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FEATURE ARTICLE

A phonetic study of voiced, voiceless and alternating stops in Turkish

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A phonetic study of voiced, voiceless and alternating stops in Turkish *

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Abstract

In Turkish, there is a process of syllable-final stop devoicing. Many nouns end in stops which surface as voiced when followed by a vowel-initial suffix, but voiceless when they occur syllable-finally or word-finally. This main goal of this study was to investigate whether this devoicing process leads to complete neutralization between devoiced and underlying voiceless stops. Measurements of closure duration and voicing into closure did not differ between stops in these two cases, suggesting that neutralization is indeed complete. However, there are also some words with stops which are not subject to devoicing, suggesting that a three-way lexical distinction between voiced, voiceless and alternating stops is necessary to account for all of the data.

Introduction

Languages have numerous phonological processes which affect particular phonemes in particular contexts. Some of these processes categorically change one phoneme into another, for instance the [t] in act changes to a [š] in action, conditioned by the -ion suffix. Other phonological processes affect the articulation of a phoneme without changing it categorically into another phoneme. For instance, the [p] in port is aspirated, whereas the [p] in sport is not, even though these are both [p]s. Often it is difficult to determine whether a putatively categorical rule is truly categorical, because although it might sound to the "naked ear" that a phoneme has changed into a different phoneme, careful phonetic analysis may reveal subtle cues to the original identity of the phoneme. If any remnants of the original phoneme can be detected, this indicates that the change must not have been categorical, but rather must have been gradient in nature. It is important to be able to distinguish categorical changes from gradient ones, because the cognitive processes involved are probably quite different in the two cases. This study investigates syllable-final stop devoicing in Turkish with the aim of distinguishing between categorical and non-categorical processes.

Many nouns in Turkish end in stops which surface as voiced when followed by a vowel-initial suffix, but voiceless when they occur syllable-finally or word-finally. In (1), devoicing is seen in the nominative case, whereas (2) exemplifies stops which are voiceless throughout the paradigm.

* I would like to thank Ayşe Pınar Saygın for helping with the selection of materials and for taking part in the experiment, Mehmet Süreyya Er and Osman Çelik for taking part, and Jeff Elman and Sun-Ah Jun for helpful discussions and comments.

		Nominative	Accusative	Gloss
(1)	a.	kanat	kanadı	‘wing’
	b.	iyot	iyodu	‘iodine’
(2)	a.	sanat	sanatı	‘art’
	b.	mazot	mazotu	‘diesel’

Traditional analyses (e.g. Underhill, 1976) have postulated voiced stops in the underlying forms and a neutralizing devoicing rule.

However, there are also a smaller number of words which maintain voicing of the final consonant even when it surfaces syllable-finally:

		Accusative	Nominative	Gloss
(3)	a.	üstadı	üstad	‘expert’
	b.	metodu	metod	‘method’

Words such as these are written with voiced stops in the orthography, though they are undoubtedly devoiced to a certain extent, though not fully, in most dialects.

In this paper I will refer to these three types of stops as alternating (1), voiceless (2) and voiced (3). Note that alternating stops may surface as voiced or voiceless depending upon the context.

Words like those in (3) are relatively rare and are mostly fairly transparent loans, which has led some researchers to leave this phenomenon out of theoretical accounts of stop devoicing (e.g. Underhill, 1976; Kopkallı, 1993). Accounts which incorporate this data posit a three-way voicing distinction in the lexicon. Hayes (1990) makes probably the simplest proposal: stops can be [+voiced], [–voiced] or unspecified for [voice], in which case they surface as voiced when they appear intervocalically and voiceless when they appear syllable-finally. A related analysis is adopted by Inkelas & Orgun (1995).

This study aims to build on work by Kopkallı (1993) on the phonetic correlates of the stop voicing contrast(s) in Turkish. Studies in several other languages have shown that final devoicing processes long thought to be neutralizing probably in fact preserve the underlying contrast in the surface forms. This has been shown in German (Port & O’Dell, 1985; Port & Crawford, 1989; but c.f. Fourakis & Iverson, 1984), Polish (Slowiaczek & Dinnsen, 1985; Slowiaczek & Szymanska, 1989; but c.f. Jassem & Richter, 1989) and Russian (Pye, 1986). In Catalan, however, devoicing has been found to be truly neutralizing (Charles-Luce, 1987).

