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Turkish palatalized consonants and vowel harmony

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Abstract. This study aims to explore the nature of consonant-final Turkish roots that select suffixes with front vowels despite having a back vowel in their final syllable, thus seemingly violating palatal harmony. While there is little controversy that final laterals in such roots are palatalized, opinions vary about the phonetic and phonological nature of the other final consonants. We want to argue that all word-final (or occasionally penultimate) consonants of these roots are palatalized, and that this palatalization is the underlying cause of 'disharmony'. The phonetic evidence supporting our claims comes from an experiment in which we matched 12 irregular roots with their regular counterparts and asked 10 native speakers of Turkish to read these words. We found that, compared to 'regular' roots ending with a plain consonant, the final consonants of 'irregular' roots have a significantly higher F_2. The last vowels of 'irregular' roots were also found to have a somewhat higher F_2 than the last vowels of 'regular' roots at their offset, but the difference fairly rapidly decreases at vowel midpoint, and at vowel onset F_2 values are very similar in both 'regular' and 'irregular' roots. These combined results suggest that the final consonant of the 'irregular' roots has an underlying palatal secondary articulation, while fronting in the preceding vowels is likely due to co-articulation.

Keywords. Turkish phonology; vowel harmony; palatalized consonants

1. Introduction. Vowel harmony is probably the best known and most well-studied aspect of Turkish phonology. Yet, some of its facets are still not entirely clear. In this paper we discuss a class of apparent exceptions to harmony, i.e. roots that have a back vowel in their final syllable, but – unexpectedly – front vowels in the following suffix(es) (e.g. *saat* 'clock, hour' – *saat*-[i] 'clock-ACC').

Turkish vowel harmony is a regular phonological process, at least in suffixes;[1] a back vowel in the last syllable of a root should be followed by back vowels (as in e.g. *kat* – *kat*-[ɯ] 'floor'), just as a front vowel in the last syllable of a root should be followed by front vowels (as in e.g. *lezzet* – *lezzet*-[i] 'flavor'). Therefore, the presence of a front vowel in words such as *saat*-[i] calls for an explanation.

This paper aims to offer an account of the phonological behavior of this class of roots (that henceforth will be called 'irregular' roots – with 'irregular' between single quotes, since we will argue that they do not constitute a real exception to vowel harmony once the palatalization of their final consonant is recognized). We have three interrelated goals. First, we want to argue – on the basis of acoustic data we collected in an experiment – that the final consonant of 'irregular' roots is phonetically palatalized. Second, we interpret this phonetic palatalization as evidence that phonologically 'irregular' roots have a contrastive palatal secondary articulation (in

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[1] The issue of regularity – or lack thereof – of harmony within roots is beyond the scope of this paper; the interested reader may refer to, among others, Clements & Sezer 1982: § 3.1, Pöchtrager 2010, Kabak 2011 § 4).

other words, we want to argue that Turkish has more contrastively palatalized consonants than the commonly assumed velar stops and lateral – so, for example, we suppose that the underlying representation of *saat* is /saatʲ/). Third, we will argue that this contrastive palatalization in root-final consonants is the reason for the fronting of subsequent vowels, since palatalized consonants are specified as [–back] segments. Under such an account the presence of apparently disharmonic front vowels after these roots is not an unpredictable lexical idiosyncrasy, but the regular outcome of the interaction between consonantal secondary articulations and vowels.

Our paper is organized as follows. In section 2 we present a brief sketch of Turkish vowel harmony and its relationship with 'irregular' roots. In section 3 we provide a brief summary of consonant palatalization in Turkish outside of root-final position; in section 4 we discuss some previous analyses of 'irregular' roots, as well as our proposal; in section 5 we examine some empirical predictions of the various hypotheses, and present the results of an acoustic study that provides empirical evidence for the presence of palatalization in the final consonant of said roots. In section 6 we discuss the implications of our data for previous explanations of 'irregular' roots and our own. Finally, in section 7 we present our conclusions and outline some directions for future research.

2. A sketch of Turkish vowel harmony. In Turkish, suffix vowels agree in backness/frontness and roundness with the vowel in the preceding syllable, i.e. the last root vowel. In (1), the vowel of the past tense suffix *-DI*[2] becomes [i] after the root *git*, assimilating to the frontness of the root vowel; [ɯ] after *aç*, assimilating to the backness of [a]; [y] after *düş*, that is, front and round as the root vowel; and [u] after *dur*, due to the backness and roundness of the preceding vowel.

(1) *Zeynep g*[i]*t*-[ti]. 'Zeynep has gone.'
Zeynep [a]*ç*-[tɯ]. 'Zeynep was hungry.'
Zeynep d[y]*ş*-[ty]. 'Zeynep has fallen.'
Zeynep d[u]*r*-[du]. 'Zeynep has stopped.'

The focus of the present paper is on roots as in (2), in which the final root vowel is back but suffix vowels are front (although they still assimilate in roundness to the preceding vowel, as (2e) shows). It is to be noted that 'irregular' roots always end in a consonant (or sometimes a consonant cluster including *l* or *r*, as shown by (2c-d)); 'irregular' roots with a final open syllable are unattested. Almost all of them are loanwords from Arabic, Persian, or French, although e.g. *alp* 'brave person' has a palatalized lateral even if it is a Turkic word.[3]

(2) a. *seyahat*-[i] 'travel-ACC' **seyahat*-[ɯ]
b. *hadd*-[i] 'limit-ACC' **hadd*-[ɯ]
c. *harf*-[i] 'letter-ACC' **harf*-[ɯ]
d. *kalb*-[i] 'heart-ACC' **kalb*-[ɯ]
e. *petrol*-[y] 'oil-ACC' **petrol*-[u]

[2] Its consonant is also subject to alternation between [d] and [t], agreeing in voicing with the preceding consonant. In (1) and (2) above we are not yet providing phonetic transcriptions of the root-final consonants, because the phonetic properties of their final segments are debated, and clarifying them is one of the main goals of this paper. Hereafter, we adopt a fairly broad phonetic transcription of Turkish words when the sounds in question are of no direct concern to our discussion, omitting many allophonic aspects such as aspiration in voiceless stops, /e/ lowering before tautosyllabic sonorant consonants, and so on.

