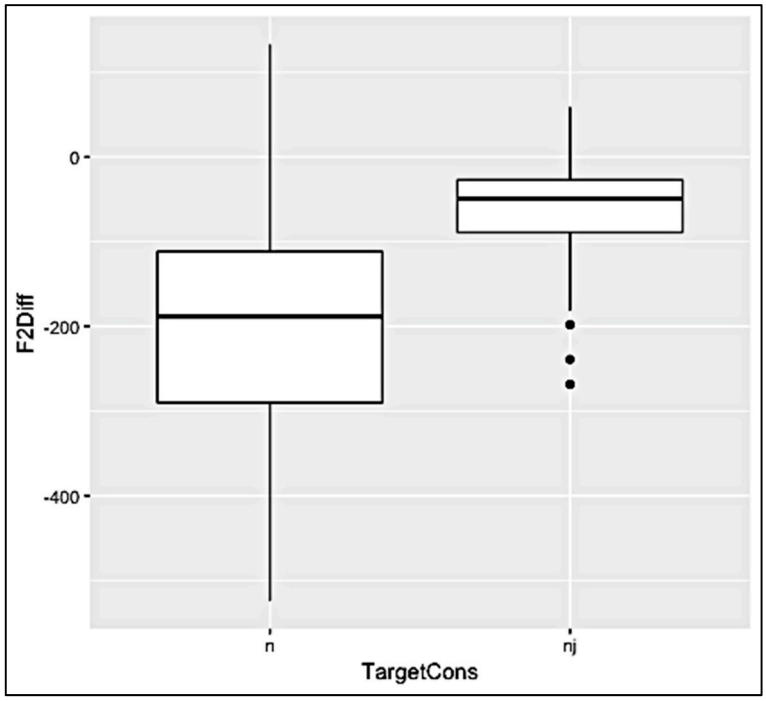

Figure 3. Plot of F2Diff (in Hz) by Auditory Code (n, nj) in all speakers. N = 138.

4. Discussion

This study was motivated by the anecdotal evidence of palatalized [nʲ] as an allophone of [n] and the absence of any acoustic or auditory study of this sound. The acoustic and auditory analyses on the speech productions of the seven speakers presented here indicate that the two types of production exist and are acoustically distinct from one another in CA.

The first main effect found for Auditory Code on the dependent variable F2Diff (the subtracted value of F2Onset-F2Midpoint) contributes to works surrounding the palatalized nasal in a few ways. First, it suggests that using auditory coding as an approach to measuring palatalized /n/ is reliable, as it correlates with the acoustic measure. This finding, along with previous informal commentaries, confirms that the list of palatalized consonants in Cairene Arabic must be expanded beyond the /t, d/ stops to include the palatalized nasal. Additionally, the linear relationship found in the points utilized in the F2Diff measure also confirm the methodology proposed by Sussman et al. (1991) and Lindblom (1963a) for analyzing nasals, and further supports the use of linear regression as a method of analysis.

The findings from the auditory coding revealed a rater agreement of 61%, which indicates that while auditory coding was effective, palatalized [nʲ] can be difficult for listeners to code. This may be an effect of perceptual compensation—a type of perceptual bias that ordinarily leads listeners to ignore, or correct for, coarticulatory effects (Garrett and Johnson 2013). It is possible that coders ignored palatalization in instances where the coarticulation was relatively milder, leading to some discrepancies in the coding process. Despite the difficulty in auditorily coding this sound, F2Diff remained effective in distinguishing (n) from (nj) codes, which suggests that the triangulated method employed can be used to measure the degree of palatalization in future studies.

The effect on borrowed words was unexpected, since palatalization had been previously observed in my informal observations on both borrowed words included in this study (particularly in *funny*) in casual speech from speakers with similar educational backgrounds to the participants. Yet, it is known that loanwords can be realized with native or non-native sounds and that topic, speaker- and word-specific sociolinguistic factors can determine the selection of one variant over another (Hashimoto 2019). Some factors that can affect this selection include level of bilingualism (Poplack and Sankoff 1984), degree of

linguistic integration (Haugen 1950), and language dominance (Aktürk-Drake 2015, 2017). More recently, Hashimoto's work on tap [ɾ]-borrowing from Māori into New Zealand English uses an exemplar-based approach (Pierrehumbert 2001; Docherty and Foulkes 2014) which posits that exemplars with native sounds and those with non-native sounds are represented in the cognitive system of a borrower and updated based on linguistic experience (Hashimoto 2019). Relevant to our discussion is the idea that exemplars with non-native sounds are stored in relation to a social category associated with the source language and its culture (Hashimoto 2019). In this study, it is possible that the context of the word-list reading task had an effect and, intersecting with the participants' mental representations of the borrowed words, in turn elicited plain [n] as the appropriate selection for the task. Future studies may be interested in further examining the effects of palatalization across speaking contexts, or specifically on loanwords, at greater length.

