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Fricative patterning in aspirating versus true voice languages[1]

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Building on the empirical insights of Beckman, Jessen & Ringen (2013), we compare the fricatives within the laryngeal systems of Russian and Turkish on the premise that the former is a final devoicing language, while the latter is not, but instead has alternations based on processes of intervocalic voicing and final fortition. This view has consequences for the analysis of fricatives in Russian vs. Turkish: Russian fricatives undergo final devoicing, while Turkish fricatives do not. By contrast, unlike Russian fricatives, Turkish fricatives induce [spread glottis] assimilation in following sonorants. We show that these differences are upheld in three phonetic studies, extending the relevance of the 'laryngeal realism' hypothesis to fricatives as well as stops.

1. Laryngeal contrasts in stops

Following the research of Kim (1970) it has been known that fortis/lenis distinctions among stops traditionally cast in terms of [voice] may be encoded either in terms of a true voicing contrast or in terms of an aspiration contrast (see Iverson & Salmons 1995, Jessen & Ringen 2002, Honeybone 2005, Vaux & Samuels 2005, Beckman, Jessen & Ringen 2009 for discussion). This paper reports on the results of experiments designed to test the different phonetic predictions made by two such distinct phonological analyses of obstruent neutralization, recently discussed in terms of voice onset time (VOT) differences by Beckman, Jessen & Ringen (2013). There is a longstanding debate about the extent to which two-way laryngeal contrasts should be encoded in terms of a single opposition in [voice].

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Stop type	Bare stem	Possessive	Gloss
/[sg]/	at^h (no change)	at^h-ɨ (no change)	'horse'
/[voice]/	ad (no change)	ad-ɨ (no change)	'name'
/[ ]/	t^hat^h (final fortition)	t^had-ɨ (V_V voicing)	'taste'

Table 1
Specifications and neutralizations in Turkish root-final stops.

Proponents of the 'laryngeal realism' approach (e.g. Iverson & Salmons 1995, Honeybone 2005, Backley 2011, Beckman et al. 2013), many coming from vastly different representational camps, contend that there is a difference between 'true voice' languages, which oppose [voice] with an unmarked counterpart (such as Russian and Dutch), and 'aspirating' languages, which oppose [spread glottis] with an unmarked counterpart (such as English and German). For the purposes of the current discussion, we employ the features [voice] and [spread glottis] noting, however, that authors such as Harris (1994) and Backley (2011) use |L| and |H| respectively for these laryngeal properties.

In the present paper, we focus on the laryngeal oppositions in Turkish, which we argue shows the properties of an aspirating language, and compare it directly with Russian, a clear-cut case of a true voice language. The novelty of the present investigation is the examination of the properties of FRICATIVES in aspirating vs. true voice languages. When looking at stops alone, the laryngeal neutralization in word-final position has led some authors to posit different accounts for the phonological contrast in the language. For example, based on the results of an experimental study indicating that stops undergo complete neutralization in word-final positions, Kopkallı (1993) concluded that Turkish has a devoicing process similar to the loss of [voice] in languages such as Russian.

However, subsequent phonological analyses (Avery 1996, Kallestinova 2004, Petrova et al. 2006) have proposed that Turkish stops should be analyzed as having underlying representations specified for both the [voice] and [spread glottis] features, suggesting that in fact there is a three-way voicing contrast between aspirated voiceless stops, voiced stops, and alternating stops. Under this analysis, what seems to be final devoicing under Kopkallı's analysis is in fact due either to the effect of final fortition (Iverson & Salmons 2007) or intervocalic voicing of the unspecified items. The three-way contrast in stops can be observed in the examples and derivations provided in Table 1, where [spread glottis] (henceforth [sg]) is a privative feature representing aspiration (we take the laryngeal features [voice] and [spread glottis] to be privative – whereby there is simply presence of a monovalued feature, and no negative value – following Mester & Itô 1989, Lombardi 1991, Harris 1994, Beckman et al. 2013).

Under this analysis, Turkish nouns such as *ad* 'name', often classified as exceptions to final devoicing, can instead be understood as falling outside of

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the structural description of the rules mentioned above, since they are inherently [voice]-final (Inkelas & Orgun 1995, Avery 1996). Such [voice]-final nouns never alternate, nor do [spread glottis]-final nouns such as *at^h* 'horse'. As the feature combination [sg, voice] is banned in Turkish, underlying [spread glottis] segments cannot gain [voice] through intervocalic voicing and underlying [voice] segments cannot gain [spread glottis] through final fortition. On the other hand, laryngeally unspecified nouns such as *t^hat* 'taste' undergo intervocalic voicing when suffixed with a vowel, and final fortition otherwise. On these analyses, therefore, the three-way possibility of specifications becomes crucial to understanding the patterns of neutralization and alternation. Due to the neutralizations induced by final fortition and intervocalic voicing, this three-way contrast is not found in a single position, but rather in the patterns of ALTERNATION: there are non-alternating voiceless stops, non-alternating voiced stops, and a series of alternating stops that pattern with the voiceless stops word-finally but with the voiced stops intervocalically, as in Table 1.

Taking as a starting point the extant analyses of Turkish stops as involving a three-way contrast between [spread glottis], [voice], and unmarked, the question arises about what underlying laryngeal features distinguish the fricatives. Beckman et al. (2009) argue that the two-way fricative contrasts in German can be set up as [spread glottis] (fortis) and [voice] (lenis), based on Vaux's (1998) typological evidence for a laryngeal specification of fricatives requiring a [spread glottis] node for all voiceless fricatives in certain languages.[2] If this prediction is correct for Turkish as well, then there should be no laryngeal neutralization among the fricatives: voiced fricatives should not neutralize in coda position in Turkish, since they cannot undergo final fortition, and voiceless [spread glottis] fricatives should not neutralize either, since they cannot undergo intervocalic voicing.

The present study offers phonetic evidence that Turkish fricatives maintain their voicing contrast without neutralization by replicating the methodology that Kopkallı (1993) used to find neutralization for the stops, and demonstrating a clear difference between the two members of the fricative opposition. We then present two additional studies, in which Turkish and Russian are compared with respect to the impact of fricatives on subsequent sonorants. By conducting a comparison with Russian, a language which does not employ the use of [spread glottis] in the laryngeal specification of its fricatives and stops, we provide further support for analyses of Turkish that appeal to both [voice] and [spread glottis] in the specification of its fricatives, and more broadly for the distinction in Beckman et al. (2013) and the work they build on in distinguishing aspirating vs. true voice languages.

[2] In Vaux (1998), a theory of markedness is proposed such that [spread glottis] is the default representation of voiceless fricatives, but languages such as Chinese are argued to deviate from this pattern.