[3] At the same time, as a reviewer has pointed out, some Turkish words borrowed from Arabic (e.g. *hak* 'right') end with a plain, non-palatalized consonant. What loanword adaptation mechanism determined the distribution of palatalized consonants in Turkish is an intriguing question, but it goes beyond the scope of the present paper.

3. Palatalized lateral and velar consonants in Turkish. Within the class of 'irregular' roots, a subclass may be immediately set apart; in roots ending in a lateral, such as *petrol*, this consonant is uncontroversially described as palatal or palatalized (among many others, Clements & Sezer 1982: 236-7, Göksel & Kerslake 2005: 8-9, Erguvanlı-Taylan 2015: 31-32). On the other hand, it is disputed whether the other root-final consonants are palatalized, as discussed in section 4 below.

In most Turkish words (but notably not in 'irregular' roots) palatalization is allophonic; Turkish laterals and velar stops have two allophones, one palatalized and one non-palatalized (and, in the case of the lateral, velarized). The occurrence of [lʲ], [c], [ɟ] vs. respectively [ɫ], [k], [g] is mostly predictable (Clements & Sezer 1982: 233-238). In syllables having a front vowel as their nucleus, velar stops are always palatalized. If a syllable is headed by a back vowel, plain [k] and [g] typically occur; however, in a relatively small but not negligible number of words [c] and [ɟ] occur in a back-vowel environment. This makes the occurrence of velar palatalization not wholly predictable – in other terms, [c] and [ɟ] are allophones of /k/ when they occur in a front-vowel syllable, but they realize the phonemes /kʲ/ and /gʲ/ when they occur in a back-vowel syllable (we explain the motivations for our phonetic and phonological transcriptions later in this section). This is directly supported by the existence of some minimal pairs, such as *kar* [kaɾ] 'snow' vs. *kâr* [caɾ] 'profit'.

The distribution of laterals is similar to that of velar stops, although not identical. As in the case of plain velars, there are no velarized laterals in syllables headed by a front vowel, but palatalized laterals occur in more environments than palatalized velar stops; "in the Istanbul dialect" laterals are predictably palatal word-initially, as in *lale* 'tulip', and "the lateral is invariably palatal when the first preceding or following vowel is [–back]" (Clements & Sezer 1982: 236). Velarized and palatalized laterals may contrast in syllables headed by a back vowel: *sol* [soɫ] 'left' vs. *sôl* [solʲ] 'G note'.

There is some disagreement about whether palatalized stops and laterals have a palatal primary place, or rather have a palatal secondary place in addition to their original (respectively velar or alveolar) primary one. Some authors consider the lateral to be a 'true' palatal [ʎ] (e.g. Levi 2001: 3989, Erguvanlı-Taylan 2015: 31-32), while others call it a "palatalized post-alveolar lateral" (Zimmer & Orgun 1999: 155, Göksel & Kerslake 2005: 8), and still others classify it as a palatalized lateral (Clements & Hume 1995: 290). The stops are believed by most to be palatal consonants, but for example Kornfilt (1997: 484) considers them to be palatalized velars.

This uncertainty may depend on intrinsic difficulties in the phonetic description of palatals. In fact, the precise place of articulation of so-called 'palatals' is far from clear in many languages. Recasens (2013) argues that none of the supposedly palatal laterals in the 11 languages he investigates (Turkish not being one of them) is a 'true' palatal; they most often are alveolopalatal, i.e. "realized through the formation of a simultaneous closure or constriction at the alveolar and palatal zones with a primary articulator which encompasses the blade and the tongue dorsum" (Recasens 2013: 2). Similar considerations apply to 'palatal' /c/ and /ɟ/.

Nevertheless, whatever the precise phonetic realization of Turkish /kʲ/, /gʲ/ and /lʲ/ (which would require further, articulatorily-based, research to be conclusively established), we will assume that, at least phonologically, they are consonants with a primary *and* a secondary place of articulation: they are phonologically palatalized segments, i.e. they have a primary place ([+coronal] in laterals, [–coronal, –labial] in velar stops) but also a secondary [–back] articulation.

Various facts point to this conclusion. First, interaction with vowels is a common aspect of secondary articulations, and this is precisely what happens in Turkish; in most cases the presence

of a palatalized sound is dictated by the quality of the tautosyllabic vowel. Even when they disagree, as in (2), the final consonant nevertheless influences the following vowels. Second, consonants that unambiguously have only a *primary* palatal place of articulation, as /j/, do not interact with vowel harmony. Third, as Hall (1997) observes, palatalized alveolopalatals are apparently non-existent cross-linguistically; if alveopalatals "are inherently palatalized then this gap follows because secondary palatalization cannot be imposed upon segments that are already palatalized" (Hall 1997: 53). Thus, [ʎ] would be an inherently palatalized consonant. Furthermore, contrasts between (alveo)palatals and palatalized velars are very rare (Hall 1997: 71), suggesting that not only [kʲ] but also [c] can be palatalized counterparts of /k/. We therefore deem it justified to represent Turkish palatalized consonants as the phonemes /lʲ/, /kʲ/ and /gʲ/, even if it were conclusively demonstrated in the future that they are phonetically closer to [ʎ], [c] and [ɟ] (we suspect that at least the lateral has a secondary place also phonetically, and so we are transcribing it accordingly, but this is not crucial to our arguments below).