As for the word *kallimiini* containing the highest proportion of palatalization in the auditory coding, without similar coarticulatory effects in other words from the same environment, the motivation is unclear. There may be socially motivated reasons related to the affective quality of this particular word, potentially combined with sound symbolism. As exemplified in Japanese, a type of palatalization exists that is not phonologically conditioned, but rather contains an iconic function, and is linked with "smallness", "childishness" or "affection" (Nichols 1971; Ferguson; Ohala 1994). Such types of "expressive palatalization" occur cross-linguistically in sound symbolism, diminutive morphology, hypocoristics, and in "babytalk" (Kochetov and Alderete 2011, p. 346). A sociolinguistic perception study on palatalization of /n/ in CA would be enlightening.

Another factor is the prosodic position of the final morpheme /ni/. The list of words analyzed include words with stress systematically placed on the penultimate, which has an effect of articulatory reduction: The morpheme /ni/ is phonologically /ni:/ with a long vowel, which undergoes vowel temporal reduction, resulting in an undershoot (Lindblom 1963b, pp. 1776–79). In languages with heavy stress, vowel reduction is a characteristic feature, especially in weakly stressed syllables (Lindblom 1963b, p. 1773). In CA, word-final vowels in open syllables are never stressed, except in monosyllables such as *di* 'this, f.' (Youssef 2013, p. 242). Youssef further recognizes the syllable-final reduction in his observation that "Short /i/ triggers palatalization only when it is word final", e.g., *hˈidʲi* 'he became satisfied,' and *nabˈaːtʲi* 'vegetarian' (Youssef 2013). The results observed in this paper follow this observation, and support the finding that syllable-final undershooting does not prevent the occurrence of palatalization in CA.

Additionally, as stated above, the high-front vowel /i/ is reported to be the main trigger of palatalization in CA (see Table 1). As Youssef's findings on weak palatalization of the stops /t, d/ revealed, WP is observed to occur as a phonetic co-articulatory effect of following /i/, since the articulation of the target consonant is affected by the high and front position of the tongue in the production of the following vowel (Youssef 2015). It is further reported that the vowel height of /i/ is a distinguishing articulatory feature of CA, and that there exists a vowel hierarchy in which long [i:] is higher than short [i], and word-final [i] is higher than non-final [i] (Haeri 1996a, p. 57; Youssef 2015).

As well, the auditory results show that words ending in /i:ni/ are somewhat more likely to be palatalized than words ending in /u:ni/, /ani/, /a:ni/ and/ Cni/. This supports the idea of palatalization as an assimilatory process in which surrounding vocoids act as triggers (Youssef 2015; Kochetov and Alderete 2011): in this case, having an i:Ci syllable somewhat increased the likelihood of palatalization.

My data on word-final /-ni:/ show that palatalization occurs nearly 50% of the time in this environment, which is fairly similar to the probability of palatalization Haeri found in the /t, d/ stops word-finally (63%, Haeri 1996b, p. 58). This probability is second to palatalization in the *stop + j* environment (i.e., a stop followed explicitly by the [j] glide and assimilating to its feature: *nadya* [nad.ja → nadʲ.ja] 'name, Nadia') in Haeri's data, with a proportion of 68% (Haeri 1996b, p. 58). If we assume that palatalization of/t, d/occurs more frequently than /n/ (Sokhey 2015), and that the two have similar phonological conditions

(see Table 1), then the fact that my data show a proportion of palatalized /n/ that is just below Haeri's data on /t, d/ support the hypothesis that the word-final environment is one of the most likely triggers of palatalization of /n/. At the typological level, my findings further support the notion that coronals are the most common sounds to undergo at least secondary palatalization in the coronal range (Bateman 2011).

The lower proportion of palatalization observed in /n/ compared to /t, d/ (based on Haeri's and my data) further begs the question of whether a change in progress is taking place, whereby palatalization is spreading from /t, d/ to /n/. Sokhey (2015) hypothesized this based on synchronic, auditorily coded /t, d/ and /n/ tokens, but a historical study tracing the emergence of the palatalized nasal, and/or an acoustic study on the relationship between the palatalized nasal and stops would be further revealing.