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2. Laryngeal specifications among Turkish stops and fricatives

For the stop system of a language such as Turkish with a three-way contrast, the proposed underlying representations of /d/, /t^h/, /t/ are such that only the voiced and aspirated stops have underlying laryngeal specifications, with [voice] for /d/ and [spread glottis] for /t^h/. This view that Turkish is a three-way system like Thai or like Armenian (Hacopian 2003) finds phonetic support in the study of Kallestinova (2004), who reports that Turkish voiceless stops (whether plain or non-alternating) have a long-lag VOT characteristic of aspiration. Under this account we expect both [voice] and [spread glottis] to be active in the phonology, as depicted in Table 1 above. Turkish has stops at four places of articulation: bilabial, coronal, velar, and palatal, where the palatal series – in fact affricates – pattern with the stops with respect to laryngeal alternations (Lombardi 1990).

Turning to the fricatives, Kaisse (1985) and Rice (1993), among others, have described the Turkish system as involving a two-way contrast, with no alternations or neutralizations, as illustrated in (1):

(1) *Turkish fricatives do not alternate or neutralize*

(a) *Voiced fricatives*
ev ∼ ev-i 'house'

(b) *Voiceless fricatives*
tef ∼ tef-i (*tevi) 'tamborine'
pas ∼ pas-ɨ (*pazɨ) 'rust'

Turkish has fricatives at the labiodental, coronal, and post-alveolar places of articulation. The descriptive generalization arising from examples such as (1) is that fricatives maintain their voicing word-finally, as well as intervocalically – where no voicing alternation is observed. However, these patterns have not been phonetically verified before, which is what we investigate in Section 3.1 below.

Crosslinguistically, two-way contrasts among fricatives have traditionally been described in terms of [voice], with voiced fricatives being specified for [voice] and voiceless ones unspecified. Vaux (1998), however, has shown that for a number of languages the unmarked state of voiceless fricatives is [spread glottis], a phonetic property which has consequences for the phonological representation as well. For the languages Vaux studied, VOICELESS FRICATIVES PATTERN TOGETHER WITH ASPIRATED STOPS in that they induce assimilation of [spread glottis] onto surrounding obstruents. A classic example is found in the pattern of consonant clusters in New Julfa, an Armenian dialect which has a four-way laryngeal contrast in its stop system. In featural terms, New Julfa Armenian allows the free combination of the presence or absence of [voice] and [spread glottis], thereby resulting in four possible laryngeal specifications. In this dialect, the future tense is formed by prefixing /k-/ to the present subjunctive, with the prefix assimilating

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in laryngeal features to the following consonant. The examples in (2) (Vaux 1998: 498) illustrate how voiceless fricatives pattern together with aspirated stops with respect to their ability to spread [spread glottis] to the prefix /k-/.

(2) *Voiceless fricatives pattern with voiceless aspirated stops in New Julfa*

(a) *Voiceless unaspirated stop*
k-t-a-m → **k**ətam 'I will give'

(b) *Voiced unaspirated stop*
k-bzz-a-m → **g**əbəzzam 'I will buzz'

(c) *Voiced aspirated stop*
k-b^{h}ieɾ-ie-m → **g$^{\mathbf{h}}$**əb^{h}ieɾiem 'I will carry'

(d) *Voiceless aspirated stop*
k-t^{t}oʁ-n-ie-m → **k$^{\mathbf{h}}$**ət^{h}oʁniem 'I will allow'
Voiceless fricative
k-savoɾ-ie-m → **k$^{\mathbf{h}}$**əsavoɾiem 'I will grow accustomed to'

We take Vaux's (1998) analysis as the basis for our proposal that voiceless fricatives may be specified for [spread glottis] and voiced fricatives for [voice], and claim that Turkish instantiates this set of specifications for its fricatives. The pattern of voiceless fricatives bearing a [spread glottis] feature can be found across many languages, including Mongolian (Svantesson et al. 2005), in which the fricatives participate in a Grassmann's Law type of dissimilation with aspirated stops. Recognizing that the specification of fricatives may sometimes diverge from that of the stops (see Rice 1994, Iverson & Salmons 2003, Beckman et al. 2009 for discussion), we hypothesize that fortis fricatives are [spread glottis] in languages such as Turkish in which the feature [spread glottis] is already activated among the stops, and that the lenis fricatives are [voice]. As such, the three-way contrast in stops is polarized to a two-way contrast among fricatives.

On the other hand, in a [voice]-only language such as Russian (Halle 1959, Padgett 2002), which has an uncontroversial two-way contrast in both its stop and fricative inventories, [voice] is the only feature that distinguishes the two types of stops. Since [spread glottis] is not invoked in the stop inventory and the fricatives have only a two-way contrast, [voice] turns out to be the only laryngeal specification required. There is thus a difference between Turkish and Russian in the specification of their fricatives: the feature [voice] is phonologically active in BOTH Russian and Turkish, while [spread glottis] is only active in Turkish and inert in Russian, since it does not enter into alternations or neutralizations in the latter. Therefore Russian, unlike Turkish, does not belong to the subset of languages that phonologically mark their voiceless fricatives as [spread glottis]. We contend that voiceless fricatives such as /s/ will not be [spread glottis] in 'true voice' languages (see also Kristoffersen 2007 and Beckman & Ringen 2009), and that phonetic evidence for the difference between the aspirating vs. true voice

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languages can be found in the patterning of fricatives in these languages as well.[3] The following section presents three production experiments intended to provide support for these claims.

3. Phonetic analyses of Turkish and Russian fricatives

3.1 *Study I: Turkish fricatives do not neutralize word-finally*

In most languages in which stops devoice, fricatives undergo devoicing as well (van Oostendorp 2007). While Kaisse (1985) and others claim that fricatives do not devoice in Turkish, Barış Kabak (personal communication) has expressed doubts about whether neutralization actually occurs or not. Despite the thorough testing of stops to show neutralization (Kopkallı 1993, Wilson 2003), Turkish fricatives have never been measured, which is what we report on in the next section.

3.1.1 *Materials and methods*

In order to test whether Turkish fricatives undergo word-final neutralization or not, eight native speakers of Standard Turkish, four male and four female participants, were recorded in a sound-attenuated booth. The participants were graduate students in North America and had lived in Turkey for the first 20 years of their lives. None of the subjects had a known speech or hearing impairment. Two of the participants had background in linguistics, but neither was aware of the purpose of this study.