It may be useful to observe that a similar conclusion is reached, in a form or another, by most analyses of Turkish palatalized laterals and velars, if we abstract away from the details of their technical implementation. So, Clements & Sezer (1982: 233) say that palatalized laterals are [+coronal] and velars are [–coronal, –labial], but both are also [–back], while they add that [±back] is otherwise not contrastive in the other Turkish consonants; Clements & Hume (1995), who only use unary features for place in their feature geometry model, abandon the binary [±back] and instead say that Turkish palatalized laterals bear the feature [coronal] under both the C-place node and V-place node; Balcı's (2006: 159) analysis, couched in a Government Phonology framework, assumes that palatalized laterals have an A element but also share an additional I element (roughly corresponding to a [–back] binary feature specification) with an immediately following silent "pseudo-empty nucleus". We will adopt Clements & Sezer's (1982) feature specification in the rest of our paper, but also this assumption is not crucial.

3.1 NON-VELAR AND NON-LATERAL PALATALIZED CONSONANTS. While palatal(ized) velars and laterals are (nearly) universally recognized as phonemes in Turkish, the status of the other word-final consonants in 'irregular' roots is more controversial. Presence of a secondary palatal articulation in the final consonants of roots like e.g. *saat* (that she accordingly transcribes as [sɑatʲ]) has been reported at least as early as Waterson (1956: 580):

> If such words [i.e., what we (SC & FD) call 'irregular' roots] are carefully examined [...], it will be observed that the final consonants are palatalized and the sounds represented by the letters *a o u* are not the same as when *a o u* are followed by back type consonants, but are more fronted in character

However, this view is not universally held. Some authors simply remain silent on the issue, while others explicitly state that "the final consonant [of 'irregular' non-lateral roots] is not palatalized" (Comrie 1997: 889), or relatedly that, unlike after a final /lʲ/, front vowels following 'irregular' roots "cannot be predicted in any regular fashion" (Underhill 1976: 27). Some (e.g. Balcı 2006: 125, 156) do state that final consonants – not only laterals – in all 'irregular' roots are palatalized; also Clements & Sezer (1982: 242) state that word-final consonants other than /k, gʲ, lʲ/ can be palatalized "for some speakers", but they add that other speakers always realize a word-final plain consonant. Waterson (1956) aside, usually no acoustic or articulatory evidence backs these claims.

An additional issue is the "more fronted character" of the last vowels of 'irregular' roots mentioned by Waterson (1956), and reported by other authors as well (for example, Erguvanlı-

Taylan 2015: 18 describes them as "slightly fronted back vowels"). To address these questions, we conducted the experiment described in section 5.

4. Previous analyses. There is little disagreement concerning the account of 'irregular' roots ending in a palatalized lateral (or a cluster including a lateral). Analyses may vary widely in terms of phonological features adopted and formalism used to represent vowel harmony, but most share a common insight: the palatalization of the root-final lateral causes following vowels to be front (among many others, Clements & Sezer 1982: 241, Erguvanlı-Taylan 2015: 74). Both its phonetics and its phonological behavior are transparent; phonetically, the lateral is clearly palatalized, and phonologically it is systematically followed by front vowel suffixes, while a final velarized lateral will always be followed by back vowels.

On the contrary, there is no scholarly consensus about how to account for vowel harmony in suffixes attached to 'irregular' roots not ending in a non-lateral consonant. In part this may be due to the fact that this topic has received relatively scant attention; but also scholars tackling it have reached rather divergent conclusions. To our knowledge, three previous approaches to 'irregular' roots exist (not counting Underhill's 1976 or Comrie's 1997 view that they are just utterly unpredictable exceptions to vowel harmony). We briefly outline and comment them here, before introducing our own proposal.

According to Avar (2015), the presence of front vowels after 'irregular' (or 'rebellious', as she calls them) roots is caused by the vowel in the final vowel of the root. While the last vowel of 'irregular' roots is routinely assumed to be back (in most cases /a/), Avar argues that they are articulated more forward than Turkish back vowels – even if not as forward as the Turkish vowels /i, y, e, ø/. This is in line with Waterson's (1956) observation above that supposedly back vowels "are more fronted" than usual in such roots. However, Avar goes further in stating that this fronting is not caused by a following palatalized consonant, but rather that these vowels are phonologically front and cause the palatalization of the following consonant (as well as the frontness of any suffix vowel). Under this account, 'irregular' roots would not be irregular at all, their only peculiarity being that their [–back] final vowels have weak phonetic cues of frontness; the selection of front vowel suffixes would be a regular instance of vowel harmony. In fact, her argument amounts to saying that Turkish does not have eight vowel phonemes but eleven, the three additional phonologically front vowels /ạ ọ ụ/ occurring in 'irregular' roots, and realized "somewhere between front vowels and back vowels in phonetic (acoustic) properties", or as "fronted back vowels".[4]

Avar (2015) raises an important question: what is, if any, the locus of frontness in 'irregular' roots that causes the following vowels to have a front vowel? Is it the last consonant, or the last vowel? We think that, although interesting, Avar's hypothesis has some problematic aspects. The putative phonemes /ạ ọ ụ/ would have a peculiar distribution: they would occur almost exclusively in root-final syllables, with the further restriction that the syllable should be closed and its coda should contain /l/, /t/ or /ɾ/. Words such as *kâr* 'profit' would be even more baffling. If the palatalization of its velar consonant were not underlying but an allophonic product of a phonologically front vowel, that word would be /kạɾ/ underlyingly. First, it would be unexplained why in *kar* the preceding consonant is palatalized, while in e.g. *harf* 'letter' (which would be /hạɾf/ under Avar's hypothesis) the following one is. Second, if *kar* were /kạɾ/, with a

[4] The reader may have noticed that this view is somehow also implicit in Turkish spelling, which marks 'irregular' roots and words as *kâr* with a diacritic on the vowel. However, this diacritic is also employed for other goals, as indicating vowel length, and its use has been declining.

phonologically front vowel, suffixes attached to it should have front vowels too, which does not occur: *kar*-[ɯ] 'profit-ACC', **kar*-[i].