Kopkallı (1993) carried out an extensive study of final stop devoicing in Turkish and concluded that it is genuinely neutralizing. She found no significant difference between alternating and voiceless stops for any of four measures: vowel duration, voicing into closure, closure duration or aspiration duration. She also carried out a perceptual study which showed that subjects were unable to distinguish between underlying voiceless and devoiced alternating stops.

The present study has three goals. Firstly, given that so many studies in other languages have shown neutralization to be incomplete, it would be worthwhile to replicate some of Kopkallı’s (1993) results. Secondly, Kopkallı did not measure, and in fact does not even discuss, words such as those in (3) which maintain voicing throughout the paradigm. These stops are therefore measured in this study to confirm that they do indeed remain voiced in devoicing contexts.

Thirdly, the analysis whereby there is a three-way lexical voicing contrast (voiced, voiceless, unspecified) raises an interesting possibility. Kopkallı has shown that alternating stops are indistinguishable from voiceless stops in word-final position. However, it has not been investigated whether alternating stops are indistinguishable from voiced stops in intervocalic position. Certainly the [d] in kanadı (nominative kanat) appears to sound the same as the [d] in baladı (nominative balad), but this is another possible way in which the voicing rules could fail to be categorical. This issue is investigated here.

Method

Speakers

Three speakers were recorded for this study. Speaker 1 was a 37-year-old male who was born in Izmir but grew up in Istanbul. Speaker 2 was a 33-year-old male who also grew up in Istanbul. Speaker 3 was a 26-year-old female who grew up in Ankara.

Materials

Speaker 1 read a long list of 552 words and phrases, whereas speakers 2 and 3 read shorter lists of 150 words each. The words and phrases used are shown the appendix, and described below.

The list which speaker 1 read contained 3 words ending in voiced [d] which do not alternate, 6 whose ending alternates between [d] and [t], and 6 which always end in [t]. Each of these words was produced in four contexts: nominative (where the consonant of

interest is word-final), accusative (where the consonant of interest is intervocalic), nominative followed by a vowel-initial verb, and nominative followed by a consonant-initial verb. All of these words were disyllabic in the nominative and consequently trisyllabic in the accusative. Each of the 3 always-voiced [d]-final words was matched to 2 alternating words and 2 voiceless words for the vowel preceding the consonant of interest. (Following vowels in the accusative case also matched due to vowel harmony.) There were 6 repetitions of each word or phrase.

Additionally, there was 1 [b]-final word which never alternates, 2 which alternate between [b] and [p] and 2 which always end in [p]. There was 1 [g]-final word, 2 which alternate between [k] and zero (the so-called 'soft [g]'), and 2 which are always [k]-final. All of these words were produced in the nominative and accusative cases, which places the consonant of interest either word-finally or before a vowel, and there were 6 repetitions of each item.

Various fillers were included, and the total number of words or phrases read was 552.

Speakers 2 and 3 read a shorter list which contained the same 9 alveolar-final words as speaker 1 produced. Each was produced 6 times in the accusative and 3 times in the nominative. Fillers were included, bringing the total number of words read to 150.

Recording

Speakers 1 and 2 read lists of words and phrases in the UCLA Phonetics Lab soundproof booth. For speaker 3, due to geographical limitations, a novel procedure was employed: a word list was e-mailed to the speaker, who then read it over the telephone. The experimenter's cell phone was turned to its highest volume and held close to a microphone in the soundproof booth. This resulted in an surprisingly clear recording, given the circumstances. A sample spectrogram recorded over the telephone is shown in figure 1. Low frequencies were unclear (e.g. voicing into the closure), and frequencies above about 3 kHz were missing entirely, but measurements of length could be made without difficulty.