The test words consisted of 30 pairs of words ending in a fricative consonant (10 labiodental {f, v}, 10 alveolar {s, z}, 10 post-alveolar {ʃ, ʒ}). Since Turkish has minimal pairs that involve the final fricative, most of the monosyllabic words tested were exact minimal pairs. In cases where exact pairs could not be obtained, specifically for disyllabic words, the pairs were compiled in such a way as to minimize the acoustic differences within them. The vowel preceding the target fricative was always held constant, with each vowel from the language's inventory appearing at least once when possible. Furthermore, the penultimate consonants within each pair were chosen so as to agree in their place of articulation. All the words were non-inflected nouns used in Turkish. When compiling this list, the stress, etymology and usage of the words were controlled for with the help of native speakers of the standard dialect of Turkish; none of the words were obvious borrowings, none were of a frequency too low to be known to native speakers, and all disyllabic tokens had final stress. In addition to the 60 test words (presented in Appendix A), 60 filler words were included; the fillers were of the same format, generally stop-final.

[3] This correlation potentially finds even further support in that varieties of Andalusian Spanish appear to be developing an aspirated stop series alongside the debuccalization of /s/ to [h] pointed out by Vaux (1998); see Torreira (2012) for a recent phonetic study.

The experiment was divided into two parts. For the first part, the participants read two randomizations of the 120-word list in isolation. For the second part, they were asked to put the words in one of two contexts, with each word produced once in each of the contexts. The carrier sentences used are listed below; in the first context the word following the target item was vowel-initial (henceforth, a prevocalic frame) and in the second the target was followed by a voiceless obstruent (henceforth, a preconsonantal frame):

(3) *Carrier sentences for Study I: prevocalic and preconsonantal frames*

(a) Bir X istiyorum.
an X want.1SG
'I want an X.'

(b) Buraya X koyduk.
here X put.1PL
'We put X here.'

The tokens were analyzed using Praat (Boersma & Weenink 2008). Cho & Giavazzi (2008) provide experimental evidence to suggest that surrounding vowels and fricative duration provide important cues to voicing distinctions in fricatives. Based on their observations, measurements of the following acoustic events were performed: vowel duration, frication duration, and voicing into frication, which represents the interval from the beginning of frication to the end of voicing periodicity. These landmarks are shown in Figure 1 below for the pair /sis/ 'fog' and /siz/ 'you (pl)'.

In Stevens (1999) the acoustic properties of voiced and voiceless fricatives are described as follows: the vowel preceding the fricative is longer for voiced fricatives, and voiced fricatives have shorter durations than voiceless fricatives. In the measurements conducted, we examined vowel duration, fricative duration, and voicing percentage, as recorded across the three contexts of isolation, a preconsonantal frame, or a prevocalic frame.

3.1.2 *Results*

In the statistical analysis a mixed-effects regression model was used (Baayen 2008), with random effects for participant and item, and fixed effects for voicing (voiced, voiceless), place of articulation (labiodental, alveolar, post-alveolar), and context (spoken in isolation, or prevocalic frame, or preconsonantal frame). A model was considered for each of the three measurements: duration of the fricative, duration of the preceding vowel, and voicing percentage, with the latter defined as the percentage of voicing duration relative to the total duration of the fricative (Beckman et al. (2009) independently use this same procedure of measuring voicing percentage for their acoustic measurements testing German fricative voicing). We report the results of the models which take into account the interaction between the voicing of the fricative and its environment, as this provides a significantly better fit to the data than one without interactions; we

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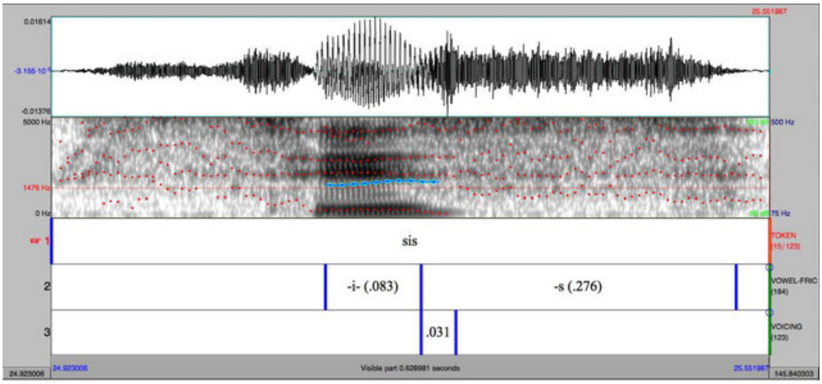
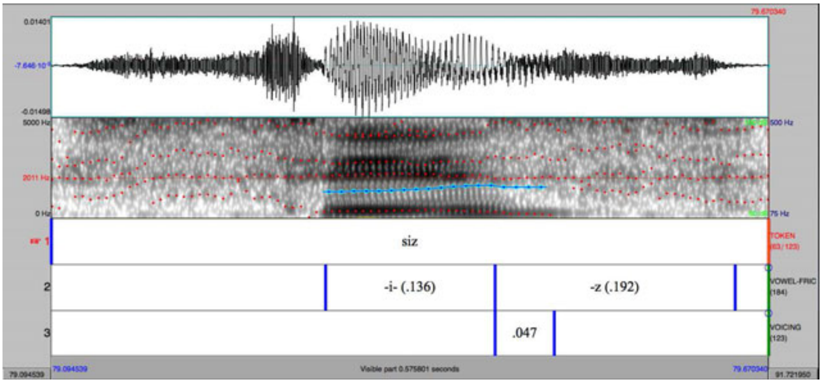


(a) /sis/
vowel duration = 0.083 s; frication duration = 0.276 s; voicing into frication = 0.031 s



(b) /siz/
vowel duration = 0.136 s; frication duration = 0.192 s; voicing into frication = 0.047 s

Figure 1
(Colour online) Spectrogram measurements for Turkish fricatives.

take voiceless and spoken in isolation as our base levels. In Figures 2–4 below we also provide the density plots for the three measurements taken across both voicing conditions, averaged across all three environments.[4]

As expected under the hypothesis that voicing is not neutralized for Turkish fricatives, vowels preceding underlying voiced fricatives are significantly longer than vowels preceding voiceless fricatives in all three environments. Table 2 below reports the results of a linear mixed-effects model. A positive coefficient means

[4] We include the visual representation of all nine separate plots in Figure A1 in Appendix B; the separate three environments for each of these measures are also considered in the statistical models below.

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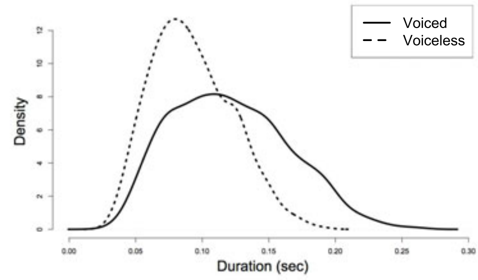

Figure 2
(Colour online) Density plots for Turkish fricatives: vowel duration.