Iskender (2015) is an account of root-final (or more precisely, t-final) palatalization couched in a Government Phonology framework. According to him, the palatalization of /t/ in 'irregular' roots is predictable. A final /t/ would be palatalized "if [it] is preceded by a short /a/ and this short *a* is preceded by (i) a vowel including [the Goverment Phonology element] I (a front vowel) or, (ii) a geminate or, (iii) a long vowel" (Iskender 2015: 159). Therefore, Iskender's account of 'irregular' roots radically departs from the others, in that palatalization is not seen as a lexical property of a segment (be it the final consonant or the final vowel), but as the result of a rule. If correct, this solution would provide a simple explanation of palatalization; however, we believe that it creates more conundrums than it solves.

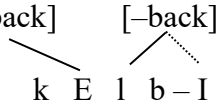
First of all, an alleged connection between palatalization on the one hand and consonant gemination, vowel length, or the frontness of a non-adjacent vowel on the other looks typologically suspicious. Consonant palatalization usually has a transparent phonetic motivation in terms of distinctive features; it is either an underlying property of a specific consonant, or is the result of an assimilatory palatalization rule to an adjacent front vowel, palatal consonant or palatalized consonant. While assimilatory palatalization is one of the most common phonological rules (see e.g. the survey in Bateman 2011), to our knowledge the palatalization rule proposed by Iskender, or something comparable, does not have counterparts in any other language.

Second, there may be an alternative explanation for the 'predictability' of t-palatalization. Most 'irregular' roots are loanwords from Arabic, a language with geminate consonants, long vowels, without vowel harmony, and with a simple vowel inventory /a i u/. As a consequence, 'irregular' roots will frequently also display geminates, long vowels, disharmonic vowels, and a final /a/; but this does not necessarily imply that Turkish speakers have a synchronic phonological rule palatalizing such roots. At most, one could posit some sort of analogical effect; Turkish speakers may infer that if a word has these properties, then it will also have a palatalized final consonant. However, this does not amount to saying that there is a phonological rule making final /t/'s palatalized. In fact, one could easily reverse the inference, stating that in 'irregular' roots vowels are expected to be long and consonants to be geminate.

Finally, the most obvious counterargument is that some roots do not conform to his prediction: for instance, *kabahat* 'fault' does not have a geminate, is not disharmonic and does not have long vowels, yet is an 'irregular' roots.

Clements & Sezer's (1982) paper is an early application of autosegmental phonology to a vowel harmony process. In their framework, root-final palatalized laterals are a straightforward example of autosegmentally 'opaque' segments – segments that are underlyingly associated with a feature value on an autosegmental tier, and thus do not undergo harmony, block spreading from other segments and start their own harmony domain. To account for Turkish vowel harmony, they assume two tiers for the features [back] and [round]; palatalized laterals are underlyingly associated to a [–back] feature specification that blocks the spreading of a preceding [+back] feature value and starts its own autosegmental domain. (3), based on Clements & Sezer (1982: 241), shows how the palatalized lateral in *kalb-i* 'heart-ACC' causes the suffix vowel to be front, even if the root vowel is back.

(3)



Things get more complicated with the 'irregular' roots not ending in a lateral. According to Clements & Sezer (1982: 242), "some speakers" have final palatalized non-lateral consonants also in these roots. These cases lend themselves to a straightforward generalization of the phonological representation in (3): their final consonant is [–back] too (and thus /tʲ/, /ɾʲ/ and /dʲ/ would be part of the consonant inventory of Turkish). However, they also state that for other speakers the final consonant has no phonetic palatalization when it occurs word-finally; they assume that the consonant is underlyingly palatalized even for such speakers (to account for the frontness of suffix vowels), who however neutralize the [±back] contrast word-finally.

Even if it is not explicit stated by Clements & Sezer (1982), the latter solution implies that for some speakers 'irregular' roots ending in non-laterals are a case of absolute neutralization (Kiparsky 1968/1982); Clements & Sezer postulate an underlying contrast between plain and palatalized consonants that is never observable on the surface, since underlying palatalized consonants are (allegedly) never realized as such, always becoming plain (actually, it might be argued that the stop is palatalized in words such as *saat-i*, but this may be ascribed to an allophonic palatalization rule targeting all Turkish /t/'s followed by a front vowel). The only evidence for underlying palatalization is therefore indirect, i.e. its effect on the following vowels. Discussing whether phonological explanations based the concept of absolute neutralization are legitimate is beyond the scope of this paper. However, a common objection against them worth mentioning here is the risk of circularity in the argument. The only evidence to postulate underlyingly palatalized consonants, if they are never palatalized on the surface, is the presence of [–back] vowels in the following suffixes – but at the same time the [–back] feature value in suffix vowels is accounted for assuming a root-final underlyingly palatalized consonant.

Consequently, we believe that an analysis of Turkish 'irregular' roots that does away with the assumption of a complete neutralization of palatalization would be preferable to one adopting it (another, more obvious motivation to dispense with it is empirical: if root-final consonants do surface as palatalized segments in 'irregular' roots, as we argue below, an explanation assuming their absolute neutralization would be empirically unjustified to begin with).