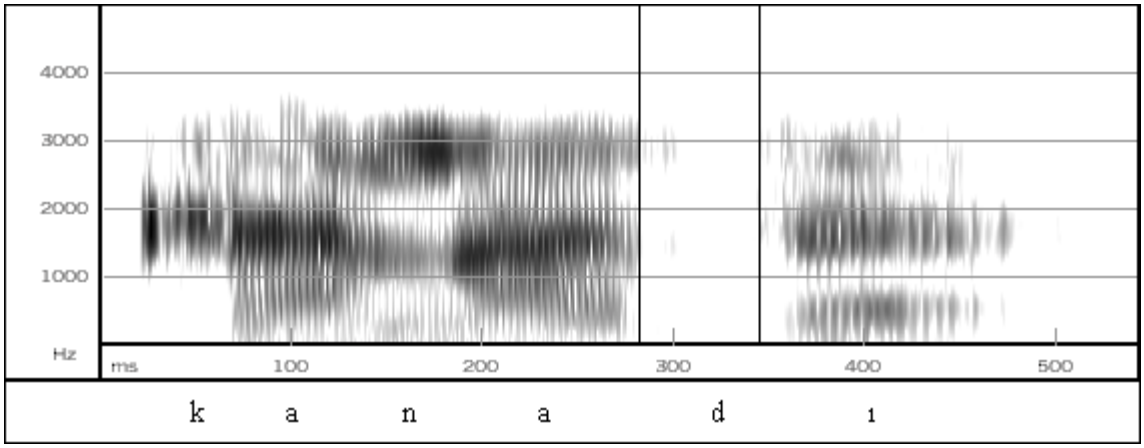

Figure 1. A spectrogram of the word *kanadı* 'wing-ACC' recorded over the telephone.

Measurement

The data were digitized at 22 050 Hz and analyzed with PCQuirer (Scicon R&D, Los Angeles, CA). All measurements were made using spectrograms and waveforms in tandem. For final stops, two measurements were made: length of the stop, and voicing into closure. Length was measured from the end of the vowel to the beginning of the release burst. Stops in Turkish are practically always released; just one token had to be excluded due to having an inaudible release. Examples can be seen in figures 3 and 6 below; in each case, length was measured from the first to the third line. Voicing into closure was measured from the end of the vowel to the end of periodic voicing, which was usually clearest on the waveform rather than the spectrogram. In figures 3 and 6, voicing into closure was measured from the first to the second line in each case. In figure 3 it is impossible to see any voicing into the

closure, but at the appropriate resolution it was generally not difficult to judge. For speaker 3, it was not possible to measure voicing into closure because the telephone seemed to cut out these low frequencies.

Voiceless intervocalic stops were also measured but are not reported in this paper. They were generally significantly longer than voiced intervocalic stops. For voiced and alternating intervocalic stops, just one measurement was made, since they were without exception voiced throughout the closure. The length measurement was made from the end of the preceding vowel to the onset of noise associated with the release. An example can be seen in figure 9 below.

Analysis

For speaker 1, only 4 of the 6 repetitions of each word were measured, except for the voiced and alternating accusative forms for which all 6 were measured. For speakers 2 and 3, all repetitions were measured. In all cases, repetitions were averaged together for each word or phrase prior to any further analysis. The data were analyzed with StatView (SAS Institute, Cary, NC). Most statistical tests were t-tests. Two ANOVAs were carried out, treating words as cases. No attempts were made to calculate inferential statistics across speakers. These moves circumvent the problems pointed out by Max & Onghena (1999) in using ANOVAs with phonetic data.

Results

Final devoicing

The results for alveolar stops will be presented first, before moving to the other places of articulation for which less data were recorded.

Speaker 1 produced underlying voiced, underlying voiceless and alternating alveolar stops in three devoicing environments: citation form (nominative), before a vowel-initial verb, and before a consonant-initial verb. Two measurements were made: length and voicing into closure. For length (figure 2), a 3 (voicing, between) by 3 (environment, within) repeated-measures ANOVA over items was carried out. This revealed a main effect of environment [$F(2, 12) = 359.424$, $p < 0.0001$] but no effect of voicing [$F(2, 12) = 0.177$, $p = 0.84$] and no interaction.

Post-hoc tests revealed that all three environments differed significantly from one another (Fisher's PLSD, $p < 0.0001$).

It is notable that length did not differ a great deal depending on whether the stop was followed by a vowel-initial or a consonant-initial verb. This may be because speaker 1 produced all of the phrases in a relatively formal style, and there was usually a substantial gap between the offset of the stop burst and the start of the next segment, regardless of whether it was a vowel or a consonant. In figure 3, an example is given of the phrase iyot aldım 'I got iodine'. The stop in iyot is alternating, but here it is clearly pronounced as a syllable-closing [t].