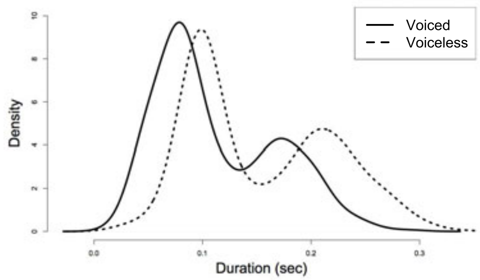

Figure 3
Density plots for Turkish fricatives: fricative duration.

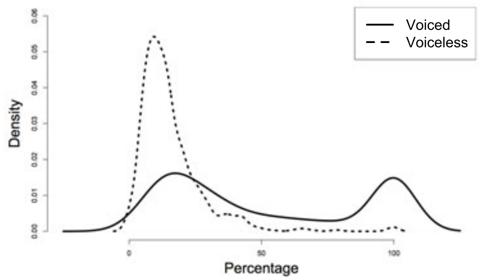

Figure 4
Density plots for Turkish fricatives: voicing percentage.

that the factor is likely to increase vowel duration; thus vowels before voiced fricatives have a longer duration in Table 2. Similarly, while both non-isolation frame environments reduced the length of the vowel compared to isolation (as indicated by a negative coefficient), the effect is much smaller before voiced fricatives (these coefficients are smaller when the frame type is crossed with the

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	Coefficient	t-value	p-value
(Intercept)	105.077	17.188	.0001
Voiced	40.435	9.456	.0001
Prevocalic	−33.267	−21.074	.0001
Preconsonantal	−38.796	−24.576	.0001
Voiced: Prevocalic	−22.010	−9.859	.0001
Voiced: Preconsonantal	−24.419	−10.938	.0001

Table 2
Mixed model results for durations of vowels preceding the Turkish fricatives in Study I.

	Coefficient	t-value	p-value
(Intercept)	223.509	46.16	.0001
Voiced	−58.163	−20.38	.0001
Prevocalic	−107.394	−42.69	.0001
Preconsonantal	−111.152	−44.18	.0001
Voiced: Prevocalic	29.879	8.40	.0001
Voiced: Preconsonantal	40.738	11.45	.0001

Table 3
Mixed model results for durations of the Turkish fricatives in Study I.

	Coefficient	t-value	p-value
(Intercept)	5.120	1.683	.0880
Voiced	29.246	10.507	.0001
Prevocalic	5.519	3.756	.0001
Preconsonantal	5.518	3.754	.0002
Voiced: Prevocalic	34.096	16.405	.0001
Voiced: Preconsonantal	−7.707	−3.708	.0002

Table 4
Mixed model results for voicing percentages of the Turkish fricatives in Study I.

fricative being voiced), again confirming a durational difference conditioned by the laryngeal properties of the following fricative. In Tables 2–4, the t-value can be interpreted as reflecting the strength of the effect statistically, while the p-value represents the significance level of the effect.

The duration of the fricative itself was significantly different between the voiced and voiceless segments as well, with the voiced fricatives being shorter than their voiceless counterparts. Note that the bimodal peaks observed in Figure 3 are a consequence of utterance-final pronunciation, with fricatives

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produced in isolation (224 ms voiceless and 165 ms voiced) being on average longer than when produced in contextual frames, be it prevocalic (116 ms voiceless and 87 ms voiced) or preconsonantal (112 ms voiceless and 94 ms voiced). The difference between voiced and voiceless was significant for all three environments, as shown in Table 3.

Finally, we observed a clear separation between voiced and voiceless fricatives with respect to voicing percentages, as illustrated in Figure 4. In particular, all participants produced their voiceless fricatives with an average of 15% voicing. The voiced fricatives show a bimodal distribution, with a great degree of voicing at one end of the spectrum and much less at the other, and an overall average of 40% voicing across participants. We attribute the bimodal effect partly to a slight tendency for devoicing in preconsonantal context, but more likely to the fact that in isolation contexts some of the participants did not fully voice these underlyingly voiced fricatives, an effect of being in phrase-final positions.[5] Nonetheless, we report this devoicing as being non-neutralizing since these participants still produced longer vowels and maintained shorter durations for the voiced fricatives. As Table 4 shows, there is a clear difference in voicing percentages for the two classes of fricatives, and an effect of preconsonantal frames, which induced assimilatory effects from the following fortis stop.

Finally, we point out that these statistical differences also held when looking at fricatives individually for each of the three places of articulation. The alveolars and post-alveolars were statistically indistinguishable with respect to their neutralizing patterns, while /v/ was significantly more voiced than /z/ or /ʒ/, confirming a longstanding observation that word-finally, Turkish voiced /v/ patterns more like approximant /w/ than like a fricative.[6]

3.1.3 *Interim conclusion*

Based on the results of the above study, there is no laryngeal neutralization among fricatives in word-final positions in Turkish. In Figure 5 below we provide a side-by-side illustration of the mean durations for all three parameters for the stops (based on data from the experiment conducted by Kopkallı (1993), which in our terms, would include a neutralization between plain and aspirated voiceless stops in final position) and fricatives, aggregated data from Study I. As the reader can see, in Kopkallı's (1993) study, the values for voiceless versus voiced STOPS in final position are virtually indistinguishable for all three phonetic parameters, while in our present study, the voiceless versus voiced FRICATIVES show consistent differences.

[5] It is a well-attested phenomenon that in utterance-final positions there is a coarticulation effect of the transition from speech to non-speech, caused both by a decline in subglottal pressure over the course of the utterance and by an assimilation to a state of no vocal fold vibration (see Myers 2012, among others).

[6] We thank Michael Becker, personal communication, for discussion of this point; see also Hamann (2006) and Botma & van 't Veer (2013) for a more general discussion of the sonorant status of non-sibilant voiced fricatives.