Sociolinguistic categories must also be taken into consideration. While the data presented here do not reveal a gendered pattern, preliminary work using free speech data reported avoidance of [nʲ] by men and more frequent use by women (Sokhey 2015). Given that there is strong evidence that palatalization of /t, d/ are features of a sociolect in CA (i.e., palatalization covaries with the larger sociolinguistic categories such as socioeconomic class and gender; Haeri 1996a; Youssef 2015), a sociolinguistic examination of the palatalized nasal is warranted. Haeri found in her work that weak palatalization of the stops /t, d/ is an innovation of upper-middle class women, and Youssef found that strong palatalization (i.e., affrication) of the same stops have been phonologized into the sociolect of a group of speakers who use it to index covert prestige in opposition to the upper classes (Youssef 2015). Decades after the first sociolinguistic work was conducted on /t, d/ in CA, it is not unlikely that weak palatalization has advanced to neighboring consonants. The Cairene nasal, as an available palatalized sound, is an ideal candidate for such ideological extensions.

5. Conclusions

This paper concludes that the palatalized Cairene [nʲ] is acoustically distinguishable from the coronal /n/, and examining the CV transition proves to be a useful distinguishing cue. Borrowed English words observed in the word-list data produced fewer palatalized nasals while intervocalic /n/ with both a preceding and following high front vowel appears to render palatalization stronger. Given that the palatalized nasal is not uncommon in Cairene speech today, future studies may examine the sociolinguistic status of palatalized /n/ in relation to the palatalized /t, d/ stops, as well as determine whether palatalization has spread to other consonants. This advancement warrants further examination of the status of the proposed sociolects involving WP and SP—i.e., whether WP continues to covary with upper-classness, and if/how this affects the social status of SP and those who use it to display opposition to upper-classness.

Furthermore, a comparative study of palatalization across other dialects and/or a historical study that traces the appearance of this phenomenon would be a worthwhile and informative study on the progression of social salience that can be used not only to study Arabic dialects, but also to study other speech communities. As a phenomenon that is linked to socioeconomic class in CA, palatalization is a sociolectal feature that requires a culturally appropriate index for measuring social class in order to be studied at a larger scale. While this has not been widely done in Arabic sociolinguistics, some scholars began work on this: Haeri created an index for her study of palatalization using a group of socioeconomic indicators with varying degrees of importance (Haeri 1996a). Rania Habib examined socioeconomic indicators in Christian rural migrant speakers in Hims, Syria and found that income, followed by residential area, were the strongest indicators of social class, which differs from the situation in the western world (Habib 2010). In the Gulf (e.g., Bahrain and the UAE), family name and communal background have weighty impacts on the internal evaluations of social status and economic opportunities, but no Arabic sociolinguistic work has considered these variables. It is apparent that socioeconomic indicators differ between Arabic speaking communities, and the aforementioned communities are

promising venues for further (and updated) investigation on the intersection of linguistic variation and social class. It is hoped that the work outlined here provides a basis for future studies involving not only palatalization, but further sociolinguistic work within other Arabic speech communities.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of The University of Texas at Austin (protocol code: 2014-04-0121; date of approval: 4 May 2014).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Gloss of items in word list (transliteration note: H = ħ, 3 = ʕ)

kallimiini	all, 2nd f.sg. me
Hosni	male name
ʔibni	my son, m.sg.
istanniini	wait 2nd f.sg. for me
istannuuni	wait 3rd, f.sg. for me
sallimni	hand over, 2nd m.sg. to me
taani	again, m.sg.
warriini	show, 2nd sg. me
sallimiini	hand over, 2nd fs. to me
biiHibbuuni	they love me
bitHibbuuni	you, 2nd pl. love me
haani	male name
kallimni	call, 2nd m.sg. me
mistanni	waiting, m.sg.
teHibbeni	you, m.sg. love me
yeHibbeni	he loves me
inni	that I
any	any
funny	funny
ya3ni	I mean/meaning

Notes

1 ʻAbu ᶜAbd al-Rahman Al-Khalil Ibn ʻAhmad. *Kitab al-ᶜayn*. 1967. Ed. by ᶜAbdallah Darwish. Baghdad: Matbaᶜat al-ᶜAni, vol. I.

2 Sībawayhi, ʻAbu Bishr ᶜAmr b. d.177/793. In ᶜUthman Sībawayhi, *Al-Kitab*. 1889–1900 Repr., Baghdad: Al-Muthanna, n.d. Cairo: Bulaq.

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