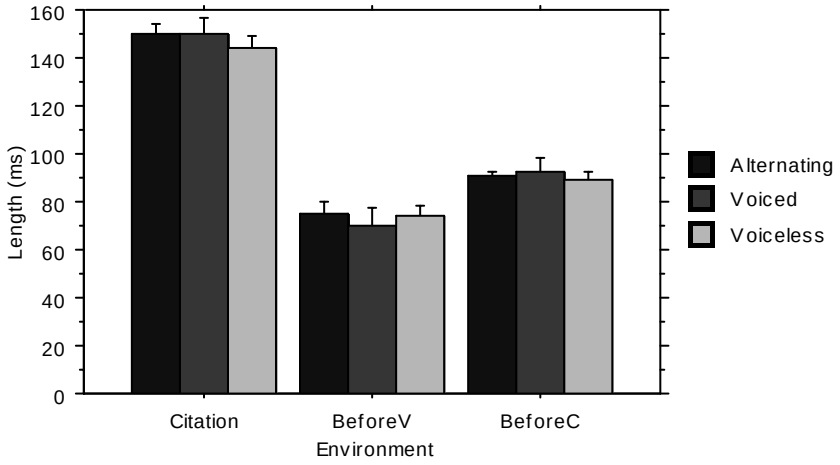

Figure 2. Effect of voicing and environment on length for subject 1.

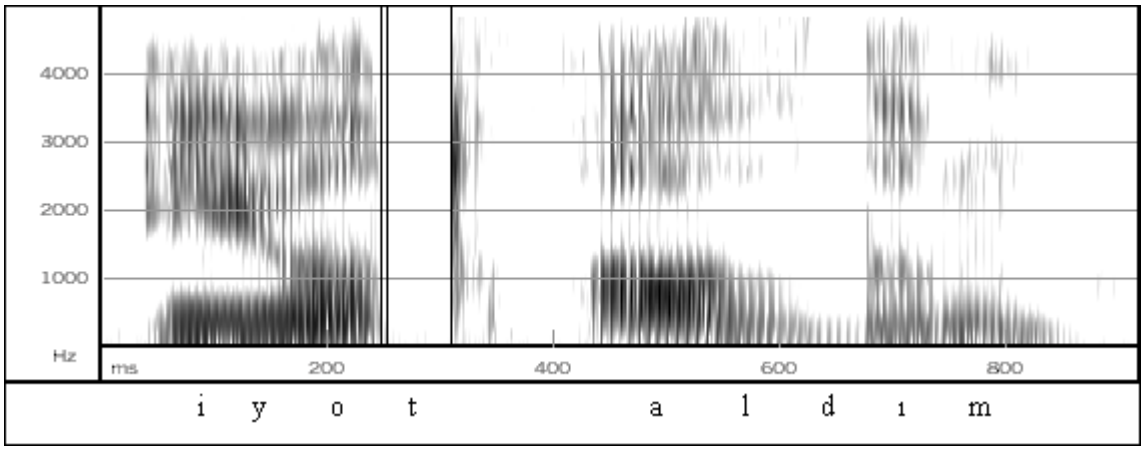

Figure 3. A spectrogram of *İyot aldım* showing the gap between the words.

There were just three tokens in which the stop preceding a vowel was resyllabified with the following syllable, a process which is common in everyday speech. These three tokens were not included in the ANOVA described above. An example is given in figure 4.

This is a particularly interesting example because the alternating stop actually surfaces as voiced as a consequence of being resyllabified with the following vowel (this process is discussed by Kaisse, 1986). Unfortunately, this was the only such example recorded, although this process is much more common in everyday speech. However, even this single example is useful to examine. It can be seen on the spectrogram above that the [d] is voiced throughout the closure. The length of this token was measured at 60.5 ms which is consistent with other intervocalic [d]s (see figure 10 below). Although it would be premature to conclude anything based on a single token, the spectrogram above provides evidence against the claim of Rice (1990) that these type of stops are 'neither voiced nor resyllabified, but ambisyllabic' (p. 296). The token above at least appears to be fully voiced and resyllabified.

For the second measure taken in devoicing contexts, voicing into closure (figure 5), a 3 (voicing, between) by 3 (environment, within) repeated-measures ANOVA of items was carried out. There were main effects of both voicing [$F(2, 12) = 10.585$, $p = 0.0022$] and environment [$F(2, 12) = 7.332$, $p = 0.0033$]. There was no interaction.