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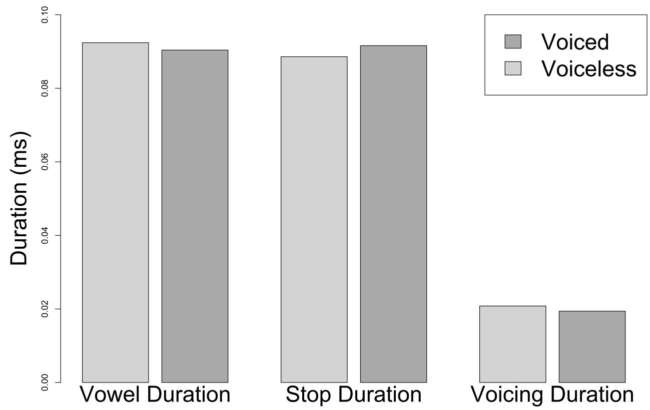
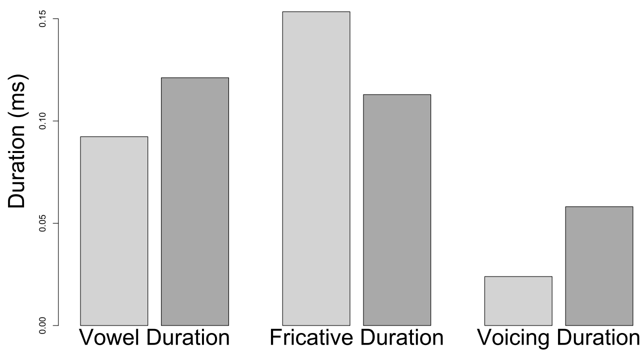


(a) Stops (Kopkallı 1993)



(b) Fricatives (Study I)

Figure 5
Mean durations for word-final stops and fricatives in Turkish.

The data confirm the claims made in the phonological literature that fricatives are not neutralized, and in particular, do not neutralize either word-finally or intervocalically. However, these acoustic data on their own do not necessarily bring us closer to clarifying the fricatives' phonological representations. We have modified Kopkallı's (1993) claim that there is a general process of final devoicing in the language, by showing a radical difference in the neutralization patterns of stops and fricatives – findings that offer indirect support for an analysis of Turkish fricatives as having both [voice] and [spread glottis] in the laryngeal representations, neither of which can be neutralized. However, the exact nature

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Tokens	Type of sequence	Sequence
38	fricative–sonorant	V**sl**V and V**sn**V
49	voiceless.stop–sonorant	V**tl**V, V**tn**V and V**pm**V
20	voiced.stop–sonorant	V**dl**V, V**vl**V, V**mn**V
8	vowel–sonorant	V**l**V

Table 5
Study II: Turkish sonorant devoicing (types and numbers per condition).

of laryngeal specification for Turkish fricatives must be further elucidated by other types of evidence, such as the pattern of post-voiceless fricative sonorants in Turkish, which we take on in Study II.

3.2 *Study II: Turkish fricatives spread [spread glottis] to sonorants*

The first study demonstrated that there is no word-final neutralization for fricatives, a fact that would follow straightforwardly given the view that the fortis fricatives are [sg] and the lenis fricatives are [voice]: final fortition, responsible for final neutralization occurring with the unmarked stops, cannot apply to the [voice] fricatives, akin to the ‘exceptional’ lack of final devoicing in words such as *ad* ‘name’. This explanation for the lack of final devoicing or final fortition for the fricatives in this specific kind of two-way system should in turn predict that there is identifiable phonetic evidence for the [spread glottis] specification of the fortis fricatives. We therefore examined whether sonorants occurring after the voiceless fricative [s] in Turkish undergo a process of sonorant devoicing of the kind that is found in [spread glottis] languages such as English. We present the experimental verification of this prediction below.

3.2.1 *Materials and methods*

Five native speakers of standard Turkish were asked to produce words that contained either fricative–sonorant sequences, stop–sonorant sequences, or intervocalic sonorants. In the present study we employed only stimuli with the coronal fricative /s/, leaving a comparison with other voiceless fricatives for potential future research. Given the morpheme-internal phonotactic sequences of Turkish roots, the majority of such sequences were heteromorphemic. A breakdown of the 115 stimuli that were presented is shown in Table 5. The participants were asked to read the words embedded in the carrier sentence *ʃimdi X diyorum* ‘I say X now’.

Following Beckman & Ringen (2009), the effect of sonorant devoicing was measured by looking at the average VOICING PERCENTAGE: the duration of voicing relative to the total duration of sonorant.

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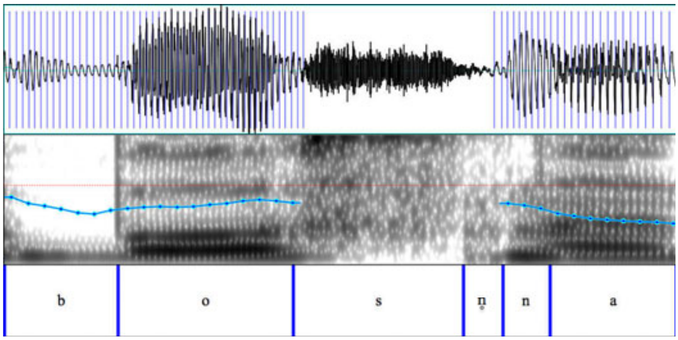
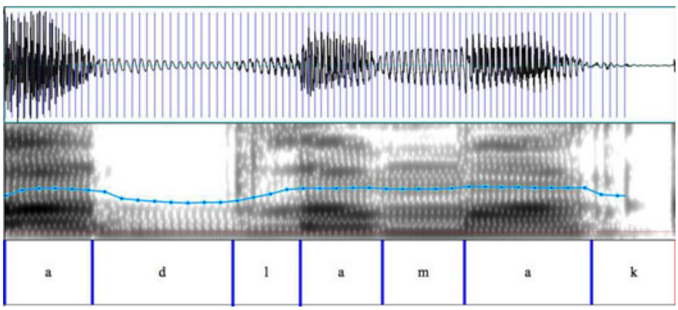


(a) /bosna/



(b) /adlamak/

Figure 6
(Colour online) Segmentation of Turkish sonorants.

3.2.2 *Results*

The sonorant duration and its voicing duration were measured across these four environments using Praat. In Figure 6 we provide a sample illustration of the segmentation into sonorant duration and the voiced portions for representative forms with a nasal and a lateral and following a fricative vs. a voiced stop in /bosna/ 'Bosnia' and /adlamak/ 'to name something'.

In Figure 7 we present density plots for three sequences. The results indicate that while sonorants remain fully voiced (100%) following voiced stops and vowels (labeled dl/dn below), in post-voiceless fricative positions Turkish sonorants are on average 43.5% voiced (labeled sl/sn), while in post-voiceless stop positions they are 90% voiced (labeled tl/tn). The differences between average voicing percentage following voiceless fricatives was significant in a linear mixed-effects model comparison with voiceless stops (t = 20.77, $p < .001$) and voiced stops (t = 26.67, $p < .001$).