4.1. OUR PROPOSAL**.** Aside from this disagreement, our analysis is in fact quite close in spirit to Clements & Sezer's (1982) – indeed, it can be seen as a generalization of the representation in (3) to some seemingly recalcitrant cases. We suppose that *all* final consonants – not only laterals – are palatalized in roots that select front vowel suffixes. Furthermore, we suppose that this palatalization is not neutralized in word-final position – all final consonants in 'irregular' roots show acoustic cues of palatalization when compared to otherwise similar final consonants in regular roots. Finally, we interpret the phonetic data from our study as supporting the view that final consonants in 'irregular' roots are the underlyingly [–back] segments. We did find some phonetic fronting in these vowels (in agreement with Waterson's 1956, Avar's 2015, Erguvanlı-Taylan's 2015 observations), but we will show that it is best accounted for in terms of coarticulation proceeding from the final consonant to the final vowel, rather than the other way round. This amounts to saying that Turkish has more contrastively palatalized consonants than the routinely assumed /kʲ/, /gʲ/ and /lʲ/, to which at least /tʲ/, /ɾʲ/ and /dʲ/[5] should be added.[6]

[5] Turkish devoices word-final [–continuant] consonants, but there are a handful of lexical exceptions to this rule. The final consonant of *had* 'limit' seems to be one of these exceptions, as most of our subjects realized a voiced final sound.

[6] 'Irregular' roots ending in velar or bilabial stops (as in *idrak* 'comprehension' and *Rab* 'God' respectively) are reported in the literature, but none of our subjects realized them with palatalization; apparently, they have been

5. The phonetics of root-final palatalization and its phonological implications. As emerged from the discussion in sections 3 and 4, there are at least two interrelated questions concerning the phonetics of root-final segments in 'irregular' roots and its significance to the understanding of their phonological status: 1) whether consonant palatalization/vowel frontness is present or not in the final syllable of 'irregular' roots; 2) if either is present, whether it is a lexical property of the last consonant or the last vowel.

A positive answer to the first question would provide crucial evidence in favor of treating 'irregular' roots as a regular instance of vowel harmony; if either their final vowel were shown to be fronted or their final consonant were shown to be palatalized, this would support their phonological specification as [–back], and consequently they would be legitimate triggers of frontness in suffix vowels. Conversely, if the final syllable of e.g. 'irregular' *dikkat* were found not to significantly differ from 'regular' *kat* 'floor', we should conclude that 'irregular' roots are an unpredictable exception to Turkish vowel harmony, or at least that we have to assume complete neutralization or resort to other 'abstract' analyses.

The second question touches on a common problem in the investigation of secondary articulations and palatalization processes. If we find that in certain CV or VC sequences of a language the vowel is higher and more forward that usual, *and* the consonant is produced with a gesture that is closer to the front palate than usual, how do we know if we are in front of a phonologically [–back] vowel that has a coarticulatory effect on the consonant, or a consonant with a phonologically palatalized secondary articulation that causes some coarticulatory vowel fronting?

In either case we would expect to find articulatory and acoustic correlates of vowel frontness and consonant palatalization, but with a crucial difference. The intensity of coarticulation is typically gradient, and decreases as the distance from the source of coarticulation increases; the coarticulatory effect of segment A on a following segment B is most evident at the start of B, then it progressively decreases (and analogously, if B precedes A the coarticulatory effect caused by the latter will be most evident towards the end of B). This means that, if vowels in 'irregular' roots were phonologically [–back], consonant palatalization should be more prominent at the onset of the following consonant than at its offset. Additionally, a phonologically [–back] vowel would plausibly display a more or less stable front tongue position across most of its duration (the vowel's 'steady state'), not only when closer to the following consonant.

If, on the contrary, consonants of in 'irregular' roots were [–back], they would be expected to influence the offset of the preceding vowel more than its onset. Conversely, in words such as *kâr* we should observe the opposite pattern, with coarticulation more prominent at the onset of the following vowel than at its offset. Moreover, underlyingly palatalized consonants would display a more or less stable front tongue position across most of their duration. Another possibility is that the peak of palatalization in underlyingly palatalized consonants is observed at the moment of their release; it is known that the release of alveolopalatal consonants often "proceeds gradually from front to back, thus leaving automatically a [j]-like configuration at closure offset" (Recasens 2013: 3).

5.1. EXPERIMENTAL PREDICTIONS AND METHODOLOGY. In order to investigate the phonetic properties of 'irregular' roots and test the above-mentioned hypotheses, we conducted an acoustic study. Our goal was to verify whether, to what extent and in what way their final vowel

levelled to the more general pattern of the other roots, their final consonant now being non-palatalized and their suffix vowels being regularly back (*idrak*-[ɯ], etc.).

was fronted and their final consonant was palatalized. It is well known that vowel frontness/backness is correlated to the frequency of the second formant; raising and fronting of the tongue diminishes the size of the front cavity, raising the value of F_2. Also consonant palatalization affects this acoustic parameter, which is therefore commonly assumed to be one of its main acoustic correlates (see e.g. Ní Chiosáin & Padgett 2012, Hacking et al. 2016 as examples of previous acoustic studies on palatalization in Russian and Irish respectively). We were also interested in the pattern of F_2 (relatively stable frequency across the segment, or rising, or falling), so we measured each root-final vowel at its onset, midpoint and offset. We did the same for the root-final sonorants; the acoustic cues of place of articulation in stops are most salient not so much during their closure (which is basically a short period of silence in voiceless stops), but in the formant transitions at the onset of the following vowel, so we embedded the relevant words within a carrier sentence in order for root-final consonants to be followed by a vowel, and measured it at its onset.