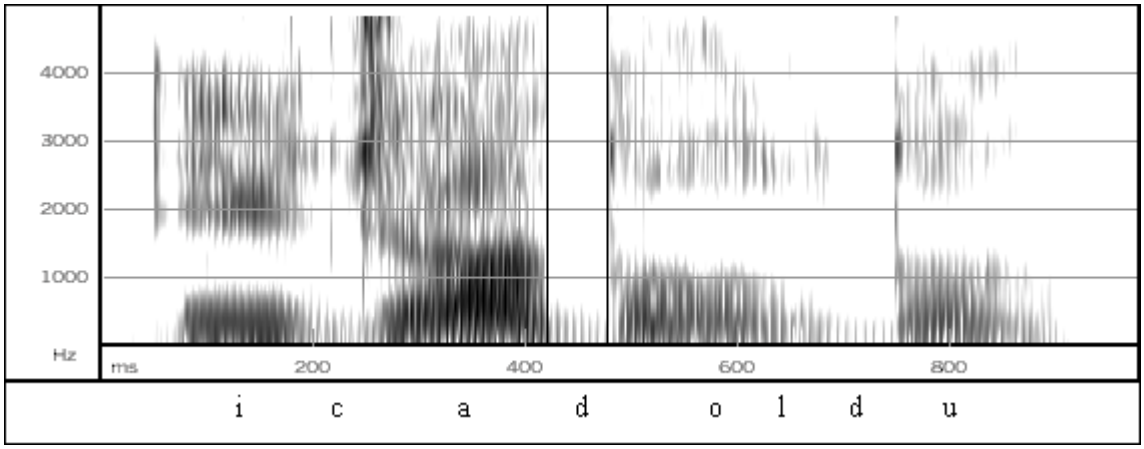

Figure 4. A spectrogram of *İcat oldu* with intervocalic postlexical voicing.

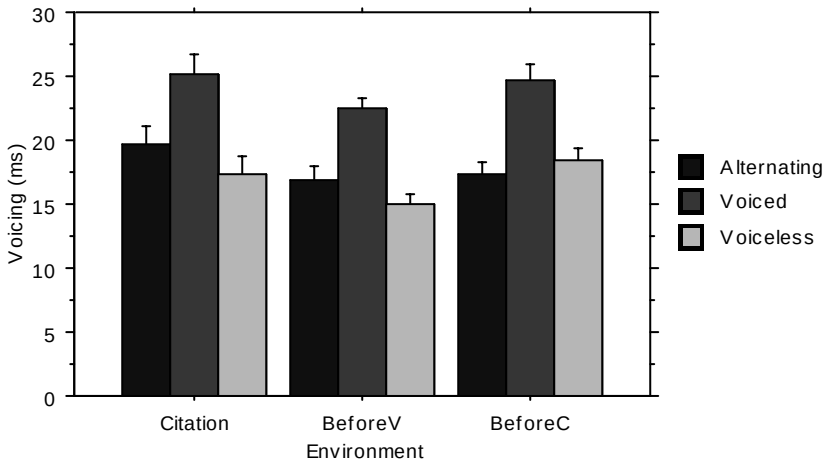

Figure 5. Effect of voicing and environment on voicing into closure for subject 1.

Post-hoc tests (Fisher's PLSD) showed that voiced stops had more voicing into closure than either alternating ($p < 0.0001$) or voiceless ($p < 0.0001$) stops, but alternating and voiceless stops did not differ from one another.

An example of a final voiced stop is given in figure 6. This token shows a relatively large amount of voicing into the closure.

The comparison between voiceless and alternating stops continued to be nonsignificant even when much more liberal (and dubious) statistical methods were used, i.e. treating each token as a separate case (which makes the degrees of freedom very large). A t-test for the effect on length was not significant ($p = 0.63$, $N = 71$ alternating, 71 voiceless). Nor was a t-test for the effect on voicing ($p = 0.27$).