The density plots illustrate the large degree of devoicing (in our terms, assimilation of [spread glottis]) undergone by sonorants in post-fricative sequences. While this devoicing of the sonorants is not 100% complete in the results, the same is

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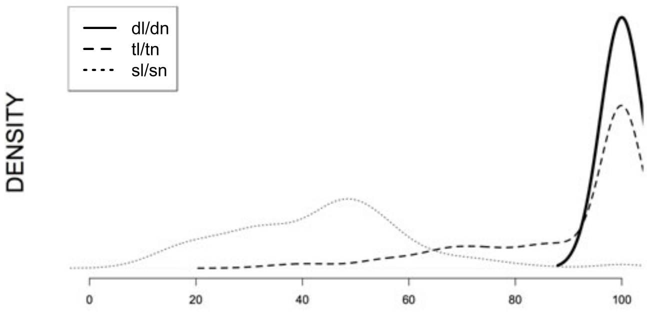

Figure 7
Voicing percentage for **sl/sn** vs. **tl/tn** vs. **dl/dn** in Turkish.

true of English post-/s/ devoicing – both cases can be interpreted as the phonetic implementation of a categorical phonological rule, as argued in Tsuchida, Cohn & Kumada (2000). The pattern of devoicing found after Turkish /s/ is to be directly contrasted with the minimal amount of devoicing that occurs following voiced and voiceless stops (naturally, there is negligible devoicing when following a vowel). These results are expected given the phonological representations of fricatives in Turkish, as proposed in Section 2 above: the voiceless fricative is specified for [spread glottis] and as such, when it precedes a sonorant, the laryngeal properties of the fricative spread over to the sonorant.[7]

In other words, the fricatives in Turkish not only fail to undergo laryngeal alternations in a manner parallel to the stops; they also consistently induce a process of sonorant devoicing (in our terms, [spread glottis] assimilation) to the following laterals/nasals. As Iverson & Salmons (1995: 373–374) argue about the difference between sonorant devoicing of this sort in English (where it occurs) vs. Spanish (where it does not), ‘this difference now derives not from the presence of a sonorant devoicing rule in English vs. its absence in Spanish, but rather from the general dynamics of [spread glottis] realization, a feature which simply is not represented in Spanish’.

It is worth emphasizing the interest of the fact that the fortis fricatives pattern differently from both the voiced stops and the voiceless stops with respect to their effect on following sonorants. Recall from our discussion in Section 1 that word-final voiceless stops in Turkish may correspond to two phonologically-specified variants: either underlyingly unspecified – those that undergo alternations – or

[7] Statistical analysis indicates a significant difference between /l/ and /n/ with respect to their devoicing when following fortis fricatives, as shown in Figure A2 in Appendix B; in particular, /l/ is voiced for ∼36% of its duration, compared to ∼51% voicing for /n/. We leave it to further research to discuss why /l/ should be more prone to devoicing than /n/, but note that no such difference is found following voiced stops, e.g. /dn/ vs. /dl/.

underlyingly aspirated. In the present study, the presonorant stops overwhelmingly patterned like the unspecified ones, in not triggering sonorant devoicing. This result is perhaps to be expected: as presonorant stops in words like *atlanmak* 'skipped' would not, by definition, undergo either final fortition OR intervocalic voicing, and since the orthography makes no distinction between these two types of stops, it is likely that unmarked, laryngeally unspecified representations are more likely for speakers to posit in such forms (in fact, regardless of whether the stop in question is root-final or not). We therefore conjecture that the /tl/ sequences contained, for the most part, underlyingly unspecified stops, with no ability to trigger [spread glottis] assimilation.

In summary, the results of the present study demonstrate that, alongside better-studied [spread glottis] languages like English, Turkish is also a language in which the fortis fricatives induce sonorant devoicing, confirming the hypothesis that the fricatives, unlike the stops, undergo no laryngeal alternations, as both fricatives are laryngeally specified. In other words, in languages like Turkish, one expects that if voiceless fricatives do not undergo voicing neutralization, then they will cause sonorant devoicing. By contrast, languages in which fricatives undergo laryngeal alternations completely parallel to the stops, e.g. final devoicing and voicing assimilation within clusters, as in Russian, evince a series of laryngeally unspecified fricatives, which will not trigger sonorant devoicing. We turn to such a comparison in the next study.

3.3 *Study III: Russian fricatives do not spread voicelessness to sonorants*

Turkish and Russian, from a distance, appear to have similar patterning, in that both show what is descriptively called final devoicing. However, recall the discussion in Section 1: Turkish does not have final devoicing of one set of its stops (the ones specified [voice], such as *ad* 'name'), demonstrates a long-lag VOT system characteristic of a [spread glottis] specification, and does not final-devoice any of its fricatives, as shown in Study I above. Given these differences, while Turkish is a more complex system with a three-way specification in the stops and a two-way specification in the fricatives (neither of the latter of which is unspecified), Russian is a traditional two-way system of [voice] vs. unspecified in both the stops and the fricatives. We therefore expect Russian voiceless fricatives to remain inert in terms of sonorant devoicing, as its system, unlike Turkish, does not possess [spread glottis] specification in the fricatives. The aim of the present study is to directly compare the Turkish results in Study II with those of Russian.

3.3.1 *Materials and methods*

Four native speakers of standard Russian were recorded in a sound-attenuated booth. Since the purpose of this experiment was to test the effect of fricatives (/s/) on following sonorants (/l, n/), the target words were selected so as to include fricative–sonorant sequences word-medially. In the present study we employed

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Tokens	Type of sequence	Sequence
42	fricative–sonorant	V**sl**V and V**sn**V
14	voiceless.stop–sonorant	V**tl**V and V**tn**V
14	voiced.stop–sonorant	V**dl**V and V**dn**V
14	vowel–sonorant	V**l**V and V**n**V

Table 6
Study III: Russian sonorant devoicing (types and numbers per condition).

only stimuli with the coronal fricative /s/, leaving a comparison with other voiceless fricatives for potential future research. In addition, the stimuli included words containing stop–sonorant sequences and words with intervocalic sonorants. In Table 6 the numerical breakdown of the stimuli is presented, which totals 84 items. We note that the total number of stimuli slightly differed from the those in Study II, but not in a way likely to impact the qualitative pattern of results. The words were presented in Cyrillic orthography and the participants were asked to read them embedded in the carrier sentence *Ja govorju X u menja* 'I say I have X'.

The tokens were analyzed using Praat, following the same measurement points in Study II: sonorant duration and voicing duration.

3.3.2 *Results*

In order to measure the effect of the fricative on the following sonorant, we took the following two measurements: total duration of the sonorant and duration of voicing within the sonorant. In Figure 8 below we provide a side-by-side illustration of this segmentation for /daslat/ 'addendum' and /kudlatej/ 'shaggy'.