We wanted to test the following predictions: first, if consonant palatalization and/or vowel fronting are present, at least one of the two final segments in 'irregular' roots should show significantly higher F_2 values when compared to an otherwise similar regular root (e.g. 'irregular' *dikkat* vs. 'regular' *barikat*). Second, if final vowels are the underlyingly [–back] segments in 'irregular' roots, their onset, midpoint and offset F_2 values should be relatively stable.

On the other hand, if final consonants are the underlyingly [–back] segments in 'irregular' roots, 1) the onset, midpoint and offset of the preceding vowel should display rising F_2 values, consistent with a coarticulation effect, while 2) onset, midpoint and offset F_2 values of sonorant consonants should be relatively stable, or alternatively rising (as mentioned above, palatalized consonants fairly often have a [j]-like articulation when their constriction is released). To test these predictions, we designed an experiment divided into two parts. The next section provides a description of the experiment.

5.2. EXPERIMENT. Our participants were 10 native Turkish speakers, 9 of them female. They were all Boğaziçi University undergraduate students, their age ranging from 18 to 22 (the choice of subjects was based on availability). Before each experiment, they were asked to fill out a consent form and told that they would be audio-recorded during the experiment. Their participation was compensated with course credit.

The experiment consisted of two tasks. First, the participants were presented with the target items and asked to read them. There were 12 target 'irregular' roots, and each of them was matched with a corresponding 'regular' one. These word pairs are either minimal pairs, or near-minimal ones if a minimal pair was not available. In any case, word pairs were included in the experiment only if at least the final syllable of both items was identical (or the rhyme was identical, if one of the words was onsetless and the other had [h] in the onset, as glottal fricatives have no intrinsic constriction in the vocal tract that may affect the formant values of the following vowel), apart from the supposed presence vs. absence of palatalization in the final[7]

[7] In items (k) and (l) in Table 1 the relevant consonant is actually not the final one, but the preceding rhotic. Reportedly, at least one word (i.e. *yar* 'lover') exists in which an absolute root-final /ɾ/ is supposedly palatalized, but from a preliminary investigation we realized that at least younger speakers have regularized this root, so we did not include it in our list. This surprised a reviewer, who contrasts *yar* 'lover' and *yar* 'split' in her/his idiolect, and asks how the distinction between these words might have been lost. We do not have a definitive answer, but we conjecture that two non-mutually exclusive causes might have led to this change. First, such a marginal occurrence of the absolute root-final palatalized rhotic may have made levelling more likely. Second, even if we found that F_2 is higher – and hence that plausibly the rhotic is palatalized – in some rhotics that are the first member of a word-final

consonant/vowel. This was done in order to minimize the effect of preceding vowels and consonants on the F_2 values of the last two segments. Table 1 lists the word pairs presented to the participants.

	'Irregular' roots		'Regular' roots	
		Stops		
(a)	*saat*	'clock'	*sat*	'sell'
(b)	*dikkat*	'caution'	*barikat*	'barricade'
(c)	*vaat*	'promise'	*fosfat*	'phosphate'
(d)	*seyahat*	'travel'	*hat*	'line'
(e)	*Sebahat*	'a proper name'	*at*	'horse'
(f)	*kabahat*	'fault'	*at*	'horse'
(g)	*had*	'limit'	*ad*	'name'
(h)	*idrâk*	'comprehension'	*orak*	'grasshook'
(i)	*Rab*	'God'	*Arap*	'Arab'
		Sonorants		
(j)	*sôl*	'G-note'	*sol*	'left'
(k)	*harf*	'letter'	*zarf*	'envelope'
(l)	*harp*	'war'	*arpa*	'barley'
		'Reference-point' words		
(m)			*aç*	'hungry'
(n)			*ay*	'moon'
(o)	*kâr*	'profit'	*kar*	'snow'

Table 1: Items used in the experiment

In 'irregular' roots, the items (a) to (l) in Table 1 hypothetically end with a palatalized stop consonant (or alternatively have a front vowel triggering fronting in the suffix). Items (m) and (n) do not have a corresponding irregular root. They were included because their final segments are the palato-alveolar [ʧ] and the palatal glide [j] respectively, thus allowing us to compare the F_2 value of unequivocal palatal consonants (or, in the case of palato-alveolar, similar to palatal) to those of the supposedly palatalized obstruents and sonorants in (a) to (l). Finally, *kâr* and *kar* (o) were included to examine pre-vocalic palatalization (or pre-consonantal fronting, if the vowel is the underlyingly [–back] segment).

In order to minimize the effect of spelling (Turkish orthography does not use separate symbols for palatalized and non-palatalized consonants – but see fn. 4), we provided instructions in English (all the subjects had a good command of that language) as well as visual information to elicit the relevant Turkish words. We asked the subjects to say a Turkish word of which a definition was provided; in order to make sure that they uttered the intended word rather than one of its synonyms, when necessary we also provided some hints, which included the initial letters of the relevant word (three letters at most, but never the final vowel or the final consonant).
A sample of the experimental materials we used is shown in Figure 1 below.

cluster, the difference between them and plain rhotics is not as wide as the difference between the other palatalized and plain consonants (see § 6 below), suggesting that phonetic cues of palatalization in Turkish rhotics are weaker than in other consonants.

Figure 1. A sample experimental item

After the subjects had produced the word in isolation, they were also asked to say the word within either of the carrier sentences <*Word*> *addır/ad değildir* '<Word> is a noun/is not a noun'. Of course, the correctness of their meta-linguistic judgment about word classes was not relevant to the goals of the experiment; we asked this judgment only to ensure that word-final consonants were always followed by the same vowel (i.e., /a/). Each word was repeated five times by each speaker. A small number of tokens had to be discarded from the study, mainly because speakers occasionally paused during a sentence (thus suppressing coarticulation between words), or were too distant from the microphone. We also included 11 filler words to prevent participants from guessing the real goal of our experiment. Indeed, none of the subjects seemed to have understood it, judging from short informal interviews we had with them immediately after they had completed their tasks.