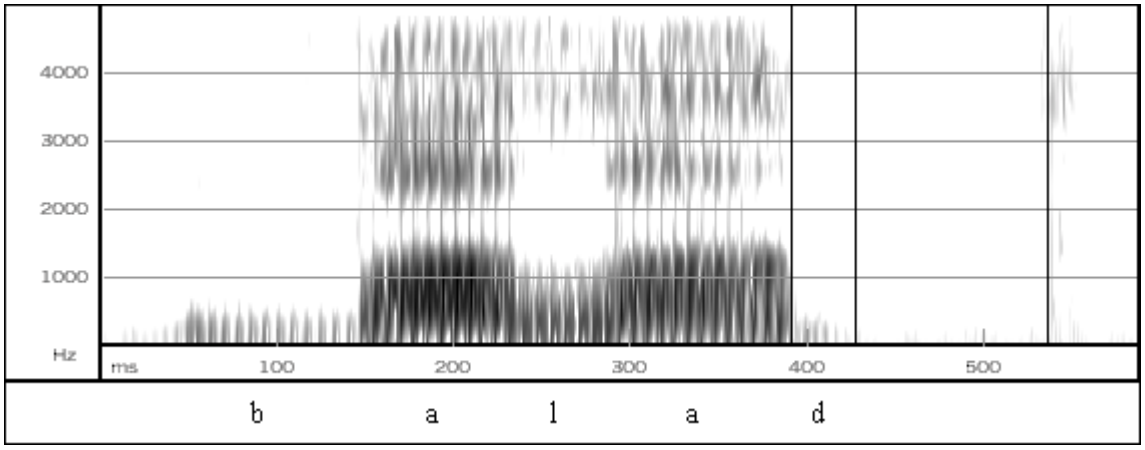

Figure 6. A spectrogram of *balad* showing substantial voicing into the closure.

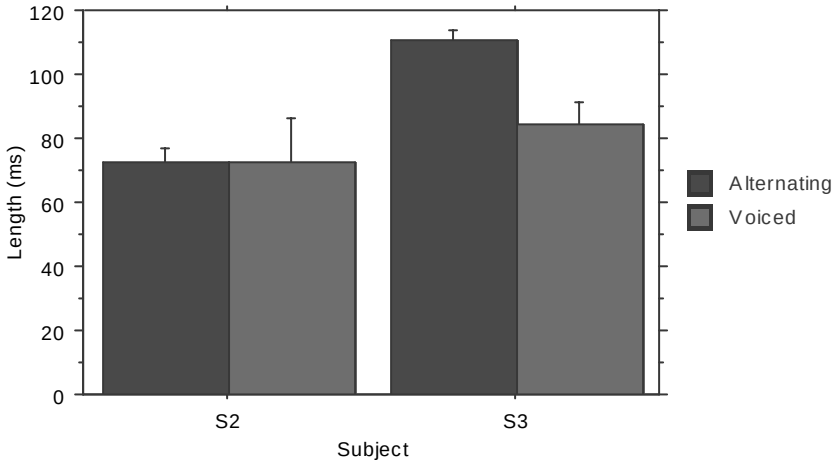

Figure 7. Length of alternating and voiced stops word-finally for subjects 2 and 3.

Subjects 2 and 3 were tested only on voiced and alternating stops in word-final position (because the primary purpose in testing these subjects was to examine stops intervocalically). For subject 2, these differed neither in length (voiced mean 72.6 ms; alternating mean 72.4 ms; $p = 0.99$) nor voicing (voiced mean 19.7 ms; alternating mean 16.5 ms; $p = 0.30$). For subject 3, the difference in length was significant (voiced mean 84.3 ms; alternating mean 110.9 ms; $p = 0.0031$ or $p = 0.04$ assuming unequal variance). Subject 3 could not be tested on voicing into closure, as mentioned above. Graphs for length are shown in figure 7.

Subject 1 also produced bilabial and velar stops in a handful of words. No inferential statistics are reported here because there were too few words. For bilabial stops, the differences in length between conditions were moderate (voiced mean = 157.1 ms; voiceless mean = 150.0 ms; alternating mean = 140.7 ms), but significance cannot possibly be determined based on this sample. Similar trends were seen with velar stops (voiced mean = 133.7; voiceless mean = 121.6; alternating mean = 122.6).

The differences in voicing into closure are shown in figure 8, and suggest that voiced stops remain voiced for both places of articulation, while there is no difference between alternating and voiceless stops. However, it should be borne in mind that these data reflect just 4 tokens each of 1 voiced, 2 voiceless and 2 alternating words for each of these two places of articulation.

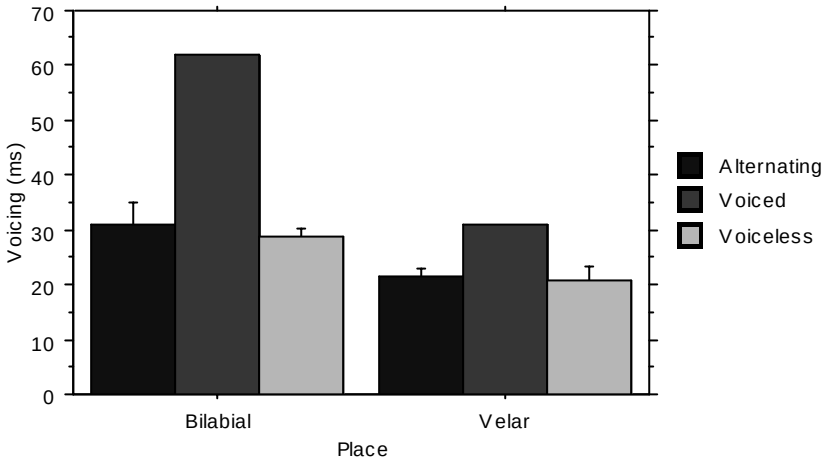

Figure 8. Voicing into closure in bilabial and velar stops for subject 1.