All 84 items were analyzed in the same manner, and the average voicing percentage (duration of voicing relative to total duration of sonorant) was compared across all four types of sequences. The results indicate that sonorants are 85.7% voiced when following voiceless fricatives, versus 98.7% voiced when following voiceless stops and completely voiced if following either voiced stops or vowels. Figure 9 presents density plots illustrating these results. While it may appear that voiceless fricatives induce slight devoicing on following sonorants, we take this to be a gradient articulatory effect related to the production of voiceless fricatives; many tokens have fully voiced sonorants, and even those that are somewhat devoiced remain more than 80% voiced. In fact, in Study III, of the 168 tokens of Russian sonorants following a fricative, 120 (71%) showed over 80% voicing. By contrast, in Study II, of the 226 tokens following a fricative, only 7 (3%) showed over 80% voicing. While the differences between average voicing percentage following voiceless fricatives in Russian was significant in a linear mixed-model comparison with voiceless stops (t = 1.12, $p < .001$) and voiced stops (t = 12.59, $p < .001$), there were observably smaller effect sizes

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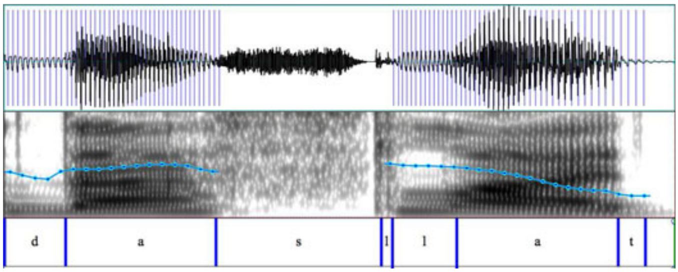
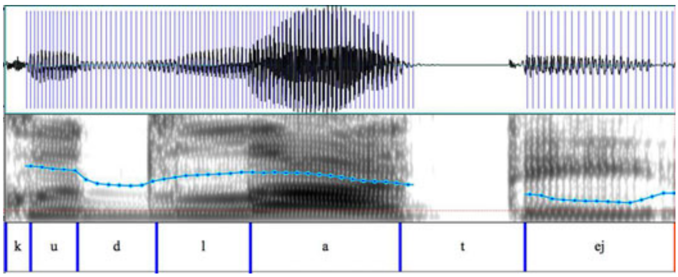


(a) /daslat/



(b) /kudlatej/

Figure 8
(Colour online) Segmentation of Russian sonorants.

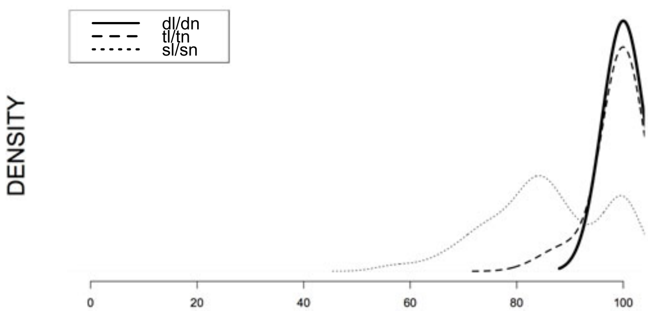


Figure 9
Voicing percentage for **sl/sn** vs. **tl/tn** vs. **dl/dn** in Russian.

(as indicated in the *t*-values) than the corresponding comparisons in Turkish. Looking at the differences in means (15% devoicing in Russian following fortis fricatives, versus 56% in Turkish), we conclude that the phonological specification

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of voiceless fricatives in Russian does not consistently display a devoicing effect on following sonorants.

We take the results of this experiment to indicate that Russian voiceless fricatives do not cause following sonorants to devoice. This is an expected outcome under an analysis of Russian fricatives where the contrast is, like with stops, simply one of [voice]; that is, that voiced fricatives are specified for [voice] while voiceless ones are unspecified, and hence have no [spread glottis] specification in which to induce sonorant devoicing, quite differently from Turkish.

4. Conclusions

The phonetic findings of these three studies support distinct phonological representations for Turkish stops versus Turkish fricatives, as well as for Turkish fricatives versus Russian fricatives. Based on studies such as Avery (1996), Kallestinova (2004), and Petrova et al. (2006), the Turkish laryngeal system shows a three-way contrast for stops, using a combination of [voice] and [spread glottis] specifications alongside an unspecified plain stop, which is the one that undergoes laryngeal alternations.

Up until the present paper, there has been little discussion of the phonological specification of Turkish fricatives. We have demonstrated that neither the fortis nor the lenis fricatives show alternations, and thereby concluded that both are specified for one of the laryngeal features, either [voice] or [spread glottis]. In order to demonstrate that the fortis fricatives are indeed [spread glottis] even in a two-way contrast, we compared the behavior of Turkish fricatives to that of Russian fricatives – whose two-way contrast is one of [voice], with the voiceless fricative being unmarked. The results of Studies II and III showed that with respect to the effect of voiceless fricatives on following sonorants (/l, n/), Turkish and Russian behave drastically differently. Where sonorants were at most 15% devoiced in Russian, they were at least 56% devoiced in Turkish.

Although Turkish has sometimes been characterized as a final devoicing language (e.g. Inkelas & Orgun 1995), we believe that the set of results collected here strongly points towards a specification in terms of [spread glottis], not only for the stops but also for the fricatives. The emerging consensus that there are 'true voice' versus 'aspirating' languages (Iverson & Salmons 1995, Honeybone 2005, Backley 2011, Beckman et al. 2013) not only in terms of phonetic realization but also in terms of phonological processes has focused more on stop consonants, and in the present work we have extended this hypothesis to fricatives. In other words, the two-way contrast among the fricatives is 'overspecified' in the sense of Beckman et al. (2011), who find that the two-way contrast among Swedish stops is also one between [voice] and [spread glottis], with no use of an unmarked pole of opposition. The phonological patterning of non-neutralization in the fricatives and of sonorant devoicing caused by the fortis fricatives thus leads to the overall set of specifications for Turkish illustrated in Table 7.

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Stop type	Bare stem	Possessive	Gloss
/[sg]/	at^h (no change)	at^h-ɨ (no change)	‘horse’
/[voice]/	ad (no change)	ad-ɨ (no change)	‘name’
/[ ]/	t^hat^h (final fortition)	t^had-ɨ (V_V voicing)	‘taste’
/[sg]/	tef (no change)	tef-i (no change)	‘tamborine’
/[voice]/	ev (no change)	ev-i (no change)	‘house’

Table 7
Specifications and neutralizations in Turkish stops and fricatives.

The two-way laryngeal specification on Turkish fricatives renders them immune to alternations, and enables [spread glottis] spreading to adjacent sonorants. By contrast, in Russian, a pure final devoicing language, no such activity of [spread glottis] is found, and the fricatives alternate just like the stops. In sum, not all two-way contrasts are created equal: apparently, the presence of a three-way contrast elsewhere in the obstruent system has ramifications for both neutralization and assimilation processes even in a manner of articulation with only a two-way contrast.