After completing the first task of the experiment, participants were given a fill-in-the-blanks task in which they were asked to write down inflected forms of the words used in the first task. The aim of the second task was to understand whether these words are 'irregular' in the participants' lexicon, or they rather regularized them (that is, whether they use front or back vowel suffixes when they inflect them).

5.3. MEASUREMENTS. We recorded the subjects in a quiet room using an Audio-Technica AT 2020 microphone connected to a Marantz PMB 661 solid state recorder. All measurements were carried out via Praat, version 6.0.49 (Boersma & Weenink 2019). As for the roots ending with a word-final obstruent (Table 1, (a-i)), we measured the onset, midpoint and offset of the vowel in their final syllable. The aim of this measurement was to see whether final vowels' F2 values are higher in irregular roots than in regular roots across their durations. Second, we measured the word-final consonants of (a-i) in Table 1 to see whether there are differences between 'irregular' and 'regular' roots. These consonants are stops, therefore we measured F_2 values where the acoustic cues of their place of articulation are most salient – at the release of the stop, which is the onset of the first vowel in the word/phrase *ad-dır/ad değildir* 'is/is not a noun'. The word *aç* [aʧ] was measured too, so as to compare F_2 values of its palato-alveolar consonant to the final stop consonants of 'regular' and 'irregular' roots. For the same reason, the word *ay* /aj/ 'moon' was included to provide a reference point for the supposed palatalization of sonorant consonants in 'irregular' roots.

We applied the same procedure to the words having a final sonorant consonant, or a cluster including a sonorant consonant ((j-l) in Table 1). Thus, we measured F_2 at the onset, midpoint and offset of the syllable-final vowel in the relevant regular and irregular roots, as well as the onset of the initial vowel of the word/phrase *addir/ad değildir*. Since sonorant consonants have a relatively clear formant structure across their whole duration, we also measured the F_2 values of

the sonorant consonants at their onset, midpoint and offset.

6. Results and analysis. Figure 2 reports the averages of the F_2 values at the release of the root-final stops. It is clear that final coronal stops of supposedly 'irregular' roots have markedly higher F_2 values than final coronal stops in 'regular' roots. The consonant in *aç* was added for comparison; the F_2 values of coronal stops in 'irregular' roots are much closer to that consonant than to plain coronal stops. This is not true of *Rab* and *idrak* (two of the few allegedly irregular roots with a non-coronal stop), but in fact they are not counterexamples to our claim that only roots with a final palatalized consonant select front vowel suffixes; in the fill-in-the-blanks task that followed the recording task, all our subjects inflected both words with back vowel suffixes.

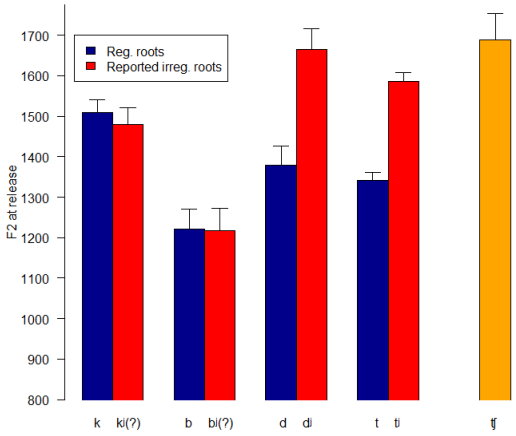


Figure 2. F_2 values at stop release, 95% confidence intervals

Also root-final liquids have significantly higher F_2 values when they occur in 'irregular' roots. This is anything but unexpected for laterals (virtually all authors recognize that palatalized laterals occur in Turkish), but Figure 3 shows that also rhotics have a higher F_2 in every phase of their production (even if the difference is not as large as for laterals) if they occur in 'irregular' roots.

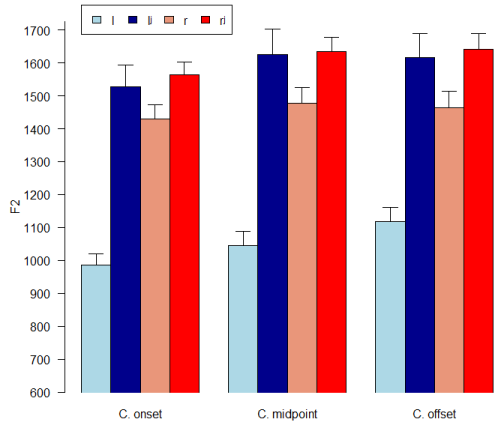


Figure 3. F_2 in root-final sonorants, 95% confidence intervals

A linear mixed-effects model (Table 2) was used to analyze our experimental data (*lmer* function, *lme4* R package). In this model the F_2 value at the onset of the vowel /a/ following the root-final consonant in the carrier sentence is the dependent variable. 'Speaker' and 'word' are random factors; the fixed effects that are supposed to influence F_2 are whether the consonant belongs to a

‘regular’ or ‘irregular’ root (‘RtSelectsFrontV’), and the manner and primary place of the consonant (this latter parameter has no direct bearing on vowel harmony, but of course also manner and primary place affect formant values).

The results (the rhotic in word-final clusters is the reference level; only the fixed effects are shown due to space limitations) confirm the impression given by the visual display of the data; final consonants of ‘irregular’ root are correlated with significantly higher F_2 values at the onset of the following vowel in the carrier sentence.