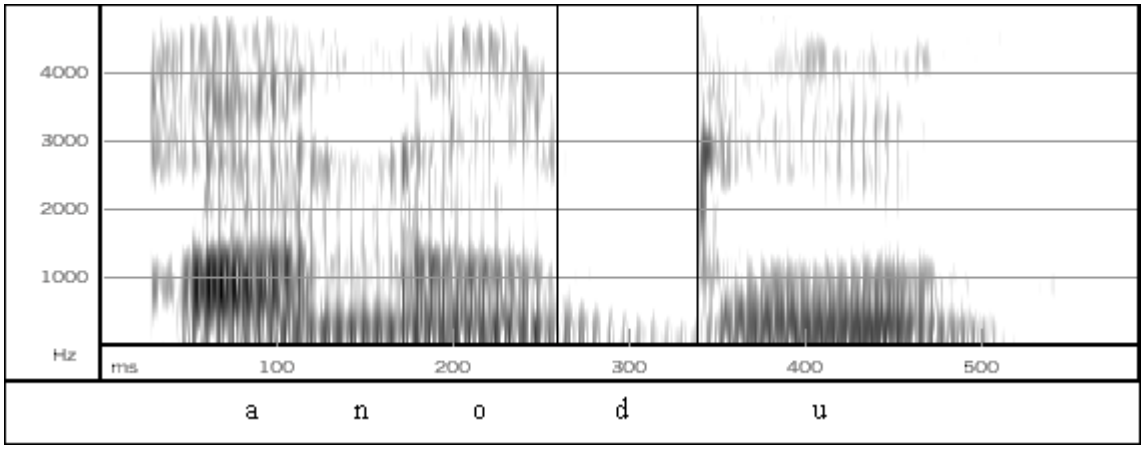

Figure 9. An intervocalic alternating stop in the word anodu.

In summary, there is plenty of evidence that voiced stops do remain voiced: for subject 1, final voiced stops had significantly more voicing into closure than voiceless or alternating stops. This was highly significant for alveolar stops and suggestive for the other two places of articulation, though little data was collected. Furthermore, subject 3's voiced stops were much longer than her alternating stops.

However, there was no evidence for any difference between voiceless and alternating stops in any of the analyses carried out, which supports Kopkallı's (1993) findings that these are genuinely neutralized in Turkish.

Intervocalic voicing

For all subjects, voiced and alternating stops were compared in intervocalic positions. An example of an intervocalic alternating stop (heard as voiced) is shown in figure 9. Intervocalic voiced stops appeared similar if not identical. The results are shown in figure 10.

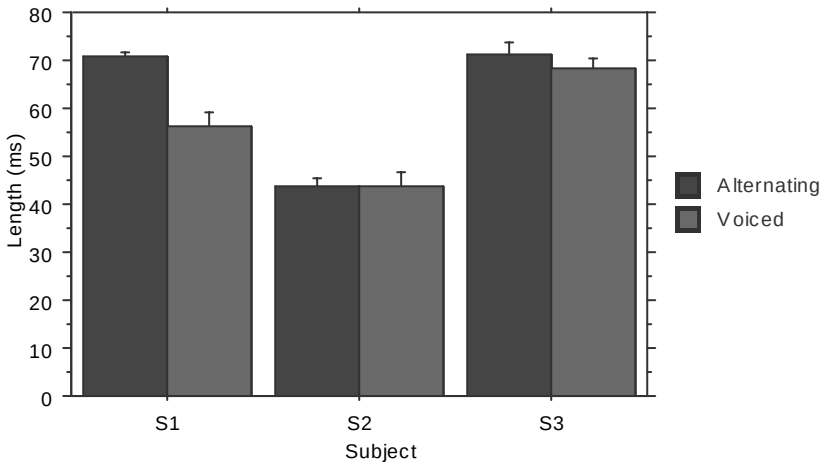

Figure 10. Intervocalic alternating and voiced stops.