Appendix A

Experimental items

Voiceless	Voiced	Voiceless	Voiced	Voiceless	Voiced	Voiceless	Voiced
kaf	kav	pöf	söv	lif	yiv	dövüş	röfüj
redif	hidiv	keşif	hiciv	rozbif	civciv	faraş	şantaj
selef	verev	kof	kov	saf	sav	traş	tiraj
cafcaf	havhav	kos	koz	has	haz	sırdaş	kürtaj
kös	köz	kulis	galiz	kıyas	niyaz	bağdaş	sondaj
tenis	deniz	kes	kez	tırıs	cılız	çağdaş	bandaj
nufus	nüfuz	çerkes	çerkez	keleş	kolej		
türdeş	kortej	kardeş	manej	buruş	ruj		

Table A1
Study I: Turkish fricatives.

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sl/sn	sl/sn	tl/tn	tl/tn	pm	dl/vl	mn/VL
aslan	müslüman	altıpatlar	gözetleme	kapmaca	adli	memnu
puslu	sislenmek	bitlenmek	katlanmak	tapmak	adlandırma	emniyet
uslu	süslemek	böğürtlen	kontluk	yapmacık	tevlid	omnibüs
asli	ıslah	butlanmak	külfetli	tepme	mevlevi	cimnastik
eşsesli	paslaşmak	çatlamak	matlaşmak	çarpmak	evliya	memnun
hisli	vuslat	çiftleşmek	merhametli	çırpmak	avlamak	jimnastik
teslim	beslek	çiftlik	patlamak	kapma	davlumbaz	kilit
yaslı	fesleğen	çitlembik	altlık	serpmek	mevla	güler
şanslı	islemek	dertlenmek	senetleşmek	tepmek	evli	halic
aslık	meslek	dikkatli	sertlenmek	kapmak	evlenme	velet
kaslı	esnemek	emniyetli	arıtlama	yapmak	devlet	milis
esnaf	hırslanmak	antlaşma	üstlenmek	kopmak	avlu	valiz
musluk	nesnel	fitne	sırtlan	kopma	ödlek	saloz
kasnak	nesne	zıtlaşma	armutlu	öpmek	adlamak	galat
esneme	bosna	atlanmak	atlatılmak			
esnek	müstesna	atlatmak	atlı			
mesnevi	tasnif	basitleşmek	fitnecilik			
istisna	mesnet	etnik				
kasnakçı	hüsnü					

Table A2
Study II: Turkish sonorants.

sl/sn	sl/sn	sl/sn	tl/tn	dl/dn	Vl/Vn
doslat^j	naslat^j	t^{j}esno	atlant	podlij	galantno
nasliʃan	slabij	zapasnoj	dotla	podlodka	obald^{j}elo
sliʃno	sladko	prisnut^j	v^{j}etla	s^{j}edlo	talant
v^{j}islij	slava	usnut^j	patli	b^{j}edlam	galstuk
vzroslij	slavno	d^{j}esna	utlij	dlan^j	kr^{j}esalo
slog	v^{j}isla	v^{j}isnut^j	kotlovan	kodla	konsul
slom	k^{j}slij	zasnut^j	sv^{j}etlo	kudlatij	kulon
slonovij	bl^{j}esna	snar^{j}ad	azotnij	b^{j}ezdna	ant^{j}enna
slovo	jasno	glasnij	bolotnij	bludnij	ran^{j}enij
v^{j}eslo	krasnota	parusnij	rotnij	m^{j}ednij	gangr^{j}ena
zaslon	l^{j}esnoj	t^{j}esnij	statnij	b^{j}edno	karant^{j}in
jislam	opasno	uksusnij	vatnij	l^{j}udno	f^{j}inansi
sluʒka	snob	uʒasnij	plotno	podnoʒka	sanuz^{j}el
usluga	snova	v^{j}irusnij	smutno	skladnoj	falanga

Table A3
Study III: Russian sonorants.

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Appendix B

Additional figures

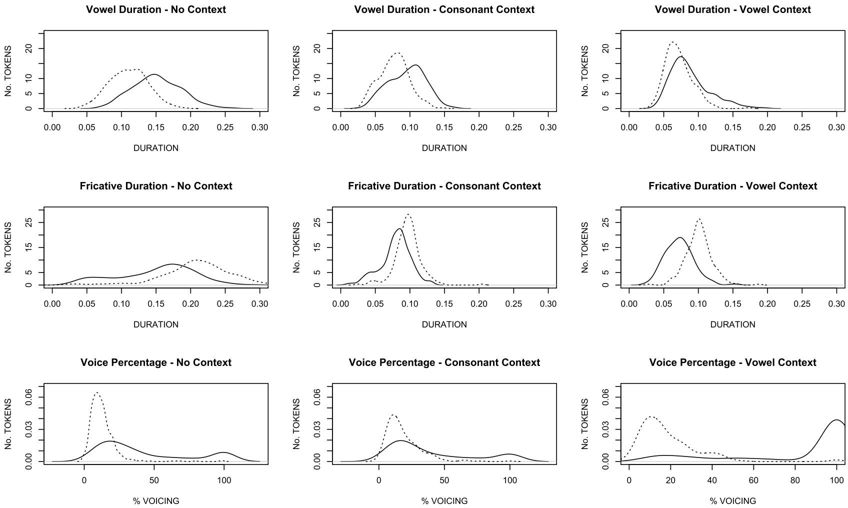

Figure A1
Turkish fricatives (Study I): phonetic measurements across the three carrier frame environments (dotted line = voiceless; solid line = voiced).

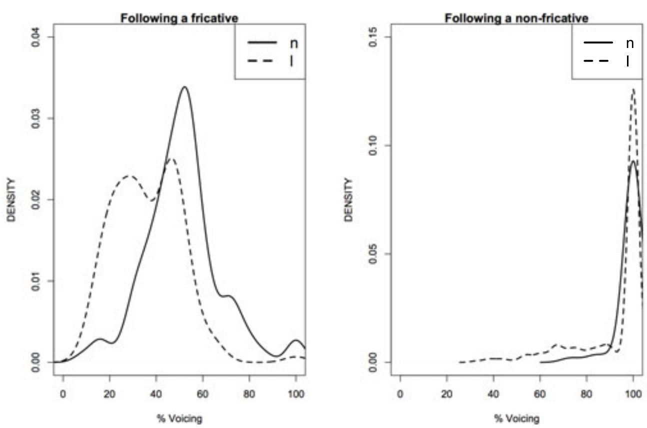

Figure A2
Turkish sonorant devoicing (Study II): voicing percentages for **l** and **n** following voiceless fricatives versus all other preceding sounds.

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