As expected, also the manner and primary place of the consonant have an impact on F_2: rhotics have higher F_2 than coronal stops, which in turn have higher F_2 than laterals. What is more interesting for our purposes is the interaction between the manner and primary place of a consonant and it selecting front or back vowel suffixes. As also shown by figures 3 and 4, F_2 in final laterals of roots selecting front vowel suffixes is about 500 Hz higher than in final laterals of ‘normal’ roots. As also shown by figures 2 and 4, the difference is smaller for coronal stops, and even smaller for clusters having a rhotic. It may be useful to point out that these data, however, do not necessarily imply than palatalization is more pronounced in laterals than in coronal stops; final laterals in ‘normal’ roots having a final back vowel are not only non-palatalized but also velarized, a fact that increases the phonetic difference between the two segments.

	Estimate	Std. Error	t value
(Intercept)	1451.42	50.68	28.639
RtSelectsFrontVYes	179.69	40.10	4.481
/l/	-344.88	48.76	-7.073
/d/	-71.74	47.85	-1.499
/t/	-107.90	31.86	-3.386
RtSelectsFrontVYes:/l/	318.31	69.12	4.605
RtSelectsFrontVYes:/d/	99.07	67.93	1.458
RtSelectsFrontVYes:/t/	60.11	45.57	1.319

Table 2. Linear mixed-effects model of F_2 at the release of root-final consonants

Final laterals, coronal stops and rhotics of roots selecting front vowel suffixes therefore have increased F_2 at their release, which is consistent with them having a palatal secondary articulation. We can thus suppose that the palatalized consonants of Turkish not only include [l^j] and [k^j], but [t^j], [d^j] (in the word *had*) and [r^j] (in final clusters) as well, at least in the idiolects of our subjects. Roots with non-coronal palatalized final consonants were few in the first place, and they seem to have undergone levelling; now they have a final non-palatalized consonant, and also take back vowel suffixes.

The final vowels of ‘irregular’ roots also have higher F_2 values (Figure 4). However, this is true mainly of the vowel offset; as can be seen in the same figure, F_2 is clearly lower at vowel midpoint, and even lower at vowel onset. In fact, at vowel onset its value is nearly identical in ‘irregular’ and ‘regular’ roots. We interpret this as evidence that whatever fronting can be found in vowels, it depends on coarticulation, not on an underlying [–back] specification of the vowel; F_2 values in vowels fade away when the distance from the final consonant increases, while (liquid) consonants show a broadly stable F_2 pattern (Figure 3). Moreover, F_2 shows the opposite pattern in *kâr* (not shown here as a figure due to space limitations); it starts at 1810 Hz at vowel onset, drops to 1603 at midpoint and remains at 1616 at vowel offset. This is consistent with the supposition that the underlyingly [–back] segment in that word is the stop /k^j/.

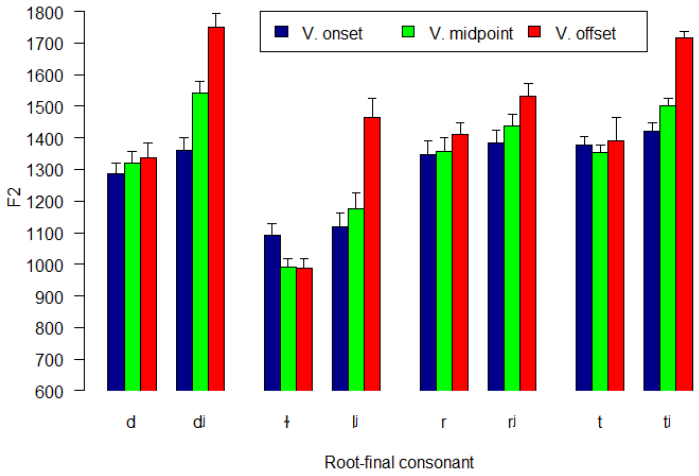


Figure 4. F_2 across root-final vowels in 'regular' and 'irregular' roots, 95% confidence intervals

7. Conclusions. The results of our experiment suggest that 'irregular' roots are phonetically different from regular ones; their final vowel is more fronted, and their final consonant is palatalized also when it is not a lateral. Vowel fronting exhibits properties typical of coarticulation: it gradually increases when the following consonant is palatalized, but gradually decreases after a pre-vocalic [c]. On the other hand, consonant palatalization is relatively stable across the consonant, with no decrease of F_2 when the distance from the preceding vowel increases (actually, Figure 3 shows a moderate increase, consistent with the common presence of a [j]-like configuration at the offset of (alveolo)palatal consonants). We therefore found support to claim not only that Turkish does have phonetically palatalized root-final consonants, but also that their palatalization is an intrinsic phonological property of these consonants; the data are consistent with the conclusion that Turkish has the palatalized phonemes /tʲ/, /rʲ/ (at least in clusters), and /dʲ/ (as already suggested by Waterson 1956 and, if only for some speakers, by Clements & Sezer 1982), in addition to the nearly universally accepted /lʲ/, /kʲ/ and /gʲ/.

Finally, we would like to outline some directions for future research suggested by our results. One is the integration with articulatory data; our acoustic measurements consistently point towards the presence of palatalization, but at least some phonetic details remain undetermined. Another is the generalizability of our findings to the speech community. For practical reasons, the subjects of our study were university students; they were all young, and most of them were speakers of the Istanbul dialect. This raises the question whether speakers with truly irregular roots – that is, roots ending in a plain consonant, yet taking front vowel suffixes – may exist in other varieties of Turkish. What our necessarily limited survey already appears to indicate is a recent – if not ongoing – phonological change. Roots once reported to be 'irregular', such as *yar* or *idrak*, have become 'normal' roots; their final consonant is not palatalized and they take back vowel suffixes. Therefore, differences related to age, level of education and other sociolinguistic variables cannot *a priori* be excluded even within the same geographical variety. Of course, the ultimate answer to these questions can only come from the investigation of a sociolinguistically more heterogeneous pool of speakers.

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