Due to the small number of subjects, each subject was analyzed individually. For subject 1, a t-test was significant ($p = 0.0007$ or $p = 0.03$ assuming unequal variance). However, due to small N (3 voiced words, 6 tokens each, 6 alternating words, 6 tokens each), this result should be interpreted with caution. A more conservative nonparametric Mann-Whitney U test was carried out, yielding $p = 0.02$, which is still significant.

For subjects 2 and 3, there was no difference between the two conditions ($p = 0.98$ for subject 2, $p = 0.47$ for subject 3), thus the result for subject 1 was not replicated.

Discussion

The main results can be summarized as follows:

- For the one speaker for whom devoicing was examined (i.e. whether there is a contrast between voiceless and alternating stops after devoicing), no evidence was found that the neutralization is not complete. This is in line with the findings of Kopkallı (1993).

- However, certain stops do remain voiced in devoicing environments: this was signified by length for one speaker and voicing into closure for another; for a third no significant variable was found but due to low power a distinction should certainly not be ruled out.

- For one of the three speakers, there appeared to be a distinction between voiced and alternating stops in intervocalic position, i.e. perhaps the alternating stops are not fully voiced in this position. However, the data sets for the second and third speakers, explicitly selected in an attempt to replicate this result, failed to obtain any significant differences.

The first of these results is important support for Kopkallı's (1993) findings that devoicing in Turkish is truly neutralizing, and is thus a categorical process. This means that Turkish patterns with Catalan in this respect, and appears to be different from languages such as German, Polish and Russian in which devoicing is not categorical.

The second finding provides support for a three-way stop voicing contrast in the Turkish lexicon. There is no doubt that voiceless and alternating stops are distinct, since they clearly contrast in intervocalic position. This study confirms that voiced stops do indeed contrast with alternating stops, in that the former remain voiced at least to some extent in devoicing environments. This provides support for accounts such as Hayes (1990) which attribute to Turkish a three-way lexical contrast between voiced, voiceless and underspecified stops.

The third possible finding is intriguing, but it should be stressed that it remains only a possibility, as only one speaker showed the pattern. If it were true that alternating stops (which are underlyingly unspecified for voicing according to the Hayes (1990) account) are not fully voiced intervocalically, then this would be an interesting twist on incomplete neutralization. Further work with more speakers, items and a wider variety of measurements should be able to answer the question of whether or not this is a genuine phenomenon.

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Appendix

These are the words and phrases used for the first speaker. Those marked with an asterisk were used for the second and third speakers

Word	**Acc.**	**Gloss**	**Condition**	**Phrase _V**	**Phrase _C**
üstad*	üstadı*	expert, master	voiced	Üstad oldu.	Üstad gördüm.
ispat	ispatı	proof, evidence	voiceless	İspat oldu.	İspat gördüm.
hayat	hayatı	life	voiceless	Hayat oldu.	Hayat gördüm.
icat*	icadı*	invention	alternating	İcat oldu.	İcat gördüm.
damat*	damadı*	bridegroom	alternating	Damat oldu.	Damat gördüm.
balad*	baladı*	ballad	voiced	Balad istiyorum.	Balad gördüm.
sanat	sanatı	art	voiceless	Sanat istiyorum.	Sanat gördüm.
surat	suratı	face	voiceless	Surat istiyorum.	Surat gördüm.
kanat*	kanadı*	wing	alternating	Kanat istiyorum.	Kanat gördüm.
avrat*	avradı*	woman	alternating	Avrat istiyorum.	Avrat gördüm.
metod*	metodu*	method	voiced	Metod aldım.	Metod gördüm.
pilot	pilotu	pilot	voiceless	Pilot aldım.	Pilot gördüm.
mazot	mazotu	diesel	voiceless	Mazot aldım.	Mazot gördüm.
iyot*	iyodu*	iodine	alternating	İyot aldım.	İyot gördüm.
anot*	anodu*	anode	alternating	Anot aldım.	Anot gördüm.
Rab	Rabbı	God	voiced	Rab istiyorum.	Rab gördüm.
hap	hapı	pill	voiceless	Hap istiyorum.	Hap gördüm.
kap	kabı	pot, vessel	alternating	Kap istiyorum.	Kap gördüm.
hep	hepi	every	voiceless		
cep	cebi	pocket	alternating		
arkeolog	arkeoloğu	archeologist	voiced		
fok	foku	seal	voiceless		
çok	çoğu	much	alternating		
kök	kökü	root, origin	voiceless		
gök	göğü	sky	alternating		